Initial Environmental Evaluation

# British Antarctic Survey
# *REWIND* Ice Core Drilling Project

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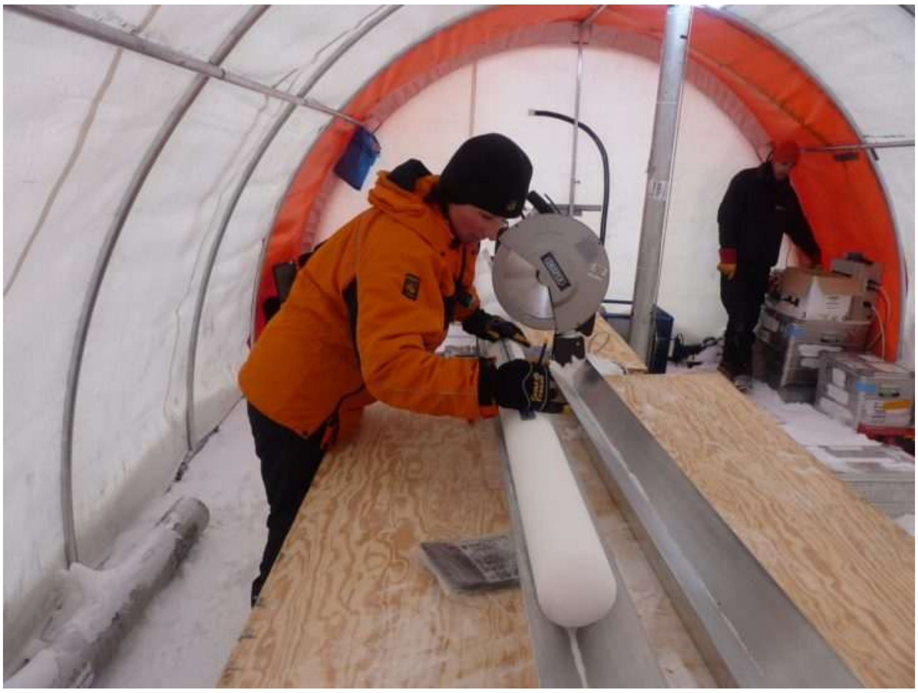

British Antarctic Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

Submitted to the Polar Regions Department, Foreign, Commonwealth and Development Office, as part of an application for a permit / approval under the Antarctic Act 1994.

Submitted by:
*British Antarctic Survey*

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IEE Prepared by:
*BAS Environment Office*

For further information on this environmental impact assessment contact the BAS Environment Office:
*Rachel Clarke* – racl@bas.ac.uk
*Steph Walsh* - steals@bas.ac.uk

**Cover image: Ice core work. Source: British Antarctic Survey**

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# Acronyms and Abbreviations

| | |
|---|---|
| asl | Above Sea Level |
| ACBR | Antarctic Conservation Biogeographic Region |
| ATCM | Antarctic Treaty Consultative Meeting |
| ATCP | Antarctic Treaty Consultative Party |
| ATS | Antarctic Treaty Secretariat |
| ALE | Antarctic Logistics and Expeditions |
| ASPA | Antarctic Specially Protected Area |
| ASMA | Antarctic Specially Managed Area |
| AWS | Automated Weather Station |
| BAS | British Antarctic Survey |
| CCAMLR | Commission for the Conservation of Antarctic Marine Living Resources |
| CEE | Comprehensive Environmental Evaluation |
| CEP | Committee for Environmental Protection |
| $CO_2$ | Carbon Dioxide |
| COMNAP | Council of Managers of National Antarctic Programs |
| EIA | Environmental Impact Assessment |
| FCDO | Foreign, Commonwealth and Development Office |
| GHG | Greenhouse Gas |
| GIS | Geographical Information System |
| GPR | Ground Penetrating Radar |
| GPS | Global Positioning System |
| HCFC | Hydrochlorofluorocarbons |
| HDPE | High Density Poly Ethylene |
| HSM | Historic Site and Monument |
| IBA | Important Bird and Biodiversity Area |
| IEE | Initial Environmental Evaluation |
| ISPM | International Standards for Phytosanitary Measures No. 15 |
| Kg | Kilograms |
| km | Kilometres |
| $km^2$ | Kilometres square |
| km/h | Kilometres per hour |
| kW | Kilowatts |
| KvA | Kilo-volt-amperes |
| L | Litre(s) |
| $Mkm^2$ | Million square kilometres |
| m | Metre(s) |
| $m^2$ | Meters square |
| m/sec | Meters per second |
| ODP | Ozone Depleting Potential |
| ODS | Ozone Depleting Substance |
| PAX | Personnel |
| RRS | Royal Research Ship |
| S | South |
| SBR | Sky Blu Depot |
| SCAR | Scientific Committee on Antarctic Research |

| | |
|---|---|
| $tCO_2e$ | Tonnes of Carbon Dioxide Equivalent |
| SDA | Royal Research Ship Sir David Attenborough |
| UN | United Nations |
| UOM | Unit of Measure |
| V | Volts |
| °C | Degrees Centigrade |

# Non-Technical Summary

## Introduction

The British Antarctic Survey (BAS) is the UK's national Antarctic operator, responsible for much of the UK's scientific research in Antarctica.

This Environmental Impact Assessment (EIA) reviews the significance of the environmental impacts that will or could arise from the proposed Geophysics and Deep Ice Core Drilling Project in Palmer Land, Southern Antarctic Peninsula (*REWIND*) comprising drilling and geophysics activities, during the 2024-25 and 2025-26 seasons.

This EIA identifies mitigation measures to minimise identified environmental impacts.

## Legal context and guidance material

All activities in Antarctica are subject to the provisions of a series of international agreements that constitute the Antarctic Treaty System.

The Protocol on Environmental Protection to the Antarctic Treaty (the Protocol) was adopted by the Antarctic Treaty Consultative Parties in 1991. It entered into force in January 1998.

The EIA provisions of the Protocol are enacted in UK law through the Antarctic Act 1994 and Antarctic Act 2013 and Antarctic Regulations 1995/490 (as amended). The Act applies to both governmental and non-governmental activities in Antarctica.

The EIA documented here has been undertaken to meet the requirements of the Protocol and relevant UK legislation.

## Scope of the EIA

***Proposed work***

The *REWIND* project proposes to drill through the Antarctic Peninsula ice sheet to bedrock, retrieving an ice core from the entire depth to approximately 600-800 m, using deep drilling methods during the 2024-25 and 2025-26 seasons.

The principal scientific objective is to obtain new reconstructions and a high-resolution record of sea ice, westerly winds, and $CO_2$ in the Pacific sector of the Southern Ocean, during the Holocene which spans approximately the past 11,000 years.

***Geographical scope***

The proposed drilling site is in Palmer Land, on the Southern Antarctic Peninsula, and is 2,200 m above sea level, where the ice is approximately 750 m thick (see Figure 1).

The final deep drill location (and associated camp site) will be determined by the geophysics surveys, which will focus on the proposed drill sites, identified as C1 (S 74.543°, W 70.883°), and C3 (S 74.552°, W 70.808 °); further sites, at C5 (S 74.550°, W 71.633°), and C6 (S 74.567°, W 72.226°), are approximately 15 and 30 km away from the C1/C3 sites, respectively, and will be investigated for their potential (Figure 2). The aim being to provide the deepest core possible with the BAS drill.

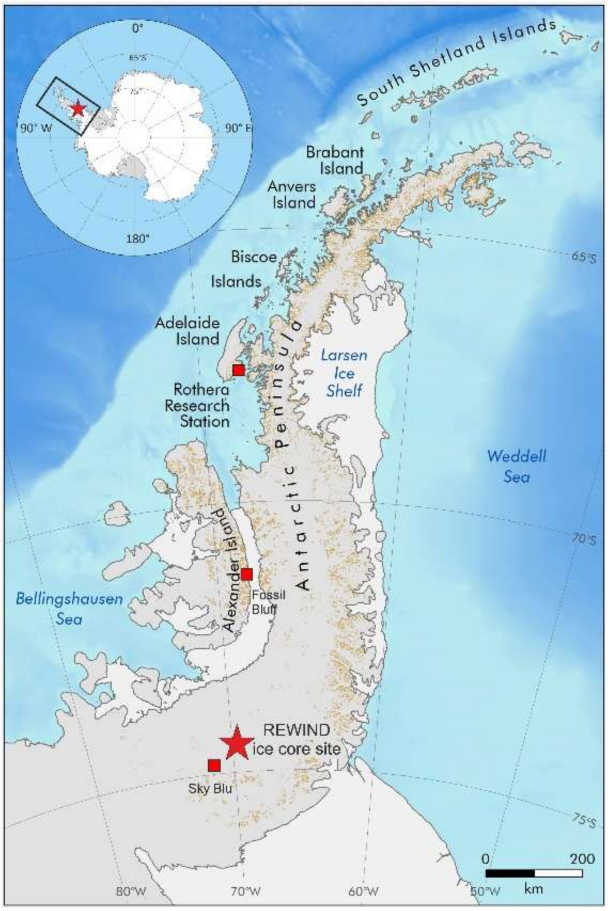


*Figure 1: General Location of Proposed REWIND Drilling Project, Indicated by Red Star. Produced by the Mapping and Geographic Information Centre, British Antarctic Survey, 2024.*

***Temporal scope***

The proposed project will span two Antarctic summer field seasons in 2024/25 and 2025/26. Geophysics is proposed to take place in the first month of the 2024/25 season.

The field camp will be occupied, and equipment flown in once the geophysics survey has confirmed the drill location. In total, geophysics surveys and drilling will occur for approximately 80 days per season, with seven to nine people at the camp for the drilling. Equipment will be overwintered near the camp location (approximately March to October), and then removed in March 2026.

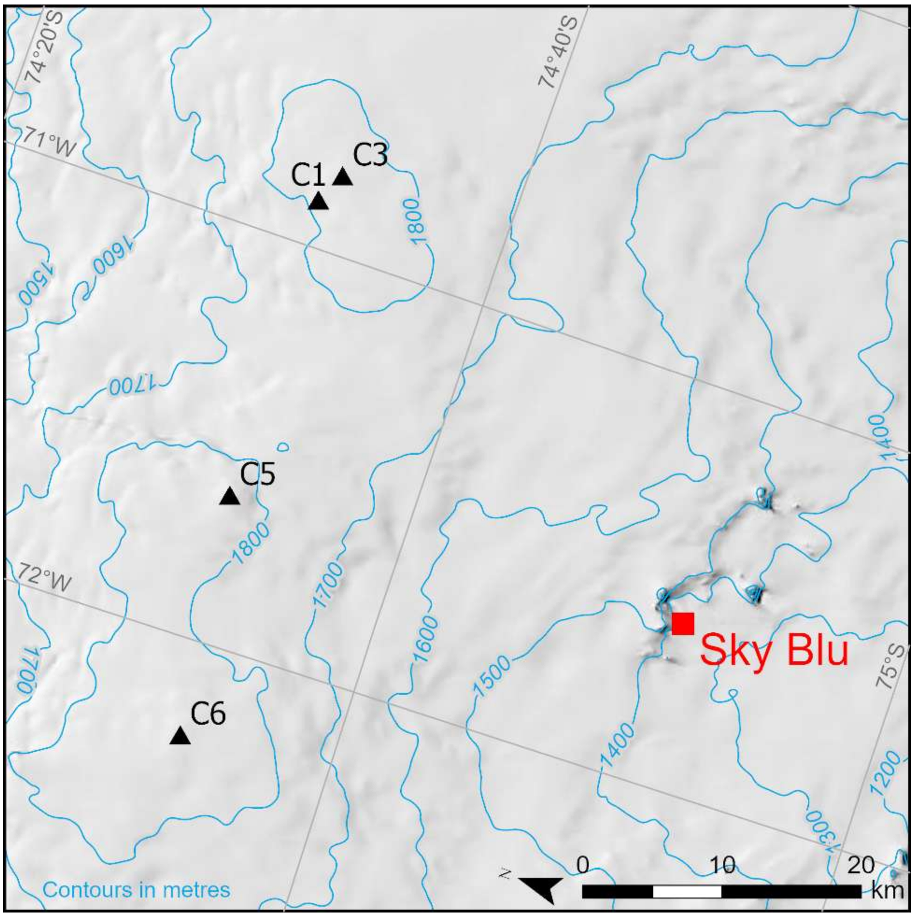


*Figure 2: Overview of potential Drilling Locations C1- C6 Produced by the Mapping and Geographic Information Centre, British Antarctic Survey, 2024.*

Season one (2024/25) will include:

- geophysics surveys, using ground penetrating radar (GPR), to locate the ice core drilling location, and associated temporary camp(s) for two people;
- input of geophysics team (2 people) and drill team (5-7 people);
- shallow drilling at the deep drill location;
- potential for deep drilling to 200 m, in the same borehole as shallow drilling;
- overwintering equipment.

Season two (2025/26) will include:

- deep drilling to full depth 600-800 m, depending on site, in the same borehole as season one;
- firn[1]-air sampling in second (shallow) borehole, up to 5 km from the deep drill site; and
- equipment, including ice cores, and overwintering depot removed from site.

[1] Firn is usually defined as snow that is at least one year old and has therefore survived one melt season, without being transformed to glacier ice. Firn is transformed gradually to glacier ice as density increases with depth, as older snow is buried by newer snow falling on top of it.

### *Logistical Scope*

This EIA also includes consideration of logistics needed to facilitate the proposed *REWIND* project, in the form of Twin Otter flights from Rothera Research Station to the field site, travel on the *RRS Sir David Attenborough* (SDA) for personnel, equipment, ice core storage and shipping, and the use of skidoos.

## Proposed Approach

### *Geophysics Surveys*

During the first three to five weeks of the project, the geophysics team will be input and will complete surveys to identify the deep drilling location, using ground penetrating radar towed by skidoo.

The geophysics survey will operate out of one or two temporary camps, with two skidoos and two people.

### *Drilling*

Once the location has been identified by the geophysics team, and the drill team are input, drill camp set up and equipment received, drilling will start. The shallow drilling will take place first, during season one, in the austral summer of 2024/25. This involves the electromechanical dry drill (the dry drill does not use drilling fluid). This drill is also known as the ‘shallow drill’.

The deep drilling will be carried out during seasons one (if possible) and two in the austral summer of 2024/25 and 2005/26 using an electromechanical drill, which will use drilling fluid. This drill is also known as the ‘BAS deep drill’. Deep drilling will occur in the same borehole as the season one shallow drilling.

### *Use of Drill Fluid*

As the borehole depth increases (past approximately 150 m), fluid is added to the borehole during drilling to maintain a pressure in the borehole and prevent reduction in diameter of the borehole due to ice deformation. Drill fluid will also be used overwinter, and if not already being used, drill fluid will be introduced to the borehole to maintain the opening ready for further drilling in season two. This project proposes to use the hydrocarbon Exxsol D60.

### *Drilling Camp*

Once the drill location is confirmed the drill team will be input (along with cargo, including the drilling tent, drilling equipment, and remaining camping equipment) and the geophysics team and equipment will become part of the drilling team, and will be based at the drilling camp.

The camp will include up to five personnel tents (pyramid or clam tents), one ‘Weatherhaven’, one ‘Polarhaven’ and related infrastructure.

### *Firn-air Sampling*

During season two (2025/26), a second borehole will be drilled into the firn (the porous layer between snow and glacial ice) close to, or up to around 5 km from the deep drilling location (depending on conditions). This drilling will use the BAS electromechanical dry drill (shallow drill), without drilling fluid. The aim of this second borehole is to extract air from the firn column, from the surface to approximately 60-100 m, to provide a more recent methane and $CO_2$ record than is available in the ice core.

***Testing Borehole Properties***

While the borehole is open in seasons one and two, it is proposed to lower equipment into the borehole and test air chemistry, ice chemistry, and the integrity and properties of the borehole wall.

***Over winter Depot***

Equipment and fluids will be stored in an overwinter depot near the field camp location during the winter of 2025, ready for season two.

## Area of Disturbance

The area likely to be impacted by the geophysics survey is approximately 100-250 $km^2$ from C1/C3 potential drill locations, representing 10-15 km radius. However, two satellite locations, C5 and C6 will also be investigated, and while it is likely that the surveys will remain within 5 km of those locations (25 $km^2$), it is possible that there will be a need to travel further (10-15 km from the identified sites) if the under-ice topography shows potential for a deep core. Therefore, each of these areas may also be subject to 100-250 $km^2$ of over ice disturbance from skidoos and radar surveys.

Once the location is identified, the area of disturbance at the drill site is estimated at a maximum of 750 $m^2$, including the field camp and depot.

The deep borehole will descend to a depth of approximately 750 m (600-800 m depending on the site chosen) and will be 135 mm in diameter over most of its depth.

The firn-air sampling will have an area of disturbance of approximately 250 $m^2$, being just the drill at that location. This borehole will descend approximately 60-100 m.

## Environmental Aspects

A number of environmental aspects have been identified for this proposed project, including:

- input flights of personnel and equipment;
- skidoo, surveying, personnel movements, and drilling activities to the ice sheet surface;
- impacts of camp set up and living on the snow/ice surface (e.g., tent footprints and wastewater discharge);
- emissions from generators, skidoos. snowblower and cooking equipment;
- potential for spills of drilling fluid, fuel, and other liquids;
- transport and storage of ice cores;
- wastes produced by the project, and their transportation to Rothera;
- establishment of an overwintering depot line for equipment;
- potential for introduction of non-native species and biosecurity concerns;
- potential for lost equipment; and
- potential impact on wilderness values.

## Alternatives

Several alternatives were considered in the environmental impact process.

***Do Not Drill – Do Nothing***

Not drilling would eliminate all associated environmental impacts; including those that arise from aircraft operations.

Such an approach would also assist in maintaining perceptions of Antarctic wilderness.

However, this option would be contrary to BAS' vision of being a world-leading centre for polar science. It would also curtail the UK's understanding of Antarctica's response to changing climate conditions, including the behaviour of Antarctica's ice sheets under warming conditions.

**Drill Elsewhere in Antarctica – Alternative Location**

The proposed drill site was chosen due to several factors, including previous shallow drilling on the Antarctic Peninsula and aerial surveys. Alternative locations have been rejected as it is believed this location has the best potential for retrieving a deep ice core.

**Use Alternative Drilling Technologies – Alternative Methods**

The drilling method proposed is the best suited for this location and the proposed ice core extraction. Alternative technologies (thermal drilling and alternative drill fluids) have been rejected based on ice core quality, power requirements, and health and safety reasons.

## Current Environmental State

***Physical Environment***

The proposed drilling site on the southern Antarctic Peninsula ice sheet is relatively flat, slow moving, and free of features, which is desirable for ice core drilling. All glaciers flow, but a slow moving one retains its characteristics longer, holding the bubbles of historical air in the ice for longer. The proposed site is at one of the highest points and roughly in the middle of the ice sheet, which is the slowest moving section, free of crevassing and fissures.

***Climate***

Antarctica is the coldest and driest continent on Earth.

Antarctica's average annual temperature ranges from about −10 °C on the coast to −60 °C at the highest parts of the interior. Near the coast, the temperature can exceed +10 °C in summer and fall to below −40 °C in winter. Over the elevated inland, it can rise to about −30 °C in summer but fall below −80 °C in winter.

Antarctica's environment has special conditions that make it the windiest continent on Earth. Wind speeds can exceed 100 km/h for days at a time.

Rain has been observed near the coast, but most precipitation over Antarctica is in the form of snow or ice crystals. The average accumulation of snow over the whole continent is estimated to be equivalent to about 150 mm of water per year. Over the elevated plateau, the annual value is less than 50 mm. Near the coast, it generally exceeds 200 mm.

Loose snow can be picked up and carried along by the wind, which can reduce visibility significantly and make it challenging to conduct activities.

***Ice-free areas***

The nearest ice-free area to the drilling location is close to the Sky Blu depot (Sky Hi Nunataks), which is approximately 38 km away.

The *REWIND* geophysics and drilling activities are confined to snow and ice-covered terrain, and therefore will not be visiting any ice-free areas.

***Wildlife***

With a few exceptions (i.e., seabird breeding colonies located a few kilometres from the coast), the majority of Antarctic wildlife is constrained to coastal ice-free regions. Inland areas of the ice sheet support very little life other than lichens, algae, microinvertebrates and microbial communities in some locations. It is not expected that any wildlife will be present at the proposed project site.

***Important Bird and Biodiversity Areas (IBAs)***

IBAs generally encompass bird breeding sites (as opposed to foraging) locations. The closest IBA to the proposed project is AQ203, Sims Island at 275 km away, followed by AQ100, Smith Peninsula, which is 298 km away. Therefore, the geophysics and drilling operations are not in the vicinity of any IBAs.

***Protected or Managed Areas and Historic Sites***

The closest ASPA to the proposed *REWIND* project area is ASPA 147, Ablation Valley and Ganymede Heights, Alexander Island, which is 412 km from the proposed *REWIND* site.

The nearest ASMA is located at Southwest Anvers Island and Palmer Basin (ASMA 7). ASMA 7 is 1,072 km from the proposed activity.

No Historic Sites and Monuments (HSMs) will be visited by the proposed drilling project.

***Human activity and Antarctic wilderness***

Research studies have estimated that 99.6% of the Antarctic continent can still be considered wilderness, but pristine areas, free from human interference cover a much smaller area (less than 32% of Antarctica) and are declining as human activity escalates (Leihy et al., 2020).

The drilling project will take place in an area that has previously been visited.

## Carbon Assessment

The carbon emissions for this project have been estimated using activity-based carbon metrics both developed by BAS and available externally. These are based on annual baseline activity data models and sets of assumptions, therefore provide an indicative figure of estimated carbon emissions for the project.

For the proposed *REWIND* project, Table 1 shows a summary of the expected Carbon emissions, using available data.

*Table 1: Estimated Project Carbon Emissions by GHG Protocol Scope*

| Scope | Total tCO2e | Percentage Split |
|---|---|---|
| 1 (Fuels) | 1,094.7 | 95.7% |
| 2 (Purchased Energy) | 0.0 | 0.0% |
| 3 (inc. Business Travel) | 49.4 | 4.3% |
| **Total** | **1,144.1** | **100.0%** |

The majority (95.6%) of the estimated emissions for this project fall within Scope 1, as they are the emissions resulting from BAS owned aircraft and the fuel used for the ice core drill and field team.

The Scope 3 emissions shown are the result of the business travel required for the project teams to travel to Antarctica and back to the UK for each of the two seasons.

## Cumulative Impacts

The Jurassic and Gomez cores were the deepest cores to be collected from sites that are close to where this project proposes to drill (70 km and 108 km respectively). Both were approximately 150 m long, with the Gomez core collected in 2006 and the Jurassic core in 2012. These cores, along with airborne geophysics, informed the selection of the current proposed location. Other recorded cores are much shorter with SKBL 21.8 m, UK-81 21 m, and UK-92 24 m, (40 km, 59 km, and 59 km respectively).

While there has been some previous human presence in the region of the proposed location, there are few records of other activities in the area, other than at the Sky Blu depot.

The Sky Blu depot has been subject to several activities including:

- operation of automatic weather stations;
- fuel drops and refuelling activities (an average of 176 aircraft movements per season);
- airborne geophysics surveys across the region;
- rock and lichen surveys at Sky Blu.

## Assessment of Environmental Impacts

The actual or potential environmental impacts of the activity are assessed by means of a four-step analysis involving:

1. identifying the **aspects,** i.e., the physical change imposed on, or an input released to the environment;
2. identifying the **exposure,** i.e., the interaction between an identified potential output and the receiving environment;
3. identifying the **impacts,** i.e., the change in environmental values or resources attributable to the activity;
4. assessing the **significance** of the identified impacts.

Identified impacts are summarised in Table 2, and are summarised below.

Given that all activities associated with the proposed *REWIND* drilling project will be constrained to the ice and snow surfaces, the glacial environment has the potential to be most heavily impacted. The *RSS Sir David Attenborough* (SDA) will be involved in logistics, so there is also potential to impact the marine environment; however, as these are routine operations involving the transportation of cargo and personnel to Rothera Research Station, no additional impacts are expected for this proposed project.

Use of aircraft, skidoos, generators and cooking equipment create heat, gas and particulate emissions that may impact the immediate snow and ice environment through the release of particulates.

Physical disturbance will occur through drilling, skidoo use and movement of snow for the camp, ice core storage and overwintering. Any accidental releases of hazardous substances or waste materials will contaminate the ice sheet environment.

Waste will need to be managed and removed, except for human liquid waste and sieved grey water, which will be disposed to the ice sheet.

Loss of drilling equipment or drill fluid could impact the environment, both from inputting compounds into the natural environment, and from being visually intrusive both at the time, and in future as ice moves.

It is unlikely that wildlife would be impacted by the presence of the drilling camp.

All human activity could impact on perceptions of Antarctic wilderness.

### The Assessment of Risk

Risk is evaluated, and given a score (as used by Oerter, 2000), using the significance of a given potential impact, the spatial extent, duration, severity, and likelihood of the identified potential impacts. A low-risk impact (1 to 15) would be local in extent, short term, have a minimal severity affect, and be unlikely to occur. Medium-risk (16 to 35) would have a more than local extent, would be over a medium term would have an effect on the environment, and be possible but unlikely. While a high-risk (36 to 143) impact would have a major extent, be long term, have high severity, and be likely to occur or be probable. With the most potential for harmful impact, very high-risk (144 to 256) activities would have a large-scale impact, be permanent, irreversible, and unavoidable.

With no treatments in place, four of the activities are assessed as 'high-risk', three as 'medium-risk' and one as 'low-risk'; however, once the mitigations are in place two are reevaluated as 'medium risk' and the remaining six are 'low-risk' predominantly due to the scale and duration of the activity.

*Table 2: Overview of those Environmental Elements that have been Identified as Potentially being Susceptible to the Aspects Arising from the Proposed Activities.*

| **ASPECTS OF ACTIVITIES** | **ENVIRONMENTAL ELEMENTS THAT WILL / MAY BE IMPACTED** | | | | | | |
|---|---|---|---|---|---|---|---|
| | **FAUNA AND FLORA** | **FRESHWATER** (*ponds, streams, rivers, lakes*) | **MARINE** *(including sea ice)* | **GLACIOLOGICAL** *(glaciers, ice sheet and ice shelves)* | **TERRESTRIAL** (*ice-free ground, soil and rocks*) | **ATMOSPHERE** | **WILDERNESS VALUES** |
| **Atmospheric emissions** | | *No impacts have been identified for freshwater environments* | ✓ Particulates in exhaust emissions will settle on sea ice | ✓ Particulates in exhaust emissions will settle on ice surfaces | *No impacts have been identified for terrestrial environments* | ✓ Gases in exhaust emissions, including GHG, will be released to air | ✓ Visible particulates on the surface would impact on wilderness values |
| **Noise emissions** | ✓ Noise sources have potential to disturb wildlife – if wildlife is transitioning the area | | ✓ SDA movements may cause noise impacts to the marine environment | | | | ✓ Geophysics/drilling/camp noise may impact on wilderness values. |
| **Heat emissions** | | | | ✓ Heat could potentially impact the surface of the ice sheet | | ✓ Heat from various sources will be released to air | |
| **Mechanical action** | ✓ Potential for ship strike of wildlife (e.g., whales) | | ✓ SDA may impact sea ice | ✓ Physical disturbance to ice and snow surfaces from drilling; skidoo movements; camp set up, ice core storage etc. | | | ✓ Visual holes/disturbance could impact wilderness values |
| **Loss of Equipment** | ✓ Potential for future impact if melts out into environment | | ✓ Potential for lost equipment from SDA | ✓ Physical impact with any equipment or fluid lost to icesheet, in drill hole. | | | ✓ Equipment may become exposed and visible with melting of icesheet |
| **Fuel spills/loss of drilling fluid** | ✓ Potential for fuel spill impacting marine wildlife and ecosystems | | ✓ Potential for spills from SDA | ✓ Accidental releases to snow / ice surfaces | | ✓ Evaporation of fuel/drilling fluid | ✓ Visual impacts could impact wilderness values |
| **Wastes** | | | ✓ Potential for waste to be discharged from SDA | ✓ Releases to snow / ice environment | | | ✓ Visual impacts could impact wilderness values |
| **Introduced species / relocated native species** | ✓ Potential for introduction | | ✓ Potential for marine biofouling from SDA | | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Presence / Visual disturbance** | ✓ Human presence has potential to disturb wildlife | | ✓ Presence of SDA has potential to disturb wildlife and wilderness perception | | | | ✓ Human presence and activity may alter perceptions of wilderness |

## Mitigations

Generally, BAS aims to prevent or reduce potential environmental impacts from activities through careful planning, pre deployment training, and effective execution of field programmes. Also, for almost all sources of impact, practicable treatment options to mitigate those impacts have been identified, including:

- choosing the most appropriate and environmentally safe drilling fluid, and using a bailer to recover as much drilling fluid as practicable;
- removing all equipment, camp infrastructure, fuels and waste from the field on project completion (no equipment is planned to be left in the field);
- running only one generator at a time, where possible;
- using geophysics to choose the drilling site prior to flying in most personnel and equipment;
- using the fewest flights possible and coordinating logistics for least impact;
- minimising fuel use to the maximum extent practicable, including by using the most efficient fuel options for use at low temperatures and regularly servicing engines and generators;
- minimising the risk of fuel spills by minimizing volumes, and careful refuelling practices (e.g., drip trays, funnel use), for hazardous liquid substances including drilling fluid and fuel, taken into the field;
- actively managing and monitoring fuel and other hazardous substances in accordance with standard BAS procedures and using secondary containment to the maximum extent practicable;
- minimising the impact of spilled fuel by having spill kits available and providing relevant training in oil spill response;
- managing all waste, including hazardous waste in accordance with the provisions of the Protocol, the BAS Waste Management Handbook and BAS Field Operations Manual and minimising the materials and items taken into the field that will generate waste to the maximum extent practicable; and
- following BAS Biosecurity Regulations.

Provided the mitigation measures identified in this EIA are adhered to, the environmental impacts of the planned activities are considered to be largely avoidable or can be minimised and therefore are no more than minor or transitory.

## Monitoring and Record Keeping

This assessment has not identified the need for dedicated monitoring to be undertaken. Nonetheless, records will be maintained for post-season reporting purposes, including:

- the volume of drilling fluid used and recovered;

- the volumes and types of fuel burnt during drilling activities;
- digital records (such as GPS) of drilling locations, and geophysics survey routes and locations;
- digital records of camp sites, the overwintering storage location, the volumes of fuel and drilling fluid stored, types and volumes of waste stored, and human liquid waste and grey water disposed to the ice sheet;
- records of the types and quantities of any materials or equipment that is lost to the environment;
- observations of any other environmental incidents, such as inefficient burning of fuel resulting in excessive release of airborne pollution;
- location of any spill events, volumes and type of fluid lost, and approximate volumes recovered.

Every effort will be made to avoid unnecessary impacts. Where an incident results in impacts, such as lost equipment or fuel spills, this will be documented and reported to the BAS Environment Office and to the FCDO in accordance with the conditions of the BAS Operational Permit. Post season reporting will also be undertaken.

## Gaps in Knowledge and Uncertainties

Due to the extreme, changeable, and unpredictable environmental conditions, geophysics and drilling activities will need to retain a degree of flexibility to accommodate changing weather, logistical and scientific requirements.

Accordingly, there remain a number of gaps in knowledge and uncertainties, including:

- precise drill location uncertainty (no input of drilling equipment or drilling personnel until identified);
- field season uncertainties (e.g., flexibility in length of season or input dates);
- the use of and amount of hazardous substances at site, which will depend on the drill site location and the potential depth of the ice core;
- implications of Antarctic weather, which can disrupt planned activities in any one season;
- future plans for Sky Blu depot;
- the availability of funding for the borehole investigation project (ice chemistry and borehole wall properties);
- use of the 'Tractor Traverse'.

The uncertainties associated with these factors is assessed as being unlikely to have significant implications for the identified environmental impacts nor for the overall conclusion of the EIA.

## Summary and conclusion

Overall, this environmental impact assessment considers that the potential environmental impacts arising from the *REWIND* geophysics and drilling programme will have **no more than a minor or transitory impact** on the environment.

It is concluded that this level of predicted impact is acceptable given the significant scientific knowledge that will be gained as a result of BAS' ongoing ice core research and the anticipated knowledge gained during the *REWIND* project.

# 1 Introduction

## 1.1 British Antarctic Survey

The British Antarctic Survey (BAS) is the UK's national Antarctic operator, responsible for much of the UK's scientific research in Antarctica.

The BAS Vision is: To be a world-leading centre for polar science and polar operations, addressing issues of global importance and helping society adapt to a changing world.

The BAS Mission is a research-driven organisation recognised for:

- commitment to excellence in science.
- operational professionalism and innovation in everything we do.
- a partner of choice for science, operations and business wherever polar expertise can be applied.
- safely delivering complex operations in extreme environments.
- commitment to environmental stewardship of the polar regions.
- developing our staff to reach their full potential.
- sustaining an active and influential presence in Antarctica on behalf of the UK, and playing a leadership role in Antarctic affairs.
- engagement with policy makers, government and the public.

Operationally, BAS' strategic aim is to provide and operate world-leading research infrastructure that enables scientists from the UK, and colleagues from many nations, to work safely and effectively in the polar regions. A key goal is for BAS to be recognised nationally and internationally as a partner of choice for polar operational expertise wherever it can be applied.

BAS currently operates the year-round Rothera Research Station on Adelaide Island to the west of the Antarctic Peninsula (Figure 3).

BAS also has a summer only depot site at Sky Blu, which has a permanent blue ice runway, is used mainly for refuelling for deep field operations, and is the closest infrastructure to the proposed *REWIND* drill site.

In relation to the proposed project, BAS also operates the *Royal Research Ship (RRS) Sir David Attenborough* (Figure 4) and an aircraft fleet which currently includes a DASH-7 and four De Havilland Twin Otter aircraft (Figure 5).

The *REWIND* project team will be input into the project site from Rothera with Twin Otter aircraft. Equipment will arrive at Rothera on the *RRS Sir David Attenborough*, and then be flown by Twin Otter to site. The teams and equipment will likely transit through the Sky Blu depot but may only refuel there.

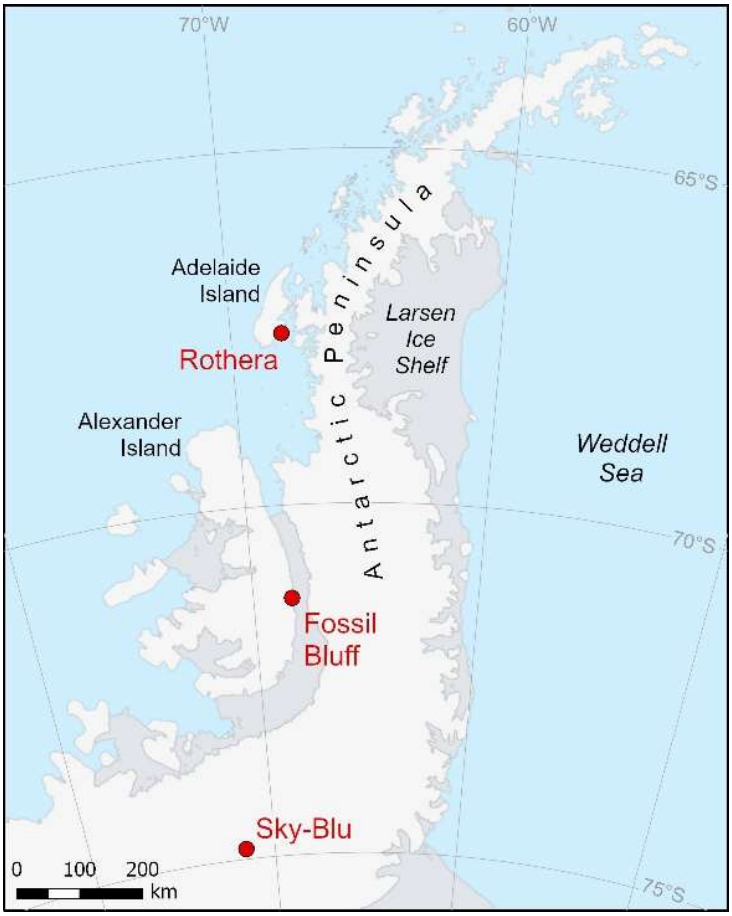


*Figure 3: BAS Rothera Research Station and Depots Locations. Produced by the Mapping and Geographic Information Centre, British Antarctic Survey, 2024.*

*Figure 4: Royal Research Ship Sir David Attenborough.*


*Figure 5: BAS Twin Otter.*

## 1.2 Antarctic Research

In the context of its published Science Strategy ‘Polar Science for a Sustainable Planet’, BAS facilitates an array of multi-disciplinary research programmes to investigate and monitor environmental change in Antarctica and the Southern Ocean.

The vision over this 10-year strategy is to deliver the scientific evidence needed by decision-makers in policy, industry, and society, to move us towards a sustainable future. The strategy focuses on five key themes of global significance, almost all of which require some degree of deep field research.

Theme 1: ‘Climate Change Science for Developing Resilience’ - targets how the Arctic and Antarctic respond to and mitigate climate change.

Theme 2: ‘Conserving Polar Biodiversity’ - focusses on how biodiversity at the poles responds to change.

Theme 3: ‘Protecting Coastal and Technical Infrastructure’ - addresses the impact on infrastructure and societies of sea level rise and space weather.

Theme 4: ‘Sustaining Livelihoods and Societies’ - considers environmental changes across Earth’s frozen regions and how these affect societies and livelihoods.

Theme 5: ‘Safeguarding our Future’ - addresses potential severe impacts of reaching thresholds and triggering extreme changes in the polar environment.

# 2 Legal Context and Guidance Material

All activities in Antarctica are subject to the provisions of a series of international agreements that constitute the Antarctic Treaty System. These international agreements are enforced through domestic legislation enacted by those countries with active Antarctic involvement, achieved through, for example, the mounting of regular research expeditions and/or establishing a presence in Antarctica through the operation of Antarctic stations or bases.

This Chapter of the EIA:

- describes the relevant international agreements and domestic legislation that applies to BAS field activities, and
- summarises relevant measures agreed under the auspices of the Antarctic Treaty System.

## 2.1 International Requirements

The Protocol on Environmental Protection to the Antarctic Treaty (the Protocol) was adopted by the Antarctic Treaty Consultative Parties (ATCPs) in 1991. It entered into force in January 1998.

Article 3 of the Protocol sets out environmental principles for the conduct of activities in Antarctica. Article 3 provides that the protection of the Antarctic environment and the intrinsic value of Antarctica, including its wilderness and aesthetic values and its value as an area for the conduct of scientific research, in particular research essential to understanding the global environment, shall be fundamental considerations in the planning and conduct of all activities in the Antarctic Treaty area.

Article 3 also requires that activities in the Antarctic Treaty area are planned and conducted so as to limit adverse impacts on the Antarctic environment and that those activities must be planned and conducted on the basis of information sufficient to allow prior assessments of, and informed judgments about, their possible impacts on the Antarctic environment. Such judgements must take account of:

i. the scope of the activity, including its area, duration and intensity;
ii. the cumulative impacts of the activity, both by itself and in combination with other activities in the Antarctic Treaty area;
iii. whether the activity will detrimentally affect any other activity in the Antarctic Treaty area;
iv. whether technology and procedures are available to provide for environmentally safe operations;
v. whether there exists the capacity to monitor key environmental parameters and ecosystem components so as to identify and provide early warning of any adverse effects of the activity and to provide for such modification of operating procedures as may be necessary in the light of the results of monitoring or increased knowledge of the Antarctic environment and dependent and associated ecosystems; and
vi. whether there exists the capacity to respond promptly and effectively to accidents, particularly those with potential environmental effects.

Article 8 of the Protocol formalises these requirements by requiring an environmental impact assessment to be prepared in advance of any activity taking place in the Antarctic Treaty area. The level of the environmental impact assessment is determined by whether the activity in question is identified as having ‘less than’, ‘no more than’ or ‘more than’ a ‘minor or transitory’ impact on the environment.

The detailed procedures for preparing and processing environmental impact assessments are set out in Annex I to the Protocol. If a proposed activity is determined, by means of a preliminary assessment, to have less than a minor or transitory impact, then it may proceed. If an activity is determined as being likely to have no more than a minor or transitory impact, then an Initial Environmental Evaluation (IEE) must be prepared. If a preliminary assessment or IEE indicates the potential for the activity to have more than a minor or transitory impact, or if such an impact is otherwise determined to be likely, then a Comprehensive Environmental Evaluation (CEE) must be prepared.

Preliminary assessments and IEEs are processed within the domestic legal and administrative systems of each Antarctic Treaty Party. Draft CEEs are, however, required to be made publicly available, and to be made available for consideration by the Antarctic Treaty System’s Committee for Environmental Protection (CEP). The CEP’s advice on the quality of a draft CEE is provided to the Antarctic Treaty Consultative Meeting (ATCM). Comments and advice provided by other Antarctic Treaty Parties and the ATCM must be addressed in a final CEE, which is used as the basis for making a decision about whether and how the activity in question will be conducted.

The CEP has prepared guidance material to assist those preparing EIAs. The most recent version of these guidelines was adopted by the 39$^{th}$ ATCM (Resolution 1 (2016)). These guidelines have been consulted in the preparation of this EIA.

## 2.2 National Requirements

The EIA provisions of the Protocol are enacted in UK law through the Antarctic Act 1994 and Antarctic Act 2013 and Antarctic Regulations 1995/490 (as amended). The provisions of the legislation apply to any person who is on a British expedition to Antarctica, where a British expedition is defined as an expedition “that is organised in the United Kingdom, or the place of final departure for Antarctica of the persons on the expedition was in the United Kingdom”. The Act applies to both governmental and non-governmental activities in Antarctica.

The Act is administered by the Foreign Commonwealth and Development Office (FCDO) and the Secretary of State makes the final determination on whether an activity may proceed taking into account the FCDO’s recommendations. It is an offence under the Act to enter Antarctica without a permit issued by the Secretary of State.

The Act also prohibits the following activities unless a Specialist Activity permit is obtained:

- undertaking mineral resource activities;
- intentionally, killing, injuring, capturing, handling or molesting any native mammal or native bird;
- intentionally disturbing native mammals or native birds;
- removing or damaging any native plant so as to significantly affect its local distribution or abundance, or significantly damaging a concentration of native plants;
- causing significant damage to the habitat of any native mammal, bird, plant or invertebrate;

- introducing any species of non-native animal or plant;
- entering an Antarctic Specially Protected Area (ASPA), or an area designated as protected by the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR); or
- damaging, destroying or removing a designated historic site or monument.

Logistical activities are covered by the BAS Operating Permit, which, for BAS-led activities is organised directly between BAS and the FCDO.

The Secretary of State has discretion under the Act to set conditions regarding the proposed activity. Such conditions may relate to, for example, managing compliance, undertaking environmental monitoring and post-activity reporting. Under the provisions of the Act, non-compliance is an offence carrying a penalty of up to two years imprisonment or a fine or both.

## 2.3 Applicable ATCM Measures and Resolutions

In addition to the general provisions of the Protocol outlined above, the ATCM has, over time adopted a suite of additional agreements (in the form of Recommendations, Resolutions or Measures) several of which are pertinent to the proposed activities in that they relate specifically to the issue of Antarctic logistical and operational activities, or environmental management.

Relevant agreements are highlighted here for completeness and will be considered in this environmental impact assessment and in the conduct of the planned activities.

### 2.3.1 Environmental Management in Antarctica

Measures related to environmental management in Antarctica that may be relevant to the proposed *REWIND* drilling project include:

- Recommendation XV-5 (1989) – Environmental Monitoring Activities
- Resolution 2 (2005) – Guidelines for Environmental Monitoring
- Resolution 5 (2015) – Important Bird Areas in Antarctica
- Resolution 1 (2016) – Revised Guidelines for Environmental Impact Assessment in Antarctica
- Resolution 4 (2016) – Non-native Species manual (revised 2019)

## 2.4 COMNAP Guidance Material

The Council of Managers of National Antarctic Programs (COMNAP) provides a forum for cooperation among National Antarctic Programmes that have responsibility for delivering and supporting scientific research in the Antarctic Treaty area on behalf of their respective governments. COMNAP guidance material that may be relevant to the proposed *REWIND* geophysics and drilling operations include:

- Checklists for Supply Chain Managers for the Reduction of Risks of Introduction of Non-native Species; and
- COMNAP Guidelines for Emergency Response and Contingency Planning

The above obligations and guidance material, along with BAS guidance materials, have been considered in the preparation of this EIA and, where relevant, in the various control measures identified to minimise the impacts of activities undertaken in Antarctica.

Consideration of the additional provisions of the Protocol as they relate to waste management, prevention of marine pollution and area protection and management are considered in later chapters of this EIA.

# 3 Scope Of The EIA

This Environmental Impact Assessment evaluates the environmental consequences that will or could arise from the proposed *REWIND* project geophysics and drilling activities for the austral summer seasons 2024/25 and 2025/26, and overwintering depot for winter 2025.

This Chapter describes the scope of the EIA.

## 3.1 Deep Ice Core Drilling in Antarctica

Ice core drilling originated in the 1950s, with the first Antarctic deep ice core in 1968 at Byrd Station during the International Geophysical Year (Brook and Buizert, 2018).

BAS provides the UK's only capability to recover and analyse ice cores (up to 1000 m), providing ice core drills for deployment by research teams in Antarctica (and around the World) and operate state-of-the-art laboratories to provide a wide range of climatologically and environmentally relevant chemical, gas and stable isotope analyses.

Ice cores are drilled, processed and analysed by BAS scientists and engineers. Laboratory facilities in Cambridge allow the analysis and interpretation of ice cores dating from hundreds to hundreds of thousands of years old. The current facilities allow ice to be stored, processed, and analysed, using a number of analytical chemistry, isotopic and gas extraction techniques to provide information from the past to help to predict the future.

BAS has been involved in a number of ice core projects, which have varied in drilling depths and techniques, many of which have been with international partners. From this work BAS now has a leading role in ice core research, which includes deep drilling at specified locations, and using the data to increase scientific understanding of climate change.

BAS has been involved with approximately seven of these ice core drilling projects that have been on the Antarctic Peninsula. These Antarctic Peninsula ice cores have helped determine that the proposed location is the most likely to provide a suitable deep ice core.

Information from some of these other projects has been used to inform this EIA.

## 3.2 Geographical Scope

The proposed *REWIND* drilling site (in the region of S 74.56°, W 70.84°) is in Palmer Land, on the Southern Antarctic Peninsula, and is 2,200 m above sea level, where the ice is approximately 750 m thick.

The proposed field site is approximately 38 km northwest of the British Antarctic Survey's Sky Blu facility (at 1435 m a.s.l.), which is also the location of the nearest outcrop of exposed rock (see Figure 6).

Proposed geophysics and deep drilling activities will be exclusively on snow and ice-covered areas on the Antarctic Peninsula ice sheet, and the drilling project does not require visits to any ice-free areas or protected areas.

The final deep drill location will be determined by the geophysics surveys that will focus on the proposed drill site, identified as sites (C1 and C3) at: C1 (S 74.543°, W 70.883°), C3 (S 74.552°, W 70.808°), further sites, at: C5 (S 74.550°, W 71.633°), C6 (S 74.567°, W 72.226°) are approximately 15 and 30 km away from the C1/C3 sites, and will be investigated for their potential (Figure 7). The aim being to provide the deepest core possible with the BAS drill.

Specific travel routes for geophysics surveys across the Ice shelf are not yet known, and will be subject to findings, operational and weather constraints.

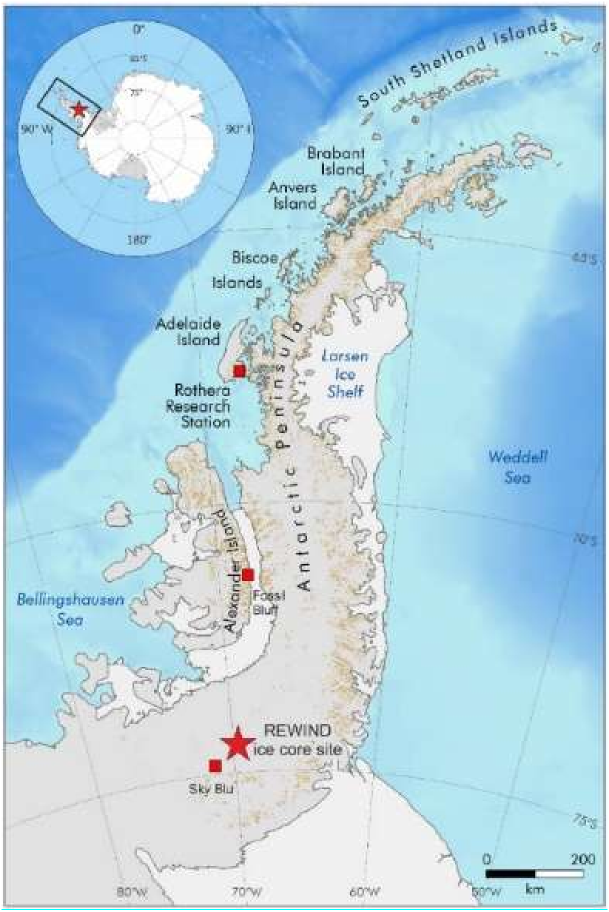


*Figure 6: General Location of Proposed REWIND Ice Core Drilling Project. Produced by the Mapping and Geographic Information Centre, British Antarctic Survey, 2024.*

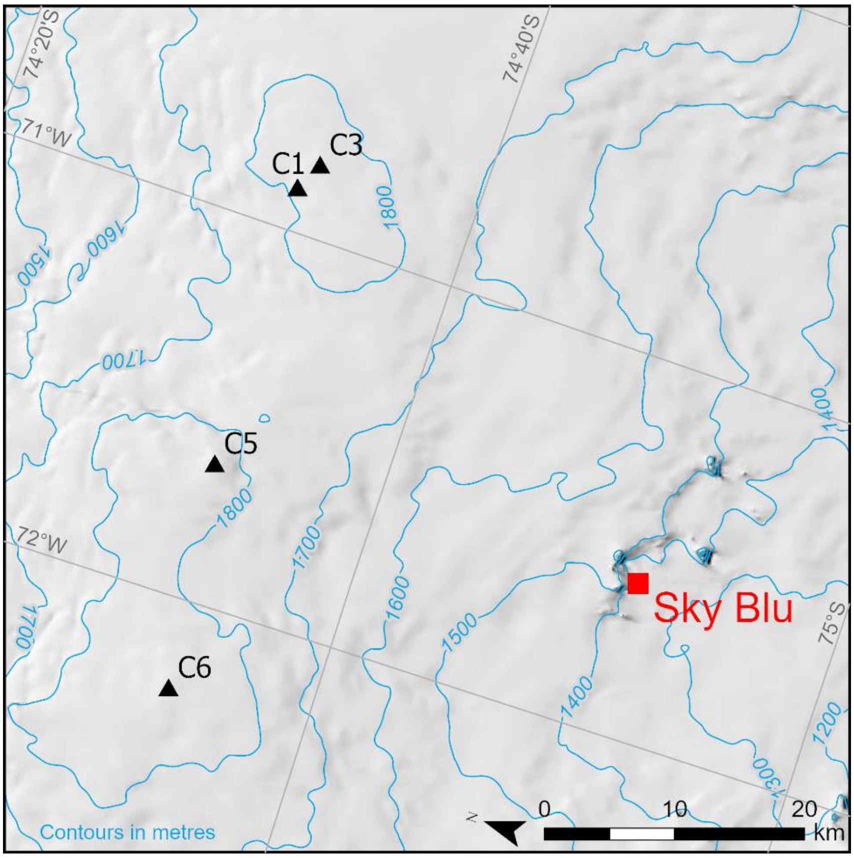


*Figure 7: Overview of Potential Drilling Locations C1-C6. Produced by the Mapping and Geographic Information Centre, British Antarctic Survey, 2024.*

## 3.3 Temporal Scope

This evaluation covers two years of planned deep drilling activities from the 2024/25 and 2025/26 austral summer seasons, and the 2025 overwintering of equipment. The timeframe of this IEE falls within the timeframe of the current BAS Operating Permit granted under Section 3, Section 4, Section 6, Section 7, Section 8, Section 9 and Section 10 of the Antarctic Act 1994, which is valid from 1 October 2022 to 30 September 2027.

The proposed *REWIND* drilling and associated activities (deep and shallow drilling, geophysics surveys, and drilling camp) only occur during the austral summer months (approximately November to early March), with equipment overwintered near the camp location (approximately March to October).

Season one (2024/25) will include:

- input of geophysics team (2 people)
- geophysics surveys, using ground penetrating radar, to locate the ice core drilling location, and associated temporary camp(s) for two people;
- hand drilling during the geophysics surveys;
- Input of drill team (5 – 7 people);
- set up of drill camp and depot, once location identified;
- shallow drilling at the final deep drill location;
- potential for deep drilling to 200m, in the same borehole as shallow drilling (with use of drill fluid if reach 150 m);

- testing the properties of borehole (air chemistry and borehole wall properties);
- overwintering equipment.

Season two (2025/26) will include:

- deep drilling to full depth 600-800 m (using drill fluid) depending on site, in the same borehole as season one;
- testing the properties of borehole;
- firn-air sampling in second (shallow 60 – 100 m) borehole, up to 5 km from the main drill site;
- equipment, including ice cores, removed from site.

## 3.4 Logistical Scope

The *REWIND* drilling project will rely on a number of logistics to facilitate the project. These will also be assessed and include:

- travel by ship (equipment and people). Equipment, and potentially team members will move to Rothera by the SDA in the 2024/25 season;
- movement of drilling fluid from Union Glacier to Rothera (recovered fluid from the Sky Train ice rise, traversed to Union Glacier by ALE, and then flown to Rothera in 2022/23 season);
- input into, and uplift from the field by Twin Otter aircraft (equipment and people);
- use of two snowmobiles for geophysics surveys;
- ice core storage in the field, Rothera and UK.

# 4 BAS *REWIND* Drilling Activities – Proposal

The proposal for the *REWIND* activities is presented in this chapter as well as a detailed description of the typical components of drilling equipment used, geophysics surveys and associated camps. The chapter also considers associated activities including waste and fuel management, and the over-wintering of drilling equipment.

This chapter also identifies the environmental aspects that will or may arise from the various activities. These aspects or outputs are the ways in which the planned activity will or may interact with the environment. The consequences and significance of these aspects are then assessed in Chapter 8.

## 4.1 Purpose

The purpose of the deep drilling operation over the next two summer seasons is to support global understanding of climate change by:

- drilling an ice core to bedrock (but not touching bedrock);
- to retrieve an ice core that spans the full Holocene covering approximately the past 11,000 years;
- firn-air sampling for recent climate information;
- borehole properties investigations.

The ice core will provide a proxy for the continuous record of westerly winds, and sea ice in the Pacific sector of the Southern Ocean, and a new high-resolution record of $CO_2$.

## 4.2 Proposed Activities

### 4.2.1 Geophysics Surveys

During the first few weeks of the first season (2024/25) geophysics surveys will be completed, to determine the ice thickness and under-ice bedrock topography.

Ground penetrating radar will be pulled using skidoos over a region of approximately 10-15 km x 10-15 km to an area of 100-250 km$^2$ at the proposed drilling site (C1/C3), and additional surveys of the same size may occur at two outlier sites (C5 and C6) as shown on Figure 7. This will provide a grid of radar transects extending approximately 10-15 km from the proposed sites.

These surveys will assist in identifying the best location for the ice core drilling, as they will identify the under-ice topography, and locate areas with up to 800 m of ice available to drill, within the proposed project area.

During geophysics surveys, around five shallow ice cores will be drilled to approximately 5 m depth using a Kovacs hand-drill, to explore the spatial variability of snow accumulation.

The geophysics team of two people will camp during the surveys in either a static or small temporary camps depending on the need at the time. Once the geophysics is complete, and the drill team are input to site, the geophysics team and their equipment will become part of the drill team.

### 4.2.2 Drilling

The shallow drilling will take place during season one, in the austral summer of 2024/25. This involves the electromechanical dry drill (the dry drill does not use drilling fluid).

The aim of the first season is to drill through the firn, which is approximately the upper 60-100 m of the ice sheet. If time allows, the team will switch to the deep drill and obtain approximately a further 100 m, reaching a final depth of around 200 m of ice core. After approximately 150 m, drilling fluid will be used, and will be left in the borehole overwinter.

Season two drilling will continue from where season one stops. Both the shallow and deep drilling will be conducted in the same borehole; however, these are two different drill set ups.

The deep drilling will use an electromechanical drill, like that described in Mulvaney et al. 2007 and Mulvaney et al. 2014. This drill set up being designed specifically to fit inside a Twin Otter aircraft, and able to be manhandled into position, without the need for lifting equipment on site.

The final depth of the deep borehole will be determined by the location chosen once the geophysics survey has been completed. The aim of the *REWIND* project is to find the deepest possible ice core for the area and is aiming for approximately 600-800 m depth. There is no plan to touch bedrock, but to get as close as possible, without damage to the drilling equipment.

#### *4.2.2.1 The drill set-up*

The drills (see Figure 8) consist of a drilling head with ice cutters mounted on a rotating inner barrel driven by an electric motor. The inner barrel is contained within an outer barrel, which is connected to an anti-torque device. This device is designed to grip the borehole walls to counter the rotational torque generated by the drilling action.

On both the shallow and deep drills, the drill is suspended by a wire cable with internal conductors carrying power from the snow surface to the drill. The deep drill, with an overall length of 9 m and weighing 170 kg, can take a 98 mm diameter core of approximately 1.1 m in length on each drilling run, in a borehole 135 mm diameter.

Raising and lowering of the drill in the borehole is controlled by a winch and a mast at the surface which is rotated to the horizontal to facilitate extraction of the ice core from the barrel.

Power to run the deep drill is provided by a 16 kVA petrol generator, while the shallow drill uses the smaller 2 kVA petrol generator.

*Figure 8: Drill in Situ (Source: Liz Thomas).*

A typical drilling run, which includes lowering the drill to the bottom of the borehole, drilling 1.1 m of core, returning the drill to the surface, and removing the core and chippings, takes approximately 30 minutes at 300 m depth.

### *4.2.2.2 Drill fluid and ice chips*

The amount of drill fluid needed for the *REWIND* deep drilling project will depend on the final depth of the borehole, however it is expected that the project will need approximately 13.2 L per meter drilled, and with current ice thickness knowledge, this would mean up to 12,000 L will be required on site.

Fluid that was recovered from the Skytrain ice rise project was traversed to Union Glacier by ALE (a third-party contractor), and then flown to Rothera by BAS during the 2022/23 season. Reusing recovered fluid reduces the amount of new drilling fluid required for this project. Based on similar experiences, it will be possible to recover in the region of 85%-99% of the drilling fluid, with some being lost to evaporation, and some possible loss from the drill transiting the borehole in the porous firn layer. Efforts will be made to maximise the amount of drill fluid recovered during the project.

Ice chips which are generated during the drilling process will be separated from the drilling fluid using a centrifuge. The ice chips remain in the drill until the ice core is removed, they are captured by a metal tray under the core as it is extracted from the drill in a horizontal position. The chips are placed in a bucket and transferred to the centrifuge. The centrifuge is a drum that spins out the drill fluid, which then leaves the drum via a tap on the side. This fluid is then introduced back into the borehole, and the chips placed in a designated location.

The centrifuge is used after every ice core is removed from the borehole.

Drill fluid will be used after 150 m drilling depth, and will be left in the borehole overwinter, to prevent the hole closing completely, and so drilling may resume in season two. If drilling fluid has not yet been used by the end of the first season, it will be introduced into the borehole to maintain an opening over winter. The level of fluid will be calculated to ensure that even if there is slight closure, the drilling fluid will not enter the firn layer over winter, where it would more easily enter the environment.

At the end of the drilling project (season two), any drill fluid left in the borehole will be retrieved using a bailer mechanism (Figure 9) that was designed by BAS and has previously been used for deep drilling operations. As the borehole will not touch bedrock, it is not anticipated that drill fluid will be lost via the bottom of the borehole.

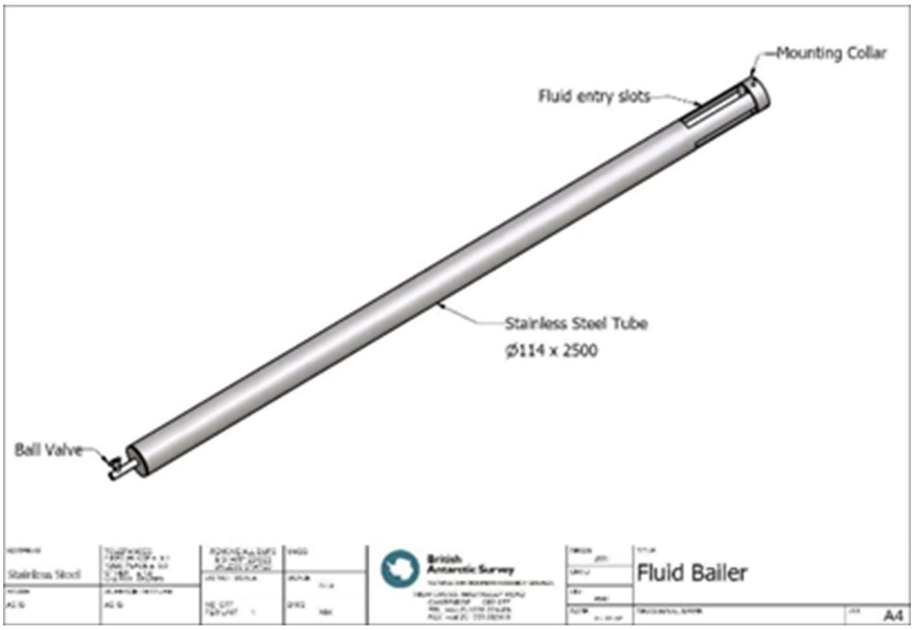


*Figure 9: Drilling Bailer Designed by BAS to be Used in The Borehole to Recover Fluid After Drilling.*

### 4.2.3 Use of Drilling Fluid

As the borehole depth increases, fluid is added to the borehole to maintain a pressure in the borehole and prevent reduction in diameter of the borehole due to ice deformation. Therefore, the proposal is to use drilling fluid for the deep core (past about 150 m), while the initial shallow drilling will be completed 'dry'.

In addition, it is a well-recognised characteristic of ice core drilling that the quality of cores deteriorates rapidly beyond a depth of about 120 m. If drilled in a dry hole without the use of fluids, ice becomes brittle with depth, and the mechanical working during the drilling fractures the ice into small pieces which cannot be used for the modern range of analytical techniques. For this reason, all deep ice cores are drilled using fluid filled holes, and the deep ice core drills are optimised for use in fluid filled holes, relying on the fluid for transport of chips away from the drilling head.

Based upon extensive laboratory analysis of deep ice core drilling fluids carried out at the University of Copenhagen (Talalay and Gundestrup, 1999), the most appropriate fluid for use at the proposed site on the Antarctic Peninsula has been identified as Exxsol D60. For this project, only a partial column of the fluid (past 150 m) will be used at the bottom of the borehole (so for a 650 m borehole, the bottom 500 m will use drilling fluid).

Exxsol D60 is a complex hydrocarbon mixture, it is a petroleum-derived aliphatic cycloparaffinic hydrocarbon. It is a highly volatile substance that will rapidly evaporate and degrade in the atmosphere. It is readily biodegradable (where appropriate conditions exist) and has a low ecotoxicity (see Appendix 1 for the safety data sheet).

### 4.2.4 Drilling Camp

The logistical operation to establish the camp will be via Twin Otter aircraft operating out of Rothera. The camp will include up to five personnel tents (pyramid or clam tents), one 'Weatherhaven', one 'Polarhaven' and related infrastructure.

The location of the drilling camp will be determined by the deep drilling borehole location, as identified by the season one geophysics surveys. The drilling team and cargo, including the drilling tent, drilling equipment, and remaining camping equipment will only be received on site once this location has been confirmed. The geophysics team will also become part of the drill team.

The drill tent area of about 15 m x 4.5 m will be covered over with a wooden floor comprising approximately 3000 kg of new timber compliant with the International Standards for Phytosanitary Measures No. 15 (ISPM 15) and covered with a 'Weatherhaven' shelter, to accommodate the mechanical drill system (see Figures 10 and 11).

*Figure 10: Drilling Camp (Source: Liz Thomas).*

*Figure 11: Drilling Camp (Source: Liz Thomas).*

A trench (12 x 3 x 3 m) will be dug and covered with a wooden roof of approximately 1100 kg of new timber compliant with ISPM 15, to serve as an ice core storage facility (Figure 12).

*Figure 12: Ice Core Trench (Source: Liz Thomas).*

Two 16 kVA petrol generators (2x EP18000TE generators, each 17.5 kW, each capable of supplying up to 16 kW to the winch), only one to run at a time, will be installed at the field camp to operate the deep drilling equipment and to supply power to the field camp.

Two 2 kVA petrol generators will on site for shallow drilling, and to service low power requirements, only one will run at a time. Should deep and shallow drilling be running at the same time, then one of each size of generator would be operational concurrently; however, mostly only one generator will be running at a time.

### 4.2.5 Firn-air Sampling

During season two (2025/26), a second borehole will be drilled close to, or up to around 5 km from the deep drilling location. This drilling will use the BAS electromechanical dry drill (shallow drill), without drilling fluid. The aim of this second borehole is to extract air from the firn column, from the surface to approximately 60-100 m.

Air sampling equipment will be lowered down the borehole, after each core section is removed. The borehole will be sealed from the surface using an inflatable bladder, and the air from the firn layer, pumped directly into glass containers at the surface, and sent to the UK for later analysis.

Firn-air sampling will sample methane and $CO_2$. Compared to ice core sampling, firn-air sampling provides information on recent climate, as the air sampled has not yet been compressed into the ice record. Once compressed and available in the ice core, this record is generally decades old, a more complete analysis is therefore available when firn-air is also sampled.

### 4.2.6 Testing of Borehole Properties

While the borehole is open in seasons one and two, it is proposed that the ice chemistry, as well as the integrity and properties of the borehole wall will be investigated.

Using specially designed instruments lowered into the borehole, a probe will be pushed into the wall of ice inside the borehole, and advanced borehole logging equipment will test for chemical properties of the ice.

This work will take approximately two days and will use the same resources and the main drilling project.

### 4.2.7 Conclusion of Drilling Operations

Once retrieved, the cores will remain stored on site until the end of season two, unless an earlier opportunity arises to fly them to freezer storage at Rothera using BAS Twin Otter aircraft. Later, the cores will be shipped in a freezer unit (‘reefer’) at -20 to -25°C via the *RRS Sir David Attenborough* to the UK for analysis.

When drilling has been completed, the drilling fluid will be recovered from the borehole using the bailer (Figure 9) and the top of the borehole will be sealed. The camp, drilling equipment, wooden floor of the drilling trench, drilling fluid, unused fuel, and any remaining waste, will be removed from the field to Rothera and then reused, or removed from Antarctica for reuse or safe disposal. All equipment, waste and ice cores will be flown to Rothera by Twin Otter aircraft.

## 4.3 Area of Disturbance

### 4.3.1 Geophysics

The area likely to be impacted by the geophysics survey is approximately 100-250 $km^2$ from the proposed site (C1/C3), representing 10-15 km radius. However, two satellite locations, C5 and C6 will also be investigated, and while it is likely that the surveys will remain within 5 km of those locations, it is possible that there will be a need to traverse further (10-15 km from the identified sites) if the under-ice topography shows potential. Therefore, each of these areas may also be subject to 100-250 $km^2$ of over ice disturbance from skidoos and radar surveys.

Geophysics personnel and equipment will be input at the proposed drilling location, they will then travel across the ice sheet on two skidoos with ground penetrating radar (GPR) to find the deep drill location.

The geophysics surveys will also include a small temporary camp site as the surveyors move across the area, around the cluster of sites; however, once they are investigating the satellite sites, the camp site may be moved. These camps will consist of one pyramid or clam shell tent for 2 people, (one scientist and one field guide) plus cooking equipment. The skidoos will carry fuel; however, no generators will be on site at this time.

### 4.3.2 Drilling

The area of disturbance at the deep drill site is estimated at a maximum of 750 $m^2$, including the field camp and depot.

The deep borehole will descend to a depth of approximately 750 m (600-800 m depending on the site chosen) and will be 135 mm in diameter over most of its depth.

The drilling infrastructure will be comprised of:

- a wooden drill trench floor covered by a 'Weatherhaven' shelter;
- a drilling winch and tower system;
- generators; and
- a centrifuge for recovering fluid from the chips.

### 4.3.3 Drilling Camp

Once the geophysics surveys have identified the deep ice core location, the drilling camp will be set up, and will consist of tents and infrastructure/life support for the team of up to nine people (see Figure 13) and will be close to the drilling tent. This will include, at a maximum, two 'Weatherhavens' (one being the drilling tent), one 'Polarhaven', and up to five pyramid or clam tents.

*Figure 13: Drilling Camp Set Up (Source: Liz Thomas).*

The camp will include the fuel/equipment depot, a snowblower, and the two skidoos for the geophysics work, when not in use to move equipment or ice cores.

The area of disturbance for the drilling camp is included in the 750 $m^2$above.

## 4.4 Firn-air Sampling

A second drill site for the firn-air sampling may be up to 5 km from the main site, depending on site conditions. This site would have a footprint of approximately 250 $m^2$, as there is less equipment needed at that location, primarily the shallow drill.

## 4.5 Testing of Borehole Properties

The testing of borehole properties will take place in the existing borehole, drilled by the main project. Therefore, this work is included in the 750 $m^2$ estimate for the drilling disturbance.

## 4.6 Duration of Proposed Activity

The proposed drilling project is planned to be undertaken during two austral summer seasons, 2024/25 and 2025/26. This assumes that the field party can be successfully input to the proposed field site at S 74.56°, W 70.84°, in Palmer Land on the Antarctic Peninsula in early November 2024.

An initial field camp, which will be in one or two locations depending on need once on the ground, will be used by the geophysics surveyors, for three to five weeks, followed by a temporary field camp that will be established once the remaining team and equipment arrives. The camp will be used for the two summers over the duration of the project, with a depot overwintering equipment, after which the camp and depot will be removed.

Seven to nine personnel will spend a total of around 70 – 80 days in the field per season (though it is likely two of the personnel will leave the field at the mid-point of the project when the speed of ice core recovery slows). Two of the team will be the initial geophysical team, who will stay on as part of the drill team.

# 5 Environmental Aspects

A number of environmental aspects have been identified for this proposed project, including:

- input flights of personnel and equipment;
- skidoo, surveying, personnel movements, and drilling activities to the ice sheet surface;
- impacts of camp set up and living on the snow/ice surface (e.g., tent footprints and wastewater discharge);
- emissions from generators, skidoos, snowblower and cooking equipment;
- potential for spills of drilling fluid, fuel, and other liquids;
- transport and storage of ice cores;
- wastes produced by the project, and their transportation to Rothera;
- establishment of an overwintering depot line for equipment;
- potential for introduction of non-native species and biosecurity concerns;
- potential for lost equipment; and
- potential impact on wilderness values.

These aspects have been examined here in the context of the activities they are associated with for the proposed *REWIND* project.

## 5.1 Geophysics

The geophysics will take place in the first three to five weeks of the project and will be centred on the site C1/C3 of the proposed deep drill location. The team will tow GPR trailers with skidoos to find the final deep drill location within 10-15 km from the proposed locations. The further satellite sites will also be investigated at C5 and C6, within 10-15 km of each of those locations.

During these surveys, hand drilling will also take place to assess snow and ice properties.

### 5.1.1 Environmental Aspects of Geophysics

The environmental aspects of the geophysics work include:

- input flights of personnel and equipment;
- surveying and vehicle movement (skidoos) across the ice sheet;
- use of cooking equipment;
- impacts to the snow surface from camping and working (e.g., hand drilling);
- camp set up;
- direct release of liquid human liquid waste and sieved grey water to the environment;
- collection of snow for water; and
- potential for spills of fuel from skidoos, cooking, and lighting (petrol, kerosene, oil and lubes).

## 5.2 Drilling

There are two drilling set ups proposed for use during this project, the electromechanical dry drill for shallow drilling, and an electromechanical drill with drilling fluid for the deep drilling. The dry drill can also be used at the same time as the deep drill, for other investigations.

The deep drilling project will use drilling fluids to allow free flowing drilling at deeper ice core depths (past 150 m); the 16 kVA generator is also required. Based on similar experiences, it will be possible to recover c. 85% of the drilling fluid, with up to 15% being lost to both evaporation and from the drill transiting the borehole in the firn layer (via fluid being released from the drill as drips in the top 100 m of the borehole, and entering the larger pores of the firn layer); however, improved recovery methods may reduce this, and the aim is for up to 99% recovery.

BAS has developed a bailer method to retrieve drill fluid from boreholes (see Figure 9), which will be used for this project. It is desirable to retrieve as much drill fluid as possible to reduce the potential for ice contamination from introduction of drill fluid into the environment, and to further reuse this fluid for future projects.

Shallow drilling will not use drilling fluid, but it will use a 2 kVA generator. The drill will be transported to the drilling location, and then to storage once the shallow drilling is complete, until it is required for the firn-air sampling portion of the work.

Minor spills and leaks of fuel (petrol, diesel, oils and lube) or drilling fluid, and during the use of grease, are possible. The maximum quantity of fuel or drilling fluid that is likely to be spilled at any one time is 205 L, due to a punctured drum. Spilled fuel or drilling fluid would pass quickly through the surface layer of snow. If it was spilled directly into the borehole, it would likely travel down the depth of the hole, however it is anticipated that the bailer could be used to help recover this. Some may also evaporate.

Should the drill become stuck, one method to try and release it is the use of glycol in the borehole. Glycol will be on site as a concentrate and mixed with water to a dilution depending on the depth of the stuck drill. It is expected that 2 L of glycol -water mix will be used at a time. The glycol-water mix will be put into cut sections of polythene lay flat hose (as used for ice core storage) and placed down the hole and then broken in situ to release the glycol and unstick the drill. The sections of hose are then brought up with the drill once released and removed as waste. If the drill could not be released, the hose would still be retrievable.

Re-use of drilling fluid from the previous Sky Train ice rise project reduces the amount of new fluid required for this proposed work. Recovered fluid from this project can also potentially be reused in future work.

### 5.2.1 Environmental Aspects from Drilling and Use of Drilling Fluid

The aspects of drilling and using drilling fluid that may interact with the environment include:

- input and uplift flights of people and equipment;
- disturbance of the ice environment by drilling into firn and ice layers;
- potential loss of drilling fluid (Exxsol D60) to the environment (through firn layer, at base of borehole, or fissures in borehole wall);
- spillage of drilling fluid from a storage drum;

- release of glycol to the environment (failure of storage container or released to firn layer when deploying to borehole);
- emissions from generators;
- spills of fuels/oils (petrol, diesel, oils and lubes);
- transport and storage of ice cores; and
- loss of equipment, including as a result of drill failure/sticking.

## 5.3 Drilling Camp

The drilling camp is the main location for the project. Once identified, living accommodation, drilling and storage will all be located in an approximately 750 $m^2$ area for the duration of the work.

### 5.3.1 Environmental Aspects from Drilling Camp

The aspects from the establishment and operation of the drilling camp that will or may interact with the environment include:

- disturbance of snow and ice surfaces from setting up and living in camp;
- release of fuels/oils from cooking, heating and lighting equipment;
- release of fuels (petrol, diesel, oils, lubes) from skidoos, generators or snowblower;
- particulate emissions from generators, skidoos when used for moving equipment or personnel around camp, cooking and heating apparatus;
- potential inadvertent release of waste to the environment; and
- discharge of human liquid waste and sieved wastewater.

## 5.4 Firn-Air Sampling

Firn-air sampling will involve moving the shallow drill to a new location to extract air samples from the firn layer. The drilling will be to approximately 100 m in depth. One smaller (2 kVA) generator will be used to run this drill.

During this sampling it is expected that both the shallow and deep drills will be running at the same time.

### 5.4.1 Environmental Aspects from Firn-Air Sampling

The aspects from firn-air sampling that will or may interact with the environment include:

- moving the drill and personnel to the drilling location (likely via skidoo);
- surface disturbance from working around the drill;
- firn disturbance from drilling into the surface;
- potential for spills of fuel (petrol, oils and lubes);
- emissions from generator (running a second generator); and
- liquid human waste and sieved grey water discharge.

## 5.5 Testing of Borehole Properties

The borehole sampling uses the infrastructure and borehole from the main drilling project. Additional equipment will be deployed into the borehole, but there is no use of additional travel, generators, fuel, oil or lubes. Operations for this work will be maintained inside the drilling tent.

### 5.5.1 Environmental Aspects of Borehole Testing

The aspects from borehole testing that will or may interact with the environment include:

- Disturbance to borehole wall with probe testing wall properties.

## 5.6 Waste Management

In accordance with the provisions of Annex III to the Protocol, BAS have well-established procedures for separating and retrieving waste from the field to minimise releases to the environment.

Waste is separated into different waste types as it is generated during the fieldwork and is returned to Rothera.

Clean plastics, metals, glass, paper and other recyclable wastes are separated by type and stored appropriately.

Waste batteries, oils, chemicals, and other hazardous materials (where used) are returned to Rothera in suitable UN containers, ideally their original packaging, and clearly marked as hazardous.

Drilling fluid, recovered from the borehole, will be returned to the original drums, and removed from the site, either to Rothera for storage for a future drilling project, or to the UK for safe disposal.

Food and solid human wastes are returned to Rothera in UN plastic drums for incineration. Liquid human waste and sieved grey water are disposed of in the field and the location marked and recorded.

Medical and sanitary wastes are stored in yellow bags, and then added to the human (solid) waste drum for incineration.

Clean separated waste is stored in vented and topped fuel drums for ease of storage and transport.

Any waste that will be disposed of in the UK by a licensed waste contractor will meet the requirements of the Waste (England and Wales) (Amendment) Regulations, 2014, the Duty of Care Regulations, 1991, and the Hazardous Waste Regulations, 2005.

Any waste materials from the drilling camp, such as wooden flooring and drilling fluid will be reused where possible.

### 5.6.1 Environmental Aspects from the Generation and Management of Waste

The aspects from the waste generation and management that will or may interact with the environment include:

- the potential release of waste materials to the environment if inadequately managed; and
- the potential mis-consignment of waste, incorrect segregation of waste, mixing of hazardous with non-hazardous waste.

## 5.7 Fuel Management

A storage depot will be located close to the camp, which will house any fuels, oils, lubes, equipment, generators, the snowblower and the skidoos when not in use. Fuels are needed for the drill generators, auxiliary generators and skidoos, as well as life support functions such as cooking.

Burning of fuel contributes to greenhouse gas emissions, and BAS carbon calculations (see Section 8.5).

The anticipated variety and quantity of fuels, oils, lubes and chemicals onsite include:

- Drilling fluid – 59 barrels (205 L barrels = 12,095 L);
- Petrol – 42 barrels (36 for drilling, 4 for skidoos and life support) (205 L barrels = 8,610 L);
- Glycol concentrate– up to approximately 165 L, stored in 5 x 25 L drums, and 2 x 20 L jerry cans, (to be diluted prior to use);
- Grease – 3 kg tub – general; 1kg tub – silicon; 4x100 ml lubricating grease tubes;
- Oil – generators and skidoos – 3 L;
- Kerosene for primus cooking stoves and Tilley lamps – approximately 6 x 25 L jerry cans.
- Diesel for snowblower – approximately 4 x 25 L jerry cans.

All fuel use will be recorded in a fuel log detailing volume and type of fuel used.

Skidoos and the snowblower are refuelled directly from jerry cans.

### 5.7.1 Environmental Aspects from Fuel Handling

The aspects from fuel handling and storage that will or may interact with the environment include:

- release to ice or snow environment due to spills (e.g., barrel failure);
- release to the environment due to operational failure (e.g., fuel movement/refuelling); and
- release to the environment due to equipment malfunction.

## 5.8 Overwintering Depot

Drilling equipment will be overwintered at the drilling camp for one winter, 2025; all equipment and fuel/fluid that is remaining after the first season is expected to be overwintered.

Depot set-up will be in 'depot lines' where the equipment is re-packaged into boxes, boxes are lined up and flags are placed around them to indicate their location. Berms will not be constructed at this location. However, should site C6 be chosen, it is possible the 'Tractor Traverse' may access this location, and therefore there would then be an option of having an overwintering berm constructed by a ‘Pisten Bully’, which is part of the ‘Tractor Traverse’, the BAS logistical and science support vehicle (note that this is the only location where this may be an option, though unlikely).

It is expected that the skidoos will be returned to either Sky Blu or Rothera and overwintered there.

Every effort will be made to remove waste items at the end of the season, but if for some reason this is not possible, some waste items may be overwintered at the depot.

### 5.8.1 Environmental Aspects from Overwintering Depot

The aspects from establishing an overwinter depot that will or may interact with the environment include the potential:

- loss of items (e.g., equipment, fuel) to the environment if they cannot be relocated the following summer season;
- direct release of drilling fluid/fuels to the snow/ice environment if drums leak during the winter period; and
- for leaks if snowblower/skidoos are stored overwinter.

## 5.9 Biosecurity

Biosecurity can be an issue when projects move equipment around Antarctica, or around the globe due to similar work happening in different regions with the same equipment. The equipment for this project was previously proposed to be used at the Indian base, Maitri, and was shipped and stored there for a season.

When that project did not proceed, the equipment travelled to Cape Town, South Africa, where it was also stored, before being transported to the UK, from where it will travel onward to Rothera, ready for deployment to the proposed site.

As with all cargo that leaves the UK for Antarctica, biosecurity checks will be carried out prior to the equipment boarding the SDA. This check is essential to ensure that the equipment does not contain any plant material such as seeds, roots, leaves, or any animals, such as spiders, rodents, and flies. Introduction of any non-native species to Antarctica has the potential to cause a substantial environmental impact.

The BAS Biosecurity Regulations manage the Biosecurity risk when working in Antarctica, for cargo and personnel luggage. The most relevant section to this project is *Section 10 – Field Work in Antarctica and South Georgia*, which is included as Appendix 2.

### 5.9.1 Environmental Aspects from Poor Biosecurity

The aspects associated with poor biosecurity practices include:

- introduction of non-native species – altering the biodiversity and potentially outcompeting native species.

# 6 Alternatives

The EIA process needs to consider alternatives in order to identify the optimal way of meeting the need and purpose of the proposal, by enhancing the environmental benefits of the proposed activity or by reducing or avoiding potentially significant negative impacts.

Due consideration of alternatives ensures that the EIA is not simply defending a single project proposal. Instead, the EIA provides the opportunity for an unbiased, proactive consideration of options.

Examples of alternatives include use of different locations or sites for the activity; opportunities for international cooperation; use of different technologies in order to reduce the outputs (or the intensity of the outputs) of the activity, and different timing for the activity.

The alternative of not proceeding with the proposed activity should always be included in any analysis of environmental impacts of the proposed activity (CEP EIA Guidelines, 2016).

This chapter describes the alternatives that have been considered as part of the proposed drilling activities.

## 6.1 Do Not Drill: 'Do Nothing' Alternative.

Not having a drilling project would assist in maintaining perceptions of Antarctic wilderness.

However, this option would be contrary to BAS' vision of being a world-leading centre for polar science and polar operations. It would also severely curtail the UK's ability to undertake globally relevant scientific research, particularly research aimed at understanding Antarctica's response to changing climate conditions, including the behaviour of Antarctica's ice sheets under warming conditions.

This alternative has been considered and rejected on the grounds of the predicted value of the information from the ice core record that will be gained from carrying out the project, continuing a long history of valuable scientific ice core research.

## 6.2 Drill Elsewhere in Antarctica

This alternative has been considered and rejected on the grounds that the Antarctic Peninsula ice sheet has been selected as one of the best sites for obtaining a high-resolution climate record of this region.

Previous ice cores on the Antarctic Peninsula, and aerial imagery, combined with annual snow fall, indicate that there is deep ice in the region proposed by this project, and therefore a more complete climate record is possible from this location than others in Antarctica.

# 6.3 Use Alterative Drilling Technologies

During this assessment, two alternative drilling technologies have been considered.

## 6.3.1 Thermal Drilling

This alternative has been considered and rejected on the grounds that it:

- may result in a poor-quality ice core; and
- is more energy intensive than electromechanical drilling.

Thermal drilling replaces the cutter head, as used in an electromechanical drill, with an annular ring of electrically heated wires that melt an annulus of ice. The melt water is mixed with antifreeze and drawn away from the head of the drill into a chamber. Using thermal drilling, the borehole must also be filled with bulk drilling fluid to avoid hole closure. Thermal drilling usually requires a strong ethylene glycol mixture, or pure ethanol, as the drilling fluid.

The major scientific disadvantage of thermal drilling is the thermal shock applied to the ice core, which initiates the cracking of the ice, damaging the core, and commonly soaking the core with contaminated liquid which is miscible with the ice. This can result in a poor-quality ice core, which will compromise the quality of the chemical analysis, and hence the climate record, obtained.

Thermal drilling is also more energy-intensive, requiring greater quantities of fuel, with a resulting increase in atmospheric emissions and the deposition of particulates in the immediate surface snow layer, while returning a scientifically compromised ice core that is unlikely to meet the quality criteria for the range of analyses planned.

A poor-quality ice core, and the energy intensive nature of thermal drilling, mean that this technique is now rarely used in Antarctica where an ice core is to be recovered.

## 6.3.2 Alternative Drilling Fluid

This alternative has been considered and rejected on the grounds that:

- some alternative drilling fluids may pose a risk to human health or well-being;
- some alternative drilling fluids may pose a fire hazard.

Use of an inferior substitute could result in the loss of the drill, which would compromise the scientific objective of the project.

The main purpose of the drilling fluid is to prevent the closure and sealing of the borehole due to the plastic deformation of the surrounding ice (ice is always moving to some extent), while allowing the drill to recover cores of sufficient quality for analysis. The fluid density must match as closely as possible to the density of pure ice, be liquid at ice sheet temperatures, immiscible with ice and of low viscosity to allow passage of the drill in the borehole. It is also required to transport the ice chips away from the drill head.

Bulk drilling fluids that have been used in the past include n-butyl acetate (possibly with the addition of a hydrochlorofluorocarbon [HCFC] densifier) and Exxsol D30 or D60 petroleum-based solvents, also with the addition of an HCFC densifier.

Talalay and Gundestrup (1999) have reported on the possible health effects associated with the use of n-butyl acetate as a bulk drilling fluid. It is toxic and can cause eye irritation, narcosis and further effects on the nasal and respiratory systems. It is also teratogenic (i.e. causing embryonic malformation). It has therefore been assessed by BAS that the risk to human health is too great to use n-butyl acetate as a drilling fluid.

Exxsol D30 or D60 do not have significant health risks associated with them but do normally require a significant quantity of densifier (up to 30%).

Densifiers are used to raise the density of the bulk fluid to match the ice density (0.917 Mg m–3) – critical in preventing borehole closure. The densifier identified as most suited to ice drilling is HCFC-141b, an Ozone Depleting Substance (ODS) which has an Ozone Depleting Potential (ODP) of 0.11. This substance was used for the Berkner Island deep ice core drilling programme. However, the use of a densifier has been rejected in this project in favour of a shallow column of pure D60 –the inevitable borehole closure is acceptable providing the deep drilling portion of the project can be completed in a single season, as proposed.

In Greenland, a new class of drilling fluid based on a coconut oil extract has been used in a recent drilling project, but it was left *in situ* in the borehole at the end of drilling. The oil does not evaporate and is difficult to clean from the cores, and from the clothing of the drillers. This option has been considered but it was rejected for the Antarctic Peninsula project in favour of the D60 (without the HCFC densifier) as we consider that the use of an existing stock of D60 recycled from the Sky Train drilling project, and then the recovery of the fluid from the borehole, leaves a lesser environmental impact. D60 is also substantially easier to work with in a BAS field camp environment were washing clothes and routinely taking showers is difficult (these are the normal procedures when using the newer coconut oil extracts in Greenland drilling projects).

## 6.4 Summary

BAS will continue to consider environmental impacts of drilling ice cores in Antarctica. However, given the alternatives considered, it accepts that the proposed *REWIND* project techniques are the most appropriate in this instance.

# 7 Current Environmental State

A thorough understanding of the pre-activity (or current) state of the environment is an essential basis for predicting and evaluating impacts, and for identifying relevant and effective mitigation measures.

The EIA process requires consideration of the environment including relevant physical, biological, chemical and anthropic values in the area where, and when an activity is proposed, and that the proposed activity might influence.

This chapter describes the nature and characteristics of the Antarctic Peninsula ice sheet where the planned drilling activities will occur.

## 7.1 The Physical Environment

The Antarctic continent is divided into East and West Antarctica, both of which are covered by ice. West Antarctica, to the west of the Trans-Antarctic Mountains, covers an area of approximately 1.97 M $km^2$. The Antarctic Peninsula is situated in West Antarctica.

The proposed ice core site is at one of the highest points of the Antarctic Peninsula ice sheet, and is located approximately 38 km from the nearest ice-free ground.

The proposed site is slightly domed, being a high point, slow moving and free of features, which is desirable for ice core drilling. All glaciers flow, but a slow moving one retains its characteristics longer, holding the bubbles of historical air in the ice for longer. The proposed site is roughly in the middle of the ice sheet, which is the slowest moving section.

The proposed project site is in an area of high snow fall and accumulation, with no crevassing or fissures in the ice (both of which would indicate fast moving ice).

The ice sheet is flowing in a general direction towards the English Coast, but at such a rate that it would currently take 100,000s of years for the location of the proposed drilling location to reach the ice face.

For the Antarctic Peninsula, the basal temperature is calculated to be close to -20°C (using an ice sheet model of heat flux, based on the surface temperature and accumulation, ice thickness and basal geothermal heat flux) and therefore current knowledge indicates that no liquid water hydrological system is present beneath the ice sheet that could be contaminated and disperse any liquid remaining in the borehole. The base of the ice sheet is approximately 166 m above sea level, so no immediate interaction with sea water is predicted. Once the geophysics radar surveys are complete, the project team will be able to confirm this state, as other modelling, shown in Figure 14, indicates there is potential for under ice flow in the vicinity of the proposed project. If under ice flow is found, these areas will be avoided by the drilling team.

For ice free ground, the proposed drill site is closest to the Sky Hi Nunataks, near the Sky Blu depot. These features will be approximately 38km from the proposed drilling sites (depending on the final location). A Nunatak is described by Britannica (2024) as '*an isolated mountain peak that once projected through a continental ice sheet or an Alpine-type ice cap'.* The Sky Hi Nunatak is likely to be the closest area with the potential for terrestrial biological communities.

Eric Rignot et al. (2011) developed mapping showing ice velocities in 2007-2009 and showing how the Antarctic continent today is drained by ice streams, with tributary glaciers reaching hundreds to thousands of kilometres inland. These dendritic drainage systems pass ice from the interior, near the ice divide, and flow into the ocean or ice shelves (Davis, 2024a).

Figure 14 highlights the area around the proposed geophysics and drilling site. As this shows, it is possible that the geophysics surveys will identify ice streams around the proposed drill locations.

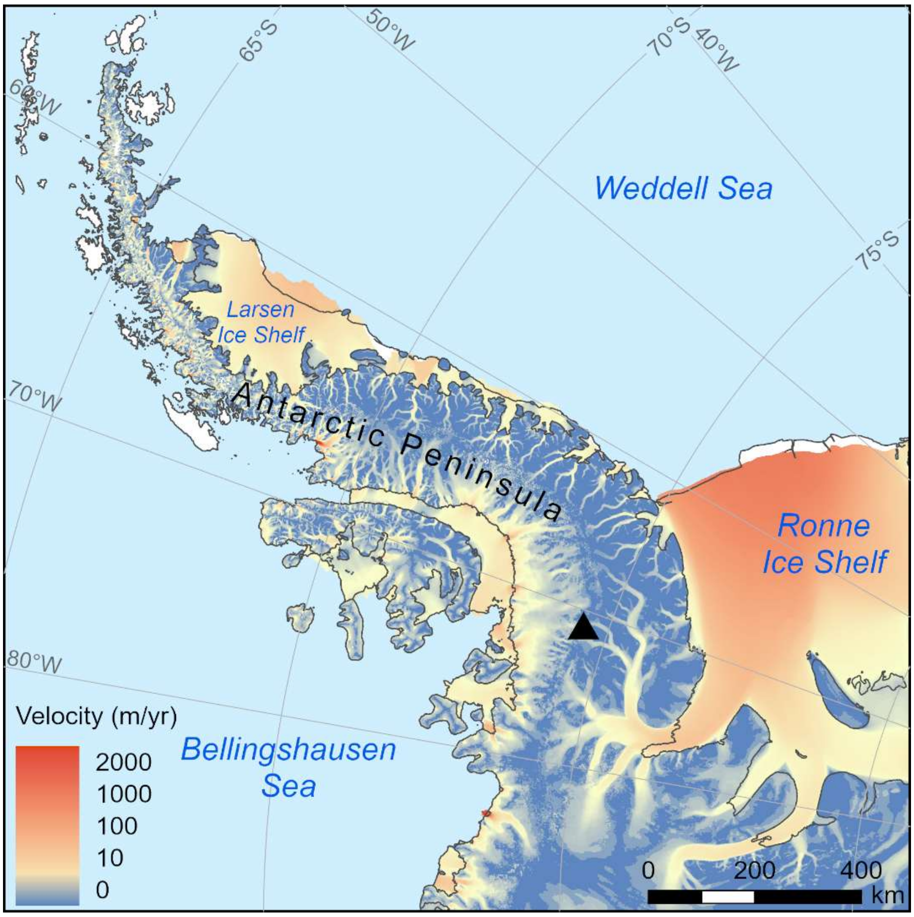


*Figure 14: Ice Flow Velocity Around the Proposed REWIND Project Site. Produced by the Mapping and Geographic Information Centre, British Antarctic Survey, 2024.*

Although there is no record of subglacial lakes in the region of the proposed project, (marked with a black triangle on Figure 14), the potential presence of ice streams provides a potential conduit for any releases of fluids to reach the ocean.

## 7.2 Environmental Domains

Environmental Domains are a system for classifying or organising subsets of environmental and geographic characteristics such as different types of ecosystem, habitat, geographic area, terrain, geology, and climate into environmental or geographic regions. Each region is distinctive or in some way different from other regions, but some might have characteristics in common (Morgan et al., 2007).

The proposed project site (shown as the black triangle on Figure 15 below) fits into Environment M – 'Continental mid-latitude sloping ice'.

Environment M (light blue) is an expansive ice sheet environment that covers four distinct areas, all focused around the 75°S parallel. Environment M (902 626 km$^2$) is the sixth largest on the continent. The environment consists entirely of ice sheet and contains no mapped geology. Climatically the Environment is cool in comparison to the other Environments. Environment M is the ninth coldest in average air temperature (–22.76°C) and the seventh largest seasonal range (–20.62°C). The average wind speed within the Environment is moderate, ranking 12$^{th}$ out of 21 environments (12.14 m/sec). The Environment is not steep with an average slope of only 7.38°. Well-known locations Environment M encompasses include David and Lambert Glaciers, Maudheimvidda, Coates Land, northern Berkner and Roosevelt Islands and Ellsworth Land (Morgan et al. 2007).

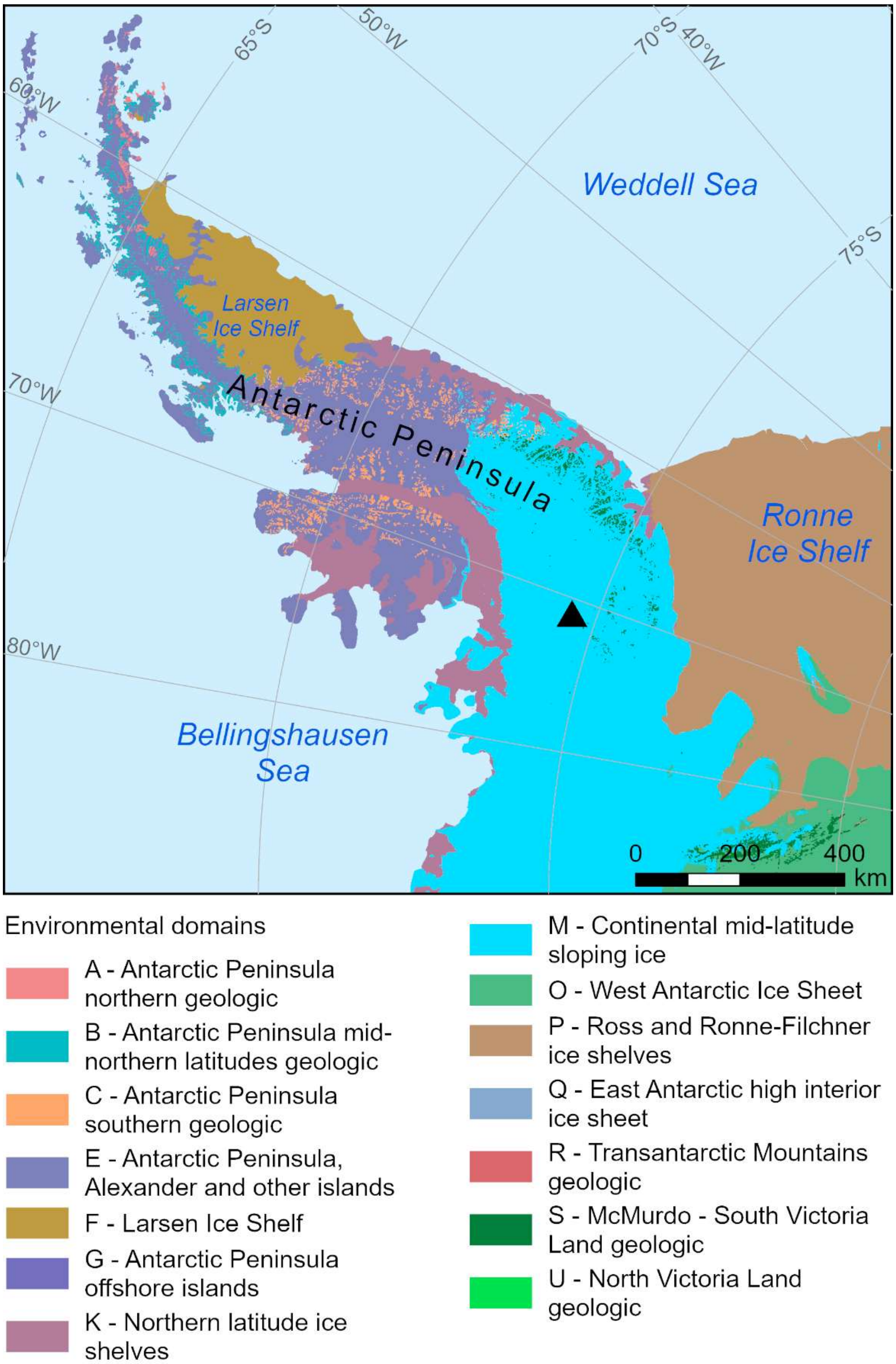


*Figure 15: Environmental Domains. Produced by the Mapping and Geographic Information Centre, British Antarctic Survey, 2024.*

# 7.3 Antarctic Conservation Biogeographic Regions

The use of quantitative analyses to combine spatially explicit Antarctic terrestrial biodiversity data with other relevant spatial frameworks has identified 16 biologically distinct ice-free regions encompassing the Antarctic continent and close-lying islands within the Antarctic Treaty area (Terauds and Lee, 2016). ACBRs are used in conjunction with the Environmental Domains, as shown in Section 7.2, to give a full picture of properties and species of the different areas of Antarctica.

The proposed project (see black triangle in Figure 16) would be located in or close to Antarctic Conservation Biogeographic Region (ACBR) 15, South Antarctic Peninsula (depending on the final coordinates, but would remain approximately 38 km from the ice-free ground).

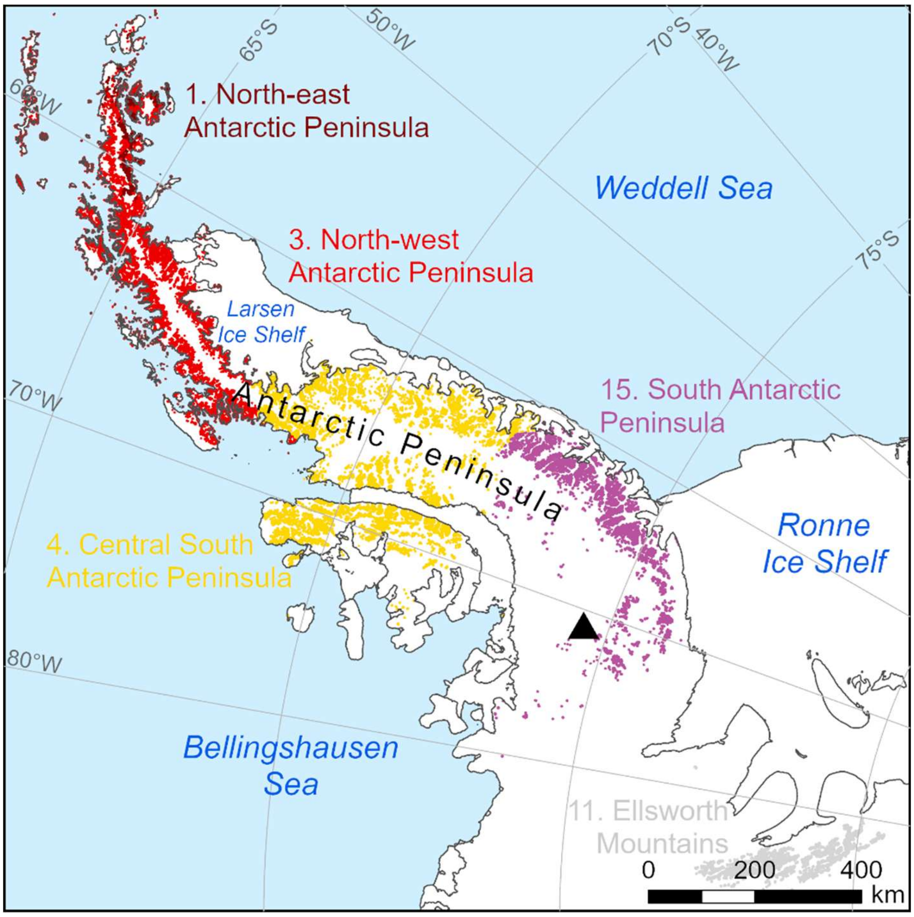


*Figure 16: The Antarctic Conservation Biogeographic Regions. Produced by the Mapping and Geographic Information Centre, British Antarctic Survey, 2024*

While ACBR 15 captures the ice-free area at Sky Hi, there are no ice-free areas at the proposed project site. Therefore, while ACBR 15 is the closest Biogeographic Region to the proposed site, it does not share the ice-free areas focused on in this classification.

# 7.4 Climate

Antarctica is the coldest and driest continent on Earth. Across the continent, high elevations, the prolonged absence of sun, and the high albedo of the ice surface account for low temperatures, and reduced precipitation through the low moisture-holding capacity of the air.

Antarctica's average annual temperature ranges from about −10 °C on the coast to −60 °C at the highest parts of the interior. West Antarctica is generally warmer than East Antarctica due to its lower elevation (Figure 17).

Antarctica's environment has special conditions that make it the windiest continent on Earth. Antarctica is usually surrounded by a belt of low pressure which contains multiple low centres. This is called the 'circumpolar trough'.

Low-pressure systems near the coast can interact with katabatic winds to increase their strength. Resulting wind speeds can exceed 100 km/h for days at a time and wind gusts well over 200 km/h have been measured.

The dry, subsiding air over the interior of Antarctica creates little cloud. Around the coast, however, more moisture is available and low-pressure systems have a greater influence. This means that cloudy conditions are more common near the coast, particularly in the region of the Antarctic Peninsula.

Rain has been observed near the coast, but most precipitation over Antarctica is in the form of snow or ice crystals.

Windy conditions make it difficult to measure snowfall accurately. The average accumulation of snow over the whole continent is estimated to be equivalent to about 150 mm of water per year. Over the elevated plateau, the annual value is less than 50 mm. Near the coast, it generally exceeds 200 mm, the heaviest being over 1,000 mm for an area near the Bellingshausen Sea.

The proposed project site, located in Palmer Land on the Antarctic Peninsula has a relatively high snow fall, which makes it ideal for high resolution ice core records looking at climate change.

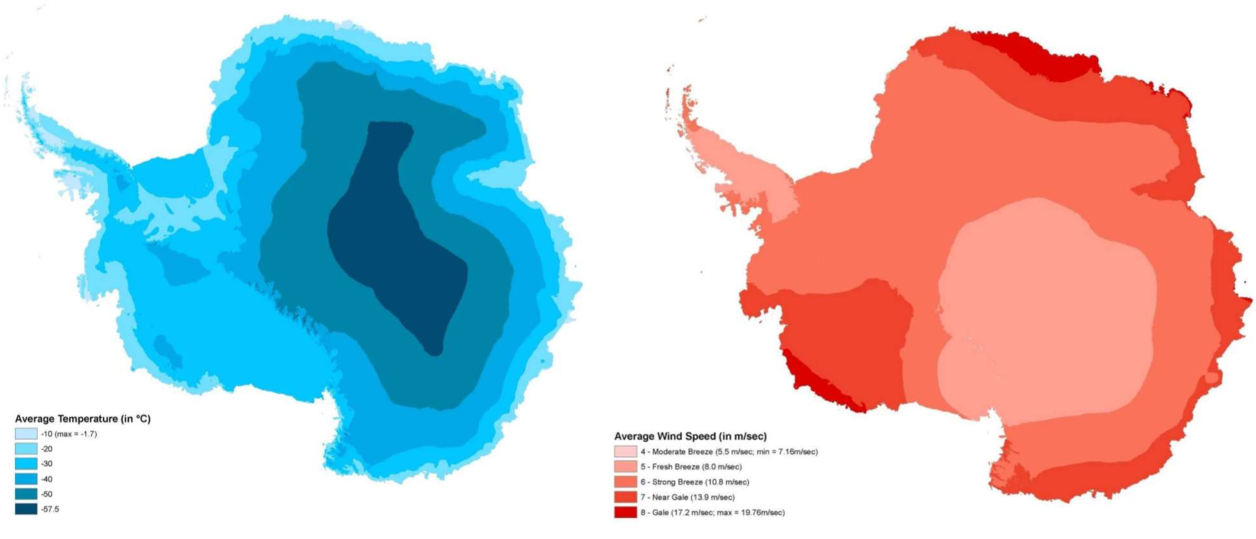


*Figure 17: Mean Temperatures and Wind Speeds Across the Antarctic Continent (Source: Morgan, 2007).*

# 7.5 Glaciology –Antarctic Peninsula Ice sheet

The proposed drilling location is located on the Antarctic Peninsula Ice Sheet, in West Antarctica.

The Antarctic Peninsula (see Figure 18) is a relatively long, thin spine alpine mountain chain. These mountains extend north towards the Drake Passage, reaching 63°S. The Antarctic Peninsula is approximately 70 km wide, with an average height of ~1500 m. It is 522,000 km$^2$ in area and 80% ice-covered.

The Antarctic Peninsula Ice Sheet is approximately 500 - 800 m thick, with outlet glaciers flowing out east and west. Summer air temperatures are greater than 0 °C at sea level, and the mass balance of Antarctic Peninsula glaciers is largely controlled by surface melting and glacier calving.

Many of these tidewater glaciers are grounded, particularly on the north-western Peninsula. However, there are large ice shelves fringing the Antarctic Peninsula south of 68°S in the east and 70°S in the west (Davis, 2024b).

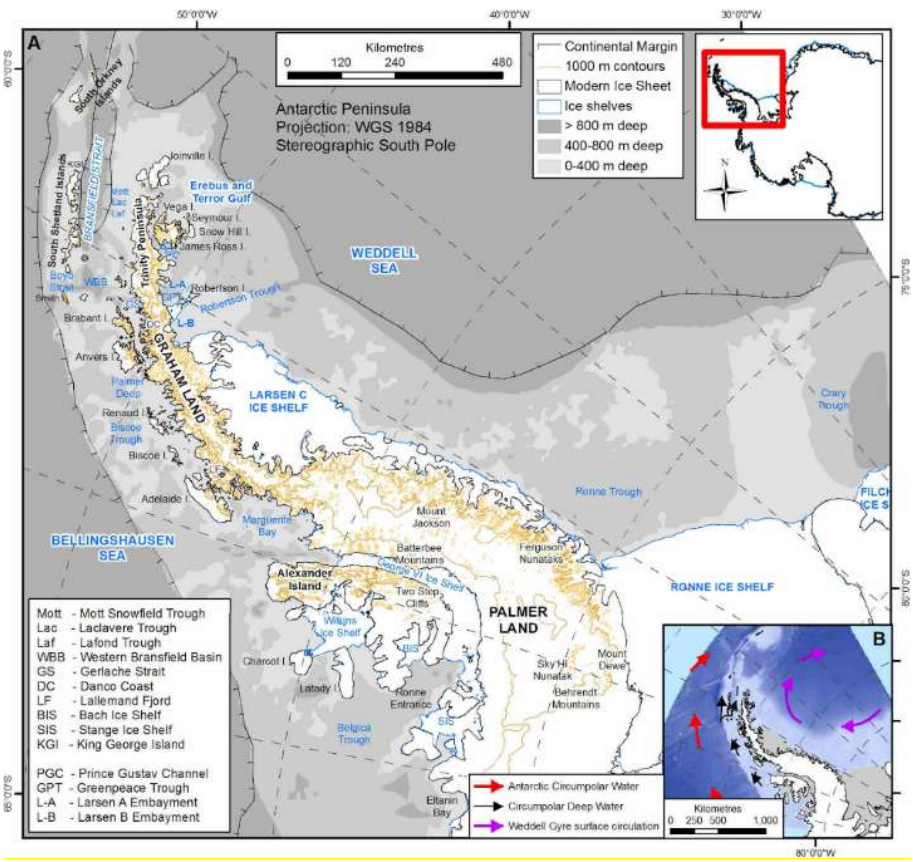

*Figure 18: Map of the Antarctic Peninsula, after Davies et al., 2012 (Quaternary Science Reviews) (Source: https://www.antarcticglaciers.org/antarctic-peninsula-2/).*

## 7.6 Ice Free Areas

The operational area for geophysics and drilling activities is constrained to snow- and ice-covered terrain. The closest Ice-Free area is near the Sky-Blu depot, approximately 38km (depending on the final location chosen) from the drilling location.

The Sky Blu natural blue ice runway is formed by the wind coming off an adjacent nunatak and scouring off the overlying snow. The presence of this blue ice runway is the primary reason for the Sky Blu depot location.

The Sky Hi Nunataks have lichen, some microinvertebrates and microorganisms present. However, the proposed project will not be visiting any ice-free areas.

## 7.7 Wildlife

With a few exceptions (i.e., seabird breeding colonies located inland from the coast), the majority of Antarctic wildlife is constrained to coastal ice-free regions with inland areas of the ice sheet supporting very little life other than microbial communities in some locations (Anesio et al, 2017). As the proposed project is near the centre of the ice sheet, no wildlife interactions are likely for the duration of the work.

### 7.7.1 Important Bird and Biodiversity Areas

Important Bird and Biodiversity Areas (IBAs) represent identified significant bird breeding (as opposed to foraging) locations (Figure 19).

The closest IBA to the proposed project is AQ203, Sims Island, which is designated for its seabird concentrations, particularly Adélie penguins. This IBA is 275 km from the proposed project area. AQ100, on the Smith Peninsula, which is designated for emperor penguins, is 298 km from the proposed *REWIND* project (ATS, 2024d).

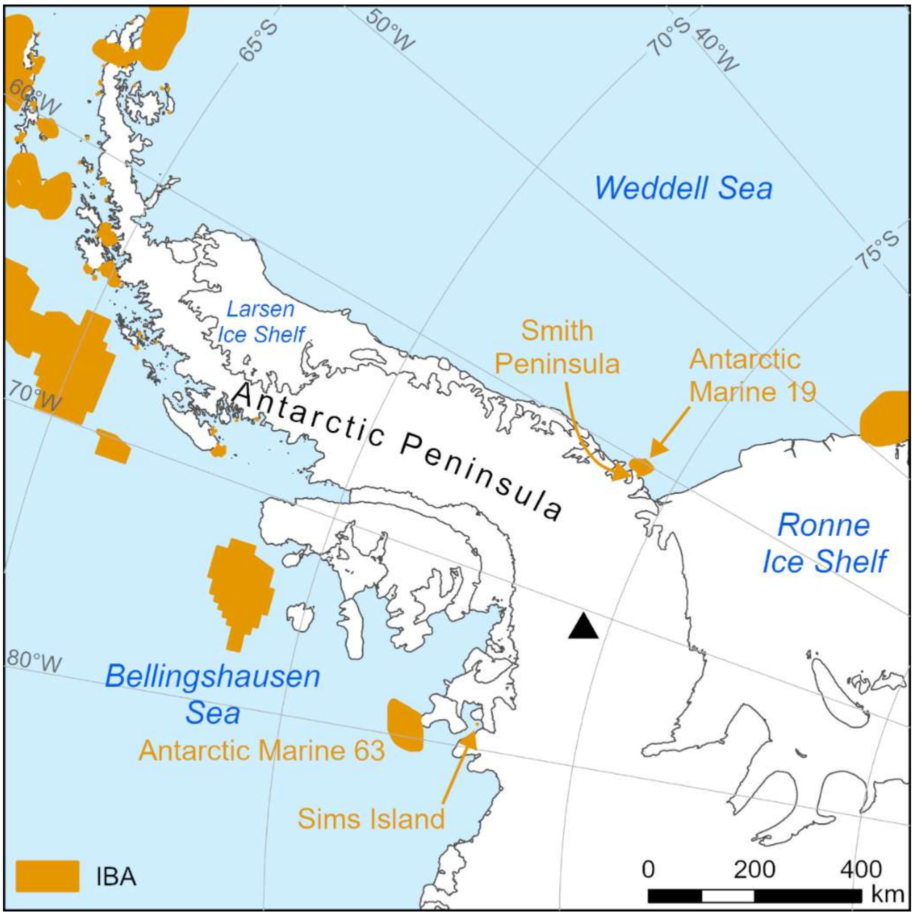


*Figure 19: Important Bird and Biodiversity Areas (IBAs), Showing those Closest to the Proposed REWIND Project Site. Produced by the Mapping and Geographic Information Centre, British Antarctic Survey, 2024.*

# 7.8 Protected / Managed Areas and Historic Sites

Antarctic Specially Protected Areas (ASPAs), Antarctic Specially Managed Areas (ASMAs) and Historic Sites and Monuments (HSMs) can be established under the provisions of Annex V to the Protocol.

## 7.8.1 Protected Areas

An Antarctic Specially Protected Area (ASPA) can be designated to protect outstanding environmental, scientific, historic, aesthetic or wilderness values, any combination of those values, or ongoing or planned scientific research (ATS, 2024a).

The nearest ASPA to the planned activities is ASPA 147 Ablation Valley and Ganymede Heights, Alexander Island (ATS, 2024b) (see Figure 20). ASPA 147 is located off the western coast of Palmer Land and is one of the largest ice-free ablation areas in West Antarctica; however, it is 412 km away from the proposed activities.

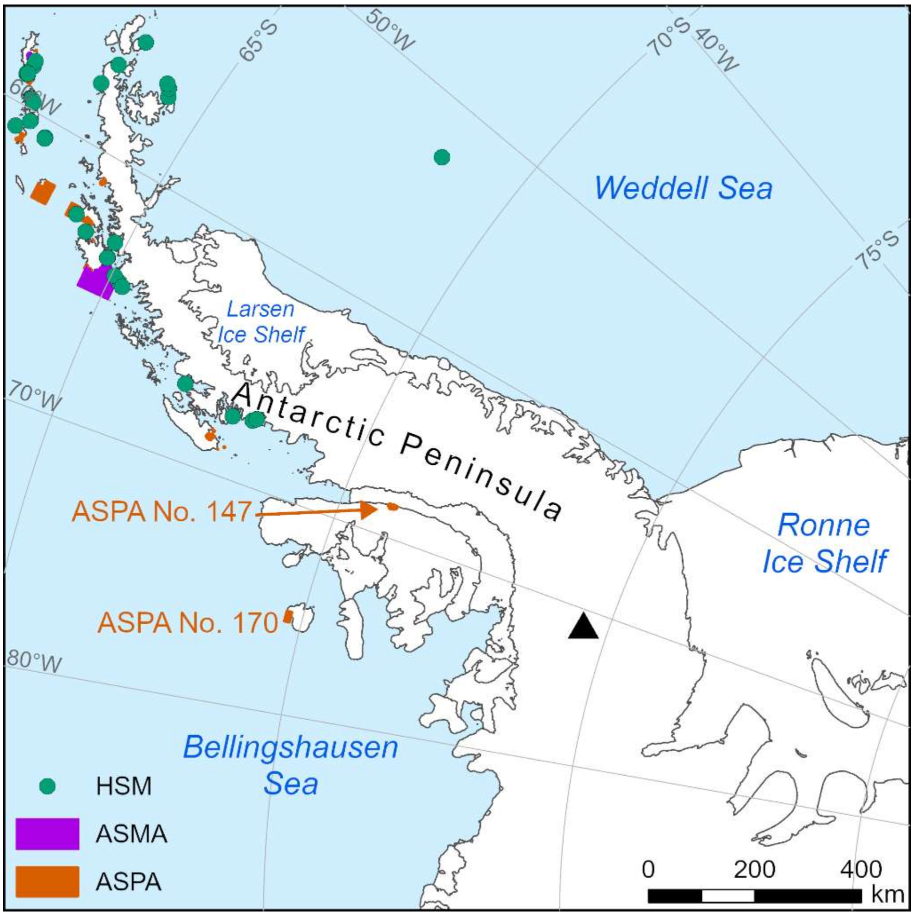


*Figure 20: Antarctic Outline Showing the Location of Designated ASPAs, as Orange. Pink Squares Represent ASMAs, and Green Dots are HSMs. Produced by the Mapping and Geographic Information Centre, British Antarctic Survey, 2024.*

### 7.8.2 Managed Areas

An area where activities are being conducted or may be conducted in the future may be designated as an Antarctic Specially Managed Area (ASMA), to assist in the planning and co-ordination of activities, avoid possible conflicts, improve co-operation between Parties or minimize environmental impacts (ATS, 2024a).

The nearest ASMA is located at Southwest Anvers Island and Palmer Basin (ASMA 7) (ATS, 2024c) (see Figure 20). ASMA 7 is 1,072 km from the proposed activity.

### 7.8.3 Historic Sites or Monuments

There are no HSMs close to the planned drilling activities (Figure 20). The closest HSM is Base E Stonington Island, which is 723 km away. No Historic Sites and Monuments (HSMs) will be visited by the proposed drilling project.

# 7.9 Human Activity and Antarctic Wilderness

Leihy et al. (2020) estimated that 99.6% of the Antarctic continent can still be considered wilderness, but pristine areas, free from human interference cover a much smaller area (less than 32% of Antarctica) and are declining as human activity escalates (Figure 21).

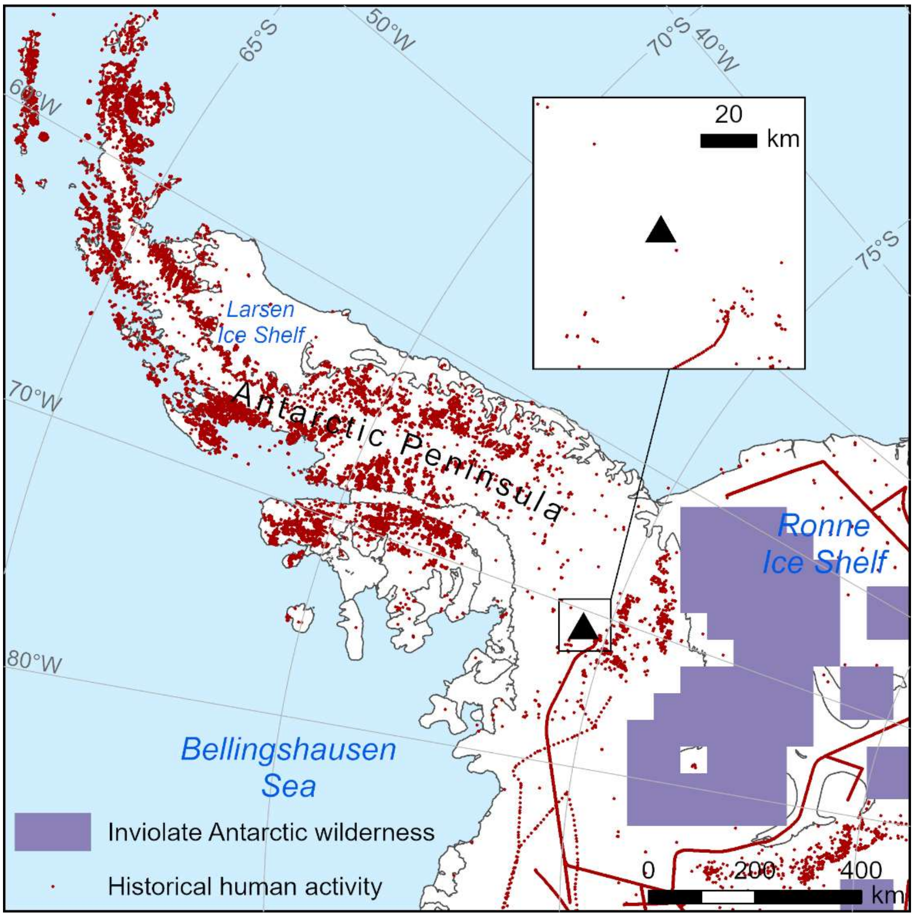


*Figure 21: Inviolate Wilderness Areas, Showing Human Activity in the Region of the Proposed REWIND Project Site. Produced by the Mapping and Geographic Information Centre, British Antarctic Survey, 2024.*

The proposed drilling activity is approximately 38 km from the Sky Blu depot (marked with the black triangle), and has had previous human activity in the region, as can be seen indicated in red on Figure 21 above.

Sky Blu started operating in 1995 and is a busy summer only field refuelling depot. In the 2023/24 season there were 176 aircraft movements at Sky Blu, which is average for a season.

Sky Blu is used by aircraft transiting to deep field locations. In a similar manner to Rothera Research Station, it is also used by international teams for refuelling.

# 8 Assessment of Environmental Impacts

Having described the nature and scale of the proposed activity and reviewed the current environmental state, this chapter assesses the actual or potential impacts that will, or could, occur as a result of the proposed drilling activities.

Consideration is also given here to the cumulative impacts of the planned activities in conjunction with other past, current, and reasonably foreseeable activities in the region.

## 8.1 Methods and Supporting Information

The actual or potential environmental impacts of the activity are assessed by means of a four-step analysis involving:

1. identifying the **aspects** i.e., the physical change imposed on, or an input released to the environment as the result of an action or activity such as emissions, dust, mechanical action on the substrate, fuel spills, noise, light, wastes, heat, introduced species, etc., arising from the proposed activities described in Chapter 4;
2. identifying the **exposure** i.e., the interaction between an identified potential output and the environment including flora and fauna, freshwater, marine, terrestrial and atmospheric environments;
3. identifying the **impacts** i.e., the change in environmental values or resources attributable to the activity;
4. assessing the **significance** of the identified impacts by considering the spatial extent, duration, intensity and likelihood of occurrence of the potential impacts to each environmental element – with reference to the three levels of significance identified by Article 8(1) of the Protocol (i.e., 'less than', 'no more than', or 'more than' a 'minor or transitory' impact).

Information to support the impact assessment is drawn from a number of sources including academic literature, BAS on-line information and manuals, BAS experts, the Antarctic Treaty Secretariat website, and the SCAR website.

## 8.2 Environmental Aspects

As recorded above, an environmental aspect is a physical change (*e.g.,* movement of sediments by vehicle passage or noise) or an entity (*e.g.* emissions, an introduced species) imposed on or released to the environment as the result of an action or an activity (CEP EIA Guidelines, 2016).

For the purposes of this environmental impact assessment the proposed activities have been divided into the following elements:

- geophysics;
- drilling;
- drilling camp;

- firn-air sampling;
- borehole properties;
- over wintering Depot; and
- logistics.

The environmental aspects of these elements were highlighted in Chapter 5 and are summarised in Table 3. This table records that expected environmental aspects of drilling and geophysics activities will include atmospheric emissions, noise, heat, mechanical action on snow and ice surfaces as well as presenting a risk of fuel leaks, which will potentially generate hazardous waste.

Field camps will also produce atmospheric emissions, noise, heat and disturbance to snow and ice surfaces. Fuel spills may also occur at camp locations and camping activities will generate wastes including human waste, which includes the deliberate release of grey water and human liquid waste to the ice sheet.

The over-wintering of equipment, drilling fluid and fuel will result in disturbance to snow and ice surfaces for depot lines and poses the risk of accidental releases of fuel or loss of materials to the ice sheet if equipment cannot be recovered the following summer.

*Table 3: Summary of Environmental Aspects that will or could Arise from the Proposed Activities.*

| | Atmospheric emissions (burning fossil fuels) | Noise emissions | Heat emissions | Mechanical action (physical disturbance to substrate) | Fuel or hazardous substances release | Wastes (Including unrecoverable equipment) | Introduction of non-native species or relocation of native species | Presence / visual disturbance |
|---|---|---|---|---|---|---|---|---|
| **Geophysics** | ✓ Fuel burn in skidoos and cooking equipment | ✓ Use of skidoos | ✓ Skidoo engines and cooking equipment | ✓ Skidoo movement over snow, hand drilling | ✓ Potential for spills of fuels | ✓ Hazardous wastes if spills occur (spill kit), food and biological | ✓ Potential for introduction of species | ✓ Visual and audible presence of skidoos |
| **Drilling** | ✓ Fuel burn for generators | ✓ Noise of drill operations, snowblower use | ✓ Heat from generators | ✓ Drilling into surface and making ice core storage with snowblower | ✓ Potential for spills of drilling fluid and fuel | ✓ Potential for loss of drill, waste wood | ✓ Potential for introduction of species | ✓ Visual and audible presence of drilling |
| **Drilling camp** | ✓ Fuel burn for generators and cooking equipment | ✓ General camp operations and generators | ✓ From generators and cooking equipment | ✓ Setting up camp and walking around area | ✓ Potential for spills related to generators and cooking equipment | ✓ Food, wastewater and biological | ✓ Potential for introduction of species | ✓ Visible presence of camp |
| **Firn-air sampling** | ✓ Fuel burn in generator and skidoo | ✓ Noise of shallow drill operation | ✓ Heat from skidoo engine and generator | ✓ Drilling into firn layer, skidoo track | ✓ Potential for spills related to generator and skidoo | ✓ Hazardous waste if spills occur | ✓ Potential for introduction of species | ✓ Visual and audible presence of drilling |
| **Borehole properties** | No additional impacts identified | | | | | | | |
| **Overwintering depot** | ✓ Fuel burn associated with moving equipment into depot lines | ✓ Skidoo and snowblower use to make depot | ✓ From snowblower and skidoo use | ✓ Moving snow to make depot lines, installing flags | ✓ Potential for overwinter releases | ✓ Potential for flags (and depot) to be lost to environment | ✓ Potential for introduction of species | ✓ Visual presence of depot line |
| **Logistics** | ✓ Fuel burn from SDA[2] and Twin Otter aircraft | ✓ Noise of SDA and Twin Otters landing | ✓ Heat from engines of SDA and Twin Otters | ✓ Twin Otter landings on snow surface | ✓ Potential for fuel spills/hydraulic leaks | ✓ Potential for equipment loss | ✓ Potential for SDA to transport | ✓ Visual presence of ship and aircraft |

[2] SDA will be operating as part of regular operations, transporting equipment and personnel to Rothera. A portion of any potential impact is attributed to this proposed project.

A summary of identified environmental aspects include:

- input flights of personnel and equipment;
- skidoo, surveying, personnel movements, and drilling activities to the ice sheet surface;
- impacts of camp set up and living on the snow/ice surface (e.g., tent footprints and wastewater discharge);
- emissions from generators (petrol), skidoos (petrol), snowblower (diesel) and cooking equipment (kerosene);
- potential for spills of drilling fluid, fuel, and other liquids;
- transport and storage of ice cores;
- wastes produced by the project, and their transportation to Rothera;
- establishment of an overwintering depot line for equipment;
- potential for introduction of non-native species and biosecurity concerns;
- potential for lost equipment; and
- potential impact on wilderness values.

## 8.3 Environmental Exposures

Exposure is the process of interaction between an identified potential aspect and an environmental element or value (CEP EIA Guidelines, 2016).

The aspects described in Section 8.2 may interact with the environment in several ways. As described above, all geophysics and drilling activities will occur on snow or ice surfaces and away from ice-free areas and concentrations of wildlife.

The main environmental aspects are linked to the drilling operation, physically disturbing the ice and ice surface via drilling and skidoo movements and digging into the surface for ice core storage. The distances travelled during the geophysics surveys, and the presence of the field camp also have impacts on the ice and snow surfaces.

The use of drilling fluid for the deep drilling has associated risks of fluid loss, and having glycol on site in case of a stuck drill is also a risk.

Skidoo movements and use of generators (one large for deep drilling, and one small for shallow drilling and firn-air sampling) result in carbon emissions, potential for particulates and heat emissions. Carbon calculations are considered in Section 8.5.

Human presence in Antarctica inherently has visual impacts on the wilderness and aesthetic values of an area, with skidoo and drilling operations adding noise impacts. Human biological wastes are also produced and disposed of as appropriate according to waste type (liquid released to ice sheet, solid returned to Rothera).

When fuel and liquids (petrol, diesel, oils and lubes) are introduced to an environment there is a risk of spills and leaks, and if these are cleaned with spill kits then hazardous waste will have been produced (e.g., used spill absorbents) and will need storage and disposal.

Although considered of low likelihood, the loss of drilling equipment (including the drill itself, drilling fluid, or the location of the overwintering depot) is a risk, especially if there are changes to the field schedule and shorter seasons, or missing a season occurs.

Logistical activities are also considered; although the SDA is following routine operations, a portion of emissions and potential impact, such as impacts to marine life, would be attributed to this proposed project.

No exposures to, terrestrial or freshwater environments are identified from the proposed geophysics and drilling project.

## 8.4 Impacts and Mitigation Measures

This section reviews the potential environmental impacts that will or may occur to each of the identified environments as a consequence of the identified aspects and exposures recorded in Sections 8.2 and 8.3 above.

This impact assessment considers the potential worst-case impacts.

The actual or potential impacts are summarised in Table 11 (page 86) which assesses the level of risk associated with the actual or potential impacts according to the spatial extent, duration, severity and likelihood of the impact occurring.

The following predicted impacts and mitigating measures are based upon BAS experience of operating similar deep ice core drilling projects (for example, Berkner Island (2002-2006), James Ross Island (2007/08), Fletcher Promontory (2011/12), and Sky Train (2018/19)).

The following definitions are used to describe the different types of impact:

A **direct impact** is a change in environmental values or resources that results from direct cause-effect consequences of interaction between the exposed environment and an activity or action (e.g., decrease of a limpet population due to an oil spill, or a decrease of a freshwater invertebrate population due to lake water removal) (EIA Guidelines, 2016).

An **indirect impact** is a change in environmental values or resources that results from interactions between the environment and other impacts – direct or indirect (e.g., alteration in gull population due to a decrease in limpet population which, in turn, was caused by an oil spill) (EIA Guidelines, 2016). Indirect impacts may not be known until a direct impact occurs.

A **cumulative impact** is the combined impact of past, present and reasonably foreseeable activities. Cumulative impacts may occur over time and should be assessed by looking at other human activities occurring in the proposed locations. As with indirect impacts, cumulative impacts may not be identified until a direct impact has occurred (EIA Guidelines, 2016).

Cumulative impacts are considered in more detail in Section 8.6.

Mitigation is divided into categories as defined in the mitigation hierarchy, there are various versions of this wording depending on the industry, but in general the levels are:

**Avoid** – do not do the activity, and therefore there is no potential impact.

**Minimise** – make changes to the design, technologies used, or location chosen to reduce the amount of potential impact.

**Mitigate** – use technology, practices, and other methods to mitigate for the predicted impacts.

## 8.4.1 Impacts That Will or May Occur to the Glaciological Environment

Given that all activities associated with the proposed geophysics and drilling activities will be constrained to the ice and snow surfaces, the glaciological environment has the potential to be most heavily impacted.

Aspects that will or may give rise to impacts to snow / ice environments have been identified as:

a. particulates and other organic compounds released in exhaust emissions from skidoos, snowblower, generators, cooking and heating equipment settling on the snow and ice surface;
b. mechanical action and physical disturbance to snow and ice from deep and shallow drilling activities, the movement of skidoos, the creation of ice core storage, the formation of the overwintering depot, and from field camp operations;
c. potential for the accidental release of hazardous substances (e.g., drilling fluid, glycol, spills of fuel); and
d. potential for the accidental release of wastes and the deliberate release of human liquid waste and sieved grey water at field camp locations, as well as the risk of release of other items and equipment through accidental loss (e.g., stuck drill, loss of drilling fluid).

### *8.4.1.1 Release of particulates and organic compounds to the glacial environment*

***Impact description***

The burning of fossil fuels in skidoo engines, the snowblower and in generators will result in emissions to air of a range of gases as well as other compounds including volatile organic compounds, heavy metals and particulates such as black carbon (arising from incomplete combustion of fossil fuels).

Particulates, heavy metals and organic contaminants will deposit on and contaminate the local snow and ice surface with the spatial extent of deposition largely determined by wind conditions.

Long-range atmospheric transport and ocean current transport from other continents are generally considered to be the principal source of contaminants that can be detected in Antarctic snow and ice (Vecchiato et al., 2015; Cheng et al., 2013).

Contaminant concentrations in Antarctic snow and ice are generally low and have little direct impact other than providing evidence of human presence (Xie, et al., 2020). Black carbon deposited on snow and ice can decrease albedo and increase surface melting. However, concentrations of black carbon in Antarctic snow and ice are also generally very low (Kang et al., 2020).

The additional contributions to snow and ice contamination from the proposed *REWIND* geophysics and drilling activities are considered to be negligible.

***Impact type: Direct and Cumulative***

Particulate emissions to the snow and ice surface will be a direct source of contamination of the ice sheet and add to any contamination already captured by the ice from local and global sources.

***Treatment and Mitigation***

- Skidoo engines, snowblower and generators are regularly serviced and maintained to maximise efficiency of operation;

- Skidoo engines, snowblower and generators will be allowed a 'warm up' period prior to engaging any load;
- The fuel types selected are the most efficient for use in low temperature conditions;
- All fuel burning will be minimised to the extent practicable.

***Monitoring or Record keeping***

Snow and ice contamination levels are not proposed to be monitored as part of proposed geophysics and drilling activities.

Volumes and types of fuel uses will be recorded as part of BAS' annual fossil fuel and carbon emissions monitoring.

#### *8.4.1.2 Mechanical action and physical disturbance to the glacial environment*

***Impact description***

The surface of the ice sheet will be physically disturbed during geophysics and drilling operations in a number of ways, including from: drilling into the ice sheet; the movement of skidoos; the digging of snow to create ice core storage; formation of depot lines for overwintering equipment or to create trench for drilling; the movement of snow when establishing camps; and tracking caused by people walking around camp sites, and landing of aircraft.

Such physical disturbance will be temporary. The surface of the ice sheet is a highly dynamic environment as a result of ice movement, precipitation and wind action.

Accordingly, evidence of disturbance to the snow surface is likely to be erased in timeframes ranging from minutes to weeks depending upon the weather conditions – wind conditions, in particular. Wind flow across the ice sheets can attain hurricane force and blow for several days. Snow lifted from the surface and carried aloft by wind is known as drifting snow (snow transported at heights <2 m) or blowing snow (snow transported at heights >2 m) (Palm et al., 2018).

In some areas it is feasible that tracks made in the snow can become raised as a consequence of less tightly bound snow being blown away from the more compressed snow where tracks have been made. Eventually, the hardened snow will also be eroded, though this can take days or weeks depending upon conditions.

Evidence of the dynamic conditions can be seen when returning to raised berms when they are used to store vehicles and equipment overwinter on the ice sheet surface (Figure 22). Even when equipment and vehicles are stored on berms built up to three metres high, it has been known for them to be totally buried and vehicle cabs to be full of snow when returning the next season on some parts of the continent. While the proposed project plans to use depot lines instead of raised berms to overwinter their equipment (as berms require large equipment to build them), this illustrates the extent of moving snow and snowfall possible on the ice sheet.

No evidence was found during the preparation of this EIA of ice coring making an area unsuitable for future science or ice coring. In generally areas are explored and then a new area is moved to, so repeat coring is not known to be a regular activity. Therefore, it is unknown how removing an ice core would impact future work in the area, although due to the plasticity of ice in ice sheets, it is anticipated that the core borehole would quickly become indistinguishable from surrounding ice.

Consequently, the impacts for the ice sheet from the physical disturbance to otherwise highly dynamic snow and ice surfaces is considered to be less than minor and transitory.

***Impact type: Direct***

Disturbance will occur from skidoo tracks, walking around camp and setting up of tents, geophysics surveys, drilling and drilling infrastructure, and aircraft landings, though effects will be transitory.

***Treatment and Mitigation***

Keep movement around ice sheet and tent numbers to a minimum. Keep flights to a minimum.

***Monitoring or Record keeping***

Records will be maintained on geophysics survey routes and hand drill locations, shallow and consequently deep drill location, camp sites used, and locations used for over-wintering skidoos and equipment (although not specifically for the purposes of recording disturbance).

*Figure 22: Example of an Overwintering Berm for a Drilling Camp (Source: Liz Thomas).*

### *8.4.1.3 Accidental release of hazardous substances (fuel, oils, lubes)*

***Impact description***

Accidental releases of fuel, or other hazardous substance, could occur either when transferring the liquids between containers (e.g., during refuelling) or as a result of damage to equipment, or failure of a fuel drum or container.

The fate of fuel or other liquid substances accidentally released to the glacial surface will depend upon the nature of the snow or ice. Any liquid substances spilt on lightly packed snow or firn is challenging to recover. Liquids can penetrate quickly into the firn layer and their distribution will depend upon the conditions at the time. During warmer temperatures the ice is more porous, and liquids will flow quickly through the firn. Under colder conditions the ice is less porous and spilt fuel will migrate less (Raymond et al., 2017).

Due to drilling activities, a borehole will be present relatively close to fuels. Therefore, there is a low risk of spilt fuel entering a borehole, either from the top drilling opening, or laterally through the firn layer. The borehole would act as a conduit for fuel to penetrate deeper into the ice, however it is unlikely to leave the borehole and should be recoverable via the bailer system used to recover drilling fluid.

Any liquid substances spilt on to hard, blue ice, which is much less porous than snow or firn, may be easier to recover.

Unrecoverable liquids will remain in the snow/ice as a contaminant and will add to previous fuel spill events that have occurred in Antarctica. Contaminated sites could be detectable in any future scientific ice coring or sampling programme with negative implications for the research in question, though the likelihood of a glaciological research programme encountering a historic spill event is considered to be extremely low. Recording the location of the event is also important for this reason.

Any spill event is also likely to create hazardous waste items such as contaminated spill response equipment.

***Impact type: Direct and Cumulative***

Any hazardous liquid spilt on snow and ice will directly contaminate the area that it penetrates to.

If a spill event were to occur, any unrecoverable liquid will add to previous fuel spill events that have occurred in Antarctica.

***Treatment and Mitigation***

- Volumes of hazardous liquid substances, including fuel taken into the field, will be minimised to the extent that is safe and practicable.
- All fuel and other hazardous substances will be managed in the field in accordance with standard BAS procedures, as set out in the BAS Field Manual (Appendix 3).
- Hazardous liquid substances (fuel and oils) will have regular checks on the integrity of their drums and storage containers.
- Trained and experienced drillers will oversee equipment and manage snowblower, skidoo and generator refuelling activities.
- Maintenance of skidoos will be conducted by a vehicle mechanic.
- Fuel spill response training will be provided to those undertaking fuel handling in the field.
- Spill kits (containing suitable absorbents) will be readily available at locations where fuel is stored, transported or transferred. Any fuel (except petrol) spilt will be cleaned up to the extent practicable in accordance with the BAS Field Manual (Appendix 3). Recovered liquids and contaminated absorbents will be treated as hazardous waste and will be contained, marked as hazardous and transported to Rothera for appropriate handling and disposal in accordance with the Protocol.

***Monitoring or Record keeping***

Any fuel or other hazardous liquid substances spill event will be recorded and reported in accordance with BAS requirements, including volume and type of substance spilt, the location of the spill and the approximate volume that was recovered.

### *8.4.1.4 Accidental release of hazardous substances (drilling fluid)*

***Impact description***

The use of a drilling fluid is unavoidable if BAS is to successfully drill for an ice core of high scientific value (long record at high resolution). Exxsol D60 hydrocarbon mixture has been chosen for this project since the alternatives are more difficult to handle, and there are already stocks of D60 in Antarctica that have been recovered from earlier UK deep drilling operations at the Sky Train ice rise and can be reused in the proposed project.

There is particular concern when considering the use of Exxsol D60, at a depth of 600-800 metres below ice level, as this may result in chemical contamination of ice which may be long term (e.g. over many millennia) resulting in eventual release into marine environment of a small quantity of drilling fluid. However, the current speed of ice flow, and the position of the proposed drilling on the ice sheet indicates that it would be 100,000s of years before this ice flows to the ocean.

Accidental release of drilling fluid could occur while transferring liquid from containers to the drilling location, or as a result of damage to the container. Release could also happen if there is a fissure in the wall of the borehole, or if the drill reaches bedrock and fluid is released onto the rock, or into subglacial water. Although the presence of fissures, reaching bedrock, and the presence of subglacial waters are considered a very low likelihood due to site selection.

Based on previous experience, up to approximately 15% of drilling fluid will be lost to the environment during drilling activities due to the nature of drilling; however, modifications have been made to the bailer, so more recovery may be possible, with the aim of only 1% loss. Final quantities of drilling fluid used, and therefore the proportion likely to be lost, will only be known once the location has been finalised, and depth of drilling determined. The use of the BAS bailer will recover most of the drilling fluid, and some will evaporate. Fluid that is left in the borehole (unrecoverable) may migrate to the surrounding environment once the diameter of the borehole reduces over time and pushes any remaining liquid up to the firn layer. As Exxsol D60 is volatile, it is likely that if it reaches the top of the borehole, it would evaporate or disperse into the firn layer.

***Impact type: Direct and Cumulative***

Any hazardous liquid spilt on snow and ice will directly contaminate the area that it penetrates to.

If a spill event were to occur, any unrecoverable liquid will add to previous spill events that have occurred in Antarctica.

Spilled drilling fluid would pass quickly through the surface layer of snow. A small quantity may also evaporate.

***Treatment and Mitigation***

- The borehole will be closed at all times, other than during drilling, to reduce the evaporation of the drilling fluid.
- A centrifuge will be used in the drilling camp to recover and recycle fluid that is mixed with the drill chips, increasing potential recovery rates.
- BAS will attempt to recover 85-99% of the fluid column from the borehole once drilling is complete, using the BAS bailer. Up to 75 lifts with the bailer will be required to recover the fluid from the borehole, taking approximately four days. A recent modification to the bailer, allows recovery from the final 2 m of the borehole, which means more of the remaining liquid

in the borehole will be recovered. Assuming 12,095 L (59 x 205 L barrels) are used for this proposed project, this means 1% (or 120 L – approximately 60% of 1 barrel), to 15% (or 1,814 L– approximately 8 barrels) of drill fluid could be lost to evaporation and the environment (including being left in the borehole).

- If the bailer fails, there is a wooden bung with a valve that fits into the drill outer barrel and acts as a back up to the bailer.
- All recovered fluid will be stored in the drums used to deliver fluid to the field and flown to Rothera for further re-use in a future drilling operation, or for return to the UK for safe disposal.
- Oil spill equipment will be located near to the drill for use in event of drill fluid spill.

***Monitoring or Record keeping***

There is a risk that the borehole without the fluid will close more rapidly than anticipated. Whilst drilling, this can be overcome by re-drilling the particular section. However, when using the bailer (which is in the borehole in place of the drill), the borehole cannot be re-drilled.

Therefore, it will be necessary to carefully monitor the force required to move the bailer through the borehole. If the risk of losing the equipment becomes too high, bailing will stop immediately.

The amounts of drilling fluid used and recovered will be recorded.

Any spill of drilling fluid will be recorded through the BAS incident management system.

#### *8.4.1.5 Accidental and deliberate releases of wastes to the glacial environment*

***Impact description***

Any unrecovered items lost to the environment are likely to become buried in snow and lost to the ice sheet environment. Such items will gradually become encapsulated in the ice. This will have no immediate impacts on the ice sheet itself other than any local contamination that may occur. Over long timeframes (hundreds or thousands of years) such lost equipment will be transported to the Southern Ocean in accordance with natural rate of flow of the ice.

*Human waste and grey water*

BAS policy requires all solid human waste to be removed from the field. Plastic UN approved drums are provided for this purpose. Solid human waste is returned to Rothera for incineration. There is negligible risk of solid human waste being released to the glacial environment.

Liquid human waste will be disposed of to the ice environment.

Small volumes of sieved grey or wastewater will also be disposed of at field camp sites. Such grey water is generated from cleaning plates and dishes, brushing teeth, etc.

Human liquid waste and grey water will be disposed of to the ice/snow at identified and recorded locations. It is normal BAS practice to dig small pits for such disposal. The disposed liquid waste will melt into the ice pit, but quickly freeze over. Once the field camp is disestablished the pits will quickly fill in as a result of ice movement, precipitation and wind-blown snow.

*Food and general waste*

Food waste and general waste, such as food packaging, paper and glass as well as (potentially) some hazardous wastes such as medical wastes and batteries, will be generated at field camps and during drilling operations. If unmanaged, such items could be released to the glacial environment, where they are likely to blow around or become trapped in the ice causing localised contamination.

Annex III to the Protocol provides for Parties to reduce the quantity of waste produced and or disposed of in Antarctica in order to minimise any impact on the environment. Emphasis is placed on the storage, disposal and removal of waste from the Antarctic Treaty area, as well as recycling and source reduction.

BAS complies with the requirements of the Annex by means of conditions attached to the Operating Permit granted by the FCDO.

BAS has prepared a Waste Management Handbook that guides the management of waste on its ships, stations and in the field in accordance with best practice and UK waste legislation.

*Lost Equipment*

There is potential that the drill or related equipment may be lost to the ice, due to malfunction, or inability to relocate the overwinter depot. While every effort is made to release and retrieve equipment, some circumstances may result in loss to the environment.

***Impact type: Direct and Cumulative***

Any equipment or waste released to the environment will have a direct localised impact and will add to the volumes of items, equipment and materials lost to the Antarctic environment over the decades of human activity in the region.

***Treatment and Mitigation***

- Waste generated in the field, including any hazardous waste, will be managed in accordance with the provisions of Annex III to the Protocol, the BAS Waste Management Handbook and BAS Field Operations Manual.
- All food and general waste will be separated into waste streams and removed from the field for correct handling at Rothera.
- Human liquid waste and sieved grey water will be disposed of in ice pits at specifically identified locations only. Solid human waste is removed from the field.
- Grey water production will be minimised to the extent practicable.
- Careful planning shall be undertaken to minimise the materials and items taken into the field that will generate waste.
- Staff involved in the *REWIND* Drilling Project will comply with BAS waste management policy and will follow the procedures outlined in the BAS Waste Management Handbook (BAS, 2023).
- The camp will be cleared of any rubbish or debris each day.
- Open burning of waste is prohibited.

- Safe drilling procedures will be followed at all times to reduce risk of loss of drill (see Appendix 4).
- Only experienced operatives will use the drills.
- All BAS field parties are supplied with a copy of the Field Operations Manual, colour coded waste sacks for the separation and disposal of wastes, and solid human waste drums that are UN approved for clinical waste.

***Monitoring or Record keeping***

Any items accidentally released to the environment, and which are unrecoverable, will be recorded and reported in accordance with BAS incident reporting requirements.

### 8.4.2 Impacts That Will or May Occur to the Atmospheric Environment

There are a number of aspects that will or may give rise to impacts on the atmosphere (see Section 8.2 and Table 3). These include:

a. Release of gases including greenhouse gases as a result of the combustion of fuel in aircraft, ships, skidoos, generators, cooking and heating equipment;
b. The release of heat from engines, generators, cooking and heating equipment.

#### *8.4.2.1 Release of gases and greenhouse gases.*

***Impact description***

Emissions to air from the burning of fossil fuels will occur throughout both seasons of planned geophysics and drilling activities. Exhaust gases will be quickly dispersed depending upon the weather and particularly wind conditions at the time. The emission of gases will pass into the atmosphere and add to regional and global atmospheric pollution.

Air pollution will result from the input of the field party by aircraft, and the use of petrol generators and diesel snowblower at the field camp. Fuel consumption from the generators used on-site during both field seasons is estimated at 36 barrels for drilling, and 4 barrels for camp and skidoos combined. All generators will be running on petrol. The snowblower runs on diesel, and it is estimated that 4 x 25 L jerry cans will be needed.

Emissions will include carbon monoxide, carbon dioxide, nitrous oxides, sulphur dioxide, heavy metals and particulates. Using UK Government Guidelines for Greenhouse Gas Reporting, carbon calculations are included in Section 8.5.

Emissions resulting from the fuel used associated with the projects logistics (ship and aircraft) will be calculated and reported as part of the overall BAS carbon footprint.

Emissions will generally be rapidly and thoroughly dispersed by the strong and regular winds. There will be some fallout of pollutants in the local area. Heavy larger particles, such as soot, are likely to have relatively short maximum transport distances, with background levels in surface snow samples probably being reached within 2 km downwind of the drill site.

Heavy metals would have greater transport distances. Based on monitoring results from Halley IV Station, it is possible that background levels of heavy metals (e.g. lead) in surface snow samples would be exceeded up to a maximum of 10 km downwind of the site (Suttie and Wolff, 1993).

Releases of gases from Antarctic activities make only a minor contribution to global pollution, and current technology has yet to provide sufficiently reliable alternatives to the burning of fossil fuels in the harsh Antarctic environment (particularly for remote field activities), although sustainable energy options continue to be explored (Dou et al., 2019; Bustos et al., 2021).

It is now well established that anthropogenic releases of greenhouses gases from the burning of fossil fuels and other sources, is the major contributor to measurable changes in the global climate (IPCC, 2014).

The climate change implications for Antarctica and Antarctic biodiversity are a major focus of the ATCMs and the CEP.

***Impact type: Indirect and Cumulative***

This will be an unavoidable impact. Emissions of gases from the burning of fossil fuels will occur and will be transported into the atmosphere and indirectly and cumulatively contribute to regional and global atmospheric pollution, and climate change, although the contribution from BAS geophysics and drilling activities will be negligible.

***Treatment and Mitigation***

- All engines, generators and fuel burning equipment are routinely serviced and maintained to ensure they run and operate as efficiently as possible.
- Maximum efficiency of logistics, using minimum flights and most efficient routes.
- Emissions minimised by only burning fossil fuels when required. Equipment is not left idling unnecessarily.
- Skidoo engines, the snowblower, and generators are allowed a 'warm up' period prior to engaging any load.
- The fuel types selected are the most efficient for use in low temperature conditions.
- All fuel use will be minimised to the extent practicable.
- Daily visual checks are to be made of generator exhausts. Any maintenance to reduce atmospheric emissions will be carried out as required.
- The generators will be shut down when not required. It is anticipated that only one generator will be operating at a time.

***Monitoring or Record keeping***

Volumes and types of fuel used are routinely recorded as part of BAS' annual fossil fuel and carbon emissions monitoring.

### *8.4.2.2 Release of heat.*

***Impact description***

Heat will be generated from a range of sources due to the planned geophysics survey and drilling activities, including from skidoos, generators and cooking and heating equipment. Any heat generated will rapidly dissipate in the cold Antarctic atmosphere, particularly so at times when the wind is blowing.

No discernible impacts are likely to arise from heat emissions.

***Impact type: Direct***

Heat will be lost directly to the atmosphere, but with no discernible impacts.

***Treatment and Mitigation***

- Fuel burn will be kept to the minimum required.
- It is anticipated that only one generator will be used at any time (except when firn-air sampling is underway).
- Skidoos will be used only when necessary for moving heavy loads after geophysical work.
- Cooking and heating equipment will only be used for specified purposes.

***Monitoring or Record keeping***

None required.

### 8.4.3 Impacts That Will or May Occur to Antarctic Flora and Fauna

Impacts to Antarctic flora and fauna will not occur as a result of BAS *REWIND* geophysics and drilling activities. All geophysics, drilling activities, field camps and the over-winter depot will occur on snow and ice surfaces and will avoid ice-free locations where wildlife and plant life occur.

***Impact description***

The drilling activities will occur in the interior of the Antarctic Peninsula ice sheet and well away from any known wildlife concentrations, and approximately 38 km from any ice-free ground (the nearest is at Sky Hi Nunataks).

No plants are resident in the proposed project area. Interactions with wildlife are considered to be highly unlikely and restricted to rare sightings of individual or small numbers of seabirds that occasionally fly into the Antarctic interior (see for example Burton, 2015).

***Impact type: Direct and indirect***

Disturbance events are assessed as being highly unlikely.

***Treatment and Mitigation***

- All geophysics, and drilling activities, including field camps and the overwinter depot are conducted on ice and snow surfaces.
- All *REWIND* geophysics and drilling activities will be constrained to the defined areas that have been identified in this EIA.
- Biosecurity measures (including actions such as ensuring equipment is free of debris, visual checks/inspections of cargo and personnel luggage prior to landing in Antarctica) are used when moving equipment between Antarctic and global locations, to prevent any potential impact on local species (see Appendix 2, for field specific requirements).

***Monitoring or Record keeping***

Any observed disturbance events will be recorded and reported in accordance with BAS incident reporting requirements.

### 8.4.4 Introduction of Non-Native Species or Artificial Relocation of Native species

Non-native species can be introduced into Antarctica due to equipment being contaminated with plant material or animals being transported in or on equipment, such as in non-sterile soil. Once they reach Antarctica, some species can adapt and outcompete the native species, so it is a priority to prevent non-native species arriving.

The most significant impacts are if non-natives arrive at ice free areas where they can grow, or survive with other flora and fauna, and potentially be spread on the wind, or feet and feathers of birds.

As recorded above all *REWIND* geophysics and drilling activities will be confined to ice and snow surfaces and will not be on or near ice-free areas, where non-native species are more likely to be able to establish.

Consequently, the proposed *REWIND* geophysics and drilling activities are assessed as posing very low to no risk for the introduction of non-native species. There is a risk of the introduction of non-native biota, particularly micro-organisms, because of the importation of materials. However, the closest ice-free ground is at the Sky hi Nunataks near Sky Blu, a distance of approximately 38 km from the proposed project. While equipment may transition through Sky Blu for refuelling, it will not be unloaded.

Emphasis will be placed on the importance of pre deployment screening and cleaning of all clothing and equipment prior to deployment to Antarctica. Any equipment, cargo or waste packaging must be checked before they are loaded onto the aircraft from snow/ice-free areas (e.g. Rothera Research Station) to ensure that they are not contaminated with any soil, plant fragments, or invertebrates.

***Impact type: Direct***

The introduction of non-native species due to this proposed geophysics and drilling project is a very small possibility; however, if it did occur, and non-native biota were able to establish, this could be detrimental for the Antarctic ecosystem.

***Treatment and Mitigation***

- All equipment and materials required for the *REWIND* geophysics and drilling project will be thoroughly cleaned before dispatch to Antarctica.
- All timber used for the drilling rig infrastructure will be new and comply with the International Standards for Phytosanitary Measures No. 15 (ISPM 15).
- All items of cargo will be checked for soil or non-native species prior to being flown from Rothera.
- The advice and procedures contained within the BAS Biosecurity Regulations will be followed where applicable (see Appendix 2).

## 8.4.5 Impacts on Antarctic Wilderness Values

Antarctica is considered wilderness, but human presence can impact the wilderness and aesthetic values.

Aspects that will or may give rise to impacts to wilderness and aesthetic values have been identified as:

a. Visible or recorded human presence at locations across the Antarctic ice sheet.
b. Changes in local topography and wilderness/aesthetic values.

### *8.4.5.1 Visible or recorded human presence*

***Impact description***

The Protocol provides for the "*protection of the Antarctic environment …. And the intrinsic value of Antarctica, including its wilderness and aesthetic values*" and requires that such values "*shall be fundamental considerations in the planning and conduct of all activities in the Antarctic Treaty area*".

Activities must be planned and conducted so as to avoid "*degradation of, or substantial risk to, areas of …. aesthetic or wilderness significance*".

However, the term 'wilderness' is not defined in the Protocol and to date the Antarctic Treaty Parties have not formed a collective view as to how the term should be defined. This makes it challenging to assess the impacts of activities on wilderness values in an Antarctic context.

Leihy et al. (2020) assembled a comprehensive record of human activity and used it to quantify the extent of Antarctica's wilderness. Drawing from definitions determined in the academic literature Leihy et al. showed that 99.6 % of the continent's area can still be considered wilderness, even when transitory human activity and cumulative impacts are taken into account. They noted however that pristine areas, free from recorded human interference, cover a much smaller area (less than 32% of Antarctica) and are declining as human activity escalates.

As recorded above, BAS drilling activities have the potential to impact upon wilderness values as a consequence of visible human presence.

The proposed geophysics and drilling activities and associated camps and depot will only be transitory, and the surface of the Antarctic ice sheet is highly dynamic. Following the removal of drills, skidoos and camps, any disturbed areas will be covered or weathered in a short period of time, erasing any visible traces of human activity. However, records of human presence will cumulatively add to all past records of human presence with potential to further erode areas that can be regarded as pristine.

***Impact type: Indirect and Cumulative***

Recorded human activities (e.g., geophysics surveys, drill sites, camp sites, depots) have the potential to impact on perceived wilderness values in Antarctica and cumulatively add to the erosion of pristine areas of the Antarctic continent. Loss of pristine areas (even due to records of human presence) could be regarded as permanent.

***Treatment and Mitigation***

There are few mitigation measures that can be used to reduce the impacts on wilderness values. However, geophysics surveys and drilling activities will be constrained to the areas that have been identified in this EIA and all practicable efforts will be made undertake the steps listed below.

- Minimise, to the extent possible, the areas used when completing geophysics surveys, establishing field camps and the depot (if a suitable deep drilling location is found early in the exploration it is likely that the other sites will not be investigated).
- Minimise disposal to the ice environment and ensure all waste materials (except for human liquid waste and sieved grey water) are removed from the field.
- Maintain a log of geophysics survey routes, drilling locations (hand, shallow and deep), camps and the overwintering depot to be kept at BAS for future reference.
- Care will be taken to avoid loss of equipment and waste at the field camp/drill site, and any accidental loss will be recorded on the BAS incident reporting system.

***Monitoring or Record keeping***

All locational information will be recorded and reported at the end of each operational season. This includes geophysics and drill sites, camp site locations, disposal sites of human liquid waste and sieved grey water and the overwinter depot. This information will be recorded in BAS' GIS.

### 8.4.6 Summary of Proposed Mitigations

The following is a summary of recommended mitigations to reduce any potential impact from the proposed *REWIND* project (for a full list of mitigation measures, see Table 11):

- choosing the most appropriate and environmentally safe drilling fluid;
- using a bailer to recover as much drilling fluid as practicable (at least 85% is expected to be recovered, with a goal of 99%);
- removing all equipment, camp infrastructure, fuels and waste from the field on project completion (no equipment is planned to be left in the field);
- running only one generator at a time, where possible;
- using geophysics to choose the drilling site prior to flying in most personnel and equipment;
- using the fewest flights possible and coordinating logistics for least impact;
- minimising fuel use to the maximum extent practicable, including by using the most efficient fuel options for use at low temperatures, and regularly servicing engines and generators;
- minimising the risk of fuel spills by minimizing volumes, and using careful refuelling practices (e.g., drip trays, funnel use), for hazardous liquid substances including drilling fluid and fuel, taken into the field;
- actively managing and monitoring fuel and other hazardous substances in accordance with standard BAS procedures and using secondary containment to the maximum extent practicable;
- minimising the impact of spilled fuel by having spill kits available and providing relevant training in oil spill response;
- managing all waste, including hazardous waste in accordance with the provisions of the Protocol, the BAS Waste Management Handbook and BAS Field Operations Manual and minimising the materials and items taken into the field that will generate waste to the maximum extent practicable;
- following BAS Biosecurity Regulations.

# 8.5 Carbon Calculations

## 8.5.1 Carbon Assessment

The carbon emissions for this project have been estimated using a combination of approaches, depending on the data available. BAS have developed a range of activity-based carbon metrics to help estimate project level carbon footprints and these are based on annual baseline activity data models and sets of assumptions, therefore provide an indicative figure of estimated carbon emissions for the project.

## 8.5.2 Carbon Summary

Table 4 below shows the tonnes of carbon dioxide equivalent (tCO2e) from the main activities of the proposed project for which there are estimated emissions available.

*Table 4: Summary of Estimated Total Project Carbon Emissions (tCO2e) by Activity.*

| **Activity Data Included within Estimated Footprint:** | | |
|---|---|---|
| **Activity** | **Category** | **Total tCO2e** |
| Flights - Rothera to Field Site | BAS Aircraft | 230.5 |
| Flights - Field Site to Rothera | BAS Aircraft | 556.6 |
| Flights - Field Site to Rothera (Ice Cores) | BAS Aircraft | 129.9 |
| Business Travel UK to Gateway | Business Travel North/South | 24.7 |
| Business Travel Gateway to UK | Business Travel North/South | 24.7 |
| DASH7 Airbridge - Gateway to Rothera (return) | BAS Aircraft | 47.8 |
| Rothera bednights (3 per PAX before and after field) | Rothera | 24.0 |
| Petrol - Drilling | Field | 90.8 |
| Petrol - Skidoos | Field | 15.1 |
| | **Total** | **1,144.1** |

Most of the carbon emissions for the project relate to the BAS Aircraft as there are a planned 15 flights to and from the Field site in each season with a further 7 flights planned in the final season to extract ice core samples.

Different carbon metrics are used for different activities. This can be seen in Table 4 above, where the 'Rothera to Field Site' and 'Field Site to Rothera' carbon values are different, even though the same number of flights (15 per season) are completed. This is because the fuel that the aircraft is using from the field site has had to be flown into the field, which comes with a carbon impact that we have accounted for. A list of the metrics and assumptions are shown at the end of this statement.

Table 5 below provides a breakdown of the carbon associated with the activities listed by GHG Protocol scope. Scope 1 relates to direct carbon emissions resulting from combustion of fuels, Scope 2 emissions relate to carbon emissions associated with Purchased Energy and Scope 3 relate to carbon emissions associated with the wider value chain (including emissions from Business Travel, Purchased Goods and Services and several other categories).

*Table 5: Estimated Project Carbon Emissions by GHG Protocol Scope.*

| Scope | Total tCO2e | Percentage Split |
|---|---|---|
| 1 | 1,094.7 | 95.7% |
| 2 | 0.0 | 0.0% |
| 3 | 49.4 | 4.3% |
| **Total** | **1,144.1** | **100.0%** |

The majority (95.7%) of the estimated emissions for this project fall within Scope 1, as they are the emissions resulting from BAS owned Aircraft and the fuel used for the ice core drill and field team. The Scope 3 emissions shown are the result of the Business Travel required for the project teams to travel to Antarctica and back to the UK for each of the 2 seasons.

### 8.5.3 Assumptions and Metrics

Standard Assumptions:

- Twin Otter flying hour is treated as using 330 litres of fuel per flying hour.

Project Assumptions:

- Assumed Twin Otter flights to field site are from Rothera and using Rothera bulk fuel.
- Assumed Twin Otter flights from field site to Rothera use drummed fuel from Fossil Bluff (collected en route to Field Site).
- Twin Otter flight time from Rothera to Field Site has been estimated as 3 hours as site is 38 km from Sky Blu (approx. flight time Rothera to Fossil Bluff = 1 hour 40 minutes + Fossil Bluff to Sky Blu flight time of 1 hour 35 minutes).
- Business Travel route has been estimated as using the MOD business travel input metric (Brize Norton -> Mount Pleasant) for 8 PAX.
- Fossil Bluff fuel drums used for field camp (including drilling, skidoos and camp).

*Table 6: Metrics / Carbon Factors Used.*

| Metric Used | UOM Final Unit | Metric (tCO2e per UOM) | Metric Version |
|---|---|---|---|
| Rothera Bulk (inc. Fuel Transportation Emissions - SDA to Rothera) | TO Flying Hours | 0.537 | BAS V1 |
| Fossil Bluff Drum (inc. Fuel Transportation Emissions - SDA to Rothera, TO to FB) | TO Flying Hours | 4.160 | BAS V1 |
| Total tCO2e per Brize Norton – gateway flight (per PAX) | # PAX | 1.542506626 | Bespoke |
| Dash - Airbridge Transit (One PAX - One way) | # PAX | 2.986663612 | BAS V1 |
| Rothera Accommodation | # bednights | 0.250239168 | BAS V1 |
| Fossil Bluff Drum (inc. Fuel Transportation Emissions - SDA to Rothera, TO to FB) | litres | 0.01260586 | BAS V1 |

### 8.5.4 Exclusions From Carbon Calculation

The below activities have been excluded from the carbon calculation for this project for the reasons shown. If the reasons for exclusion change over time, then emissions from the activities may be included in a later period of reporting.

*Table 7: Exclusions from REWIND Carbon Calculations.*

| Activity | Reason for Exclusion |
|---|---|
| Use of Drilling Fluid | Carbon conversion factor unavailable |
| Use of Glycol/water mix | |
| Use of Diesel for snowblower | |
| Use of Kerosene for cooking and lighting equipment | |
| Use of Engine Grease | |
| Use of Oil for generators | |
| Use of Oil for skidoos and other general use | |
| Ice Core Sample Storage and Delivery to UK | BAS Carbon metric not yet created |
| Ice Core Drill SDA Delivery UK to Rothera | Data for estimation unavailable |
| Ice Core Drill Maitri to UK (Scope 3) | Data for estimation unavailable |
| Drill Fluid Transport Union Glacier to Rothera | Data for estimation unavailable |

## 8.6 Cumulative Impacts

Cumulative impacts occur as a result of the combined impacts of past, present and reasonably foreseeable activities. Cumulative impacts may occur over time and should be assessed by looking at other human activities occurring in the proposed locations. As with indirect impacts, cumulative impacts may not be identified until a direct impact has occurred (EIA Guidelines, 2016).

Cumulative impacts may occur during the *REWIND* geophysics and drilling project as well as in combination with past and reasonably foreseeable activities in this region of Antarctica.

Accessing information to support cumulative impact assessments in an Antarctic context can be challenging given that the international community has placed limited emphasis on monitoring and assessing incremental, but nonetheless cumulative impacts, across broader spatial and temporal scales (Tin et al., 2009).

The qualitative method used here to assess cumulative impacts has been to:

- identify activities that have occurred or are ongoing in the area covered by this EIA;
- identify activities that are planned to take place in the area covered by this EIA, over the same time period as this EIA; and
- identify the primary impacts that have occurred or are anticipated to occur from these past and planned activities.

Sources that were used to assess past, current and planned activities in the area covered by this EIA include:

- BAS's internal database of EIAs;
- the Environmental Impact Assessment database (EIA database) maintained by the Antarctic Treaty Secretariat (ATS)[3];
- a general web search;
- subject matter experts;
- the BAS Mapping and Geographic Information Centres (MAGIC) mapping group; and
- the BAS Polar Data Centre.

A number of general terms were used for internet searches, including, for example: 'Palmer Land', 'Antarctic Peninsula Ice Sheet', 'Antarctic Peninsula', 'Ice cores', and 'Sky Blu'.

**Previous Ice Core Activity**

Ice coring has previously occurred on the Antarctic Peninsula, (see Figure 23, and Table 8), and some of these previous activities were used to inform the proposed work.

The two closest ice cores to the proposed *REWIND* location, that used the BAS electromechanical drill are Jurassic (2012), 70 km away, and Gomez (2006), 108 km away. Both of these were shallow drill

[3] https://ats.aq/devAS/EP/EIAList?lang=e

locations, to 150 m, and 140 m respectively, and used no drilling fluid. Both field sites had camps and used generators.

Further information shows that there was ice core drilling activity at Sky Blu in 2014/2015 and 2016/2016, which was a field test (no depth recorded). In addition, a firn core was drilled at Sky Blu in 2019/20 using a Kovacs hand auger, to 21.8 m for diatom sampling. The rapid access drill has also been tested at Sky Blu previously, but no further information is available at time of writing. Two other shallow cores used hand augers in 1981 and 1992 and reached 21 m and 24 m respectively.

*Table 8: Ice Cores Close to the Proposed REWIND Project.*

| **Ice Core Name/Identifier/Location** | **Distance from REWIND Proposed Site** | **Type of Ice Core** |
|---|---|---|
| SKBL (near Sky Blu depot) – 2019/2020 | 40 km | Diatoms (21.8 m) – Kovacs hand auger |
| UK-81 and UK-92 near Gomez Nunatak ) - 1981 and 1992 | 59 km | UK-81 – (81/G1) shallow core (21 m) - hand-auger (Pico drainpipe).<br>UK-92 - (92/G2) shallow core (24 m) - hand-auger (Pico drainpipe). |
| Jurassic - 2012/2013 | 70 km | 140 m - BAS electromechanical drill |
| Gomez (2006) | 108 km | 150 m - BAS electromechanical drill |

Major deep ice core drilling projects (greater than 500 m in depth) have been carried out at more than twelve locations in Antarctica since 1968.

A few key Antarctic Peninsula ice-core records extend at least back into the last century. They are the James Ross Island (14,000 years ago to present), Dolleman Island (1795 AD to present), Dyer Plateau (1505 AD to present) and Gomez (1850 AD to present) ice cores (Davis, 2024c).

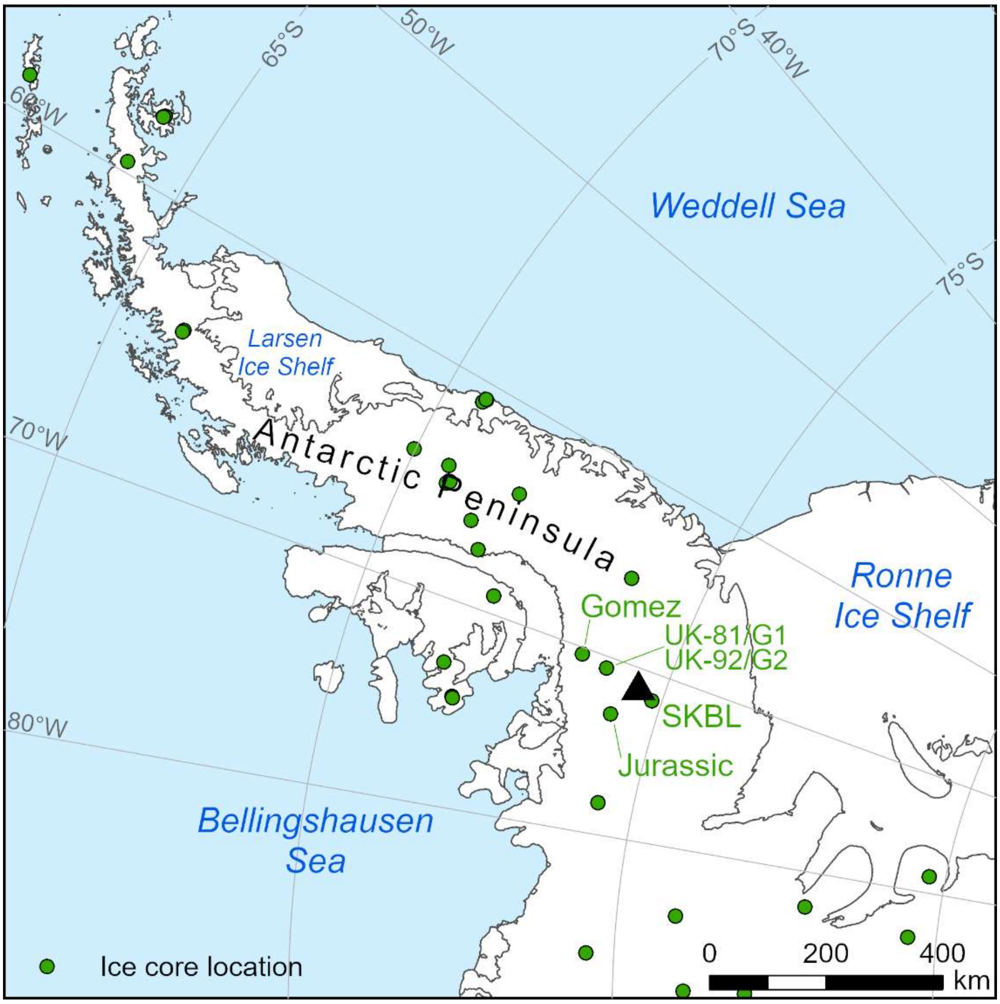


*Figure 23: Ice Core Locations Previous to the Proposed REWIND Project. Produced by the Mapping and Geographic Information Centre, British Antarctic Survey, 2024.*

**Other Activities in the Area**

The only regular activities known to be happening in and around Sky Blu are:

(i) the runway operations managed by BAS (which is used internationally), which include fuel drops to the Sky Blu depot location; and

(ii) operation and annual maintenance of an automated weather station (AWS) at the Sky Blu depot.

Sky Blu depot is approximately 38 km from the proposed drill location. Regular flight activities (176 aircraft movements occurred at Sky Blu in the 2023/24 season) occur on the blue ice runway at that site, and an automated weather station is located there. Additional recent activity (2022/23 season) included installation of 'Habit' instrumentation near Sky Blu, and a fuel airdrop by ALE, which was covered in a separate environmental assessment BAS PEA 'SBR Fuel Drop 2022-23'.

Additionally at Sky Blu, there has been a lot of airborne geophysics in the region, and in the past rock and lichen samples have been collected for analysis.

The 'Tractor Traverse', which provides logistics and science support to BAS projects operates out of Sky Blu. The Traverse does not operate in the area of the proposed drilling project (C1 – C5 locations), although if location C6 is chosen, there is a possibility that the Traverse will be within range of the camp location and would therefore potentially be available for logistical support.

### *8.6.1.1 Activities subject to EIA*

A review of the ATS and BAS EIA databases did not reveal any recent or proposed activities in the area of Sky Blu, or proposed *REWIND* location.

### *8.6.1.2 Potential future activities*

A review of information available on the internet did not reveal any proposed activities for the area around the Sky Blu depot. However, there are potentially future plans by BAS to modernise the Sky Blu depot, although details are not yet available.

Additionally, further ice core drilling has the potential to occur if either the required depth is not reached in the proposed seasons, or further ice core information is required for the location, however there are no proposals at time of writing.

### *8.6.1.3 Summary of cumulative impacts arising from this proposed project*

The assessment in Section 8.6 above shows that from the available information, the proposed geophysics surveys and drilling is not in the region of other proposed work for the duration of the drilling project.

There are a number of cumulative impacts that can be identified, to which the *REWIND* project activities will contribute including (see also Table 11 below):

a) **Contamination of the glacial environment** with particulates from the combustion of fossil fuels in skidoo engines and generators, etc. BAS geophysics surveys and drilling activities will contribute to particulates that become trapped in the ice from other local as well as global sources.
b) **Contamination of the glacial environment** from the accidental release of hazardous substances including spillage of drilling fluid and fuels. With effective implementation of the identified mitigation measures, this should not occur in the case of BAS geophysics and drilling activities, but if a spill event were to occur then the contamination would add to other spill events that have occurred historically across Antarctica (e.g., Aislabie et al., 2004). It is noted that there are poor records for such events on a continental scale.
c) **Contamination of the glacial environment** through the release of waste, including the accidental release of waste items, such as a lost drill. With effective implementation of the identified mitigation measures this should not occur in the case of BAS geophysics surveys and drilling activities, other than the anticipated small release of drilling fluid and the deliberate release of small volumes of human liquid waste and grey water. Should any items be released accidentally to the environment, this will add to other losses that have occurred historically across the Peninsula. Here also there are no readily available records of such events that are maintained on a continental scale.
d) **The release of gases, including greenhouse gases** from the combustion of fossil fuels will add to other atmospheric releases from stations, bases, vehicles, and vessels in the same seasons and from previous activities in the region.
e) Human presence in the areas of activity, and any materials inadvertently left in situ, has the potential to add to the further **loss of wilderness values in Antarctica**.

There are no comprehensive databases of human impacts in Antarctica that can be accessed to support an effective quantification of cumulative impacts. Accordingly, cumulative impacts can only be qualitatively assessed based on available information at the time of writing.

Using the assessment criteria set out in Table 9 and Table 10 below, the following points are noted:

**Spatial extent of cumulative impacts**: Whilst human activities have been undertaken across the Antarctic Peninsula ice sheet, impacts that have occurred are likely to be constrained to the immediate areas of activity. No impacts from the proposed *REWIND* geophysics and drilling activities are likely to have widespread impact.

**Duration of cumulative impacts**: Most impacts to the ice sheet will be of short duration, e.g., physical disturbance of snow and ice surfaces. However, some impacts will be much longer lasting, e.g., loss of equipment, and contamination of snow and ice surfaces from the burning of fossil fuels will be detectable for years to decades as well as the loss of perceptions of wilderness value. However, as the proposed project is on a small spatial scale and duration, if mitigation is followed then the potential impacts will be short term. However, in the case of atmospheric emissions and particulates, or if drilling equipment is lost, this would result in a long-term impact.

**Severity of cumulative impacts**: Previous impacts from human activities across the ice sheet, are considered unlikely to have caused any disruption to the natural functions and processes of the environment. This proposed project will not alter the severity of the cumulative impacts.

**Likelihood of cumulative impacts**: Impacts from activities across the Antarctic Peninsula ice sheet are known to have occurred and further impacts are likely, including those that will be contributed by the proposed *REWIND* geophysics survey and drilling activities. However, as the project is of a relatively small scale, this is considered to be a low risk if mitigations are followed.

Overall, the cumulative impacts of past, present and reasonably foreseeable activities across the Antarctic Peninsula ice sheet are considered to be 'no more than minor or transitory'.

While evidence of human activity will continue to erode perceptions of Antarctic wilderness, the contribution of the proposed BAS geophysics and drilling activities to these cumulative impacts is considered to be 'less than minor or transitory'.

## 8.7 Summary and Evaluation of Impact Significance

Section 8.4 has identified the potential (direct, indirect and cumulative) impacts of the proposed drilling and geophysics activities. This section evaluates the significance of the identified actual or potential impacts taking into account the three levels of significance identified in Article 8(1) of the Protocol.

In order to evaluate the significance of a given potential impact, the spatial extent, duration, severity (which also includes a level of reversibility) and likelihood of the identified potential impacts are considered so as to evaluate the overall significance of the identified impact of each activity.

Table 9 outlines the assessment criteria and definitions that have been used when evaluating the spatial extent, duration, intensity and likelihood of the identified potential impacts for the environmental elements (table and methodology modified from Oerter, 2000 in Gilbert, 2022).

In each case, the spatial extent, duration, severity and likelihood are scored 1 to 4, depending on whether each is considered to be 'low', 'medium', 'high' or 'very high' against the described criteria. An overall risk score (before and after treatment) is then calculated as follows:

**Risk score = spatial extent score x duration score x severity score x likelihood score**

The risk score determines whether the overall risk level is 'low', 'medium', 'high' or 'very high' as set out in Table 10.

Table 11 summarises the findings by setting out the identified impacts, assessing the raw risk without control measures in place and the residual risk after the control measures have been applied. The residual risk level is then compared to the three levels of significance set out in Article 8(1) of the Protocol as per Table 11.

*Table 9: Assessment Criteria for Evaluating the Spatial Extent, Duration, Severity, and Likelihood of the Potential Environmental Impacts (modified from Oerter, 2000).*

| | | ***Criteria for assessment*** | | | |
|---|---|---|---|---|---|
| ***Impact*** | ***Environment Element*** | ***Low (1)*** | ***Medium (2)*** | ***High (3)*** | ***Very High (4)*** |
| ***SPATIAL EXTENT OF IMPACT*** Area or volume where changes are likely to occur | ***Freshwater Marine Terrestrial Atmosphere*** | *Local extent* | *Partial extent* | *Major extent* | *Entire extent* |
| | | *Confined to the site of the activity.* | *Some parts of an area are partially affected.* | *A major sized area is affected.* | *Large-scale impact; causing further impact.* |
| | ***Flora and Fauna*** | *Confined disturbance of fauna and flora within site of activity, e.g., individuals affected.* | *Some parts of the community are disturbed.* | *Major disturbance in community, e.g., breeding success is reduced.* | *Impairment at population level.* |
| ***DURATION OF IMPACT*** Period of time during which changes in the environment are likely to occur | ***Freshwater Marine Terrestrial Atmosphere*** | *Short term* | *Medium term* | *Long term* | *Permanent* |
| | | *Several weeks to one season; short compared to natural processes.* | *Several seasons to several years; impacts are reversible.* | *Decades; impacts are reversible.* | *Environment will suffer permanent impact.* |
| | ***Flora and Fauna*** | *Short compared to growth period/ breeding season.* | *Medium compared to growth/ breeding season.* | *Long compared to growth/ breeding season.* | *Permanent* |
| | ***Freshwater*** | *Minimal Affect* | *Affected* | *High* | *Irreversible* |

| | | | | | |
|---|---|---|---|---|---|
| ***SEVERITY OF IMPACT***<br><br>A measure of the amount of change imposed on the environment due to the activity | ***Marine***<br><br>***Terrestrial***<br><br>***Atmosphere*** | *Natural functions and processes of the environment are minimally affected. Reversible.* | *Natural functions or processes of the environment are affected but are not subject to long-lasting changes. Reversible.* | *Natural functions or processes of the environment are affected or changed over the long term. Reversibility uncertain.* | *Natural functions or processes of the environment are permanently disrupted. Irreversible or chronic changes.* |
| | ***Flora and Fauna*** | *Minor disturbance. Recovery definite.* | *Medium disturbance. Recovery likely.* | *High levels of disturbance. Recovery slow and uncertain.* | *Very high levels of disturbance. Recovery unlikely.* |
| ***LIKELIHOOD***<br><br>*Chance of the occurrence of the impact* | ***All elements*** | *Should not occur under normal operation and conditions.* | *Possible but unlikely.* | *Likely to occur during span of project. Probable.* | *Certain to occur / unavoidable.* |

*Table 10: Risk Assessment Criteria*

| **Risk score** | **Risk level** | **Description** | **Ref Article 8(1) of the Protocol** |
|---|---|---|---|
| 1 to 15 | Low | Acceptable under most circumstances. Impact likely to be managed through normal operating procedures. | Less than minor or transitory |
| 16 to 35 | Medium | May be acceptable under certain circumstances. Impact requires ongoing monitoring and possible further treatment. | No more than minor or transitory |
| 36 to 143 | High | Unacceptable in most circumstances. Senior Management to be notified. Further treatment options must be explored. | More than minor or transitory |
| 144 to 256 | Very High | Unacceptable. Senior management to be alerted. Significant further treatment must be explored. Only senior management can approve proceeding if risk cannot be further treated to reduce risk level. | |

*Table 11: Summary of identified impacts and assessment of impact significance before and after mitigation measures are applied.*

| Environment type | Environmental Aspect | Potential Impact(s) | Type of Impact (Direct, Indirect, Cumulative) | Pre-treatment risk assessment: Extent | Duration | Severity | Likelihood | Raw Risk Level | Treatment (Preventative or Mitigating Measures) | Post-treatment risk assessment: Extent | Duration | Severity | Likelihood | Residual Risk Level | Ref Article 8 of the Protocol |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Glacial Environment | Burning of fossil fuels in aircraft, skidoos, generators etc. releasing particulates to snow / ice surface | Contamination of snow / ice surface around camp sites | Direct / Cumulative | 1 | 4 | 3 | 4 | 48 High | • Input and uplift flights will be kept to a minimum<br>• Only one generator will run at a time, were possible<br>• Skidoos are only used for geophysics and some equipment movements, not every-day use<br>• Site selection close to existing depot, so less field travel required<br>• Vehicle engines, generators and fuel burning equipment are regularly serviced and maintained to maximise efficiency of operation<br>• Vehicle engines and generators will be allowed a 'warm up' period prior to engaging any load<br>• The fuel types selected are the most efficient for use in low temperature conditions<br>• All fuel burning will be minimized to the extent practicable | 1 | 4 | 1 | 4 | 16 Medium | No more than minor or transitory |
| | Mechanical action on snow / surface from: vehicle use; camp establishment; creation of a depot line for overwinter storage | Physical disturbance to snow / ice surface | Direct | 1 | 2 | 2 | 4 | 16 Medium | • Tent numbers kept to a minimum<br>• Geophysics surveys targeted to reduce travel across snow surface<br>• Camp locations kept to a minimum, geophysics will use one or two camps instead of moving each day<br>• Main camp only set up after drill location identified<br>• Overwintering depot lines used rather than berm built<br>• Snow blower used to dig storage pit for ice cores and trench for drilling, to reduce disturbance<br>• The drilling tent will have a wooden floor to reduce impacts to the snow surface<br>• Input and uplift flights will be kept to a minimum | 1 | 2 | 1 | 4 | 8 Low | Less than minor or transitory |
| | Accidental release of hazardous liquid substances e.g., from drill fluid, glycol or fuel spill events | Contamination of local ice environment | Direct / Cumulative | 1 | 4 | 3 | 3 | 36 High | • Volumes of hazardous liquid substances will be minimised to the extent practicable<br>• All fuel / hazardous substances will be managed in accordance with standard BAS procedures as set out in the BAS Field Manual<br>• Hazardous liquid substances will be stored in secondary containment e.g., bunds, to the extent practicable and regular checks on the integrity of containers will be undertaken<br>• Trained and experienced operators will oversee equipment and manage refuelling activities<br>• Fuel spill response training will be provided to those undertaking fuel handling in the field<br>• Spill kits will be readily available at locations where fuel and fluids are stored and transferred | 1 | 2 | 1 | 2 | 4 Low | Less than minor or transitory |

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | • Any hazardous substance spilt[4] will be cleaned up to the extent practicable in accordance with the BAS Field Manual<br>• Recovered liquids and contaminated absorbents will be contained, labelled as hazardous and flown to Rothera for disposal<br>• Any glycol stored on site to recover stuck drilling equipment will be in limited quantities (calculated for recovery of drill)<br>• Glycol will be diluted with water and mixed in batches, to be deployed 2 L at a time in polythene lay flat hose, as required (dilution depends on drill depth) for deployment to a stuck drill<br>• Drilling fluid will be contained in barrels until use, contained within the drill tent, centrifuge and borehole when drilling is in progress, and only used for deep drilling, where required to prevent the drill becoming stuck<br>• Drilling fluid will be recovered from ice chips via the centrifuge after each ice core section is recovered<br>• Drilling fluid will be recovered from the borehole via the bailer at the end of the project<br>• Drilling fluid will be left in the borehole over the winter to prevent complete closure of the borehole, but levels will be calculated so that it cannot enter the firn layer and disperse | | | | | | |

| | | | | Pre-treatment risk assessment | | | | | | Post-treatment risk assessment | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Environment type | Environmental Aspect | Potential Impact(s) | Type of Impact (Direct, Indirect, Cumulative) | Extent | Duration | Severity | Likelihood | Raw Risk Level | Treatment (Preventative or Mitigating Measures) | Extent | Duration | Severity | Likelihood | Residual Risk Level | Ref Article 8 of the Protocol |
| Glacial Environment | Release of human liquid waste and grey water, or accidental loss of wastes and items of cargo or equipment (e.g. stuck drill) | Contamination of local ice environment | Direct / Cumulative | 1 | 4 | 4 | 4 | 64<br>High | • Human liquid waste and sieved grey water are disposed of in ice pits at specifically identified locations only<br>• Number of people on site will be minimised, and personnel will leave once their role has finished<br>• Grey water production at camps will be minimised to the extent practicable<br>• All food and general waste is separated into waste streams and removed from the field for correct handling at Rothera<br>• Waste generated in the field, including hazardous waste is managed in accordance with the provisions of Annex III to the Protocol, the BAS Waste Management Handbook and BAS Field Operations Manual<br>• Careful planning seeks to minimise the materials and items taken into the field that will generate waste<br>• Stuck drill procedures will be followed should the drilling equipment become stuck in the borehole. Limited quantities of glycol will be used to prevent the drill being left in-situ<br>• Any fluids used to recover the drill will be retrieved using the BAS bailer<br>• Drilling fluid will be recovered by the centrifuge and bailer to prevent fluids being left on site | 1 | 4 | 1 | 3 | 12<br>Low | Less than minor or transitory |

[4] Other than petrol. Generally, it is BAS policy not to contain and recover petrol but allow it to evaporate. Petrol spills must be reported to review whether a passive response is the correct response (this depends on volume/sensitivity of spill site).

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | • Overwinter depot line will be marked with flags and GPS to aid recovery in the second season<br>• All equipment, wastes and fluids will be removed from the field site by Twin Otter aircraft at the end of the second season<br>• Where possible waste will be removed at the end of the first season, to avoid overwintering | | | | | | |
| | | | | | | | | | | | | | | | |
| Atmospheric Environment | Release of gases including greenhouse gases from combustion of fossil fuels in aircraft, ship, skidoos, generators, cooking and heating equipment | Pollution of atmosphere and contribution to climate change | Direct / Cumulative | 4 | 4 | 2 | 4 | 128<br>High | • Vehicle engines, generators and fuel burning equipment are regularly serviced and maintained to maximise efficiency of operation<br>• Emissions will be minimised by only burning fossil fuels when required<br>• Equipment is not left idling unnecessarily<br>• Vehicle engines and generators will be allowed a 'warm up' period prior to engaging any load<br>• The fuel types selected are the most efficient for use in low temperature conditions<br>• All fuel burning will be minimised to the extent practicable – only one generator will be used at a time for drilling operations (except where shallow firn-air sampling and deep drilling may overlap in the second season)<br>• Skidoos will be stored at camp when not in use following geophysics surveys. Infrequent use will be required to move equipment<br>• BAS ship *RRS Sir David Attenborough* and the BAS Air Unit are trialling alternative fuels to reduce GHG emissions<br>• Field site is located close to Sky Blu depot to reduce flight time<br>• Input and uplift flights will be minimized and the most efficient route used | 1 | 4 | 1 | 4 | 16<br>Medium | No more than minor or transitory |
| | Release of heat from aircraft, ship, skidoos, generators, cooking and heating equipment | Highly localised and temporary heating of air adjacent to equipment | Cumulative | 1 | 1 | 2 | 4 | 8<br>Low | Heat will be lost directly to the atmosphere, but with no discernible impacts. No mitigation is considered necessary other than reducing use of equipment as possible, while maintaining essential functions for life support. | 1 | 1 | 1 | 4 | 4<br>Low | Less than minor or transitory |
| | | | | | | | | | | | | | | | |

| Environment type | Environmental Aspect | Potential Impact(s) | Type of Impact (Direct, Indirect, Cumulative) | Pre-treatment risk assessment | | | | | Treatment (Preventative or Mitigating Measures) | Post-treatment risk assessment | | | | | Ref Article 8 of the Protocol |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Extent | Duration | Severity | Likelihood | Raw Risk Level | | Extent | Duration | Severity | Likelihood | Residual Risk Level | |
| Native Antarctic Flora and Fauna | Noise emissions from equipment and vehicles and human activity; introduction of non-native species | Disturbance resulting in acute or chronic effects | Direct / Indirect | 2 | 4 | 4 | 1 | 32 Medium | • The project is away from known congregations of Antarctic wildlife<br>• The project will not visit any ice-free areas<br>• All activities, including field camps and overwinter depot will be conducted on ice and snow surfaces<br>• All activities will be constrained to areas identified in this EIA.<br>• Biosecurity training is given to field crews<br>• Biosecurity checks will be undertaken on all equipment prior to field deployment | 1 | 1 | 1 | 1 | 1 Low | Less than minor or transitory |
| Antarctic Wilderness | Human presence and all activities associated with the research project at each location and across both seasons | Reduction in wilderness values in these areas of Antarctica | Indirect / Cumulative | 1 | 2 | 2 | 4 | 16 Medium | • Noisy activities will be confined to drilling operations, and skidoo use<br>• Number of personnel and tents will be kept to a minimum<br>• Use of generators and skidoos will be kept to key tasks<br>• All activities will be constrained to areas identified in this EIA<br>• Areas used for geophysics surveys, drilling, field camps and the overwintering depot will be constrained to the area identified<br>• Disposals to the ice sheet will be restricted to small volumes of human liquid waste and grey water. All other wastes will be removed from the field<br>• All visible trace of human presence will be removed at the end of the project<br>• All available methods will be used to free stuck equipment | 1 | 2 | 2 | 2 | 8 Low | No more than minor. Any loss of areas considered 'pristine' will be more than transitory |

# 9 Monitoring and Record Keeping

This assessment has not identified the need for dedicated monitoring to be undertaken. Nonetheless, records will be maintained for post-season reporting purposes, which are listed below.

- Digital records (such as GPS) of geophysics survey routes followed. These data will be inputted into the BAS geographical information system as the data will recording impacts on wilderness values.
- Digital records (such as GPS) of drilling sites (hand, shallow and deep), camp sites and the overwintering depot location, including the equipment stored, volumes of fuel stored and types and volumes of waste stored (if any).
- Digital records (such as GPS) of the locations of, as well as volumes of human liquid waste and grey water disposed to, the ice sheet.
- Quantities of fuel burned, which may include hours of operation for skidoos, snowblower and generators.
- Records of the types and quantities of any materials or equipment that is accidentally lost to the environment (e.g., wooden flooring, stuck drill).
- Observations of any other environmental incidents, such as inefficient burning of fuel resulting in excessive release of airborne pollution.
- Location of any spill events, should they occur, as well as the volumes and type of fluid lost (e.g., petrol, drilling fluid, glycol), and approximate volumes recovered. Events may include drilling fluid escaping the borehole via fissure, the bottom of the borehole, or the firn layer.
- Use and amount of glycol required to recover a stuck drill and/or related equipment.
- Amount of drilling fluid (and glycol if used) recovered from the borehole, and the amount unrecoverable.
- Number of flights to input and uplift the equipment, ice cores and personnel.
- Route of the Twin Otter flights to the field location, i.e., Rothera to Sky Blu, to site.

Every effort will be made to avoid unnecessary impacts. Where an incident results in impacts, such as fuel spills, this will be documented and reported to the BAS Environment Office via the BAS Incident Reporting System (Maximo) and to the FCDO in accordance with the conditions of the BAS Operating Permit.

Post activity reporting will be undertaken in accordance with BAS requirements and the conditions placed on the BAS Operating Permit (2022-2027) issued by the FCDO.

# 10 Gaps in Knowledge and Uncertainties

No activity in Antarctica can be planned with absolute certainty, due to the extreme, changeable and unpredictable environmental conditions.

Within the areas identified in this EIA (potential sites C1, C3, C5, and C6), the project will need to retain a degree of flexibility (e.g., with regard to precise geophysics routes followed and final drilling and camp locations) so as to accommodate the results of the ground penetrating radar surveys, identifying the best available locations to obtain a deep ice core, changing weather, and logistical requirements.

Accordingly, there remain a number of gaps in knowledge and uncertainties. These are discussed below.

## 10.1 Results of the Geophysics Survey

The first three to five weeks of the proposed project will involve a geophysics survey, which involves using ground penetrating radar (GPR) to survey under-ice topography and locate the final deep drilling location.

The survey will cover buffers of up to 15 km around identified potential areas of C1 to C6 (see Figure 7). These potential areas have been identified by aerial surveys and previous shallow drilling on the Antarctic Peninsula ice sheet.

The surveys will start at the C1/C3 sites, and seek a core location of 600-800 m. Once the survey here is complete, the C5 and then C6 locations will be explored; however, if under ice topography indicates a potential area early in the surveys, this location may be chosen, without continuing on to the other potential sites.

Due to the flexible nature of the proposed site, the deep drilling location will only be finalised after the geophysics surveys.

Only once the drilling location has been identified will the drilling team and equipment be deployed to site, so team input date, drilling start date, camp establishment date, and geophysics end dates are all unknowns at this time.

Geophysics surveys have implications for some environmental aspects including the:

- area covered by the geophysics skidoo, and associated camp site location(s);
- timing of input of the drilling team and equipment;
- location of the drill camp;
- location of the ice core drilling;
- location of the firn-air sampling;
- length of season available to the drilling team;
- length of ice core retrievable; and
- condition of the ice.

The uncertainty associated with the unknown implications of geophysics surveys, is unlikely to have significant implications for the identified environmental impacts nor for the overall conclusion of the EIA.

## 10.2 Precise Locations of Drilling, Depot and Camp Sites

Implications of waiting for the geophysics surveys to be completed and unpredictable weather conditions are that the locations to be used for drilling, camping or the overwintering depot line cannot be predicted with certainty.

The uncertainties associated with the inability to predict the precise locations of camp sites and the overwintering depot may have implications for some environmental aspects including the:

- location of input of personnel and equipment;
- existing characteristics of the ice sheet surface;
- risks of losing equipment to the environment; and
- risk of spill events occurring where fuel is used or stored, which has some implications for the assessment of the impacts of any emergency events (such as fuel spills).

The uncertainty associated with the unpredictable locations of camp sites and the depot, is unlikely to have significant implications for the identified environmental impacts nor for the overall conclusion of the EIA.

## 10.3 Field Season Uncertainties

Due to ongoing construction and modernisation programmes at Rothera Research Station, limited bed spaces are available for research scientists for the upcoming seasons.

The geophysics and drilling seasons may be altered (e.g., timelines shifted, season shortened) due to the need to transit through Rothera.

The potential for equipment failure is also a factor that causes uncertainty in a field program.

These are currently unknowns that could severely impact the drilling project’s ability to reach the desired deep drill depth, to retrieve a high value, high resolution ice core.

Field season uncertainties have implications for some environmental aspects including:

- deferred project, outside of IEE identified timelines;
- additional field seasons needed to complete proposed drilling;
- additional flights over a shortened period;
- removal of all equipment after season one rather than overwintering (if second season is in doubt), increasing uplift flight numbers;
- loss of equipment due to it being in depot lines that are not recovered in the second season; and
- only part of the work taking place in season one (e.g., just the geophysics).

The uncertainty associated with the unknown implications of the field season planning, is unlikely to have significant implications for the identified environmental impacts nor for the overall conclusion of the EIA.

# 10.4 Use of Hazardous Substances

The use of drilling fluid is proposed only once the deep drilling reaches 150 m depth. It is expected that this will only be achieved in season two; however, if time allows the proposal is to start deep drilling in season one, to approximately 200 m, so drilling fluid may be used in the first season after 150 m.

Glycol will only be used should the drill become stuck, and therefore it is unknown if this will be required during the proposed project. However, there will be glycol on site throughout the drilling.

Use of hazardous substance uncertainties have implications for some environmental aspects including:

- Uncertainties tied in with other field uncertainties such as storage of drilling fluid, and glycol over more than one winter due to logistical requirements;
- potential loss of glycol within borehole; and
- not being able to recover drill fluid.

The uncertainty associated with the unknown timings of drilling fluid and potential for glycol use, is unlikely to have significant implications for the identified environmental impacts nor for the overall conclusion of the EIA.

# 10.5 Implications of Antarctic Weather

The weather in Antarctica can be highly variable both within and between summer seasons. Conditions can also change dramatically in short periods of time. This variability and unpredictability may require a number of adjustments to plans.

Weather conditions have the potential to impact on the schedule of the drilling programme in a number of ways. Inter- and intra-continental flights, as well as ship itineraries, may be delayed due to poor weather conditions at points of departure or destination, which may have implications for the location and timing of aircraft input in the field.

Weather conditions may also influence the extent of any travel that can be achieved (particularly during storm events). Seasons with poor weather may also limit what can be achieved in any one season with the implication that some objectives will need to be moved to another season.

Weather uncertainties have implications for some environmental aspects including the:

- timing and location of input of personnel and equipment, and therefore the length of the available field season;
- number of drilling days available (and therefore depth of ice core achievable) due to unfavorable weather conditions on site;
- volumes of fuel burnt in any one season and the impacts on glaciological and atmospheric environments;
- locations of camp sites and the overwintering depot, and physical impacts on snow and ice surfaces;
- potential for early extraction due to forecast storm events, and necessity to leave equipment behind, until it is able to be removed at a later date; and
- volumes and types of materials and equipment, as well as waste that will need to be overwintered.

The uncertainty associated with the unknown implications of Antarctic weather, is unlikely to have significant implications for the identified environmental impacts nor for the overall conclusion of the EIA.

## 10.6 Future Plans for Sky Blu Depot

The Sky Blu depot, located approximately 38 km from the proposed geophysics and drill site, has the potential to have some future upgrades to the facility. At the time of writing, details of the upgrades, and timelines are not fully understood. This work could have impacts on the surrounding area, sense of wilderness, routing of aircraft, and carbon emissions. However, being over 30 km from the proposed project site, it is unlikely to directly impact the project location, and the timeline is likely to be after the proposed project commences. That being said, cumulative impacts over the ice sheet would be considered alongside the proposed project.

The potential Sky Blu development has implications for some environmental aspects including a potential:

- increase in human activities (reducing wilderness and aesthetic values);
- increase in carbon emissions from construction activities; and
- to require re-routing of aircraft during construction activities.

The uncertainty associated with the unknown implications of future Sky Blu development, is unlikely to have significant implications for the identified environmental impacts nor for the overall conclusion of the EIA.

## 10.7 Funding for the Mechanical Testing of Borehole Properties

At the time of writing this IEE, the 'mechanical testing of borehole properties' element of the project was not funded, and therefore it is an uncertainty in the proposed program. It remains included in the IEE in the case that it may be funded during the project timeline.

As this work is within the borehole for the drilling program, no additional environmental impacts are expected.

## 10.8 Use of the 'Tractor Traverse'

The 'Tractor Traverse' (or Traverse) is a vehicle which operates in Antarctica for logistics and science support for BAS. The 'Piston Bully' vehicles allow towing heavy loads, and snow moving (such as the formation of berms). While the majority of proposed drilling sites have no capacity to use the Traverse for logistics, due to the proposed areas being outside of the approved operating area, if site C6 is chosen there is potential for the Traverse to support the project.

Field Ops have confirmed that this is unlikely and will not happen in Season One; however, should the project be delayed, or field seasons extended, this may be possible in future.

Should the Traverse support this drill project, there may be some implications for environmental aspects including:

- volumes of fuel used and therefore carbon calculations would be altered (Traverse vs Twin Otter support);
- ship logistics would be extended to the English Coast; and
- the use of a berm for overwintered equipment.

The uncertainty of future Traverse use is unlikely to have significant implications for the identified environmental impacts nor for the overall conclusions of this EIA.

# 11 Summary and Conclusion

This EIA has considered a number of alternatives to BAS drilling and geophysics activities, described the preferred approach to be taken; described what is known about the current environmental state in the planned areas of activity; assessed the potential environmental impacts that will or could arise; outlined the mitigation measures to prevent or minimise any potential environmental impacts that may occur; described the records that will be maintained of any environmental impacts that do occur; and identified remaining unknowns and uncertainties.

Use of drilling equipment, skidoos, generators and cooking equipment creates heat, gas and particulate emissions that impact the immediate snow and ice environment, and local air quality. Vehicle tracking (skidoos) and movement of snow will also occur. These expected impacts will be minor or transitory, with the exception of the cumulative impact of greenhouse gas emissions and the accumulation of particulates in glacial surfaces.

The use of Twin Otter aircraft for input and uplift of personnel, ice cores and equipment will produce particulate emissions, greenhouse gas emissions, and impact air quality. The expected impacts of flights for the *REWIND* project are moderate in relation to greenhouse gas impacts to climate and accumulation of particulates in glacial surfaces.

The potential for loss of equipment in the glacial environment, e.g. stuck drill, would have an impact on the immediate environment. If unable to be retrieved, a stuck drill would stay in the ice until it either reaches the ice front or melts out (should the ice sheet melt down to the level of the drill). This would contribute to cumulative impacts of other lost equipment on the ice sheet and through Antarctica, since human presence started.

This assessment was undertaken on a worst-case scenario evaluation. Once mitigations and adjustments are considered, all the proposed activities are considered of a low risk of environmental impact.

As a general rule BAS aims to prevent or reduce potential environmental impacts from its activities through careful planning, training, execution and the availability of highly experienced personnel. For almost all sources of impact, practicable treatment options to mitigate those impacts have been identified.

The British Antarctic Survey has many decades of experience of operating in the region. Provided the mitigation measures described in Section 8.4 (summarised in Table 11) are adhered to, the environmental impacts of the planned activities are considered to be largely avoidable or can be minimised to an acceptable level.

Overall, this EIA considers that the potential environmental impacts arising from the next two years of BAS drilling and geophysics activities will have **no more than a minor or transitory impact** on the environment.

It is concluded that this level of predicted impact is acceptable given the significant scientific knowledge that is likely to be gained as a result of the BAS ongoing programme of globally-relevant research into ice core records.

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# Appendices

## Appendix 1: SDS for Exxsol D60

pure chems

**MATERIAL SAFETY DATA SHEET(MSDS)- EXXSOL D60**

| SECTION 1 | - | PRODUCT AND COMPANY IDENTIFICATION |
|---|---|---|

**PRODUCT**

**Product Name:** **EXXSOL D60**

**Product Description:** Dearomatised Hydrocarbons

**Product Code:**

**Intended Use:** Solvent

**COMPANY IDENTIFICATION**

**Supplier:** **Pon Pure Chemicals Group**
CHENNAI, TAMILNADU, INDIA

**24 Hour Health Emergency** (91) 8939878447
(91) 9444038694

**Transportation Emergency Phone** (91) 8939768680

| Company Name | Place | EMERGENCY TELEPHONE NUMBER |
|---|---|---|
| Pon Pure Chemicals Group | India | Day Emergency – 044-26161803-26161809 |

**SECTION 2-COMPOSITION / INFORMATION ON INGREDIENTS**

This material is regulated as a complex substance.

**Hazardous Substance(s) or Complex Substance(s)**

| Name | CAS# | Concentration* | Symbols/Risk Phrases |
|---|---|---|---|
| Naphtha (petroleum), hydrotreated heavy | 64742-48-9 | 100% | Xn;R65, R66 |

* All concentrations are percent by weight unless ingredient is a gas. Gas concentrations are in percent by volume.

**SECTION 3-HAZARDS IDENTIFICATION**

This material is considered to be hazardous according to regulatory guidelines (see (M)SDS Section 15).

CLASSIFICATION: | Xn; R65 | R66 |

PHYSICAL / CHEMICAL HAZARDS

Page **1** of **10** MSDS – **EXXSOL D60**

Material can release vapours that readily form flammable mixtures. Vapour accumulation could flash and/or explode if ignited. Material can accumulate static charges which may cause an incendiary electrical discharge.

HEALTH HAZARDS

Harmful: may cause lung damage if swallowed. Repeated exposure may cause skin dryness or cracking. May be irritating to the eyes, nose, throat, and lungs.

Note: This material should not be used for any other purpose than the intended use in Section 1 without expert advice. Health studies have shown that chemical exposure may cause potential human health risks which may vary from person to person.

## SECTION 4-FIRST AID MEASURES

**INHALATION**

Remove from further exposure. For those providing assistance, avoid exposure to yourself or others. Use adequate respiratory protection. If respiratory irritation, dizziness, nausea, or unconsciousness occurs, seek immediate medical assistance. If breathing has stopped, assist ventilation with a mechanical device or use mouth-to-mouth resuscitation.

**SKIN CONTACT**

Wash contact areas with soap and water. Remove contaminated clothing. Launder contaminated clothing before reuse.

**EYE CONTACT**

Flush thoroughly with water. If irritation occurs, get medical assistance.

**INGESTION**

Seek immediate medical attention. Do not induce vomiting.

**NOTE TO PHYSICIAN**

If ingested, material may be aspirated into the lungs and cause chemical pneumonitis. Treat appropriately.

## SECTION 5-FIRE FIGHTING MEASURES

**EXTINGUISHING MEDIA**

**Appropriate Extinguishing Media:** Use water fog, foam, dry chemical or carbon dioxide ($CO_2$) to extinguish flames.

**Inappropriate Extinguishing Media:** Straight streams of water

**FIRE FIGHTING**

**Fire Fighting Instructions:** Evacuate area. Prevent run-off from fire control or dilution from entering streams, sewers or drinking water supply. Fire-fighters should use standard protective equipment and in enclosed spaces, self-contained breathing apparatus (SCBA). Use water spray to cool fire exposed surfaces and to protect personnel.

**Unusual Fire Hazards:** Combustible. Hazardous material. Firefighters should consider protective equipment indicated in Section 8.

**Hazardous Combustion Products:** Smoke, Fume, Oxides of carbon, Incomplete combustion products

**FLAMMABILITY PROPERTIES**

**Flash Point [Method]:** 63C (145F) [ ASTM D-93]

**Flammable Limits (Approximate volume % in air):** LEL: 0.6 UEL: 7.0

**Auto ignition Temperature:** >200°C (392°F)

## SECTION 6 - ACCIDENTAL RELEASE MEASURES

**NOTIFICATION PROCEDURES**

In the event of a spill or accidental release, notify relevant authorities in accordance with all applicable regulations.

**PROTECTIVE MEASURES**

Avoid contact with spilled material. Warn or evacuate occupants in surrounding and downwind areas if required, due to toxicity or flammability of the material. See Section 5 for fire fighting information. See the Hazard Identification Section for Significant Hazards. See Section 4 for First Aid Advice. See Section 8 for Personal Protective Equipment.

**SPILL MANAGEMENT**

**Land Spill:** Eliminate all ignition sources (no smoking, flares, sparks or flames in immediate area). Stop leak if you can do so without risk. All equipment used when handling the product must be grounded. Do not touch or walk through spilled material. Prevent entry into waterways, sewer, basements or confined areas. A vapour-suppressing foam may be used to reduce vapour. Use clean non-sparking tools to collect absorbed material. Absorb or cover with dry earth, sand or other non-combustible material and transfer to containers. Large Spills: Water spray may reduce vapour, but may not prevent ignition in enclosed spaces. Recover by pumping or with suitable absorbent.

**Water Spill:** Stop leak if you can do so without risk. Warn other shipping. Remove from the surface by skimming or with suitable absorbents. Seek the advice of a specialist before using dispersants.

Water spill and land spill recommendations are based on the most likely spill scenario for this material; however, geographic conditions, wind, temperature, (and in the case of a water spill) wave and current direction and speed may greatly influence the appropriate action to be taken. For this reason, local experts should be consulted. Note: Local regulations may prescribe or limit action to be taken.

**ENVIRONMENTAL PRECAUTIONS**

Large Spills: Dyke far ahead of liquid spill for later recovery and disposal. Prevent entry into waterways, sewers, basements or confined areas.

## SECTION 7 - HANDLING AND STORAGE

**HANDLING**

Avoid contact with skin. Use proper bonding and/or earthing procedures. Prevent small spills and leakage to avoid slip hazard. Material can accumulate static charges which may cause an electrical spark (ignition source).

**Loading/Unloading Temperature:** [Ambient]

**Transport Temperature** : [Ambient]

**Static Accumulator** : This material is a static accumulator.

**STORAGE**

Keep container closed. Handle containers with care. Open slowly in order to control possible pressure release. Store in a cool, well-ventilated area. Storage containers should be earthed and bonded. Drums must be earthed and bonded and equipped with self-closing valves, pressure vacuum bungs and flame arresters.

**Storage Temperature** : [Ambient]

**Storage Pressure** : [Ambient]

**Suitable Containers/Packing** : Tank Cars; Tank Trucks; Barges; Drums

**Suitable Materials and Coatings:** Carbon steel; Stainless steel; Polyethylene; Polypropylene; Polyester; Teflon

**Unsuitable Materials and Coatings:** Natural rubber; Butyl rubber; Polystyrene; Ethylene-propylene-diene monomer (EPDM)

**SECTION 8 - EXPOSURE CONTROLS / PERSONAL PROTECTION**

**EXPOSURE LIMIT VALUES**

**Exposure limits/standards (Note: Exposure limits are not additive)**

| Substance Name | Form | Limit/Standard | | | Note | Source | Year |
|---|---|---|---|---|---|---|---|
| Naphtha (petroleum), hydro treated heavy | Vapour. | RCP - TWA | 1200 mg/m3 | 184 ppm | Total Hydrocarbons | Exxon Mobil | 2007 |

NOTE: Limits/standards shown for guidance only. Follow applicable regulations.

**ENGINEERING CONTROLS**

The level of protection and types of controls necessary will vary depending upon potential exposure conditions. Control measures to consider:

Adequate ventilation should be provided so that exposure limits are not exceeded. Use explosion-proof ventilation equipment.

**PERSONAL PROTECTION**

Personal protective equipment selections vary based on potential exposure conditions such as applications, handling practices, concentration and ventilation. Information on the selection of protective equipment for use with this material, as provided below, is based upon intended, normal usage.

**Respiratory Protection:** If engineering controls do not maintain airborne contaminant concentrations at a level which is adequate to protect worker health, an approved respirator may be appropriate. Respirator selection, use, and maintenance must be in accordance with regulatory requirements, if applicable. Types of respirators to be considered for this material include:

Half-face filter respirator Type A filter material.

For high airborne concentrations, use an approved supplied-air respirator, operated in positive pressure mode. Supplied air respirators with an escape bottle may be appropriate when oxygen levels are inadequate, gas/vapour warning properties are poor, or if air purifying filter capacity/rating may be exceeded.

**Hand Protection:** Any specific glove information provided is based on published literature and glove manufacturer data. Work conditions can greatly affect glove durability; inspect and replace worn or damaged gloves. The types of gloves to be considered for this material include:

If prolonged or repeated contact is likely, chemical-resistant gloves are recommended.If contact with forearms is likely, wear gauntlet-style gloves. Nitrile

**Eye Protection:** If contact is likely, safety glasses with side shields are recommended.

**Skin and Body Protection:** Any specific clothing information provided is based on published literature or manufacturer data. The types of clothing to be considered for this material include:

If prolonged or repeated contact is likely, chemical, and oil resistant clothing is recommended.

**Specific Hygiene Measures:** Always observe good personal hygiene measures, such as washing after handling the material and before eating, drinking, and/or smoking. Routinely wash work clothing and protective equipment to remove contaminants. Discard contaminated clothing and footwear that cannot be cleaned. Practice good housekeeping.

**ENVIRONMENTAL CONTROLS**

See Sections 6, 7, 12, 13.

## SECTION 9 - PHYSICAL AND CHEMICAL PROPERTIES

**Typical physical and chemical properties are given below. Consult the Supplier in Section 1 for additional data.**

**GENERAL INFORMATION**

**Physical State** : Liquid

**Form** : clear

**Colour** : Colourless

**Odour** : mild petroleum/solvent

**Odour Threshold** : N/D

**IMPORTANT HEALTH, SAFETY, AND ENVIRONMENTAL INFORMATION**

**Relative Density (at 15 C):** 0.792

**Density (at 15 °C)** : 792 kg/m³ (6.61 lbs/gal, 0.79 kg/dm³)

**Flash Point [Method]** : 63C (145F) [ ASTM D-93]

**Flammable Limits (Approximate volume % in air):** LEL: 0.6 UEL: 7.0

**Autoignition Temperature:** >200°C (392°F)

**Boiling Point / Range** : 187C (369F) - 216C (421F)

**Vapour Density (Air = 1)** : > 1 at 101 kPa

**Vapour Pressure** : 0.05 kPa (0.38 mm Hg) at 20 C | 0.2 kPa (1.5 mm Hg) at 38C | 0.4 kPa (3 mm Hg) at 50C

**Evaporation Rate (N-Butyl Acetate = 1):** 0.03

pH : N/A

**Log Pow (n-Octanol/Water Partition Coefficient):** N/D

**Solubility in Water** : Negligible

**Viscosity** : 1.32 cSt (1.32 mm2/sec) at 40 C | 1.64 cSt (1.64 mm2/sec) at 25C

**Oxidising properties** : See Sections 3, 15, 16.

**OTHER INFORMATION**

**Freezing Point** : <-20°C (-4°F)

**Melting Point** : N/A

**Molecular Weight** : 158 [Calculated]

**Hygroscopic** : No

**Coefficient of Thermal Expansion:** 0.00095 V/V/DEG C

## SECTION 10 - STABILITY AND REACTIVITY

**STABILITY:** Material is stable under normal conditions.

**CONDITIONS TO AVOID:** Avoid heat, sparks, open flames and other ignition sources.

**MATERIALS TO AVOID:** Strong oxidisers

**HAZARDOUS DECOMPOSITION PRODUCTS:** Material does not decompose at ambient temperatures.

**HAZARDOUS POLYMERIZATION:** Will not occur.

## SECTION 11- TOXICOLOGICAL INFORMATION

**Acute Toxicity**

| Route of Exposure | Conclusion / Remarks |
|---|---|
| **INHALATION** | |
| Toxicity: Data available. | Minimally Toxic. Based on test data for structurally similar materials. |
| Irritation: Data available. | Negligible hazard at ambient/normal handling temperatures. Based on test data for structurally similar materials. |

| | |
|---|---|
| **INGESTION** | |
| Toxicity: LD50 > 15000 mg/kg | Minimally Toxic. Based on test data for the material. |
| | |
| **Skin** | |
| Toxicity: LD50 > 3160 mg/kg | Minimally Toxic. Based on test data for structurally similar materials. |
| Irritation: Data available. | Mildly irritating to skin with prolonged exposure. Based on test data for structurally similar materials. |
| | |
| **Eye** | |
| Irritation: Data available. | May cause mild, short-lasting discomfort to eyes. Based on test data for structurally similar materials. |

**CHRONIC/OTHER EFFECTS**

**For the product itself:**

Vapour concentrations above recommended exposure levels are irritating to the eyes and the respiratory tract, may cause headaches and dizziness, are anaesthetic and may have other central nervous system effects. Prolonged and/or repeated skin contact with low viscosity materials may defat the skin resulting in possible irritation and dermatitis. Small amounts of liquid aspirated into the lungs during ingestion or from vomiting may cause chemical pneumonitis or pulmonary edema.

Additional information is available by request.

**IARC Classification:**

**The Following Ingredients are Cited on the Lists Below:** None.

--REGULATORY LISTS SEARCHED--

1 = IARC 1 2 = IARC 2A 3 = IARC 2B

## SECTION 12 - ECOLOGICAL INFORMATION

The information given is based on data available for the material, the components of the material, and similar materials.

**ECOTOXICITY**

Material -- Not expected to be harmful to aquatic organisms.

Material -- Not expected to demonstrate chronic toxicity to aquatic organisms

**PERSISTENCE AND DEGRADABILITY**

**Biodegradation:**

Material -- Expected to be readily biodegradable.

**Hydrolysis:**

Material -- Transformation due to hydrolysis not expected to be significant.

**Photolysis:**

Material -- Transformation due to photolysis not expected to be significant.

**Atmospheric Oxidation:**

Material -- Expected to degrade rapidly in air

**OTHER ECOLOGICAL INFORMATION**

**VOC:** Yes

## SECTION 13 - DISPOSAL CONSIDERATIONS

Disposal recommendations based on material as supplied. Disposal must be in accordance with current applicable laws and regulations, and material characteristics at time of disposal.

**DISPOSAL RECOMMENDATIONS**

Product is suitable for burning in an enclosed controlled burner for fuel value or disposal by supervised incineration at very high temperatures to prevent formation of undesirable combustion products.

**Empty Container Warning** Empty Container Warning (where applicable): Empty containers may contain residue and can be dangerous. Do not attempt to refill or clean containers without proper instructions. Empty drums should be completely drained and safely stored until appropriately reconditioned or disposed. Empty containers should be taken for recycling, recovery, or disposal through suitably qualified or licensed contractor and in accordance with governmental regulations. DO NOT PRESSURISE, CUT, WELD, BRAZE, SOLDER, DRILL, GRIND, OR EXPOSE SUCH CONTAINERS TO HEAT, FLAME, SPARKS, STATIC ELECTRICITY, OR OTHER SOURCES OF IGNITION. THEY MAY EXPLODE AND CAUSE INJURY OR DEATH.

## SECTION 14- TRANSPORT INFORMATION

| | | |
|---|---|---|
| **LAND** | : | Not Regulated for Land Transport |
| **SEA (IMDG)** | : | Not Regulated for Sea Transport according to IMDG-Code |
| **AIR (IATA)** | : | Not Regulated for Air Transport |

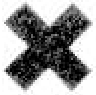
## SECTION 15 - REGULATORY INFORMATION

**Material is hazardous as defined by the EU Dangerous Substances/Preparations Directives.**

**EU CLASSIFICATION:** Harmful. The classification of this product is based all or in part on test data.

**EU LABELING:**

**Symbol:** Xn



Harmful.

**Nature of Special Risk:** R65; Harmful: may cause lung damage if swallowed. R66; Repeated exposure may cause skin dryness or cracking.

**Safety Advice:** S23; Do not breathe gas/fumes/vapour/spray S24; Avoid contact with skin. S62; If swallowed, do not induce vomiting: seek medical advice immediately and show this container or label.

**REGULATORY STATUS AND APPLICABLE LAWS AND REGULATIONS**

**Complies with the following national/regional chemical inventory requirements:** AICS, IECSC, DSL, ENCS, KECI, PICCS, TSCA

## SECTION 16 - OTHER INFORMATION

**Disclaimer:**

The information and recommendations contained herein are, to the best of **Pon Pure Chemicals Group** knowledge and belief, accurate and reliable as of the date issued. You can contact **Pon Pure Chemicals Group** to ensure that this document is the most current available from **Pon Pure Chemicals Group.** The information and recommendations are offered for the user's consideration and examination. It is the user's responsibility to satisfy itself that the product is suitable for the intended use. If buyer repackages this product, it is the user's responsibility to insure proper health, safety and other necessary information is included with and/or on the container. Appropriate warnings and safe-handling procedures should be provided to handlers and users. Alteration of this document is strictly prohibited. Except to the extent required by law, re-publication or retransmission of this document, in whole or in part, is not permitted.

# Appendix 2: Relevant Section from BAS Biosecurity Regulations (Field)

# 10 FIELD WORK IN ANTARCTICA AND SOUTH GEORGIA

## 10.1 Field activities

| Individual responsible | • Field Operations Manager<br>• Traverse Leader<br>• Project Manager/Principal Investigator |
|---|---|

### 10.1.1 Key biosecurity risks

The BAS area of operation extends over much of Antarctica and scientist and support staff operate in many different types or terrain, including ice-free habitat. Therefore, there are several main biosecurity risks:

- The introduction of non-native species to Antarctica (as discussed earlier)
- The movement of existing non-native species to new areas of Antarctica (see Appendix 9)
- The movement of species native to one Antarctic region, to another Antarctic region

To reduce the risk associated with BAS field work activities, all cargo should be free of soil and non-native species before being transported to polar regions, and as far as possible, re-checked on station before deployment to the field.

Personnel in the field must take steps to prevent local wildlife accessing food. For example, personnel should keep foods within boxes or inside tents. Waste food should be stored so that it cannot be accessed by wildlife. No poultry products other than egg powder shall be supplied to field camps working near bird colonies.

The field operations manager is responsible for ensuring field personnel are aware of non-native species issues. The project Principal Investigator is responsible for ensure all cargo and equipment is free of non-native species and soil, and that the field team is informed of biosecurity issues, in accordance with the Environmental Impact Assessment for the field project.

### 10.1.2 Antarctic locations already colonised by non-native species

Visitors must take particular care to ensure clothing and equipment is free of seeds and soil when leaving areas where non-native species are known to have established (see Figure 2). Where washing facilities are not available, the outside of boots can be washed in seawater and clothing can be brushed down to remove soil and organic material. If travelling to another Antarctic location, outer clothing should be washed using available facilities (e.g., ship washing machines) and footwear cleaned before arrival.

## 10.2 Movement of BAS field equipment between BAS stations

Field equipment (e.g., tents, boxes, sledges, etc.) may trap soil and organic material while being used in the field. In general, field equipment is repaired and serviced at Rothera Research Station and distributed, for use in locations on South Georgia and Antarctic, by ship or aircraft. At the end of the season, most equipment is returned to Rothera in preparation for the following season. Therefore, the potential exists for soil and organic material attached to equipment used at a variety of locations to be transported to Rothera.

- Field equipment sent from Cambridge to stations in South Georgia and Antarctica must be free of soil and propagules.

- Appreciating the limitations incurred by operating in the field, to the maximum extent practicable, field GAs should try to ensure their field equipment, sledges and skidoos have as little adhered soil and organic material as possible before they are returned to Rothera.
- Particular care should be taken to remove soil and organic material if camping on ice-free ground, with special attention paid to tent valances, ground sheets and pegs.
- If field equipment that is heavily contaminated with soil and organic material is returned to Rothera Research Station, it should be cleaned carefully indoors, with the soil and organic material collected and incinerated. In general, to ensure soil and organic material are contained adequately, in the first instance, vacuuming or dry brushing may be the most appropriate cleaning technique. As appropriate, vacuum cleaner waste should be incinerated using station facilities or bagged and incinerated on the ship.
- Where resources and logistic planning allow, field equipment used in one region should be reallocated to that region in subsequent seasons. For example, it may be possible for equipment to be allocated for use in South Georgia each season.

## 10.3 Antarctic field activities – further regulations

Visitors undertaking terrestrial field research, as a minimum standard, should apply the guidelines detailed in the Scientific Committee on Antarctic Research's (SCAR) *Environmental Code of Conduct for Terrestrial Scientific Field Research in Antarctica*, which includes advice on biosecurity (see Appendix 2).

Visitors undertaking activities within terrestrial geothermal environments should also apply the guidelines detailed in the *SCAR Code of Conduct for Activities within Terrestrial Geothermal Environments in Antarctica* (see Appendix 3).

# Appendix 3: Relevant Extracts from Field Operations Manual

**5.20 Waste management**

All rubbish should be separated for recycling before being sent back to station. Rubbish should be separated into cardboard, metal, plastic, food waste and glass (try to avoid taking glass jars/bottles into the field for obvious reasons). Uneaten food can go into the poo bins but packaging soiled with food will need to be incinerated back on station so will have to be bagged separately.

It can be challenging to separate all rubbish in the field, especially while on a travelling project. In such cases where it is simply not practical to have several bags for different rubbish you will need to separate it back on station – do not leave this job for someone else! It is your rubbish and therefore your responsibility to sort. If you think this may be the case with your project discuss with those on station responsible for waste management prior to deployment.

For detailed info on this topic refer to the Waste Management Handbook which is available on stations and speak to those employed to manage waste on stations.

**5.21 Conservation of flora and fauna**

Under the Antarctic Act (1994, 2013) the following specialist activities are prohibited without a permit issued by the Foreign and Commonwealth Office or under delegated authority by BAS:
• Mineral resourced activities for the purpose of scientific research
• The taking of, or harmful interference with flora or fauna
• The intentional introduction of non-native species
• Entry into an Antarctic Specially Protected Area (ASPA)
• Entry to a CCAMLR Ecosystem Monitoring Programme (CEMP) site
• Temporarily removing objects from an Antarctic Historic Site and Monument (HSM) for conservation or repair

Conducting activities in Antarctica without first obtaining a permit, or breaching of permit conditions, or breach of a prohibition, is an offence punishable by up to two year's imprisonment and an unlimited fine.

Killing or harmful interference with Antarctic wildlife is prohibited, except in accordance with a permit issued under the Antarctic Act 1994.

The following points should be observed:
• Do not feed, touch or handle any wildlife
• Do not approach or photograph wildlife in a way that causes them to alter their behaviour. As a guide, keep a minimum distance of five metres from any animal. A permit is needed to handle, tag or kill animals, collect eggs or collect significant quantities of plants
• Do not walk or drive vehicles on vegetation, particularly extensive moss or lichen-covered areas
• Do not use aircraft, vessels, small boats or vehicles in a way that disturbs wildlife. Avoid taking aircraft, particularly helicopters, within 200m of bird or seal colonies. The noise of low-flying aircraft can cause them to panic
• Do not collect biological or geological specimens unless they are taken as part of an approved BAS science project and in accordance with a specialist activities permit issued under the Antarctic Act. It is illegal to collect or remove any biological or geological specimens unless you have been specifically issued a permit. Items collected under permit and brought back to the UK, such as plant specimens or seal and whalebone, will also require import licenses, which must be arranged in advance of their

departure from Antarctica. Ensure that Cambridge and your Station Leader are aware that your project requires such licenses – the lead scientific investigator on a project is ultimately responsible for this
• Do not use a UAV in the field, particularly over wildlife, unless the activity has been specifically reviewed and approved as part of an Environmental Impact Assessment
• Do not leave any sign of your visit. This includes cairn building, snow pits, graffiti on rocks etc.

### 18.2 Uses and colour codes

| Fuel | Colour | Container(s) | Uses |
|---|---|---|---|
| **Petrol** | Red | 205 Drums (black drums with red tops)<br>20 litre jerries | Snowmobiles<br>Generators<br>Snow blowers<br>Capstan winch<br>Multi-fuel stoves |
| **50:1 Petrol mix** | Red/Yellow | 2 litre jerries | Chainsaws<br>Older models of two-stroke snowmobile |
| **Paraffin/Kerosene** | Blue | 205 Drums (black drums with blue top)<br>20 litre jerries<br>1 litre Sigg bottles | Vapalux lanterns<br>Primus stoves<br>Multi-fuel stoves<br>Refleks stoves |
| **AVTUR/Jet A1** | White | 205 Drums (black drums with white tops)<br>20 litre jerries | Aircraft<br>Refleks stoves in some huts/ cabooses |
| **Meths** | Silver | 5 litre plastic containers<br>1 litre Sigg bottles, Meths dispensers | Priming lanterns and stoves |

# Appendix 4: Safe Drilling Procedures Summary

Notes for Safe drilling procedures as provided by J Veale:

- **General**
  - Estops available, estops activated when not drilling/winching to avoid surprise injury,
  - No motor turning at surface unless clearly visible that no one within range (avoid cuts and entanglement),
  - Gloves when handling drill and core, oil proof gloves when handling drilling fluid,
  - Communicating verbally steps to be taken before taking them,
  - Shutters used to cover trench to avoid falls,
  - No stepping across the trench when shutters open.
- **Setup**
  - Must dig a narrow trench under the drilling tent (shovels and electric chainsaws) for the mast to tilt into (attached image DSCN2036). This trench is less than 5m deep.
  - No guy lines needed for the mast, which is self-supporting.
  - Drill setup is slightly different, but involves thread-locking screws to reduce risk of losing parts into the ice sheet.
- **Drilling**
  - Additional process of moving drilling fluid slurry manually from drill at surface to centrifuge for cleaning and reuse.
  - Additional process of monitoring fluid level in borehole during operations and pumping additional fluid into the borehole where needed.
  - Drill tilting and ice core removal is mechanised rather than manual.
- **Final Teardown**
  - Also have to bail the fluid out of the borehole, with time left at the end of the season to achieve this. Achieved by lowering the bailer repeatedly into the fluid and emptying at surface, centrifuging, and put back in drums.