Proposed Construction and Operation of Halley VI Research Station, and Demolition and Removal of Halley V Research Station, Brunt Ice Shelf, Antarctica

FINAL COMPREHENSIVE ENVIRONMENTAL EVALUATION

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British Antarctic Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

COVER:
Design image of the UK Halley VI Research Station by Hugh Broughton Architects.

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FINAL COMPREHENSIVE ENVIRONMENTAL EVALATION

NON-TECHNICAL SUMMARY

1. INTRODUCTION

A Final Comprehensive Environmental Evaluation (CEE) has been carried out by the British Antarctic Survey (BAS) for the proposed construction and operation of the UK's Halley VI Research Station, Brunt Ice Shelf, Antarctica and the demolition and removal of Halley V Research Station. The Final CEE has been prepared in accordance with Annex I of the Protocol on Environmental Protection to the Antarctic Treaty (1998). The Guidelines for Environmental Impact Assessment in Antarctica (Resolution 4, XXVIII ATCM, 2005) were also consulted. The Final CEE describes the proposed activity, alternatives, the local environment and the likely environmental impact. It recommends preventative and mitigation measures and outlines gaps and uncertainties regarding the Halley VI project.

The Draft CEE was presented at the XXVIII ATCM in Stockholm in June 2005 and was approved by the Committee for Environmental Protection (CEP). The full text of all comments received by the UK Government on the Draft CEE are presented in Appendix 1, together with responses to the comments from the authors of the CEE.

The UK has operated Halley Research Station on the Brunt Ice Shelf since 1956. The proposed activity assessed in this Final CEE is the construction and operation of the new Halley VI Research Station and the demolition and removal of the current Halley V station. The new facility will be located on the Brunt Ice Shelf, Caird Coast, Dronning Maud Land (75º36'56"S, 026º07'52"W; October 2006).

The Brunt Ice Shelf is a floating ice sheet and is 200m thick. It is currently flowing at a rate of 500m per annum (June 2006) towards the Weddell Sea. At irregular intervals, the ice shelf breaks off as icebergs. BAS has assessed that there is a growing risk that the ice on which the existing research station sits could be lost in a major calving event in the next decade. The UK has therefore decided to design and build a replacement station in a safe location on the Brunt Ice Shelf for initial operation in 2009/10. To cope with any future, major calving events the new station has been designed so that it can be relocated.

Halley is one of the most important research locations in Antarctica for atmospheric sciences and snow chemistry. The first Halley was established as part of the International Geophysical Year (IGY) in 1957/58 and many scientific studies have continued uninterrupted since then, producing globally important long-term monitoring datasets. It was from Halley that BAS scientists discovered the ozone hole in 1985. Since 1992 when Halley V was commissioned, well in excess of 400 internationally peer-reviewed scientific papers have been published using data collected at the station. Halley supports world-class research into atmospheric physics, geospace, atmospheric and snow chemistry, meteorology and ozone monitoring, and glaciology.

In July 2005, following a design competition which attracted 86 submissions, a design for the new Halley station by Faber Maunsell and Hugh Broughton Architects was chosen. Morrison FI Ltd. (MFL) was selected as the building contractor for the construction of Halley VI and demolition of Halley V.

2. DESCRIPTION OF THE PROPOSED ACTIVITY

The location of the proposed Halley VI Research Station (75º36’56”S, 026º07’52”W; October 2006) is approximately 20km inland from the northwest seaward edge of the Brunt Ice Shelf. The station has been designed to be relocated over several kilometres (5–10km), a maximum of once every five years, so that it can be repositioned in the same geographic location whilst the ice shelf moves towards the sea.

The principal activities covered by the Final CEE are the:

- Construction and operation of Halley VI Research Station
- Demolition and removal of Halley V Research Station

The design for Halley VI Research Station is based on a number of light-weight, semi-autonomous modular buildings that can be plugged together in a variety of ways. The modules will be raised on hydraulically operated steel legs to be clear of the snow surface and are fitted with skis to allow for relocation. The modularity allows for changing user requirements, easier construction and maintenance through repetition, easier relocation, enhanced fire safety and acoustic performance through separation, and greater overall robustness.

The design incorporates energy efficiency measures by using insulation and low energy products. This reduces the need for snow management and general maintenance requirements, and therefore the number of personnel needed to maintain the station. Some buildings from Halley V will be reused at the new station.

Halley VI will be built over the three austral summer seasons 2007/08, 2008/09 and 2009/10. During the first two seasons Halley V will be used to accommodate the construction workers. The station modules will be constructed adjacent to Halley V and then towed via a groomed route to the location of Halley VI in 2009.

The construction materials will be prefabricated as much as possible. Cargo will be delivered to the Brunt Ice Shelf, and waste removed for recycling or safe disposal using predominantly the BAS resupply vessel RRS *Ernest Shackleton*. A charter vessel will be used to deliver construction cargo during 2007/08. Aircraft will be used to input some personnel. Tracked vehicles will move cargo from the ice edge to Halley V.

Halley VI is being designed with a life span of at least 20 years. The design has taken into account the need for future removal and this will be facilitated by the ability to tow the station to the edge of the ice shelf.

The demolition and removal of Halley V will be undertaken simultaneously with the construction of Halley VI. This will ensure that the waste stream matches the BAS cargo shipping capacity out of Halley and will also allow existing buildings at Halley V to house the construction and demolition workforce.

All waste will be packaged and labelled in accordance with the BAS Waste Management Handbook (BAS, 2006) and accurate records of all demolition waste will be maintained. Waste will be securely stored in ISO shipping containers or on raised mounds/ platforms to prevent burial by accumulating snow, and will be secured to prevent dispersal by the wind. Waste will be transported by BAS from Halley V to the ice-edge relief site and shipped out on the RRS *Ernest Shackleton* to Cape Town, South Africa, where it will be recycled or disposed of by licensed waste contractors.

Certain items, buried below the ice surface, will not be removed from Halley V as it is not safe to do so or technically practicable, and removal would be likely to result in greater adverse impact than leaving them in situ. This includes buried steel tubing and support legs.

3. ALTERNATIVES

Five options for the future of Halley Research Station have been examined:

- Discontinue scientific research at Halley
- Attempt to extend the life of the existing facilities at Halley V
- Move Halley V to a safer location on the Brunt Ice Shelf
- Relocate and build Halley VI on the Lyddan Ice Rise (74°25'S, 20°45'W) to the north-east of the Brunt Ice Shelf
- Commission a new station at a safe location on the Brunt Ice Shelf that can be relocated during its lifetime

The first four options are not viable for a variety of logistical, engineering, scientific, environmental and safety reasons. Therefore, the UK has decided that the best practical option is to build and operate a relocatable Halley VI Research Station at a safe location on the Brunt Ice Shelf.

4. DESCRIPTION OF THE ENVIRONMENT

Halley VI will be located on the Brunt Ice Shelf approximately 20km from its northwest coast. Average temperatures are –5°C in midsummer, falling to –30°C in winter, with an extreme maximum of +4.5°C and an extreme minimum of –55.3°C. There is snowdrift on approximately 180 days per year. Annual snow accumulation is approximately 1m. The winds are predominately from the east-north-east. Mean annual wind speed is $7ms^{-1}$. Gales occur on average for 40 days each year. The average annual total sunshine is 1445 hours, and in winter the sun does not rise above the horizon for 100 days. There is total darkness for 55 days.

The Brunt Ice Shelf does not support any flora, and there are no breeding birds or mammals at the proposed location of Halley VI. The station may very occasionally be visited by small numbers of moulting Adélie and emperor penguins. There is an emperor penguin colony of about 15,000 breeding pairs on the sea ice at 'Windy Creek', about 30km from Halley VI and 15km from the nearest ship unloading site. Weddell seals are common on the sea ice adjacent to the ice shelf. Other seabird species recorded in the coastal region around the Brunt Ice Shelf and at Halley V include Antarctic petrels, snow petrels, Wilson's storm petrels, southern giant petrel and south polar and subantarctic skuas, but there are no known nesting sites for these birds in the region.

5. IMPACT ASSESSMENT AND MITIGATION MEASURES

The environmental impacts for the construction and operation of Halley VI and the demolition and removal of Halley V have been predicted on the basis of the experience that BAS has of working on the Brunt Ice Shelf for 50 years.

The impacts related to the construction and operation of Halley VI and the demolition and removal of Halley V are summarised in the Final CEE using impact matrices. They show that the environmental impacts will include:

- Cumulative air pollution and particulate deposition from atmospheric emissions produced by the combustion of fossil fuels
- Large volume of demolition waste which will arise as a result of the clean-up of Halley V
- Potential contamination of snow and ice by fuel spills and leaks

Prevention and mitigation measures have been identified in the impact matrices to avoid or minimise these predicted impacts.

In the case of materials left buried in the ice their removal is not safe or technically practicable and removal would have a greater environmental impact than leaving them in situ.

BAS expects that the operation of Halley VI will have a reduced environmental impact compared to Halley V because of the smaller station population, improved environmental management procedures, and the introduction of new technology leading to more efficient use of fossil fuels and decreased waste production. In addition, Halley VI is being designed with a much longer lifespan (>25% longer) than its predecessors, and to be capable of being easily decommissioned and removed when it eventually closes.

All construction and demolition works and operational activities at Halley VI will be in compliance with, and where practical exceed, the requirements of the Environmental Protocol. Stringent environmental conditions have been included in the building contract for Halley VI, and will be enforced through careful contract supervision by BAS. Appropriate environmental education, training and guidance will be provided for all staff and contractors working at Halley. All activities at Halley will be subject to a permit issued by the UK Foreign & Commonwealth Office under the Antarctic Act (1994).

6. ENVIRONMENTAL MONITORING AND MANAGEMENT

BAS will establish a station environmental monitoring programme to measure the actual impacts of the project in Antarctica. As a minimum, BAS will monitor atmospheric emissions (calculated on the basis of fuel used), wastes produced, and fuel spills. Long-term glaciological monitoring of the Brunt Ice Shelf will continue to provide early warning of a major calving event. Also, continuous measurements of black carbon aerosol will be made to identify pollution from station generators and vehicles.

BAS will undertake an environmental audit of Halley VI once operational in 2010, and of the cleaned-up site at Halley V, to assess and verify the environmental impacts predicted in this Final CEE.

7. GAPS IN KNOWLEDGE AND UNCERTAINTIES

Gaps and uncertainties in the environmental impact assessment of the construction and operation of Halley VI and demolition of Halley V have been identified. They include:

- Natural variability of the hostile environment at Halley VI, such as weather, sea ice or ice shelf conditions. For example, in extreme circumstances it may not be possible for the resupply ship to reach Halley because of heavy pack ice, as happened to the RRS *Ernest Shackleton* in 2001/02 season
- Changes in future activities at Halley VI, for example the progressive introduction of renewable energy technology and developments in the BAS global science programme beyond 2010
- Minor changes in the project management and methodology of the construction of Halley VI and demolition of Halley V
- Uncertainty about predictions of the future behaviour of the Brunt Ice Shelf

8. CONCLUSION

The UK considers that the construction and operation of Halley VI Research Station on the Brunt Ice Shelf will have more than a minor or transitory impact on the Antarctic environment. The implementation of the preventative and mitigation measures outlined in this Final CEE will reduce environmental impacts, and BAS considers the overall impact of Halley VI will be substantially less than Halley V.

The UK concludes that the global scientific importance and value to be gained by the construction and operation of Halley VI and the continued operation of the research facility by BAS on the Brunt Ice Shelf far outweighs the more than minor and transitory impact the station will have on the Antarctic environment and fully justifies the activity proceeding.

9. FURTHER INFORMATION

This draft Final CEE has been prepared by the British Antarctic Survey. It was released on 21st December 2006 for international review. The final CEE is available on the BAS website (www.antarctica.ac.uk/halleyvi/cee.html).

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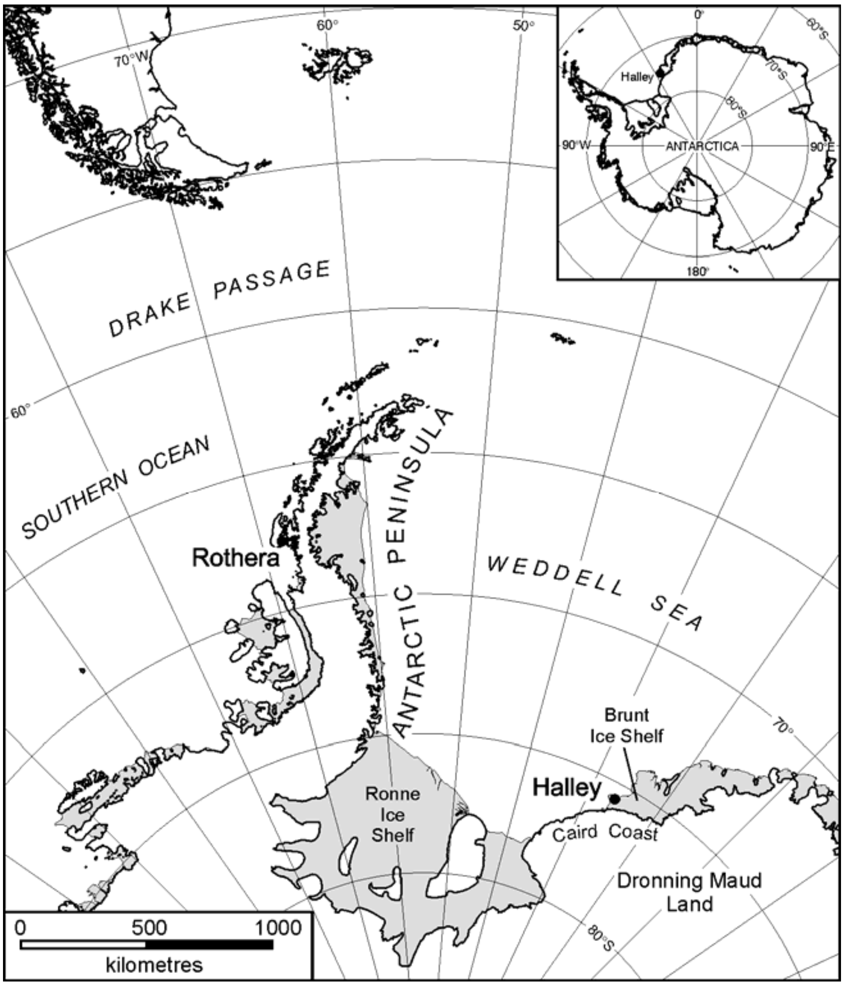
1. INTRODUCTION

1.1 THE ROLE OF HALLEY RESEARCH STATION

Halley Research Station is the UK's most isolated research facility in Antarctica, and is located on the floating Brunt Ice Shelf, Coats Land (Figure 1). The British Antarctic Survey (BAS) has operated five successive stations at Halley for 50 years.

BAS, part of the UK Natural Environment Research Council (NERC), is a world leader in research into global science in the Antarctic context and is the UK's national Antarctic operator. The majority of the BAS science programme is undertaken in Antarctica and the Southern Ocean, and Halley is one of the five research stations run by the Survey in the Antarctic and South Atlantic regions.

Figure 1. Location of Halley Research Station on the Brunt Ice Shelf, Antarctica.



Halley provides a vital research location for achieving a global perspective on climate change, ozone depletion and atmospheric pollution, and for long-term monitoring studies of weather, glaciers and ice shelves, solar storms and the upper atmosphere.

The current Halley is the fifth station to have been built by the UK on the Brunt Ice Shelf (Figure 2). It is located about 15km inland of the seaward edge of the Brunt Ice Shelf (75°34.86'S, 26°40.83'W; October 2006). The ice shelf is 200m thick, and flows northwest from Coats Land towards the sea where, at irregular intervals, it calves off as icebergs. BAS scientists assess that there is a growing risk that the ice on which the station sits could be lost in a major calving event in the next decade (Hayes, 2003).

Figure 2. Halley V Research Station, Brunt Ice Shelf.

1.2 HISTORY OF HALLEY RESEARCH STATION

The first Halley Research Station was established in January 1956 by the UK Royal Society for the International Geophysical Year (IGY) 1957/58, and was named after the British astronomer Edmond Halley. Work carried out at this station included meteorology, glaciology, seismology, radio astronomy, ionospheric physics, aurora and airglow, and geomagnetism. The station was transferred from the Royal Society to what is now BAS in 1959.

The extreme environment of the Brunt Ice Shelf poses significant building and technical challenges with blizzards and snowdrift burying everything on the surface unless it is actively managed. Buildings disappear beneath the snow, requiring vertical access shafts to be lengthened every year. Because of burial by snow and movement of the ice shelf, it was necessary to close Halley I in 1968, when it was 14m below the snow surface. Four further Halley stations were constructed on the Brunt Ice Shelf (see Table 1) in 1967, 1973, 1983 and 1992 (BAS, 2004a). All but the most recent, Halley V, have been buried under the snow until they were no longer safe to inhabit. Abandoned sub-surface buildings have been lost to sea in icebergs, which have calved off the ice shelf. Hazardous wastes were removed from Halley III in 1991 before it became impossible to access safely. Halley IV was decommissioned in 1991/92 and 1992/93 when all removable items and fittings were taken from the buildings before they were abandoned (Whittamore, 1992).

Halley V began operations in February 1992 (Blake, 2003). There are usually 14–18 people working at the station during the Antarctic winter, increasing to a maximum of 70 science and support staff during the two month summer period. The station contains a mix of building technologies. Four buildings sit on platforms 4m above the snow surface on legs that are jacked up annually to keep them clear of the accumulating snowfall. A further two buildings are mounted on skis and winched by tracked vehicles each year to a new position on the snow surface and then winched back to their original position the following year.

Table 1. History of the Halley Research stations built on the Brunt Ice Shelf.

Station	Dates of Use	Construction Type	
Halley I	1957–1968	Large wooden hut built on snow surface	
Halley II	1967–1973	Seven wooden huts built on snow surface	
Halley III	1973–1984	Series of prefabricated wooden huts housed inside corrugated steel tubes	
Halley IV	1983–1992	Two storey wooden huts inside tubes constructed from interlocking plywood-faced panels	
Halley V	1991–present	Four buildings on platforms on steel legs, jacked up annually. Two buildings on skis are towed to a new position each year	

1.3 SCIENTIFIC RESEARCH AT HALLEY

Halley is one of the most important research locations for atmospheric sciences and snow chemistry in Antarctica. BAS scientists discovered the spring-time ‘ozone hole’ over Antarctica using Halley data in 1985. Since 1992 when Halley V opened, well in excess of

400 research papers have been published in internationally peer-reviewed science journals using data collected at the station. At present, Halley supports world-class research into atmospheric physics, geospace, atmospheric and snow chemistry, meteorology and ozone monitoring, and glaciology. Many of the scientific studies have continued uninterrupted since 1956, when the station opened, producing globally important long-term monitoring datasets.

Work carried out at Halley is an integral part of BAS' five year science programme (2005–10) – Global Science in the Antarctic Context (GSAC) (see www.antarctica.ac.uk for further details). This programme has been constructed to deliver integrated, inter-disciplinary Earth System research, monitoring and survey, primarily in the Antarctic and the surrounding Southern Ocean. The programme was internationally peer-reviewed, and then approved by the UK NERC in 2004.

Halley will continue to be a globally important research location as the UK and the international science community focuses on interdisciplinary Earth System science. BAS scientists working at Halley already participate in a large number of international scientific programmes and international data-gathering activities, such as the World Meteorological Network. This is set to increase with the onset of the International Polar Year 2007/08.

1.3.1 Climate, ice and ozone studies

Meteorological data have been collected at Halley since 1956, and in combination with data from other Antarctic research stations, provide a climatic database for an area larger than Europe. The data are sent by satellite to weather forecasting centres around the world, and are vital for immediate use and for all aspects of climate change research. The data are also used to improve the representation of high latitude processes in General Circulation Models used for climate modelling.

Halley is situated in one of the best natural laboratories in the world for studying the dynamics of the atmosphere close to the ground, due to its remoteness and the flatness of the ice shelf. A sophisticated Clean Air Sector Laboratory (CASLab) at Halley is providing new insights into the chemistry of the air/ice interface, levels of pollution and a range of processes critical for interpreting ice core data. Glaciologists study past climate using ice cores.

New and existing datasets are being used to understand the relationship between Antarctic and global climate over millennial timescales. The drivers and amplifiers controlling climate over the last million years are being investigated. This should allow the correct processes to be incorporated into the predictive models, helping policy makers to make informed decisions about how to manage the Earth in the future.

The ozone layer has been measured at Halley since 1956. The spring-time depletion in stratospheric ozone was discovered by BAS scientists using Halley data in 1985 (Farman et al., 1985). The scientists observed that during each spring, ozone was almost completely destroyed over Antarctica, producing what is now known as the 'ozone hole'. These measurements attracted world-wide interest from scientists, the public and senior government policy makers. The discovery led very quickly to the agreement of the Montreal Protocol to protect the ozone layer and the global response to curtail production of chlorofluorocarbons (CFCs) and other ozone depleting substances (DEFRA, 2000).

Figure 3. Left: Scientist releasing meteorological balloon. Right: High Frequency Southern Hemisphere Auroral Radar Experiment (SHARE) at Halley V station.

1.3.2 Geospace research

The near-Earth region of interplanetary space, known as geospace, is dominated by the interaction of the Sun's atmosphere with the magnetic field of the Earth. Understanding the physics of geospace is of increasing importance as periodic increases in solar activity create magnetic storms that affect a wide range of technical systems on satellites and impact radio communications and power-line transmissions.

Halley is ideally situated for geospace research as it lies on the edge of the southern auroral zone. A high frequency (HF) Southern Hemisphere Auroral Radar Experiment (SHARE) radar is a key part of the Super Dual Auroral Radar Network (SuperDARN), which is a network of high frequency radars in the polar regions being used to observe the impact of the Sun's activity on space weather. There is also a comprehensive suite of other powerful radio and optical instruments and together they provide an unparalleled spatial picture of the consequences of geospace interactions in the upper atmosphere (above 100km) (see Figure 3). Instruments monitor an area of around three million square kilometres above the South Pole. Halley is also the focus of the BAS Low Power Magnetometer (LPM) network, a suite of ten unmanned monitoring stations distributed between Halley and the Amundsen-Scott South Pole Research Station (USA), which also contribute to geospace research.

At around 85km above sea level, the mesosphere is the coldest part of the Earth's atmosphere and is at the boundary between geospace and the stratosphere. This region has long been inaccessible to instrumentation, but Halley now has a suite of state-of-the-art radio and optical instruments for observing the mesosphere's structure and dynamics. This instrument suite completes the ensemble at Halley and allows the Earth's atmosphere to be studied from ground level to its very outer limits.

1.4 THE FUTURE DEVELOPMENT OF HALLEY

The Brunt Ice Shelf is a floating ice sheet and is 200m thick. It is currently flowing at a rate of 500m per annum (June 2006) towards the Weddell Sea. At irregular intervals, the ice shelf breaks off as icebergs. BAS has assessed that there is a growing risk that the ice on which the existing research station sits could be lost in a major calving event in the next decade (see Section 5.3).

In 2004, the UK decided to design and build a replacement station at a safe location on the Brunt Ice Shelf for initial operation in 2009/10. To cope with any future major calving events, the new station will be designed so that it can relocated. An innovative multi-disciplinary design competition was launched to provide new and exciting concepts for the future development of Halley. A key design criterion was that Halley VI must have minimal impact on the Antarctic environment and comply with the Environmental Protocol.

1.4.1 Halley VI Research Station design competition

The Halley VI Research Station design competition, in association with the UK Royal Institute of British Architects (RIBA) (BAS, 2004b), aimed to encourage a fusion of science, architecture, technology and engineering to produce a world-class science facility in Antarctica. The competition comprises four stages (Table 2). Further details about the competition can be found on the BAS website (www.antarctica.ac.uk).

Table 2. Halley VI design competition programme.

Stage	Activity	Timescale
Stage 1	Expression of Interest (EOI)	June – August 2004
Stage 2	Concept Proposal	September – December 2004
Stage 3	Concept Development	January – September 2005
Stage 4	Procurement and Construction	October 2005 – February 2010

The design competition was launched by RIBA and BAS in late June 2004, with a call for Expressions of Interest (EOI) from design teams around the world. In August 2004, a total of 86 EOIs from different design teams based in seven nations were evaluated by a Jury Panel, chaired by the Director of BAS. Six design teams were selected to take forward their ideas and develop concept proposals.

All of the six produced innovative and creative designs, displaying ingenious new ways of building and operating the station. A major design requirement is for the station to have minimal environmental impact. Images of the six concept designs can be found on the RIBA website (www.riba.org).

A BAS technical panel, followed by the Jury Panel, assessed the six concept proposals in November 2004. Three design teams were selected to develop detailed concept designs. The Draft CEE contained a summary of these three concept proposals. As part of the final evaluation, the Jury Panel were provided with the Draft CEE and all comments made on the document.

The selected teams then undertook detailed work, together with a building contractor, on their concepts and the winner – Faber Maunsell and Hugh Broughton Architects – was selected in July 2005. The building contractor Morrison FI Ltd. was then selected for the construction of Halley VI Research Station and the removal of Halley V Research Station.

1.4.2 Project management structure

The construction of Halley VI and demolition of Halley V is being coordinated by the BAS Halley VI Project Manager, who will be on site during the construction seasons. MFL, working with the design team Faber Maunsell and Hugh Broughton Architects, will be the main contractor for the project.

1.5 PREPARATION AND PRODUCTION OF THE CEE FOR HALLEY VI

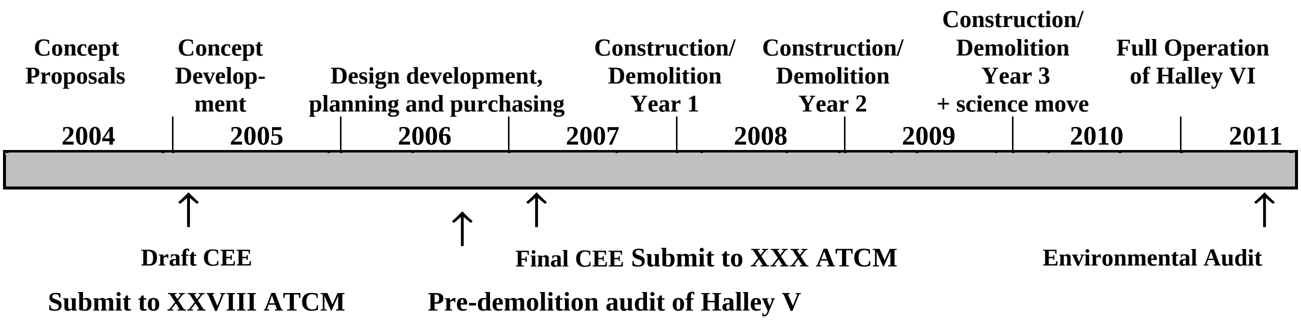
The preparation and production of the Draft and Final CEE for Halley VI is being led and managed by BAS through its Environmental Office, with support from the polar environmental consultancy, Poles Apart. Input to the CEE has been provided from across BAS, including the Halley VI Project Manager, the Halley VI Project Board, Engineering and Technology Services, Operations Group and scientists from Physical Sciences Division and Biological Sciences Division.

The Draft CEE was made available to the public via the BAS web site (www.antarctica.ac.uk/halleyvi/cee.html). It was circulated by the UK Government to the Governments of the other Antarctic Treaty Consultative Parties (ATCPs) more than 120 days before the XXVIII Antarctic Treaty Consultative Meeting (ATCM) held in Stockholm, Sweden in June 2005. The Draft CEE was considered by the Committee for Environmental Protection (CEP) at the ATCM. The full text of all comments received by the UK Government on the Draft CEE are presented in Appendix 1, together with responses to the comments from the authors of the CEE. The relevant section of the CEP report and CEP advice to ATCM XXIII are also included in this Appendix.

The draft Final CEE was also made available on the BAS website for comment in December 2006 (www.antarctica.ac.uk/halleyvi/cee.html) and two Antarctic Treaty Consultative Parties provided useful comments.

The timeline for the design competition and for the Draft and Final CEE for Halley VI is shown in Figure 4.

Figure 4. Timeline diagram showing the stages of the planning and construction of Halley VI and the demolition of Halley V.



2. DESCRIPTION OF THE PROPOSED ACTIVITY

2.1 SCOPE

This final Comprehensive Environmental Evaluation (CEE) has been carried out by the BAS for the proposed construction and operation of the UK's Halley VI Research Station and the demolition and removal of Halley V. It has been prepared in accordance with Annex I of the Protocol on Environmental Protection to the Antarctic Treaty (1998). The Guidelines for Environmental Impact Assessment in Antarctica (Resolution 4, XXVIII ATCM, 2005) were also consulted.

2.1.1 Key changes to the Draft CEE

Key changes to the proposed activity since the production of the Draft CEE are as follows:

- The construction team will use the accommodation and support facilities at Halley V instead of building a temporary construction camp (see Section 2.6.3)
- A number of existing buildings from Halley V station will be reused for Halley VI (see Section 2.5.2)
- The demolition and removal of Halley V will be undertaken during the construction of Halley VI and will be completed as Halley VI becomes operational. The demolition works are considered in this CEE (see Section 3)

2.2 LOCATION

The location of the proposed Halley VI Research Station (75º36'56"S, 026º07'52"W; October 2006) is approximately 20km inland from the northwest seaward edge of the Brunt Ice Shelf. The ice shelf at this point is floating and is approximately 200m thick, and currently moving at a rate of 500m per annum (June 2006) towards the Weddell Sea.

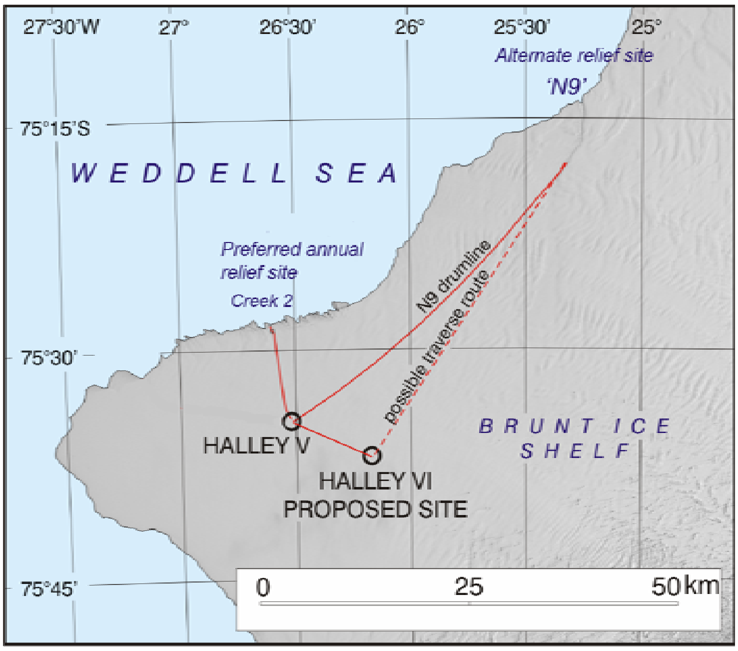
As the ice shelf advances towards the coast, the station will periodically be towed back to the same geographic location on the ice and therefore there will be no net movement westwards as with the previous stations. It is expected that any relocation of the station will coincide with either a major predicted calving event on the ice shelf, or with the BAS five year science research programme cycle. In this context, relocation is defined as the movement of the facilities over several kilometres (5–10km), a maximum of once every five years with at least one year's notice to prepare.

Figure 5 shows the location of the Brunt Ice Shelf, the current location (February 2005) of Halley V and the proposed site of Halley VI (February 2005).

2.2.1 Geographical boundaries of the Final CEE

The geographical boundaries of this Final CEE include the location of Halley V Research Station and the location of the proposed Halley VI Research Station on the Brunt Ice Shelf. The transport routes for associated activities, such as shipping, aircraft and tracked vehicles within the Antarctic Treaty Area are also included.

Figure 5. Brunt Ice Shelf showing Halley V and the proposed location of Halley VI.



2.3 PRINCIPAL CHARACTERISTICS OF THE PROPOSED ACTIVITY

The principal activities covered by the Final CEE are the:

- Construction and operation of Halley VI Research Station;
- Demolition and removal of Halley V Research Station (see Section 3); and
- Transport and movement of personnel and cargo to Halley VI within the Antarctic Treaty Area.

One of the major planning objectives is that the environmental effects of Halley VI will be reduced compared to Halley V.

2.4 GENERAL SPECIFICATION FOR HALLEY VI

The general specification of Halley VI is as follows:

- New accommodation and laboratory facilities for 16 people in the austral winter and 52 people in the austral summer, which will be safe, comfortable and stimulating to live and work in
- Design life of all the new facilities of at least 20 years
- Methods of construction, operation and decommissioning will comply with and, where practical, exceed the requirements of the Environmental Protocol
- The environmental impact of the whole station throughout all phases of its life will be kept to a minimum
- The use of fossil fuels will be minimised and the use of renewable energy maximised where practical
- A comprehensive waste management programme, including the treatment of human waste, will be designed into the station
- The modular nature of the design will allow for the replacement of individual facilities without significant interference to, or requiring the replacement of, the whole station

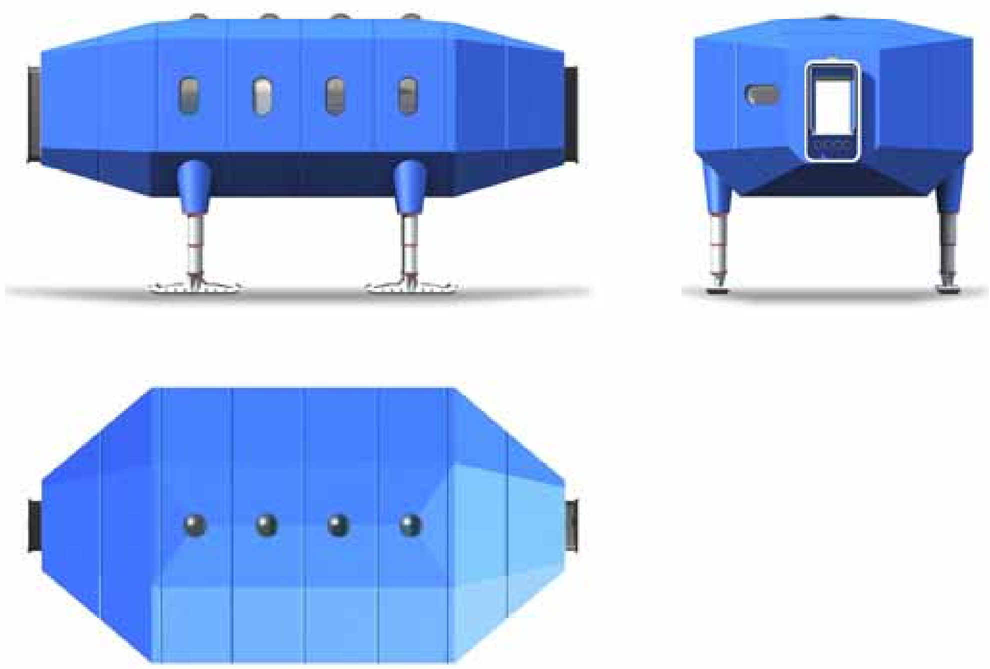
- The station will be built above the snow surface, and the main buildings will be capable of being relocated by several kilometres if required
- The facilities will be completed, commissioned and handed over to BAS by the end of February 2010
- The facilities will minimise the requirement for snow management in all aspects of the station's operation in order to reduce maintenance and minimise fuel consumption
- The manual handling and multiple handling of all stores and equipment will be minimised across all operations, including annual relief, normal operation and eventual decommissioning of the facilities
- The requirement for maintenance of the facilities will be reduced and simplified (less labour/specialist trade intensive)
- Risks to Health and Safety of staff working at the station will be minimised.

Appendix 2 shows a schedule of the accommodation for the domestic, technical and science facilities planned for Halley VI Research Station.

2.5 HALLEY VI DESIGN

The winner of the design competition (see Section 1.4.1) was Faber Maunsell and Hugh Broughton Architects. The station design is based on a number of semi-autonomous modular buildings on skis (see Figure 6) that can be plugged together in a variety of ways. The modularity allows for changing user requirements, easier construction and maintenance through repetition, easier relocation, enhanced fire safety and acoustic performance through separation, and greater overall robustness.

Figure 6. The standard module for Halley VI.



Grouped around a central living module, the accommodation, workspace and energy generation modules will form an integrated research facility designed to deal with the extreme conditions on the Brunt Ice Shelf and future science needs.

Each module will be highly insulated to incorporate low energy and sustainability principles. All areas are designed to be as space efficient as possible to minimise the overall footprint on the ice, the volume of materials used, environmental impacts of transportation and snow management.

The modules will be raised on hydraulically operated steel legs to be clear of the snow surface and are designed to be relocated to deal with snow accumulation and movement of the ice shelf. Each leg will sit on a specially developed ski so that the modules can be towed by tracked vehicles. The skis will be designed to be manually handled and interchangeable to allow for future flexibility and mobility. Each ski will be secured with a dagger board driven through the ski into the ice to prevent sliding of the modules once in position.

Components are standardized to maximize interchangeability of parts and to reduce the number of spares stored on site. Separate energy modules will house power generators, fuel storage facilities and a sewage treatment plant. A larger, central living module will house operations, communications, dining and recreation areas.

The cladding will be formed from relatively lightweight glass reinforced plastic (GRP) panels fixed to the structure and joined with a silicone rubber gasket. The panels consist of closed cell polyisocyanurate foam insulation encapsulated within the GRP, finished with a layer designed to minimise discolouration, resist UV and the abrasive impact of wind driven snow and ice.

The selection of building materials with minimal impact has been carefully considered at all stages of design. This includes:

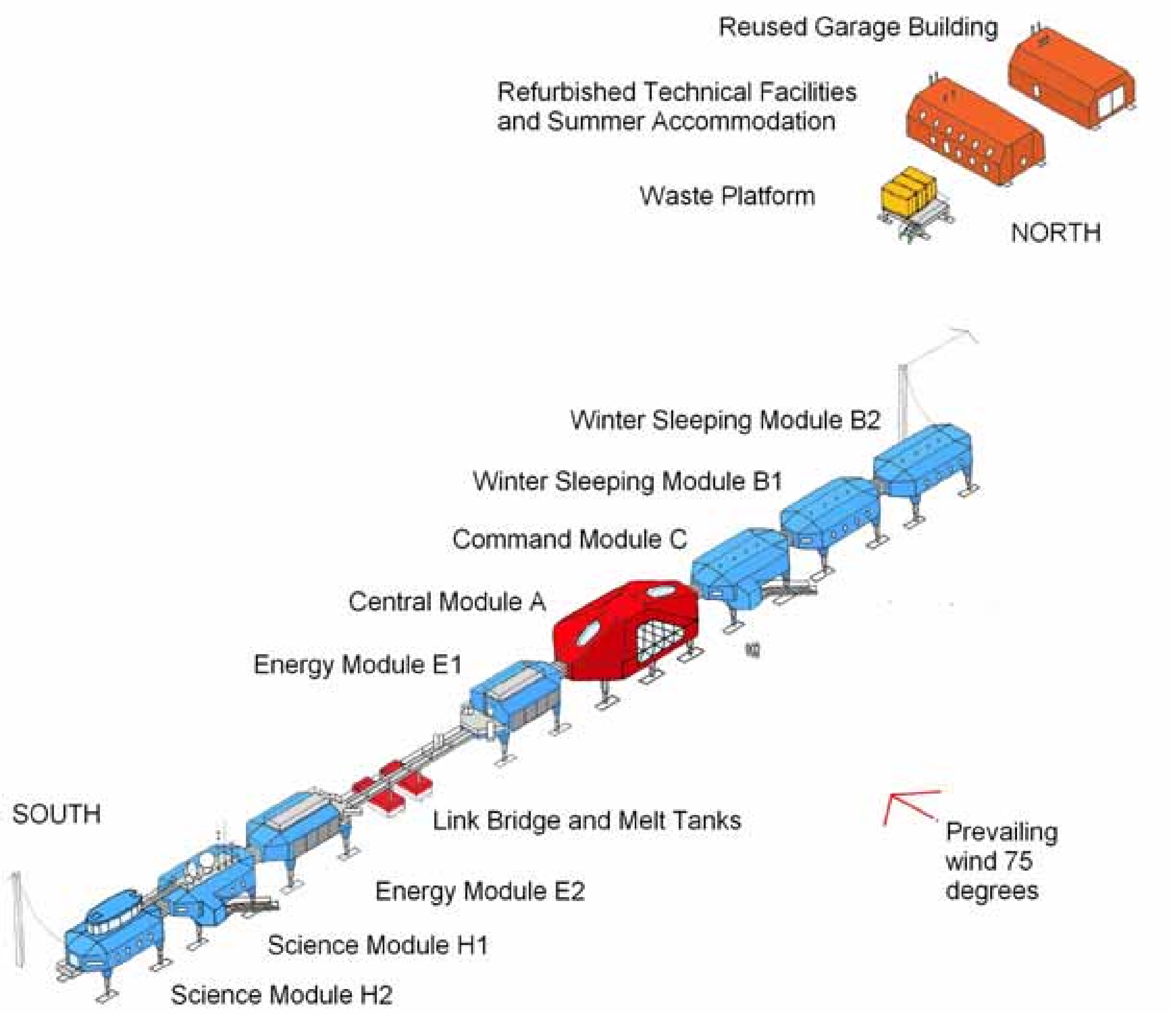
- The use of a highly insulated sealed cladding system to give an air tight building and achieving exceptional U values (coefficient of heat transmission) of $0.113 W/m^2K$ for the external cladding and $1.1 W/m^2K$ for the windows
- All sub-contractors and suppliers to the contract have been asked to advise on the content of recycled and recyclable material that will be used in the production of all items
- All timber and timber products will originate from well-managed forests and all suppliers to the contract will be in possession of their own current and valid chain of custody certificate

The station facilities have been designed in direct response to the process demands of the construction, operation, and annual resupply of Halley VI. They incorporate survival, maintainability and sustainability principles that will allow the station to function reliably and economically, taking full account of the requirements of the Environmental Protocol.

2.5.1 Site layout

The station modules are connected to form two main platforms (see Figure 7). The northern platform provides the principal living accommodation. The southern platform contains the science modules. Separation into two platforms creates a refuge in case of catastrophic failure of one platform or energy module. Stand alone structures will provide garage, technical, waste management and summer accommodation facilities.

Figure 7. Elevation of Halley VI with science modules to the left and living quarters to the right



The key features of the site layout are:

- The platforms are perpendicular to the prevailing wind to minimize snow management
- A pedestrian and services link bridge connects the energy modules. Two melt tanks are placed under the bridge and provide potable water. Water treatment, fuel, electrical services, data and communications will be linked between the platforms
- The bridge provides an above-ice passageway for staff between the two platforms, for use in poor weather
- Science modules are placed to the southern end of the station, close to the clean air sector, optical dark zone and geospace radar arrays
- The southern-most science module has an upper level observatory with a clear panoramic view of the southern skies for the meteorological operations room and ozone laboratory

The northern-most winter sleeping module includes a quiet lounge with panoramic views.

2.5.2 Reuse of buildings and materials from Halley V

Where possible and appropriate, existing buildings and structures from Halley V station will be reused. This will reduce the need to ship materials to Antarctica and will also reduce the amount of waste generated by the demolition of Halley V. The following buildings and facilities will be relocated:

- Drewry building – technical facilities and summer accommodation
- Garage building
- Clean Air Sector Laboratory (CASLab) used for atmospheric science
- Waste platform
- Science cabooses (Optics, SHARE, Balloon, AIS/Dynasonde)
- The Air support caboose and Air support ISO
- The Codis satellite dome and sledge
- The Mobile Refuelling Bowser
- ISO Containers (Emergency food and SAR ISO)
- 10 bulk fuel tanks
- Skids and Sledges
- The BAS fleet of vehicles

These buildings and structures will be refurbished as necessary. These structures may not have the 20 year life expectancy of the new modules and may need to be replaced during the lifetime of Halley VI.

Some reusable items of equipment at Halley V will also be transferred to the new station such as doctor's equipment, science and laboratory equipment, waste compactors, and breathing apparatus equipment (see Section 3).

2.6 CONSTRUCTION OF HALLEY VI

The construction of Halley VI will be conducted under contract by MFL. Shipping and vehicles will be supplied by BAS. The construction of Halley VI will take place during the austral summer seasons (December–February) of 2007/08, 2008/09 and 2009/10 with handover to BAS in the final season. During the construction seasons the scientific work at Halley V will be reduced to maintain long-term monitoring activities.

The construction work will take place at Halley V, where the construction workers will be accommodated. During the second part of the 2008/09, the modules will be towed to the Halley VI site for completion of the station.

2.6.1 Shipping and logistics

The BAS logistics vessel RRS *Ernest Shackleton* will be used for the transport of personnel and cargo for the construction of Halley VI and removal of Halley V. In addition, an ice-strengthened cargo/passenger vessel will be chartered to transport the estimated 14,000m^3 of Halley VI cargo for the first construction season. The ships will call at Cape Town, South Africa for loading of cargo and personnel.

In total, eight return ship journeys to the Brunt Ice Shelf from Cape Town will be made by BAS ships and one return journey by the charter ship during the three seasons from 2007–10, as summarised in Table 3.

Table 3. Planned ship movements during the construction of Halley VI station

Date	Ship movement
December 2007	Offload cargo and personnel. Accommodation during relief operations Offload 14,000m^3 construction cargo (charter ship)
February 2008	Remove all waste and summer personnel
December 2008	Offload 500m^3 construction cargo and personnel. Remove all waste
January 2009	Remove waste
February 2009	Remove all waste and summer personnel
December 2009	Offload 500m^3 construction cargo and personnel. Remove all waste
January 2010	Remove waste
February 2010	Remove all waste and summer personnel

<u>Personnel input</u>

There will be three routes for personnel input to Halley:

1. Early input using Dash–7 air link via Rothera Research Station and DHC–6 Twin Otter onward transport to Halley
2. Input on RRS *Ernest Shackleton* from Cape Town (maximum 49 pax)
3. Input via Dronning Maud Land Air Network (DROMLAN) airlink from Cape Town via Novolazarevskaya blue ice runway

The aircraft will land at a 1000 x 50m snow skiway at Halley V.

The provisional numbers of passengers using each of the input routes during each season is shown in Table 4. A small number of personnel may also be input on the charter vessel.

Table 4. Provisional numbers of BAS and MFL personnel by input route each season

	2007/2008	2008/2009	2009/2010
Input via Rothera	3 or 4	6	0
Input on RRS Shackleton	49	49	49
Input via DROMLAN	32	29	18

2.6.2 Movement of cargo and people from the supply ship to Halley V

Offloading of cargo and people will take place from the supply ship onto seasonal sea ice formed within a small creek or bay in the Creek 2 area along the north-west coastline of the Brunt Ice Shelf (see Figure 5). The route to the site will be inspected and tested for suitability for delivery of cargo.

Cargo will be off-loaded onto sledges on the sea ice, towed by tracked vehicles across the sea ice, up a bulldozed snow ramp, and onto the ice shelf. Vehicles will follow a route marked with flags or drums from the Creek 2 area around 15km across the ice shelf to Halley V.

If a suitable creek cannot be found or a ramp cannot be bulldozed safely in the Creek 2 area, or if the sea ice conditions are poor, then a longer resupply route from N9, around 60km from Halley V (see Figure 5), will be used. At this location cargo and people can be offloaded from the ship directly onto the ice shelf.

Full advantage will be taken of the 24 hour daylight available during the austral summer, with cargo operations taking place around the clock.

2.6.3 Construction team accommodation and site facilities

The MFL construction team will consist of approximately 60 personnel during the first two summer construction seasons. During the final season, 2009/10, the team will consist of approximately 25 personnel. It is not planned to overwinter any of the construction team. In addition, BAS personnel will be responsible for operating Halley V as an accommodation facility and operating some vehicles. The maximum number of people at Halley V during the two main construction seasons will be approximately 100 people.

Halley V will be used to accommodate BAS personnel and the Halley VI construction team. Accommodation will be provided as follows:

- Laws Building has a capacity to accommodate 40 people
- Drewry Building has a maximum capacity of 38 people
- MFL will provide a temporary accommodation building, and ablutions facility for 20 people
- Existing refuge cabooses will have capacity for a further 8 people

The Piggott and Simpson science buildings will be used as warm storage and office accommodation. During relief operations and removal of waste, a refuge caboose will be sited on the ice shelf near the ramp.

The construction site will have its own self-contained toilet, which will empty into a hole in the ice. A site cabin will provide facilities for morning and afternoon breaks.

A site cargo handling shelter may be provided for the unpacking of materials. Temporary, sledge-mounted containers, used for the transportation of materials to Halley, will act as mobile stores.

Mobile generators will be required at the Halley VI construction site. A number of small, lightweight and efficient Honda petrol generators up to 3kVA will be used. Larger generators will use AVTUR. Kerosine heating equipment may also be used.

2.6.4 Vehicles and fuel for cargo movement and station construction

The key items of plant used for the proposed station construction will be:

- Crane - expected to be tracked mobile crane
- 3 Nodwells (tracked vehicles with cab, tray and crane) full time with a further Nodwell part time as and when available
- 2 Scissor lifts
- 2 Cherry Pickers
- 1 Telehandler
- 4 Sno-cats
- 2 Argo Challenger 765Bs
- 2 John Deere 7820s with track conversion
- 4 Bulldozers

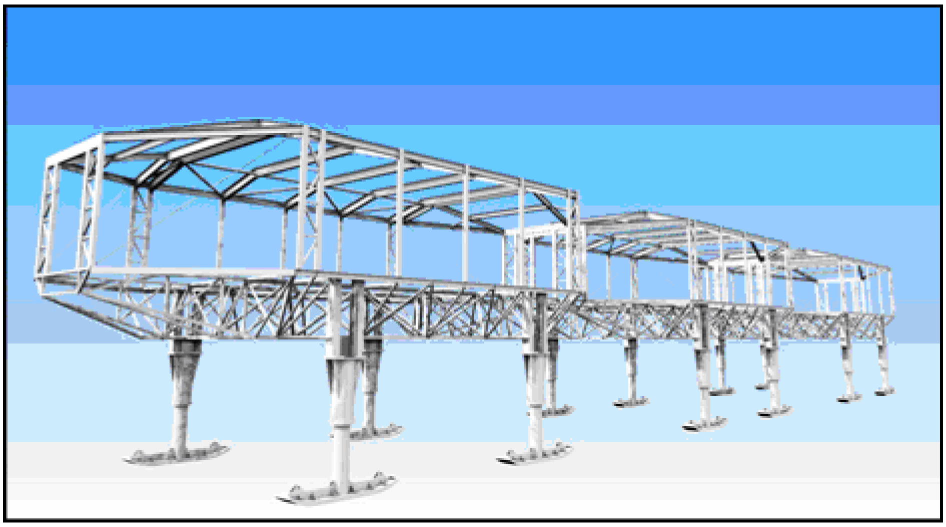
There will also be other vehicles on site to support the operation of Halley V and as back-up vehicles. For example, a number of snowmobiles are used at the station.

Most of the vehicles are fuelled with AVTUR. Snowmobiles use lead replacement petrol, which is unleaded petrol with additive. Small amounts of synthetic lubricants, grease and oil will be used for vehicle servicing.

2.6.5 Prefabrication and construction of modules

Figure 8 shows the steel structure of the modules, which consists of a steel space frame (lower steel work), superstructure steelwork, legs and skis. To reduce the build time in Antarctica, the lower space frame will be constructed in Cape Town and mechanical and electrical (M&E) equipment will also be fitted to a maximum weight of around 9.5 tonnes. This is the expected bearing capacity of the sea ice for unloading. These units will be offloaded onto the sea ice and towed to the construction site.

Figure 8. Space frames, superstructure steelwork, legs and skis of three standard modules



The construction of Halley VI will follow a production line approach based around five workstations.

Station 1: The transit legs and skis will be replaced by the permanent legs and skis. The unit will be towed to the next station.

Station 2: Floor cassettes will be lifted by crane and under floor cladding will be installed.

Station 3: Sealed pre-fabricated pods and any large prefabricated mechanical and electrical items will be craned onto the deck. The portal frame superstructure steelwork will be lifted onto the pod and fitted.

Station 4: Cladding panels will be bolted to the steelwork. Cladding will be installed with mechanical fixings to enable easy removal when the station is decommissioned. Glazed items and any external steel work, including roof decks and ladders, will also be fitted. External openings will be sealed to make the module “weather-tight” and ready for moving to its winter position.

Station 5: Modules will be moved to the wintering position. Further internal works will be completed during the following season.

2.6.6 Move from Halley V to winter location at Halley VI

The completed modules will weigh around 80 tonnes. The station will be constructed adjacent to Halley V and then moved 12km to the Halley VI location. It is expected that it will take a day to move each module to its new location. A groomed route will be prepared between the two locations prior to relocation.

Extensive vehicle testing was conducted at Halley with trial sledges in the 2005/06 season that demonstrated the modules could be pulled using D5 Caterpillar bulldozers over a prepared snow surface. The central module will weigh more than 125 tonnes and further testing was undertaken during the 2006/07 season, which demonstrated that this module can be relocated using either D5 bulldozers or CAT Challengers which will be on site during construction.

2.6.7 Waste Platform

A new waste platform for Halley VI will be constructed on site at Halley V reusing the trial sledge. The platform will house three containers, and a clear area for access. The containers will be fitted with a mechanical waste compactor and twin chamber high temperature incinerator. The third container will be used for storage. The platform will be located at Halley V during the first season and will be transferred to Halley VI when required.

2.7 OPERATION OF HALLEY VI

Halley VI has been designed to produce a minimal environmental impact on the Antarctic. BAS operational experience in this region for 50 years has been used to devise the most efficient, cost effective and low impact way of running the station. Many improvements have been made compared with the station at Halley V. These include:

- Improved design to reduce snow management
- Improvements in fuel and water management
- Reduction in number of personnel and vehicles
- Relocation of station to allow for longer life span and facilitate decommissioning
- Improvements in waste management facilities
- Use of renewable energy

A comparison of operations at Halley V and Halley VI is shown in Appendix 3.

2.7.1 Halley VI staff complement

The new design will minimise the requirement for building maintenance and snow management, and will therefore require less technical support. In addition, BAS will make more use of automated data collection and satellite transmission to reduce staff numbers.

Compared to staffing levels at Halley V in 2004/05, planned total summer numbers at Halley VI will reduce by 26% (from 70 to 52 staff) and in winter will initially remain the same (16 staff), but may be reduced to 10 or 12 in the future.

2.7.2 Heat and power

A Combined Heat and Power (CHP) system will provide electrical power and heat for the platforms in the most efficient manner possible to minimise waste energy and, therefore, reduce fossil fuel consumption. CHP generators are at their most efficient when operating close to full load and the generators have therefore been sized to match closely the daily electrical demand profile throughout the year.

The CHP plant will be located in two separate energy modules, E1 and E2 containing two 150kVA generators with Cummins diesel engines on each module. To enhance the heat output from the units, all off-platform facilities (Cabooses, Garage, Drewry, CASLAB, etc.) will be connected into the CHP units.

The combination of a well insulated, sealed enclosure and good controls will ensure efficient energy consumption. The heating sources within the accommodation will provide the correct mix of convective and radiative heating to optimise comfort. Heat recovery on all ventilation air will keep airflows at the most energy efficient rates.

All electrical equipment within the modules will generate and supply heat to their respective areas. When electrical demand is at its maximum in the middle of the day, heat demand is likely to be at its lowest and waste heat can be used in the melt tank. In the evening, when electricity demand is likely to be at its lowest and heat demand at its highest, all waste heat will be used to heat the building and not the melt tank. In principle, the melt tank will be used as a heat buffer. When the heating demand rises above the level of waste heat from the CHP plant, then the boiler will top up the heat required.

A reduction in the general fuel requirement will be achieved by implementing the following measures:

- Best use of natural lighting
- Long life, low energy lighting will be used with daylight controls, presence detection and timed on/off operation. Long life lamps also mean low maintenance and less waste. The use of standardised lighting components means less storage of spares and movement of parts around the site
- Reduced water usage per person using a vacuum drainage system and water saving devices
- Use of energy and water efficient white goods such as washing machines, dishwashers, and low energy AAA rated fridges and cookers
- Use of energy efficient fans and pumps
- Use of low energy flat screen displays for computers
- Use of a Buildings Management System to turn off the ventilation system at certain times of the day
- Limited and timed operation of humidification for essential areas only
- Use of passive solar heating in the summer months

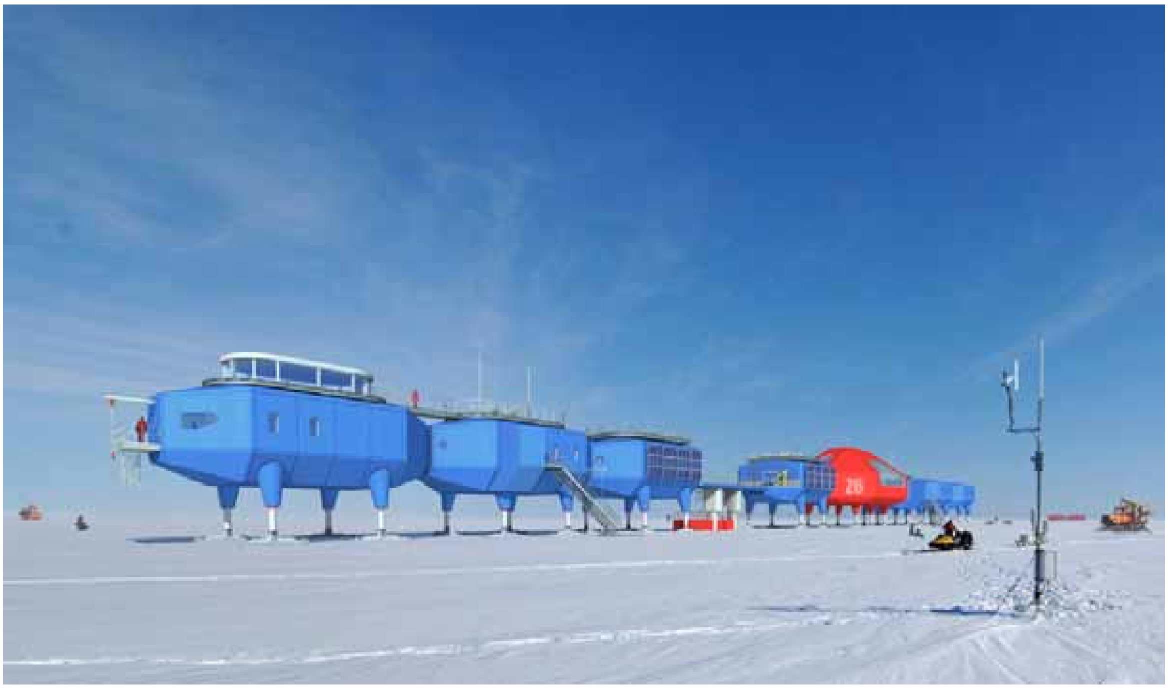
Because the design will use lower amounts of primary energy, other environmental impacts at Halley VI will be minimal. The building's thermally efficient design and ability to be managed in a more environmentally benign way will impose a lower load on the electrical and heating equipment.

<u>Renewable energy</u>

The station design allows for future integration of sustainable sources of energy such as wind turbines and photovoltaic arrays. The electrical distribution system has been designed to allow for "plug and play" renewable devices. It is intended to test a range of different types of PV panels that could be installed.

It is proposed that both energy modules will include solar thermal panels to supplement the waste heat collected from CHP generator engines for water heating. The availability of solar energy coincides with the station's periods of peak occupation and highest hot water demands. Evacuated tube solar panels will be positioned on the vertical surfaces of the energy modules E1 and E2, sized to integrate with the vertical side cladding panels to capture as much solar energy as possible.

Figure 9. Design image of Halley VI Research Station



2.7.3 Water generation

Vehicles will be used to fill the station melt tanks with snow. The tanks will have sufficient water storage for 3–4 days in summer and 10–14 days in winter.

The use of water will be minimised by providing spray and aerated taps, low-flow showers and a vacuum drainage system. The use of water efficient laundry and dishwasher machinery will also reduce water demand.

Reduced water consumption will require less energy input to melt snow, less pump power to circulate the water, and lower volumes of wastewater to process and dispose of. Careful design and planning is expected to reduce water consumption by 50% compared to existing demand at Halley V.

2.7.4 Waste management

At Halley VI, a Microbac bioreactor sewage treatment plant will be used for the main platform. The biological sewage plant will provide an excellent growth environment for bacteria, as the tank is fitted with a rigid PVC matrix with an internal surface area 150 times larger than any traditional active sludge plant or tank. The tank will introduce some modified bacteria that will reduce the amount of sludge produced. De-sludging the tank will be required only once a year. Sludge will be incinerated and treated wastewater will be discharged to the ice.

A Surefire incinerator will be installed on the waste platform for food waste, sewage sludge and waste oil. This incinerator has a maximum operating temperature in the primary chamber of 1400°C. The secondary chamber maximum operating temperature is 1600°C and is designed to retain the exhaust gases at a temperature in excess of 850°C for at least 2 seconds.

2.7.5 Fuel use and fuel handling

The BAS resupply ship has a bulk fuel capacity of 150,000 litres. Six of the 24,000 litre bulk fuel tanks will be transported to the ice shelf edge for annual refuelling via the transit tank from the ship and will then be towed back to the depot line at Halley VI. This will speed up relief operations and reduce fuel, labour and plant usage compared to Halley V operations. The remaining 90,000 litres of bulk fuel will be drums, which will be decanted into the remaining bulk fuel tanks at the station.

At Halley VI, one of the sledge-mounted bulk fuel tanks will be transported from the fuel depot line to the energy modules once a month in the summer and once every 6 weeks in the winter. The content of one bulk fuel tank will refuel the whole station, so there will be no repeat trips with half empty tanks. The tank will be connected to the energy modules with dry break connectors that reduce the risk of fuel spills. There will be three 10,000 litre capacity tanks at Halley VI, two on one energy module and one on the other.

Annual fuel use at Halley VI is estimated at 240,000 litres (111 litres/m^2 floor area of station), compared to 225,000 litres (150 litres/m^2) at Halley V, so the fuel efficiency at the new station is improved by 26%.

2.7.6 Raising the modules

A new jacking system will represent a significant reduction in the overall maintenance burden of Halley VI compared to Halley V. The main effort will be to push snow beneath the platform feet using D5 Caterpillar bulldozers. The whole operation for the entire station can be completed in approximately one week, deploying two or more vehicle operatives and one supervisor who will control the leg movements.

2.7.7 Procedures, operations manuals and staff training

Best practice management techniques will be included in the operations and maintenance manuals for Halley VI. The manuals will provide staff with clear instructions on how to operate the facilities. The BAS Mechanical and Electrical Supervisor and winter tradespeople will be part of the commissioning team so that they receive the required training for the following winter season.

Halley VI will have a building management system that can be monitored by BAS staff in Cambridge. This will allow the Building Services team to provide a much improved diagnostic service during the winter.

2.8 AREA OF DISTURBANCE

The area of disturbance will include:

- Storage and construction areas at Halley V
- Routes from the coast to Halley V
- The route from Halley V to Halley VI
- The area around Halley VI

Once operational, the area of disturbance around Halley VI will include the buildings and facilities within the station perimeter, and all outlying facilities, such as the CASLab, magnetometer tunnels, ski-way and cargo depots. Based on the experience at Halley V, this area will be about 20km^2. In addition, there will be disturbance caused by the annual resupply of the station using tracked vehicles driving from the resupply ship to and from Halley VI, and the movement of limited numbers of people and small amounts of cargo to the station using the BAS DHC-6 Twin Otter aircraft.

The layout of Halley V is shown in Figure 10 and the proposed layout of Halley VI is shown in Figure 11.

Figure 10. Layout of Halley V Research Station

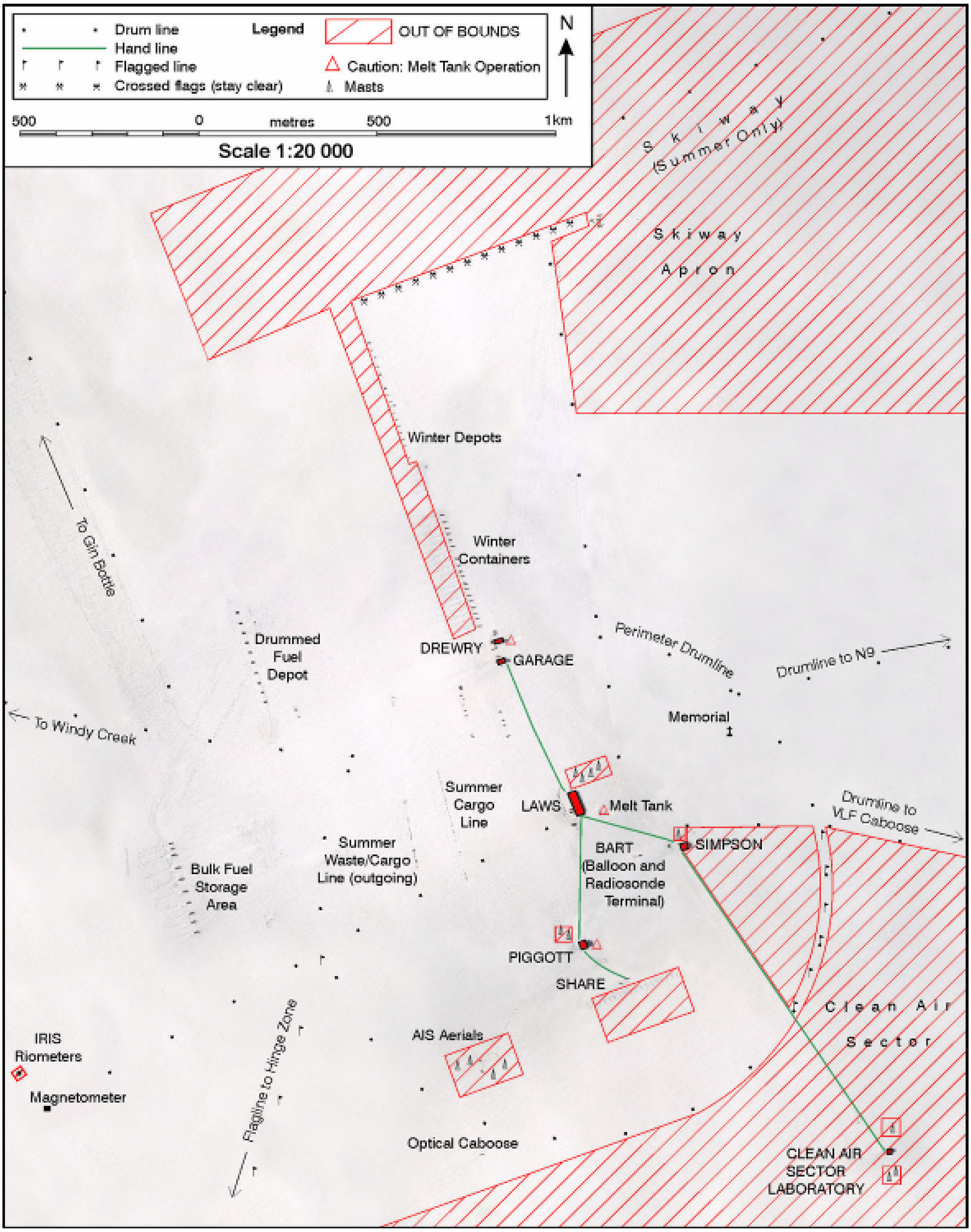
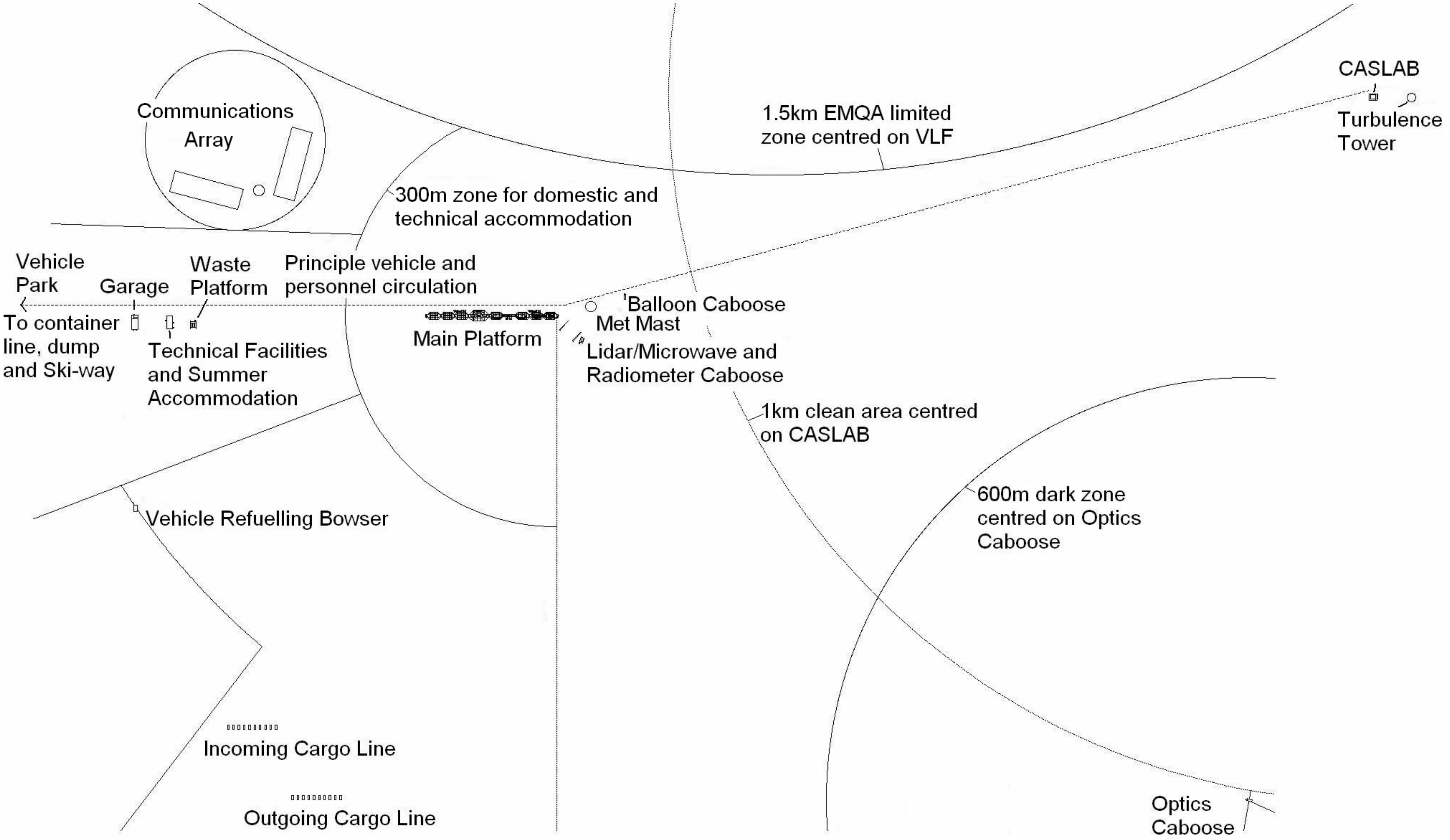


Figure 11. Proposed layout of Halley VI Research Station.



2.9 TIMESCALE, DURATION AND INTENSITY

The timescale of the construction of Halley VI has been determined by the need for replacement of the existing facilities at Halley V. Research into the movement of the Brunt Ice Shelf suggests that after 2010, the portion of the ice shelf on which the current station is situated may be at an increased risk of break-off (see Section 5.3). The timetable for the construction of Halley VI and demolition of Halley V is shown in Table 5.

Table 5. Project timescale for construction of Halley VI Research Station and demolition of Halley V

Stage	Timeframe
Concept Proposals	June 2004 – December 2004
Site Visit	January 2005 – March 2005
Concept Development	January 2005 – Sept 2006
Design and Build Contract	September 2006 – February 2010
Pre-demolition Audit	January – February 2007
Construction and Demolition Year 1	December 2007 – February 2008
Construction and Demolition Year 2	December 2008 – February 2009
Construction and Demolition Year 3 Transfer of Science Equipment	December 2009 – February 2010
Site Handover	February 2010
Full operation of Halley VI	February 2010 –

The construction of Halley VI is likely to take 10–12 months. All construction works are planned to be complete at Halley by February 2010, with all services commissioned and all fixtures, fittings and equipment installed. BAS will occupy the station during the 2009/10 season, installing and commissioning all scientific equipment in parallel with the commissioning of fixtures, fittings and services. BAS plans to start scientific research and logistics operations at Halley VI in February 2010. BAS expects Halley VI to remain operational until at least 2029.

BAS plans to reduce significantly the time taken to build Halley VI compared to Halley V. Four summer seasons and one winter were required to build Halley V, whilst Halley VI is estimated to take three summers only. This is because much of Halley VI will be pre-fabricated outside of Antarctica and will be designed for easy assembly on the ice shelf. The construction team required for Halley VI is likely to be similar in size to that used for Halley V and will be around 60 MFL construction workers for the first two seasons and 25 for the final season.

2.10 DECOMMISSIONING OF HALLEY VI

Halley VI has been designed with a 20 year intended life span, which is much longer than its predecessors. For example, Halley III and Halley IV were only operational for a decade. Near the end of its design life, Halley VI will be assessed to determine whether a refit and life extension is feasible.

At the end of its design life removal will be facilitated by the ability to tow the station to the edge of the ice shelf for decommissioning and demolition. The modules have been designed for deconstruction, for example, the use of mechanical fixings in preference to adhesives, the use of fixings that allow disassembly in an appropriate sequence and the preparation of a decommissioning manual. The eventual clean-up of Halley VI will be subject to a future Environmental Impact Assessment.

3. DEMOLITION AND REMOVAL OF HALLEY V

3.1 INTRODUCTION

The Environmental Protocol requires that ‘abandoned work sites of Antarctic activities shall be cleaned up by the generator of such wastes and the user of such sites’ (Annex III, Article 1 (5)).

The demolition and removal of Halley V will be undertaken simultaneously with the construction of Halley VI. Halley V Research Station is described in Section 1.2.

3.2 DEMOLITION WORKS

3.2.1 Duration and intensity

Demolition will be carried out over three austral summer seasons concurrently with the construction of Halley VI. A further season may be required for the removal of any remaining waste. This phased approach will ensure that the waste stream matches the BAS cargo shipping capacity out of Halley. It will also allow existing buildings at Halley V to house the construction and demolition workforce, reducing the requirement for a specific work camp.

3.2.2 Phased approach to Demolition

<u>Pre-demolition site audit (2006/07)</u>

A demolition planning site visit was undertaken in 2006/07. The Halley VI Project Team, the BAS Environmental Manager and the MFL Project Manager were on site for 3 weeks. The overall aim of the site audit was to verify the scope of the demolition works. The key objectives were to:

- Assess demolition requirements under the BAS Antarctic Act permit
- Verify deconstruction methodology, sequence and timetabling
- Ground-truth the estimated quantity of waste cargo for removal, and waste steel for recycling
- Plan the storage and depoting of waste
- Predict potential delays, bottlenecks and risks
- Identify appropriate artefacts to be transferred to BAS archives and/or Halley VI

Some surplus redundant chemicals and other hazardous substances were removed during this site visit.

Demolition Year 1 (2007/08)

During the first year of demolition, BAS will remove most science equipment, redundant technical and logistical stores and some shipping containers for safe disposal or recycling in South Africa.

The Magnetometer and IRIS science shafts will be stripped, leaving only the wooden support and access structure.

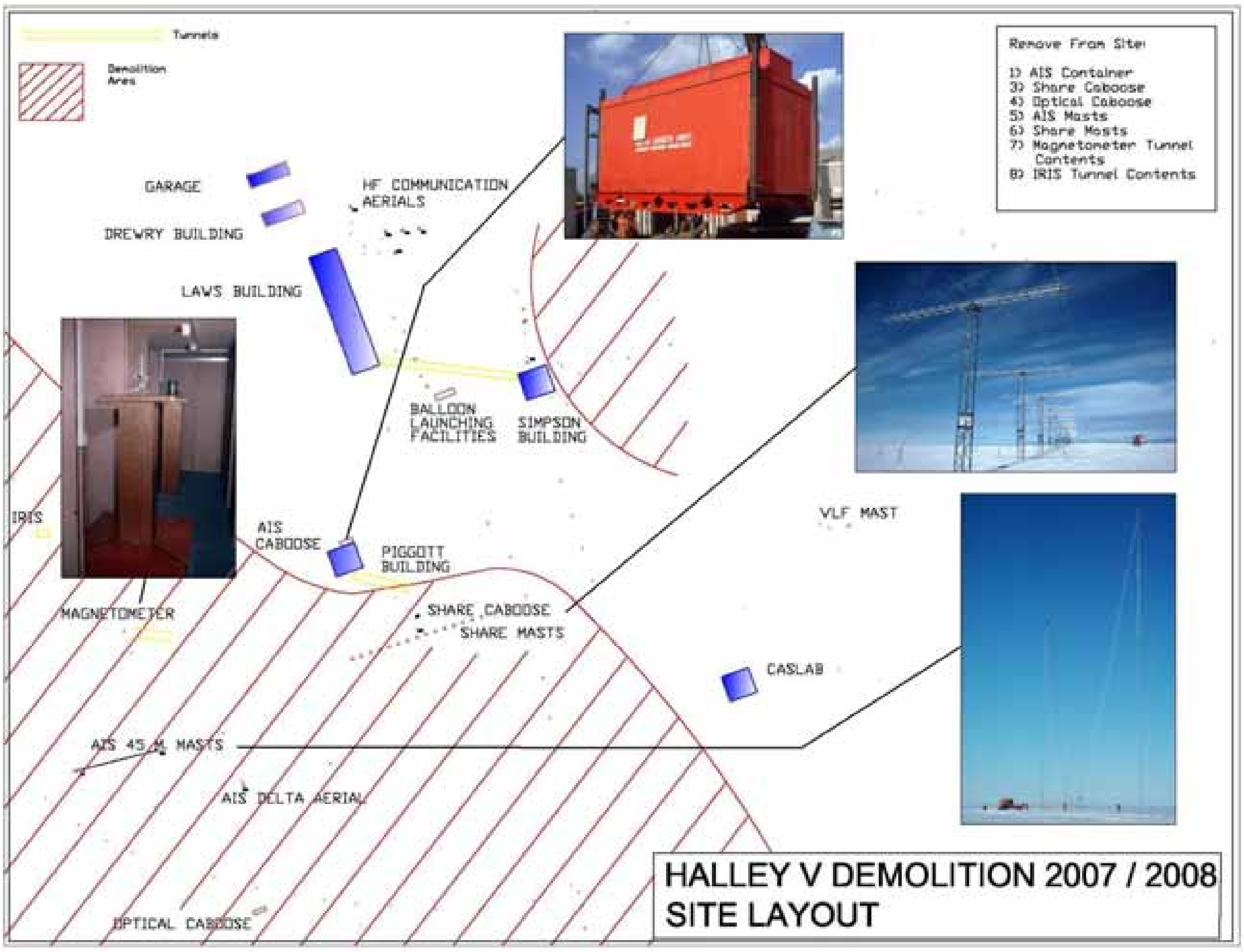
The following cabooses, masts and towers will also be dismantled for removal:

- AIS caboose and two 45m AIS masts
- 2 SHARE cabooses and 16 associated aerials
- Optical Caboose

All masts will be cut and banded or welded into manageable lengths for removal.

Figure 12 shows the structures to be demolished and removed in 2007/08.

Figure 12. Structures to be demolished or transferred to Halley VI in 2007/08



<u>Demolition Year 2 (2008/09)</u>

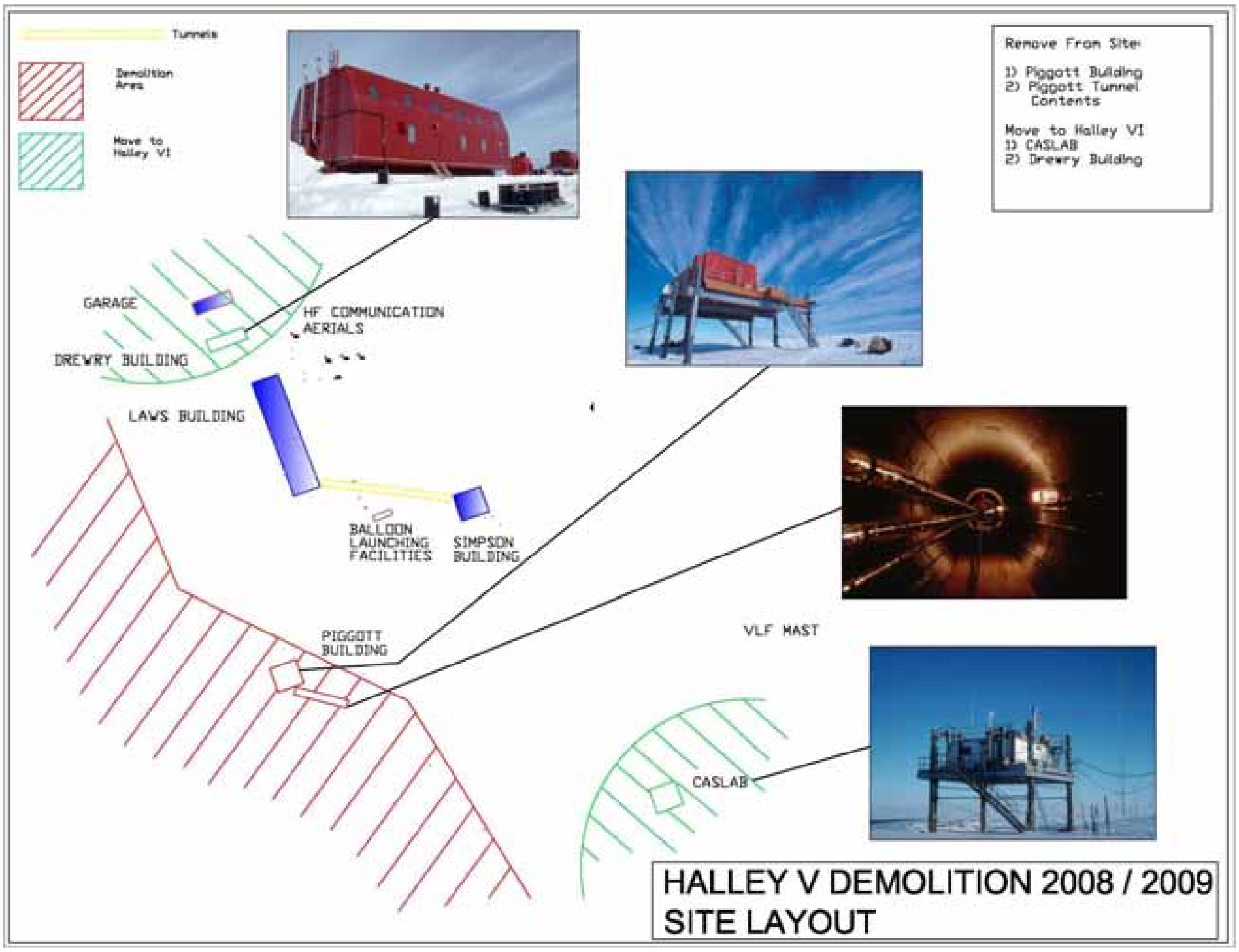
During the second year of demolition, BAS will strip and remove materials from the Piggott Tunnel, including bulk fuel storage flubbers, fuel pumps and pipe-work, electrical cable and ventilation ductwork (see Appendix 4). The Armco steel tubes which form the tunnels will remain in place. This service tunnel will then be capped.

The CASLAB and Drewry Building will be relocated to Halley VI.

At the end of the summer season, MFL will strip the Piggott building and demolish it. The Piggott comprises a large scale steel frame with timber, insulated sandwich panels and aluminium. Internal fittings include generators, mechanical and electrical equipment, pipe-work and ducting.

Figure 13 shows the structures to be demolished and removed, or transferred to Halley VI in 2008/09.

Figure 13. Structures to be demolished or transferred to Halley VI in 2008/09



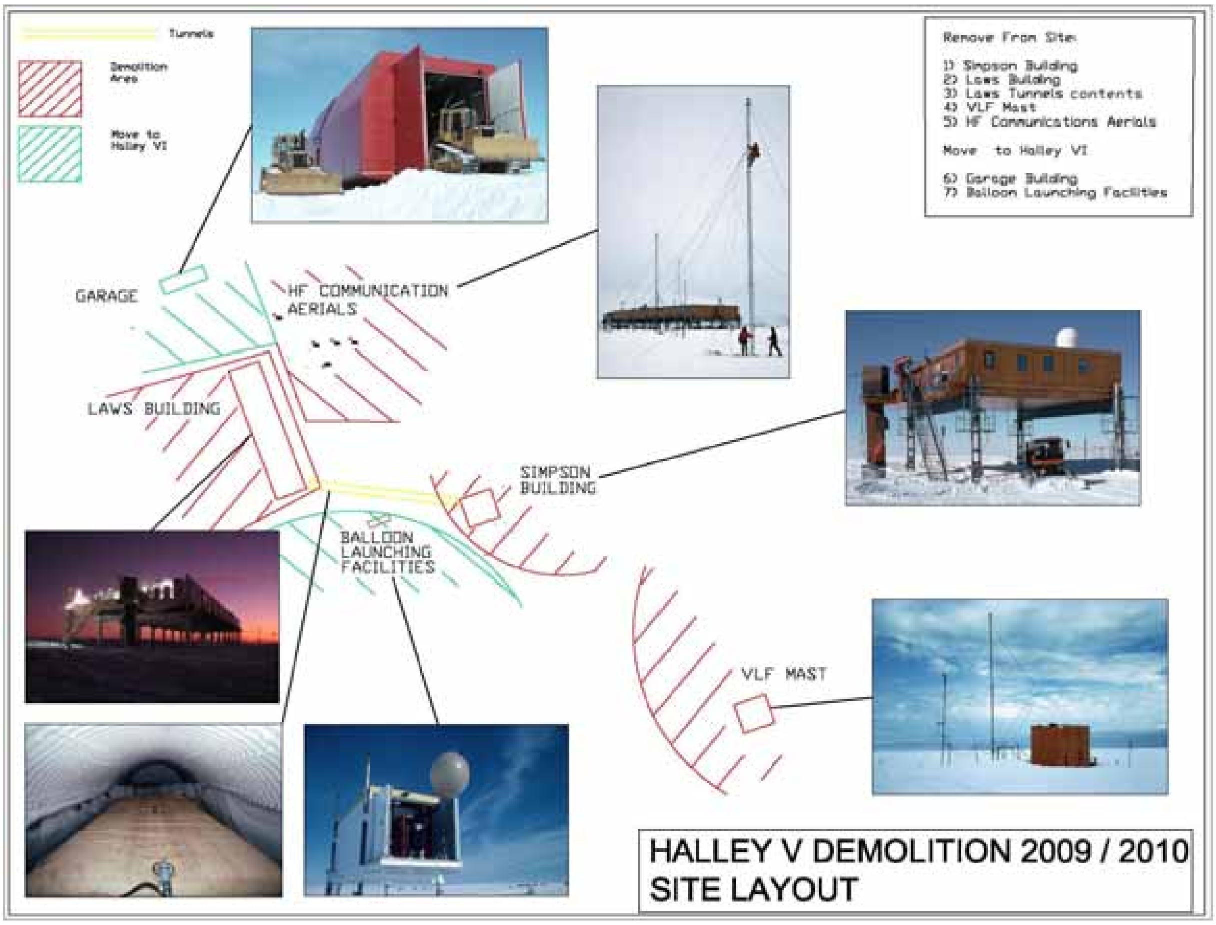
<u>Demolition Year 3 (2009/10)</u>

During year three, the refurbished Garage will be relocated to Halley VI. The Laws tunnels will be stripped by BAS of most of their contents, including bulk fuel storage flubbers, fuel pumps and pipework, electrical cable and ventilation ductwork. This service tunnel will then be capped. The Laws building will simultaneously be demolished by MFL. Demolition waste, including steel, aluminium, timber, insulated sandwich panels and electrical cable, will be safely stored for removal by BAS.

The sledge mounted satellite communications dome will be relocated to Halley VI. The four HF communications aerials and a 15 metre VLF mast will be demolished. The Simpson Building will be demolished at the end of the season, and all remaining equipment or facilities will be cleaned up.

Figure 14 shows the structures to be demolished and removed in 2009/10, or towed to Halley VI.

Figure 14. Structures to be demolished or transferred to Halley VI in 2009/10



3.2.3 Demolition Methodology

All buildings at Halley V will be demolished according to the following sequence:

1. BAS will remove all Science equipment
2. MFL will remove all fixtures and fittings including furniture
3. Materials will be taken out of the building and stored on the platform outside. Waste will be segregated and compacted to reduce volume for shipping

4. Mechanical and engineering components will be removed (e.g. cables, pipes etc) and stored on the open platform. Waste will be segregated and compacted to reduce volume for shipping
5. Working from the open platform end moving towards the back of the building, each room will be carefully dismantled. As the walls are load-bearing the priority will be to un-laden them by removing the roof first.
6. Lifting points will be identified within the roof section. A Nodwell crane will lift the weight of the roof section. Where a Nodwell cannot be used propping or shoring will be used to prevent movement.
7. Once the roof has been supported, mechanical fixings will be loosened if possible, and cut using hand saws or mechanical cutting tools.
8. Once a roof section has been isolated it will then be lowered to the floor in a controlled manner using the Nodwell crane.
9. Having unloaded most of the walls, all non load-bearing walls will be lowered to the ground. Walls will again be supported at the top using a Nodwell. Once walls have been isolated they will be lowered in a controlled manner with the crane.
10. To minimize movement of materials all panels will be stored adjacent to their original position.
11. Panels will be cut into sections and securely bundled together.
12. Once all items have been bundled or packaged BAS will take responsibility for the haulage and final disposal of items.

3.3 WASTE MANAGEMENT AND DISPOSAL

All waste will be packaged and labelled in accordance with the BAS Waste Management Handbook (BAS, 2006). MFL will maintain accurate records of all demolition waste generated.

Waste will be securely stored in ISO shipping containers or on raised mounds or platforms to prevent burial by accumulating snow. It will be secured to prevent dispersal by the wind. It will be transported by BAS from Halley V to the ice-edge relief site and shipped out on the BAS re-supply vessel RRS *Ernest Shackleton* to Cape Town, South Africa, where it will be transferred to licensed waste contractors. The BAS Environmental Manager will audit the waste contractors to determine their suitability prior to contracts being placed. The BAS will ensure that steelwork will be recycled to the greatest extent practicable.

Some hazardous waste, including batteries, decommissioned fuel flubbers and fuel tanks will be generated by the demolition works. BAS will package, label and transport this waste in line with the International Maritime Dangerous Goods Code. Final disposal in South Africa will be with licensed hazardous waste contractors.

The Environmental Manager at BAS will be responsible for ensuring that all waste arising from the demolition and removal of Halley V is disposed of safely.

3.3.1 Estimated Quantity of Demolition Waste to be Removed from Halley V

A detailed survey of the platforms, tunnels and depot lines was undertaken during the pre-demolition audit to ground-truth the estimated volume of waste cargo (including hazardous waste) for removal, and waste steel for recycling.

Approximately 3,145m^3 of waste will arise from the demolition and removal of the station. Table 6 shows a summary of all waste (including demolition, construction and operational waste) to be removed from Halley over 3 to 4 seasons, commencing in 2007/08. An average bulking factor of 30% has been assumed (derived from on-site analysis and from figures provided by the UK Building Research Establishment, see www.bre.co.uk). This bulking factor allows for the irregular shape of non-compacted demolition waste when packaged or bundled. A total of 518m^3 of structural steelwork was identified for recycling.

The quantity of hazardous waste for removal is estimated to be 96m^3, largely comprising empty fuel drums, decommissioned fuel day-tanks, fuel flubbers and liners, paints, adhesives, batteries and gas cylinders. A small quantity of surplus hazardous chemicals, paint and adhesives was identified, packaged and labelled for removal in February 2007.

Table 6. Total quantity of waste to be removed from Halley V

Year	Demolition waste	Construction Waste	Operational waste	Total
1	164	1000	375	1539
2	461	300	375	1136
3 [&4]	2463	100	375	2996
Total	3145	1400	1125	**5670**

3.4 BURIED MATERIALS WHICH WILL NOT BE REMOVED FROM HALLEY V

Some items which are buried deep in the ice will not be removed from Halley V. This includes the steel ARMCO tubes (see Figure 15) and steel shafts from the Laws, Piggott and Helium Storage tunnels, and the steel legs of the platforms below surface level. It also includes buried aerials, antennae and the sewage bulb. A feasibility study undertaken in 2003, which was updated in 2006 (see Appendix 4), concluded that to remove such items buried 30–40m below the surface is not practicable from a safety, technical or environmental perspective. It would pose significant safety concerns, be highly energy intensive and removal would result in greater adverse environmental impact than leaving it in situ.

Figure 15. Laying the ARMCO steel tunnels on the snow surface in 1991/92

4. ALTERNATIVES TO THE PROPOSED ACTIVITY

Five options for the future of Halley Research Station have been examined by BAS in light of environmental, logistical, engineering, and health and safety requirements.

4.1 DISCONTINUE SCIENTIFIC RESEARCH AT HALLEY

This option examined whether the UK should discontinue scientific research at Halley and close down the research station. This would mean the loss of one of the most important research and long-term monitoring locations in Antarctica. It was decided that this was not an acceptable option. A variant to this option, replacing Halley V with a smaller and fully-automated station, was also considered. This was considered to be not feasible. Although BAS envisages greater automation at Halley VI, complete automation is not practical.

4.2 ATTEMPT TO EXTEND THE LIFE OF THE EXISTING FACILITIES AT HALLEY V

This option examined whether the existing facilities at Halley V could be updated and the design life of the station extended. However, there is a growing risk that Halley V could be lost due to a calving event on the Brunt Ice Shelf within the next decade (see Section 5.3). Risk assessment indicates that Halley V needs to be replaced by 2010 and the facility decommissioned, demolished and removed from Antarctica before there is a significant risk of it being lost on an iceberg.

The existing facilities at Halley V are approaching the end of their design life. The station has been operating since 1992, and was originally designed in 1986. The buildings, especially the steel platform legs, require significant maintenance. Also, the steel sub-surface tunnels, which carry services such as electrical power and sewage, are being buried deeper and deeper under the snow surface and becoming difficult to access and service. Some of the tunnels are now more than 30m beneath the snow surface. A specialist building team is required each season to replace platform legs, raise the platforms and clear snow. In addition, the main buildings at Halley V were designed and built before the Environmental Protocol and therefore do not provide for best environmental practice.

Given these circumstances, it was decided that extending life of the facility was not a feasible option and the existing facilities cannot be used beyond 2010.

4.3 MOVE EXISTING FACILITIES AT HALLEY V EASTWARDS ON THE BRUNT ICE SHELF

The third option examined was to move the existing facilities at Halley V eastwards to a safer location on the Brunt Ice Shelf, towards Coats Land.

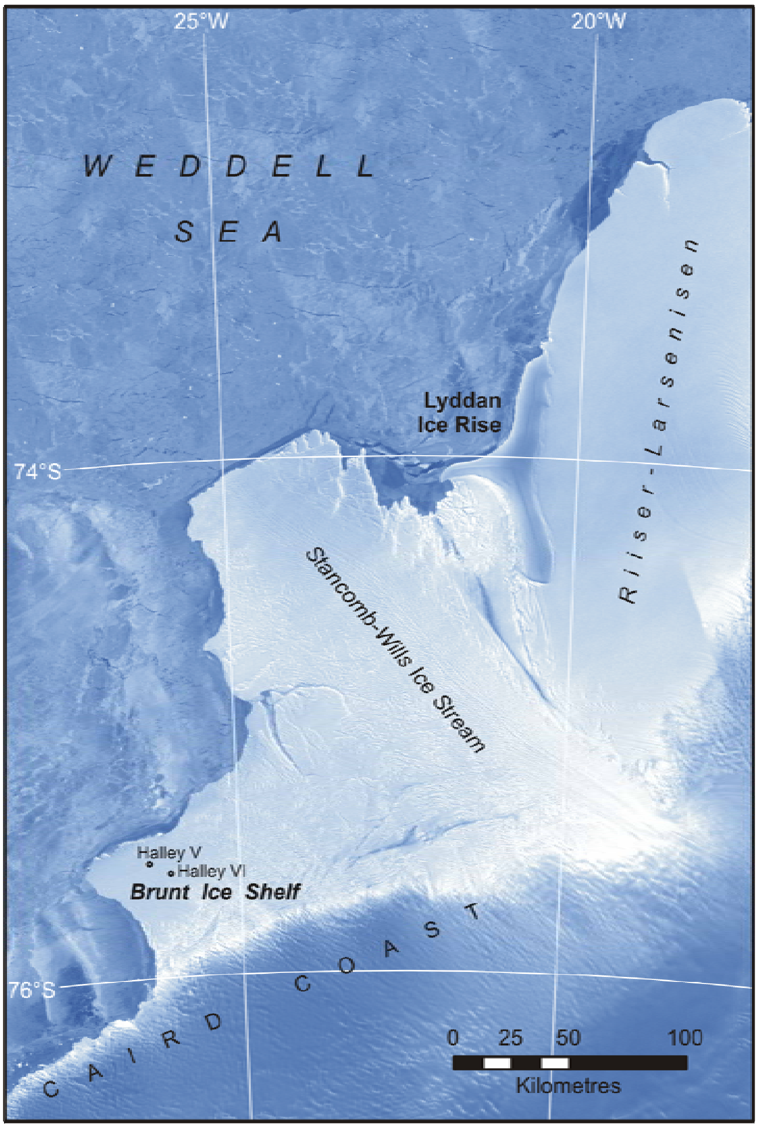
The main buildings at Halley V are permanent structures, which are mounted on platforms kept above the snow surface by jackable legs, and were not designed to be moved. Also, the steel sub-surface tunnels are now permanently buried. It would be more cost-effective to design and build new structures than relocate the old ones.

The summer accommodation building (Drewry) and the garage are mounted on skis. Each building weighs about 60 tonnes and is moved several tens of metres over prepared ground each season to prevent burial by snow. They are winched forward using two tracked bulldozers. It is now planned to move these facilities to the Halley VI site and reuse them as part of the new station. A number of small science facilities and cabooses will also be hauled by tractor or Snocat from Halley V to Halley VI.

4.4 RELOCATE AND BUILD HALLEY VI ON GROUNDED ICE AT THE LYDDAN ICE RISE

The fourth option examined was to build Halley VI away from the Brunt Ice Shelf on grounded ice at the Lyddan Ice Rise (74º25'S, 20º45'W). The Lyddan Ice Rise is located on the coast, about 200km north-east of Halley V (see Figure 16). Here the ice is grounded on rock and movement of the ice is minimal. This would make building and maintaining Halley VI much simpler. Also, because the Lyddan Ice Rise is further north, it would be easier to reach by resupply ship. It was also considered to be an acceptable alternative location for the atmospheric research and snow chemistry currently undertaken at Halley.

Figure 16. Satellite image showing location of Lyddan Ice Rise.



BAS carried out a major reconnaissance of the Lyddan Ice Rise during the 2002/03 and 2003/04 seasons. The site was visited by an air-supported BAS field survey party in 2003/04. The party carried out glaciological monitoring and installed an automatic weather station. In 2003/04 season, the RRS *Ernest Shackleton* also visited the Lyddan Ice Rise to investigate further the area and determine whether it was safe and practical to offload personnel and cargo.

After careful analysis of the field survey reports, BAS decided that constructing and operating Halley VI on the Lyddan Ice Rise was not practical. It was not possible to find a safe access route from the sea ice up onto the grounded ice rise because of a series of major crevasses. Also, the safe area on top of the ice rise was small and would not have enabled the full range of scientific research to be continued. In addition, cloud cover was considered to be greater on the Lyddan Ice Rise compared to Halley and this would have also affected air operations. A further complication for air operations would be that an extra refuelling stop would have to be made by aircraft flying across from the BAS Rothera Research Station to Halley, because of the additional distance between the two.

4.5 COMMISSION A NEW DESIGN FOR HALLEY VI STATION AT A SAFE LOCATION ON THE BRUNT ICE SHELF

After looking at the above alternatives, the UK decided that the best practical option was to build Halley VI at a safe location on the Brunt Ice Shelf and ensure that the station can be relocated during its lifetime to counter ice movement. This would provide world-class laboratory facilities to pursue science topics of global relevance and assure the continuation of vital long-term environmental datasets. BAS decided that the best way to design the station was to launch an international design competition together with the UK Royal Institute of British Architects (RIBA) (see Section 1.4.1).

5. INITIAL ENVIRONMENTAL REFERENCE STATE OF THE BRUNT ICE SHELF

5.1 THE BRUNT ICE SHELF

Halley VI will be located approximately 20km from the northwest coast of the Brunt Ice Shelf (75º36'56"S, 026º07'52"W; October 2006) (see Figure 17). The Brunt Ice Shelf is a floating ice shelf situated on the Caird Coast on the eastern edge of the Weddell Sea. It borders the coast between the Stancomb–Wills glacier tongue and the north-east end of the Dawson–Lambton glacier. The topography around the station is generally flat up to the grounding line, which is around 40km southeast of the station, where the ice rises steeply to the Coats Land plateau (Wolff et al., 1998).

Figure 17. The seaward edge of the Brunt Ice Shelf, Caird Coast.

5.2 SEA ICE

The sea-ice extent in the Weddell Sea has a pronounced annual cycle and is at its minimum in February – March and maximum in September – October. Sea ice variation in the Weddell Sea is associated with the Weddell Gyre, a strong coastal current flowing from the east southward along the coast. During winter, sea ice almost completely covers the Weddell Sea, although a number of polynyas (areas of open sea surrounded by ice) form where the ice front has a north-south orientation. These polynyas may close up during periods of westerly winds. South-west of the Brunt Ice Shelf is Precious Bay, which is an area of perennial open water (Anderson, 2002). During summer, a lead, which may be several tens of kilometres wide, extends along the front of the ice shelf, and allows ice-strengthened vessels to gain access to Halley.

5.3 GLACIOLOGY

An ice shelf is the floating extension of a grounded ice sheet, composed of freshwater ice that originally fell as snow. The Brunt Ice Shelf is approximately 200m thick, and the surface of the ice shelf at Halley V is approximately 30m above sea level. The ice shelf has a flat surface and small gradient of less than 5% towards the west. There are slight undulations that increase in frequency towards the hinge zone at the Caird Coast. The ice shelf is fed by ice discharging from the Stancomb–Wills Glacier in the east and from a smaller glacier and ice sheet to the west (Hulbe et al., 2003). Most of the shelf in the hinge zone is severely rifted, with marine ice filling the space between rift walls and around ice rafts. Approximately 20 to 30% of the Brunt Ice Shelf area is marine ice. The nearest rock exposure is 320km to the south in the Theron Mountains.

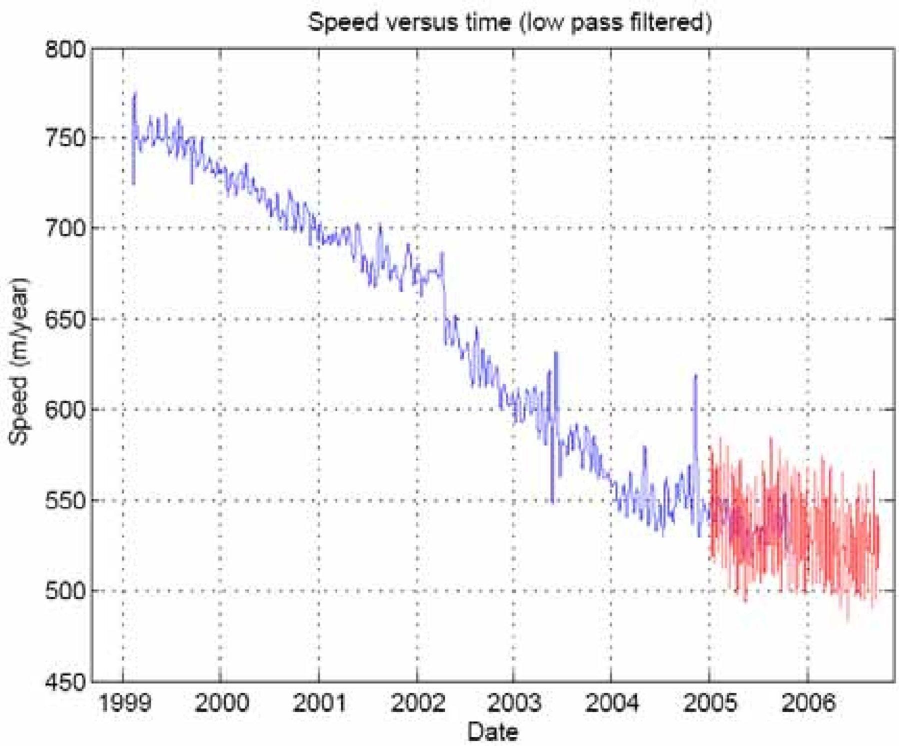
The Brunt Ice Shelf is currently moving at a rate of around 500m per annum (June 2006) in a westerly direction from Coats Land towards the Weddell Sea. Historically the ice shelf has displayed two velocity phases.

- 1956–70 velocity averaged approximately 380m per annum; and
- 1970–99 velocity almost doubled to 750m per annum.

From 1999 to 2005, velocity has been decelerating at a rate of about 40m per annum as the ice shelf wraps itself around the grounded area of the McDonald Ice Rumples (Hayes, 2004). This deceleration now appears to have stopped (personal communication, K. Hayes 2006). Figure 18 shows a plot of the speed of the ice shelf between 1999 and 2006.

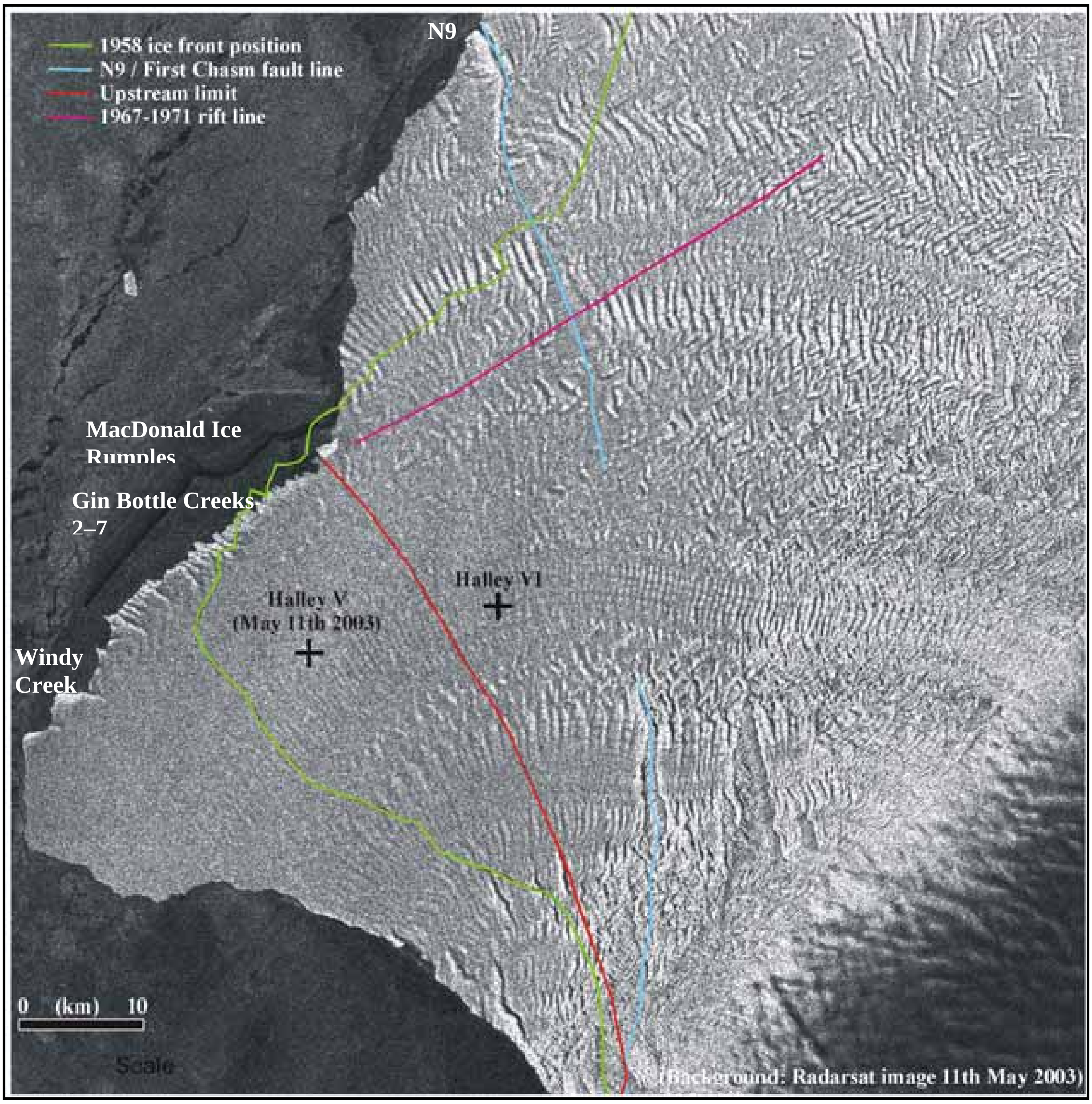
The McDonald Ice Rumples are a small zone of grounded ice at the ice front approximately 20km from Halley V. The effect of the deceleration on the stability and dynamics of the Brunt Ice Shelf is unknown. The ice shelf also moves vertically due to tidal displacement, and some variation in its horizontal velocity may also be attributable to tidal changes (Doake et al., 2002).

Figure 18. Movement of Brunt Ice Shelf as measured at Halley V between 1999 and 2006.



Periodically sections of the ice shelf calve off into the sea to form icebergs. A possible position of the calving front has been estimated using ice fronts surveyed in 1915, 1958, 1968, 1978, 1986, 1992, 1997, 2001, 2003 and 2005. The last major calving event is predicted to have occurred between 1949 and 1955. The closest and most reliable ice front position to this time period is from 1958 (see Figure 19), thus providing a record of the last calving front. Once Halley reaches and passes the 1958 ice front position the risk of losing the station to calving increases significantly. Halley V is presently 7km from the 1958 ice front and at its current velocity will reach it in around 14 years.

Figure 19. RADARSAT satellite image of Brunt Ice Shelf.



The risk of losing Halley V to calving stems from four known risks:

1) The Brunt Ice Shelf - currently at its most advanced state since 1915, implying a calving event is imminent.
2) Iceberg collision - risk due to: a) Iceberg collision from the calving of Stancomb-Wills (currently at its most advanced state since 1915) and b) Iceberg collision from bergs originating from elsewhere. Consequently an extensive iceberg monitoring program has been established utilising GoogleEarth, European Space Agency, US National Ice Centre and the meteorology teams at both Halley and Rothera. With the continuous advance of Stanbcomb-Wills and icebergs from

elsewhere being transported into the Weddell Sea, the risk of calving through iceberg collision remains a serious threat.

3) 1967-1971 calving line - during this time period a section of ice shelf near the McDonald Ice Rumples calved and resulted in the observed increase in ice shelf velocity and the formation of First and Second Chasms. Comparison of aerial photography from 1967 (prior to calving) and 2003 in conjunction with the decelerating velocity has revealed that conditions today are beginning to resemble those in 1967. This suggests a similar calving event could be developing.

4) N9 fault line and First Chasm - First Chasm is a large rift in the ice shelf formed in response to 1967-1971 calving event. Directly opposite is a second feature called the N9 fault line. It is believed that this formed in response to activity further north such as the calving of Stancomb-Wills. The combination of Stancomb-Wills being at its most advanced state since 1915 and the current conditions near the McDonald Ice Rumples resembling those of 1967-1971 mean a possible calving event or trigger is possible. For example, calving of Stancomb-Wills and/or a similar calving event to that observed in 1967-1971 could result in First Chasm and the N9 fault line joining across the ice shelf, leading to a major calving event of the Brunt Ice Shelf.

In summary, the risk of the Brunt Ice Shelf calving is clearly increasing with time. The ice shelf is at its most advanced state since 1915 and Halley V is only 7km from the predicted position of the last calving front. There is also the risk of iceberg collision because of the advanced state of the Stancomb–Wills glacier and possible movement and growth of the N9 fault line and ‘First Chasm’. How the observed decelerating velocity and conditions near the McDonald Ice Rumples are affecting the stability and dynamics of the ice shelf are unknown. However, availability of historical survey data of the ice front position, combined with velocity measurements, satellite image analysis, iceberg monitoring and extensive Global Positioning System (GPS) monitoring will help provide the basis for both understanding the dynamics of the ice shelf and monitoring crack propagation.

5.4 CLIMATE

The weather in the region of the Brunt Ice Shelf is characterised by below freezing temperatures, moderate to strong winds and drifting and blowing snow. Precipitation events occur throughout the year. The sun stays permanently above the horizon from 2 November to 9 February and permanently below the horizon from 30 April to 13 August (König-Langlo et al., 1998). The average annual total sunshine is 1445 hours (34% of the maximum possible). There is total darkness for 55 days.

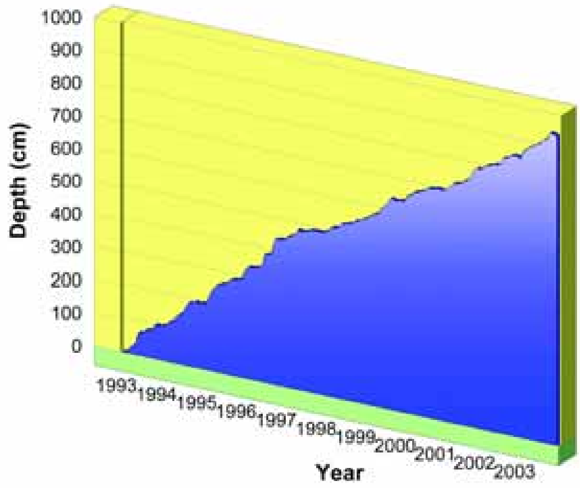
In mid-summer, average temperatures are around –5°C, but in winter the monthly mean temperatures are in the region of –30°C. Monthly mean temperatures always stay below zero, as seen in Table 7, but slightly positive temperatures may occur at times from December to February.

Table 7. Mean monthly temperature data for Halley, based on data from 1956 to present.

Month	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Temp (°C)	–4.6	–9.8	–16.2	–20.8	–24.7	–26.5	–28.5	–28.3	–26.3	–19.5	–11.6	–5.1

The annual snow accumulation at Halley is approximately 1m. Figure 20 shows the progressive snow accumulation at Halley between 1993 and 2003.

Figure 20. Snow accumulation at Halley V (courtesy of RWDI Consultants)



The prevailing wind direction is 075° (true). The secondary wind direction is 270° (true). Easterly winds occur 68.8% of the time and winds with a strong northerly or southerly component are rare (König-Langlo et al., 1998). It is calm for only 2.4% of the time. Mean annual wind speed is $7ms^{-1}$, and extreme gusts of up to $40ms^{-1}$ may occur. The majority of strong and moderate winds are from the east-north-east. Moderately strong winds from the south-west also occur.

A study of data from Automatic Weather stations (AWS) on the slopes of Coats Land and the Brunt Ice Shelf indicate that there are well-defined katabatic wind flows in Coats Land. However, strong katabatic winds are rare at Halley (Renfrew and Anderson, 2002).

Weather systems move rapidly within the Brunt Ice Shelf area. The wind causes drifting or blowing snow on about 180 days each year. Rain has never been reported, but freezing drizzle may occur.

Polynyas are a significant local water vapour source and can cause super-cooled water fogs on the Brunt Ice Shelf (König-Langlo et al., 1998). Surface inversions, created by radiative cooling typical during anti-cyclonic conditions, are common at Halley.

Climate data for Halley is summarised in Figure 21 and Table 8.

Figure 21. Summary of Halley climate data (courtesy of BDSP Partnership)

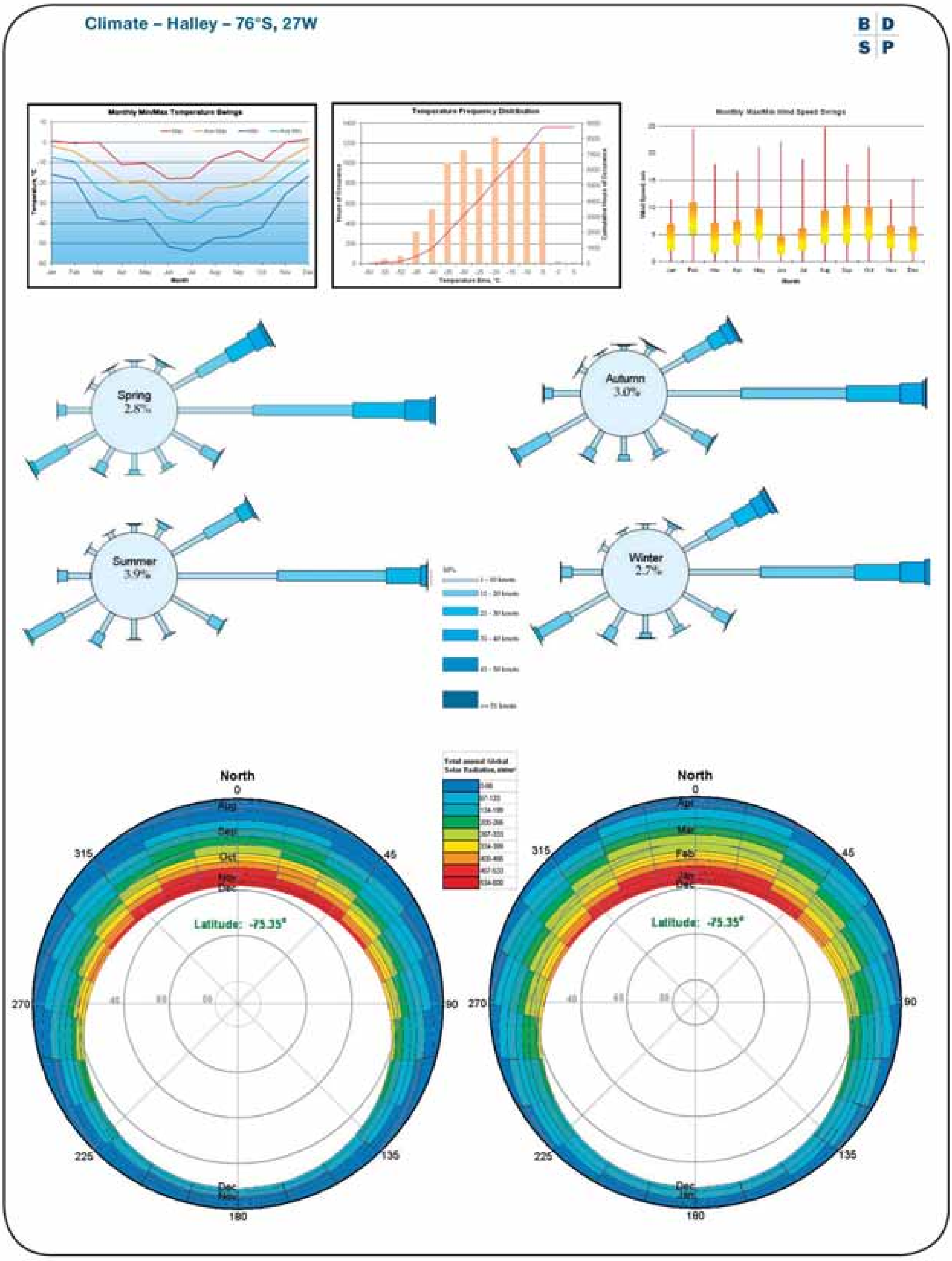


Table 8. Summary of climatic conditions at Halley.

Annual snow accumulation	~1m
Snowfall frequency	175 days per year
Drifting/blowing snow	180 days per year
Relative humidity	30–100%
Water vapour pressure	0.05–3.0mb (mixing ratio 0.02–1.5g kg^{-1})
Mean annual wind speed	6.5ms^{-1}
Extreme mean hourly wind speed	31.4ms^{-1}
Gales	40 days per year
Maximum solar incidence angle	37.8º
Mean annual temperature	–18.5°C
Extreme maximum temperature	+4.5°C
Extreme minimum temperature	–55.3°C.
Average annual total sunshine	1445 hours (34% of maximum possible)

5.5 FLORA AND FAUNA

The Brunt Ice Shelf does not support any flora. There are no breeding birds or mammals at the proposed location of Halley VI, although emperor penguins (*Aptenodytes forsteri*) breed nearby at the coast. Seabirds fly over the site on their way to breeding grounds to the south, and penguins and other seabirds have been known to visit the Halley V area occasionally.

5.5.1 The pelagic food web

The southern area of the Weddell Sea forms a conspicuous biogeographical province known as the permanent pack-ice or coastal fast-ice zone (Knox 1994). This zone encompasses the continental shelf of the Antarctic continent and is covered for almost the entire year with pack ice or fast ice anchored to the coast and ice shelves, but also includes polynyas (Eicken 1992).

Primary production in the permanent pack-ice zone is highly variable, both spatially and temporally. Although algae can grow under sea ice, significant production is possible here only during the brief open water period. Ice conditions in the south-east Weddell Sea are highly variable from year to year, and the presence of polynyas and open leads, crucial for primary production and predator foraging, is unpredictable. This unpredictability is perhaps why most of the photosynthetically-fixed carbon sinks out of the system to the benthos rather than entering the pelagic food web.

In the coastal fast ice zone of the Weddell Sea food webs involve krill (*Euphausia superba*) and krill-dependent higher predators, but smaller grazers, including the ice krill *Euphausia crystallorophias,* are probably more important. The ecosystem is also unique in the Southern Ocean because pelagic, planktivorous fish such as Antarctic silverfish (*Peuragramma antarcticum*) and *Euphausia crystallorophias*, replace Antarctic krill as the staple food of some of the vertebrate higher predator species.

Squid from four different families (Onychoteuthidae, Psychroteuthidae, Neoteuthidae and Gonatidae) have been identified in the eastern Weddell Sea. The most common species is *Psychroteuthis glacialis* (Piatkowski and Pütz, 1994). Squid are a major prey species of penguins and seals.

During the break up of the sea ice in early summer, large numbers of marine mammals and sea birds migrate into the region to take advantage of these food sources.

5.5.2 Penguins

Emperor penguins (*Aptenodytes forsteri*) breed during the winter on the fast ice at the foot of the Brunt Ice Shelf at a location known as 'Windy Creek', approximately 12km from Halley V (see Figure 22). Even during winter, when the Weddell Sea is largely frozen, the penguins have easy access to the open sea as a polynya forms along the coastline. Most of the chicks will have moulted and departed in late November to early December. By January only few individuals will be present.

Figure 22. Emperor penguin colony at 'Windy Creek', Brunt Ice Shelf.

In 1993, the colony was estimated to contain around 15,000 breeding pairs (approximately 7.5% of the global population; Woehler, 1993), and similar numbers were recorded during counts made in the mid-1980s (14,300 and 15,700 breeding pairs; Aslin, 1986; Aslin, 1987). Emperor penguins have occasionally been sighted at Halley V.

Adélie penguins (*Pygoscelis adeliae*) feed in open water adjacent to the Brunt Ice Shelf during the summer months. There are no breeding colonies in the eastern Weddell Sea. Occasionally, Adélie penguins are seen at Halley V. They walk to the station and shelter in the lee of buildings to moult, before returning to the coast.

Gentoo (*Pygoscelis papua*) and chinstrap penguins (*Pygoscelis antarctica*) have also been recorded at the coast feeding in creeks close to the Brunt Ice Shelf.

5.5.3 Other seabirds

Other seabird species recorded in the coastal region around the Brunt Ice Shelf and at Halley V include Antarctic petrels (*Thalassoica antarctica*), snow petrels (*Pagodroma nivea*), Wilson's storm petrels (*Oceanites oceanicus*) and south polar and subantarctic skuas (*Catharacta maccormicki, Catharacta lonnbergi*) (Allan, 1983), and southern giant petrels (*Macronectes giganteus*) (personal communication P. Thorode, 2007) The ice shelf offers no nesting sites for such birds as there are no nearby rock exposures, suggesting that they are feeding or flying to their breeding colonies.

5.5.4 Seals and whales

Weddell seals (*Leptonychotes weddellii*) are common along the sea ice, adjacent to the Brunt Ice Shelf. They come up onto the fast ice at the foot of the ice shelf in the spring to give birth to their pups in August. Pupping is complete by November (Bonner, 1989). Crabeater seals (*Lobodon carcinophagus*) and leopard seals (*Hydrurga leptonyx*) have been sighted in the water off the Brunt Ice Shelf during the summer months.

Several cetacean species have been recorded close to the Brunt Ice Shelf, including minke whales (*Balaenoptera acutorostrata*) and killer whales (*Orcinus orca*) (see Figure 23). The rare Couvier's beaked whale (*Ziphius cavirostris*) has also been sighted.

Figure 23. Killer whales (*Orcinus orca*) in sea ice near the Brunt Ice Shelf.

5.6 PROTECTED AREAS

There are no Antarctic Specially Protected Areas or Historic Sites and Monuments in the vicinity of the proposed Halley VI station.

5.7 HUMAN ACTIVITIES

5.7.1 Research and logistical support

A British research station has been located on the Brunt Ice Shelf since 1956 (see Section 1.2). The stations, which have been named Halley I-V, are supported by the BAS resupply vessel, which visits at the beginning and end of the summer season in December and February. Twin Otter aircraft are used to support scientific field parties and to connect Halley with Rothera station and the DROMLAN air facility is now also used during the summer. The number of flights varies considerably from year to year.

There are a number of items of scientific equipment located on the Brunt Ice Shelf, remote from Halley V station. An Automatic Weather Station (AWS) has been deployed at the proposed location of Halley VI. Also, there is a network of stakes on the Brunt Ice Shelf used to mark out a GPS survey area, which is being used to assess ice shelf movement.

Two Simpson's micro barographs are located around 10km from Halley V, one on the main traverse route from the supply ship on the ice edge to Halley V and the other on the traverse route from N9 to Halley V.

5.7.2 Tourism

The Brunt Ice Shelf has seen little tourist activity. In 1996/97 season, one tourist visited Halley V in a Cessna aircraft operated by Adventure Network International. In December

2004, the icebreaker *Kapitan Klebnikov* visited ‘Windy Creek’ and 100 tourists were flown to Halley V by helicopter and were given a tour of the facilities and scientific activities.

Tourist groups also sometimes visit the emperor penguin colony at the Dawson–Lambton Glacier (76º15’S, 27º30’W) and colonies further south in the Weddell Sea.

5.8 PREDICTION OF THE FUTURE ENVIRONMENTAL REFERENCE STATE IN THE ABSENCE OF HALLEY VI

The location of the proposed Halley VI Research Station is on an ice shelf and over a period of decades the ice shelf will advance towards the Weddell Sea and eventually calve off as an iceberg and melt into the ocean. It is unlikely that any other human activity will take place at this location in the absence of the proposed activity.

6. IDENTIFICATION OR PREDICTION OF IMPACTS, INCLUDING PREVENTATIVE OR MITIGATING MEASURES

6.1 METHODS AND DATA USED TO PREDICT IMPACTS AND MITIGATION MEASURES

The environmental impact of the construction and operation of Halley VI and the demolition and removal of Halley V are predicted on the basis of expert judgement, using the results of scientific research and environmental monitoring undertaken at Halley V and extensive local knowledge of the Brunt Ice Shelf. Distinction is drawn between the impact caused by the construction of Halley VI and removal of Halley V, and the impact of operating the new research station. Direct, indirect, cumulative and unavoidable impacts are examined. Impact matrices have been prepared (Section 6.5) to assess the predicted impacts of construction and demolition activities and of the operation of Halley VI. Impacts are ranked according to their extent, probability, duration, intensity and significance. Reversibility and lag time of impacts are noted where applicable.

Where impacts are predicted, measures to mitigate or prevent those impacts are identified and discussed. All construction and demolition works and operational activities at Halley VI will be undertaken in compliance with the Environmental Protocol. Stringent environmental conditions are included in the building contract for the construction of Halley VI and demolition of Halley V, and will be enforced through contract supervision by BAS. Appropriate environmental education, training and guidance will be provided for all staff and contractors working at Halley VI. All activities at Halley VI will be subject to a permit issued by the UK Foreign & Commonwealth Office under the Antarctic Act (1994).

Standard procedures will be followed to mitigate the environmental impacts of the construction and operation of Halley VI and the demolition of Halley V.

The contractor, MFL, will follow BAS procedures for operations at Halley such as organising waste disposal, operations from the ship, oil spill response procedures and search and rescue.

MFL has produced an Environmental Management Plan for the construction of Halley VI to ensure that the likely environmental impacts are identified, controlled and minimised (see www.antarctica.ac.uk/halleyvi/cee.html). In addition, standard MFL procedures will be followed for site safety, safety briefings and incident response.

6.2 IMPACT OF CONSTRUCTION AND DEMOLITION ACTIVITIES

6.2.1 Impact to air from construction and demolition activities

The combustion of fossil fuels from the resupply vessels, aircraft, station generators, and tracked vehicles will produce carbon dioxide (CO_2), carbon monoxide (CO), hydrocarbons (HC), nitrogen oxides (NO_x), sulphur dioxide (SO_2) and particulates (PM_{10}).

An unavoidable and cumulative impact of the proposed activity is predicted to arise from the operation of ice-strengthened vessels to transport cargo, equipment and construction staff to Halley. BAS aims to use its own logistics vessel RRS *Ernest Shackleton* to support the construction and demolition work, but the volume of cargo needed to build the station will require an additional ice-strengthened cargo vessel to be chartered for one voyage to Halley.

Resupply vessel

During the three construction seasons, the RRS *Ernest Shackleton* will make eight return journeys from Cape Town to Halley (see Table 3). This journey is estimated to take 12 days each way, giving a total of 192 days at sea over the three seasons. An estimated 72 days will be spent by the ship tied up at the ice shelf during relief activities.

The average daily fuel consumption of the RRS *Ernest Shackleton* on passage to Halley since 1999 has varied significantly depending on weather and sea-ice conditions, ranging from 12,600 litres per day to 18,140 litres per day, although it may drop to 5,100 litres per day when the vessel is stopped in ice. When tied up alongside at Halley during cargo operations, daily fuel consumption is approximately 4,000 litres.

The charter vessel will be an ice-strengthened cargo ship around twice the size of the RRS *Ernest Shackleton*. It is likely to consume around 28,000 litres when operating one engine and 47,000 litres fuel per day when operating both engines. It will conduct one journey to Halley and will be at the station for around 20 days.

The RRS *Ernest Shackleton* is likely to burn 2,353,000 litres of fuel over the three seasons. The charter ship is likely to burn around 1,090,000 litres of fuel for one return trip to Halley from Cape Town. Predicted atmospheric emissions for the ships have been calculated and are shown in Table 9.

Generators

Generators will be used to provide heat and power at Halley V during the construction period and small mobile generators will be used to provide power at the construction site. Larger generators will run on AVTUR and small mobile ones will run on petrol. Generators will result in localised air pollution, but this is considered to be of very low significance.

Tracked vehicles

Vehicles to be used during the project are listed in Section 2.6.4. Transporting cargo and people from the resupply ship to the construction site will be the most significant use of vehicles. Vehicle fuel consumption (AVTUR) will depend on the exact unloading location for the ships, but has been estimated at 240,000 litres over the three seasons.

A small quantity of petrol will be required for the construction of Halley VI. Around 3,000 litres of petrol over the three seasons is expected to be used specifically for construction and demolition works.

The use of tracked vehicles on the Brunt Ice Shelf will result in localised air pollution, but this is considered to be of very low significance.

Aircraft

Transporting personnel to Halley via Rothera and the DROMLAN route (see Section 2.6.1) will create additional atmospheric emissions. The volume of fuel consumed is estimated at 18,640 litres for journeys to Halley from Stanley via Rothera and 64,100 litres for journeys to Halley from Novolazarevskaya blue ice runway.

BAS will be transporting people via scheduled Cape Town to Novolazarevskaya flights run by the Antarctic Logistics Centre International (ALCI) and while emissions will be generated by these flights, it is difficult to estimate the proportion of emissions attributable to the project. An estimated 135,800 litres of fuel, representing one return flight of an Ilyushin 76-TD from Cape Town to Novolazarevskaya has been included in the aircraft emission calculation.

Fuel emissions from ship and aircraft will be spread over a wide area en route to and within Antarctica. The emissions from these sources will be rapidly dispersed and will not effect ambient air quality, but will contribute to the cumulative impact of operations in Antarctica.

Predicted atmospheric emissions

The predicted atmospheric emissions for the construction of Halley VI and the demolition of Halley V are shown in Table 9. These atmospheric emissions are spread over three summer seasons and include the emissions associated with the construction and demolition activities as well as the operation of Halley V station. As a comparison, the emissions arising from the normal operation of Halley V over three summer stations are estimated at 1,800 tonnes of CO_2 as carbon, 100 tonnes of NO_x as NO_2, 30 tonnes of SO_2, and 2 tonnes of PM_{10}.

Table 9. Predicted atmospheric emissions from the construction of Halley VI and demolition of Halley V.

Source	Est. fuel consumption (m^3)	(tonnes)	Type of emission	Conversion factor (tonne/ tonne)	Total emissions (tonnes)
Ships (Marine Gas Oil)	3442	2900	CO_2 as carbon	0.857	2492
			NO_x	0.057	166
			SO_2	0.019	55
			PM_{10}	0.00107	3
Aircraft via Rothera/ DROMLAN (AVTUR)	219	177	CO_2 as carbon	0.859	152
			NO_x	0.057	10
			SO_2	0.019	3.4
			PM_{10}	0.00107	0.19
Generators (AVTUR)	459	372	CO_2 as carbon	0.859	320
			NO_x	0.00837	3.1
			SO_2	0.00000001	0.0000037
			PM_{10}	0.0002	0.074
Tracked vehicles (Principally AVTUR)	240	195	CO_2 as carbon	0.859	168
			NO_x	0.00837	1.6
			SO_2	0.00000001	0.0000020
			PM_{10}	0.0002	0.039
Snowmobiles and small generators (Petrol)	21.5	16	CO_2 as carbon	0.037	0.59
			NO_x	0.000002	0.000032
			SO_2	0.00000972	0.00016
			PM_{10}	0.00011	0.0018
Estimated total emissions over three summer seasons (tonnes)					
CO_2 as carbon					3131
NO_x as NO_2					181
SO_2					59
PM_{10}					3.4
Conversion factors provided by the UK National Atmospheric Emissions Inventory (2000) (www.naei.org.uk)					

Mitigating measures for impacts to air

Whilst acknowledging that the charter market for ice-strengthened or ice-breaker cargo/passenger vessels is limited, BAS will seek to minimise the distance required to re-position the supply vessel to the Antarctic. Ships engines will be maintained to highest standards with fuel filtration and fuel injection systems to reduce emissions if practicable and light refined fuel (e.g. MGO) with low-sulphur content to be used if practicable. The BAS resupply vessel will operate predominantly on one engine only to reduce emissions.

Vehicles and temporary generators used during construction will be maintained to high standards in order to minimise atmospheric emissions. Vehicles will not be left idling when not required. Solar panels have been fitted to some vehicles to trickle-charge starter batteries.

Logistics planning will ensure the most efficient use of vehicles for all operations to reduce fuel consumption and emissions.

6.2.2 Impact to ice from construction and demolition activities

Fuel spills

Only light refined fuels such as Marine Gas Oil, AVTUR and petrol will be used during the construction of Halley VI and demolition of Halley V. Small quantities of lubricating oils and hydraulic oils will also be used. Fuel may be transported in bulk by the supply vessel, or in UN-approved 205 litre drums.

Bulk fuel will be transferred from the supply vessel into 24,000 litre bulk fuel tanks at the ice shelf using specially designed 5,000 litre ski-mounted transit tanks (see Figure 24) to transfer the fuel from the ship across the sea ice and up onto the ice shelf. The bulk fuel tanks will be transported to the depot line at Halley V. Transit tanks will be used to transfer fuel to the tanks at Halley V during the project (see Section 6.3.3). All fuel tanks are double skinned.

Figure 24. Refuelling bulk fuel tanks at Halley V.

Fuel spills and leaks may occur during construction and demolition activities. The most likely risks include spills during fuel transfer procedures between transit and bulk fuel tanks, punctured fuel drums, leaks from faulty engines and splashes or overflows during the refuelling of vehicles. Such spills will likely be of less than 5 litres. The maximum spill size would be 24,000 litres, due to the catastrophic loss of a bulk fuel tank.

Unless recovered immediately, larger spills will be partially absorbed by surface snow, although most fuel will pass quickly through the surface layer to considerable depth (20–30m) until hard ice is reached. At this depth, fuel will remain locked within the ice for decades, until that part of the ice shelf breaks off. Once this happens, the fuel will eventually be released into the sea as the ice melts, and would rapidly disperse. It is unlikely to have any significant environmental impact.

There would be no immediate biological effect of a fuel spill or leak at the construction site. However, fuel spilled at Halley could have a serious effect on the water supply for the station. Spills could also have a delayed impact on scientific studies undertaken at Halley VI through contamination of ice cores taken for snow chemistry.

Mitigating measures

All reasonable steps will be taken to prevent fuel spills from occurring. Bulk fuel transfer operations will be carried out in line with the Halley Bulk Fuel Storage and Transfer Procedures (BAS, 2004c). Bulk fuel tanks will be sited and designed to minimise deleterious effects of the environment, such as ice and snow build up on valves and fittings, and from accidental damage caused by operational activities such as use of vehicles. All fuel tanks will have secondary containment with the capacity to contain the full contents of the tank, as well as high level cut off valves to prevent overfilling and dry break connectors to prevent leaks when connecting/disconnecting hoses. Fuel drum depots will be clearly marked and carefully managed. Drums will be handled with care to prevent ruptures.

Absorbents and fuel recovery equipment will be kept on site for immediate response to minor fuel spills, and contractors will receive training in oil spill response. The Halley Oil Spill Contingency Plan (Downie and Shears, 2005) will be implemented in the event of a fuel spill. Any spills will be reported immediately to the on-site Project Manager.

Waste disposal

The proposed construction and demolition activities will generate non-hazardous solid wastes, such as packaging materials, metal, plastic and wood. Some hazardous waste, including batteries, paints and adhesives will also be produced. If not properly managed, waste may be scattered by the strong winds, or be buried due to snow accumulation.

Sewage and grey water will also be produced at Halley V during the construction. These will be discharged directly into ice holes.

No records are available of the quantity of waste produced during the construction of Halley V, as much of the waste was burnt on site in 1990 and early 1991. Clean plastic waste and hazardous waste, including fuels, were removed from Antarctica (Lovegrove, 1991).

It is estimated that 1,400m^3 of construction waste will be produced over the three seasons. This waste will largely comprise of packaging materials.

Demolition activities will result in a large increase in the volume of waste produced at Halley. The quantity of waste arising from the demolition of Halley V is estimated at approximately 3,145m^3 (see Section 3.3).

Mitigating measures

Prefabrication of the station buildings outside Antarctica will considerably limit the volume of waste produced on site. The requirement to further reduce the quantity of waste produced to the maximum extent practicable, is included in contract specifications, enforced through project supervision by BAS. This includes:

- The use of shipping containers rather than individual packaging for cargo where practicable
- Stowage of waste in empty containers

All waste, other than sewage and grey water, will be carefully packaged, labelled, secured to prevent its dispersal, and removed from Antarctica, in line with the comprehensive BAS Waste Management Handbook (BAS, 2006). It will be reused, recycled or disposed of safely by licensed contractors. BAS will ensure that steelwork will be recycled to the greatest extent practicable.

The site will be kept tidy to ensure that materials do not inadvertently become buried in the snow. Care will be taken with storage of materials and waste to ensure that they are not spread by the wind or scavenged by birds.

<u>Buried material which will not be removed from Halley V</u>

Section 3.4 details the materials that will not be removed from Halley V. These materials will remain buried in the ice and will eventually be released to the marine environment when the ice breaks out into the Weddell Sea.

6.2.3 Impact to flora and fauna from construction and demolition activities

Minor disturbance to seals and penguins may occur due to ship and cargo operations at the ice edge. Disturbance may include transitory stress to animals, resulting in a temporary increase in heart rate, metabolism and energy expenditure. There are no breeding locations for birds or seals at any of the proposed locations for ship unloading.

There is a small risk of the accidental introduction of non-native biota, in particular micro-organisms, because of the importation of materials and food supplies. However, it is highly unlikely that any introduced species could survive outdoors at Halley. Upton *et al.* (1997) examined the presence of bacteria of human origin around Halley V. The results of this study showed that although human commensals can be detected inside station buildings, contamination levels in the environment surrounding Halley were extremely low. Bacteria deposited with waste food outdoors at Halley V were shown to quickly perish.

Construction and demolition activities will result in noise pollution at the building site. However, this will be transitory and will not cause any disturbance to fauna.

Mitigating measures

All staff and contractors will be given guidance on minimising disturbance to seals, penguins and other sea-birds. To prevent the introduction of non-native species, BAS and MFL will ensure that all equipment is cleaned, preferably by steam cleaning, before dispatch to Antarctica.

6.2.4 Impact to the marine environment from construction and demolition activities

<u>Waste</u>

Operating the resupply vessel will result in the production of solid and liquid wastes, including sewage and food waste. Treated sewage and macerated food waste may be discharged overboard, as permitted under MARPOL 73/78 (Annex IV). The Southern Ocean is a Special Area in relation to MARPOL Annex I (oil) and V (garbage) and discharges to the sea will be consistent with this designation. This could result in nutrient enrichment and contamination of seawater by bacteria, heavy metals and organic pollutants.

Mitigating measures

All waste, except for treated sewage and food waste, will be stored onboard, and incinerated or discharged to appropriate port reception facilities. The RRS *Ernest Shackleton* operates an aerobic sewage treatment plant. The treated effluent is discharged overboard. During fresh water production, sewage is retained in a 40m^3 holding tank. In the unlikely event of a failure of the treatment plant, sewage will be discharged beyond 12 nautical miles of land or ice shelf and while the ship is proceeding at a speed of no less than 4 knots.

Anti-fouling paints

The loss of anti-fouling paint from the ships hull due to scraping by sea ice is an unavoidable impact.

Mitigating measures

BAS vessels use antifouling paints which do not contain toxic organotin compounds.

Ballast water exchange

The exchange of ballast water could result in the transfer of aquatic organisms, including plankton, algae, and invertebrates, as well as pathogens. This is particularly the case in shallow coastal water, where there is generally higher species diversity. Introducing invasive marine species could have a serious and irreversible impact on marine eco-systems.

Mitigating measures

The RRS *Ernest Shackleton* and the charter vessel will only exchange ballast water when at deep sea. Ballast water taken from South American or South Atlantic waters will be exchanged in the Scotia Sea north of 60°S. Ballast water taken from Antarctic coastal waters will be exchanged in the Scotia Sea north of 60°S before the next port of call. Records will be kept of any ballast water exchange. Ballast water exchange will be undertaken according to the "Practical Guidelines for Ballast water exchange in the Antarctic Treaty Area" (ATCM, 2006).

6.2.5 Impact to aesthetic and wilderness values from construction and demolition activities

The construction site and the building of Halley VI station will result in a minor and local (within line of sight) visual impact and loss of wilderness value. Tracks caused by vehicles on the snow surface will be visible.

Mitigating measures

The construction and demolition activities will be transitory. The footprint of the construction and demolition activities will be kept to a minimum. Marked routes will be used to access the station from the coast and between Halley V and Halley VI, to keep the extent of tracks in the snow to a minimum.

Halley V Research Station will be removed and the snow surface will be allowed to return to its natural state.

6.2.6 Impact to science of the construction of Halley VI and demolition of Halley V

In order to reduce the environmental impact of the construction and demolition activities, the existing station at Halley V is being used to accommodate the construction workers. This has resulted in the suspension of all science apart from essential monitoring activities during the three summer seasons from 2007-10.

Mitigating measures

Essential monitoring activities will be undertaken. Automated systems will be used to take scientific measurements, where possible.

6.3 IMPACT OF OPERATION OF HALLEY VI

6.3.1 Impact to air from operation of Halley VI

Atmospheric emissions, including carbon dioxide, carbon monoxide, nitrogen oxides, sulphur dioxide, heavy metals and particulates are identified as the main cumulative and unavoidable impact of the operation of Halley VI. Emissions will result from the use of the resupply vessels, generators, tracked vehicles, DHC-6 Twin Otter aircraft and an incinerator.

Resupply vessel

The BAS resupply vessel RRS *Ernest Shackleton* (see Figure 25) will visit Halley VI twice a season to bring cargo and passengers to the station, to remove waste, and collect returning cargo and passengers.

The number of days' passage to Halley and time spent at Halley for relief, is highly variable. Allowance is made for 50 days passage and time alongside at Halley for two return journeys per season. Based on the average daily fuel consumption (see Section 6.2.1), it is estimated that the vessel will use approximately 591,700 litres of Marine Gas Oil per season supporting scientific research and logistical operations at Halley VI.

Figure 25. RRS *Ernest Shackleton* unloading alongside the Brunt Ice Shelf.

Generators

Initially at Halley VI, electric power generation for domestic and scientific purposes will be provided by generators, running on AVTUR. This fuel type is 10% less efficient than diesel, but is a cleaner burning fuel and better suited to low temperatures.

The design specification for Halley VI aims to minimise the use of fossil fuels and maximise the use of renewable energy. A Combined Heat and Power (CHP) system will provide electrical power and heat for the station, which includes a 150kVA generator in each of the energy modules. A total of 240,000 litres of fuel is expected to power the CHP plant at Halley VI each year. Solar thermal will be used to reduce fuel consumption during the summer.

Tracked vehicles

At Halley VI, vehicles will be used for general station support, including relief operations twice a year, and the possible relocation of the station by 5 to 10km every 5 years. The vehicle fleet will largely comprise the vehicles listed in Section 2.6.4. Based on vehicle fuel use at Halley V, it is predicted that approximately 30,000 litres of AVTUR will be used at Halley VI by the vehicle fleet per annum. Distances from the new station to the coast will be greater, but a more efficient vehicle fleet will be used to reduce fuel consumption.

There will be less snowmobiles and snow-cats used at Halley VI compared to Halley V. These vehicles will be replaced with John Deere 7820s with track conversion which are faster, more fuel efficient and are able to pull three sledges each compared to one sledge pulled by a sno-cat.

Normal usage of petrol at Halley V is around 4,000–10,000 litres a year depending on stock levels and field projects and this is likely to be similar for Halley VI.

Aircraft

The BAS ski-equipped DHC-6 Twin Otters will be used to fly passengers and some cargo between Rothera and Halley during December – February (Figure 26). Annually, the number of flights varies considerably, with an average of seven flights to Rothera plus additional flights to support scientific field parties. Some flights to connect with the DROMLAN air facility may also be made. Approximately 92,250 litres of AVTUR is supplied per annum for refuelling BAS Twin Otters for Halley V operations and this figure is not expected to change for Halley VI.

Figure 26. BAS DHC-6 Twin Otter aircraft supporting a Global Positioning System (GPS) survey

Incineration of food and sewage waste

A high temperature, twin chamber incinerator will be used to incinerate food waste and sewage sludge (see Section 2.6.7). Waste oil which cannot be used in waste oil heaters may also be incinerated. The incinerator has a maximum operating temperature of 1600°C to ensure complete combustion. The quantities of waste which will be incinerated are small and associated emissions will be of low significance.

6.3.2 Predicted atmospheric emissions

Based on conversion factors provided by the UK National Atmospheric Emissions Inventory, the total estimated annual emissions of CO_2 as carbon, NO_x as NO_2, SO_2 and Particulate Matter (PM) for Halley VI have been calculated (see Table 10).

Table 10. Predicted annual atmospheric emissions from the operation of Halley VI.

Source	Est. fuel consumption (m^3)	Est. fuel consumption (tonnes)	Type of emission	Conversion factor (tonne/ tonne)	Total emissions (tonnes)
Resupply vessel (Marine Gas Oil)	592	500	CO_2 as carbon	0.857	429
			NO_x	0.057	29
			SO_2	0.019	9.5
			PM_{10}	0.00107	0.54
Twin Otter Aircraft (AVTUR)	99	80	CO_2 as carbon	0.859	69
			NO_x	0.057	4.6
			SO_2	0.019	1.5
			PM_{10}	0.00107	0.086
Generators (AVTUR)	240	194	CO_2 as carbon	0.859	167
			NO_x	0.00837	1.6
			SO_2	0.00000001	0.0000019
			PM_{10}	0.0002	0.039
Tracked vehicles (Principally AVTUR)	30	24	CO_2 as carbon	0.859	20.9
			NO_x	0.00837	0.20
			SO_2	0.00000001	0.0000002
			PM_{10}	0.0002	0.0049
Snowmobiles and small generators (Petrol)	6.2	5	CO_2 as carbon	0.037	0.19
			NO_x	0.000002	0.00001
			SO_2	0.00000972	0.000049
			PM_{10}	0.00011	0.00055
Incineration of waste food and sewage	-	1	CO_2 as carbon	0.075	0.075
			NO_x	0.0025	0.0025
			SO_2	0.0023	0.0023
			PM_{10}	0.00007	0.00007
Estimated total annual emissions (tonnes)					
CO_2 as carbon					685
NO_x as NO_2					35
SO_2					11
PM_{10}					0.66
Conversion factors provided by the UK National Atmospheric Emissions Inventory (2000) (www.naei.org.uk)					

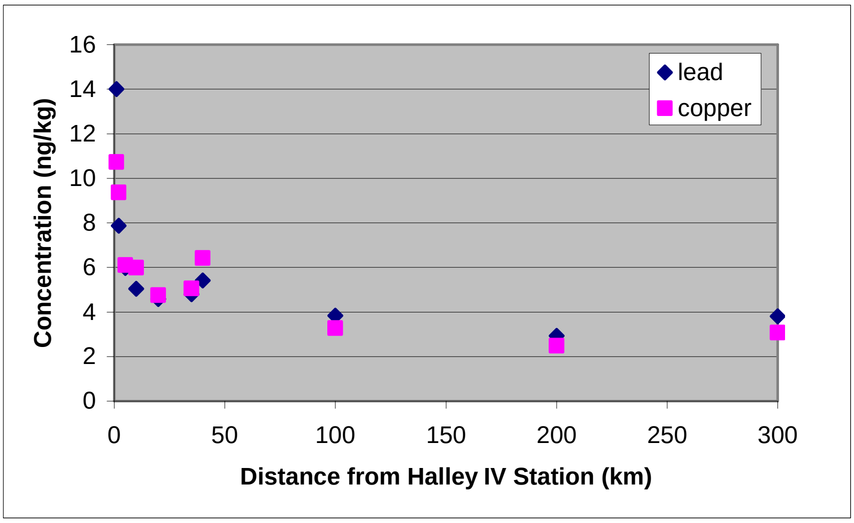
Levels of all pollutant gasses will remain at least three orders of magnitude below thresholds set in the Air Quality (England) Regulations 2000 and Air Quality (England) (Amendment) Regulations 2002 (this comparison is a guide only – these Regulations do not apply in Antarctica). Emissions will generally be rapidly dispersed by the strong and regular winds.

Sampling undertaken at Halley V in 2001 showed that concentrations of sodium, chloride and sulphates in shallow ice cores collected 10m from the station generator were three times greater than background levels. By 100m, mean concentrations had reduced to near background levels, and by 1km, there was no measurable effect from the station generators (Rankin, 2004).

Larger and heavier particles, such as soot, will also have a relatively short maximum transport distance. Soot plumes are well defined and detectable in snow downwind of station generators in the Antarctic (Warren and Clarke, 1990). Background levels are expected to be reached within 2km downwind of Halley VI.

Heavy metals have been measured in surface snow samples around Halley IV and Halley V, and show contamination by lead, copper, cadmium and zinc (Suttie and Wolff, 1993). Snow samples were taken on a traverse directly inland from Halley IV over a distance of 300km. The data showed a significant decline in heavy metal concentrations with distance from the station (see Figure 27).

Figure 27. Surface concentrations of lead and copper (ng kg^{-1}) from snow samples taken on Halley IV inland traverse.



Background levels of the metals in deep field samples arise from a combination of long-range natural and anthropogenic sources. Closer to the station, local emissions were detectable. Based on these results, it is possible that background levels of lead in snow surface samples would be exceeded up to a maximum of 10km downwind of Halley VI, but remain, even within the station boundary, three orders of magnitude below statutory limits in, for example, tap water in Europe (Suttie and Wolff, 1993).

Mitigating measures

Maintenance standards for engines and fuel systems on board the RRS *Ernest Shackleton* are high. Careful attention is paid to fuel filtration and fuel injection systems to reduce the emission of CO_2, NO_x and SO_2. The BAS vessel fleet also use low sulphur fuel. Whenever possible, fuel procurement specifies 0.2% sulphur content, far exceeding the requirements under MARPOL 73/78 of 4.5%. BAS vessels may run on one engine when practicable to do so, achieving between 10 to 20% reduction in fuel consumption and in atmospheric emissions.

Much of the science undertaken at Halley VI will depend on the integrity of the local air quality, and therefore minimising atmospheric pollutants will be accorded a high priority. A clean air sector will be established at Halley VI, up-wind of the station generators and designated as vehicle-free.

Power consumption will be monitored. All buildings and services are designed to achieve maximum energy efficiency and minimum heat loss by the use of passive design features and efficient generation methods for heating and power. Interior design will maximise the use of daylight. Energy saving controls will be used in the buildings and will be incorporated into the building management system. Kitchen and laundry facilities will incorporate energy saving and water efficiency measures. The water system will be designed to conserve water and reduce the need for snow melting. Internal drainage systems will use gravity flow where possible.

All of the station's buildings will be sited within 2km of each other. The main science laboratory will be located within 500m of the domestic accommodation. This will minimise the dependence on vehicles, and allow staff to walk or ski to work.

The long-term aim for power generation at Halley VI is to reduce fossil fuel consumption and to maximise the use of renewable and sustainable energy sources. Renewable energy will be phased in over the lifetime of the building rather than at the initial construction stage.

BAS maintains its fleet of vehicles and generators to the highest standard. Operations will be planned carefully to ensure the most effective use of vehicles, particularly during the ship relief.

Snow management and clearance at Halley V is one of the major uses of the larger tracked vehicles. It is an energy and staff intensive task. Halley VI has been designed to minimise snow management, by its aerodynamic shape, size, orientation and finish. Furthermore, the number of ISO containers will be greatly reduced, thus reducing the fuel requirement for relocating them twice a year.

The requirement to prepare and groom a 1000x50m snow runway for use by the BAS DHC-6 Twin Otter aircraft will remain unchanged.

6.3.3 Impact to ice from the operation of Halley VI

<u>Fuel spills</u>

BAS makes every effort to prevent accidental fuel spills in Antarctica. Nevertheless, fuel spills may occur during the transfer or storage of fuel, or during the operational use of vehicles and machinery.

240,000 litres of bulk fuel will be stored at Halley VI. Fuel will be stored in 24,000 litre steel fuel tanks. Each tank will be connected to the energy modules with dry break connectors that reduce the risk of fuel spills. Refuelling will take place once a month in the summer and once every 6 weeks in the winter. At this frequency the content of one bulk tank will refuel the whole station thus negating the requirement for repeat trips with partially full tanks and therefore reducing the risk of spillage.

Around 150,000 litres of drummed fuel will also be stored on the station for use by vehicles and aircraft. Table 11 contains a risk assessment for a range of possible spill sizes at Halley VI.

Since 1999, 25 very minor fuel spills have been reported at Halley, resulting in a total of 840 litres of spilled fuel and lubes. It is estimated that at least 150 litres, or 25%, was recovered. On two occasions pinhole leaks from 205 litres drums resulted in the loss of a complete drum of fuel to the ice. 16 spills were less than 10 litres, and 6 spills were between 10–100 litres. Most spills were of AVTUR, but antifreeze/AVTUR mix, oil and petrol have also been spilled.

In 2005 a large fuel spill was caused by the failure of a valve on an underground flexible rubber bulk fuel tank. The fuel spilled into the bund, but the bund pulled away from the wall mounts, resulting in the loss of an estimated 4,800 litres of fuel. This type of flexible rubber fuel tank will not be used at Halley VI.

Mitigating measures

The fuel system used at Halley VI is designed to minimise the multiple handling of fuel and reduce the risk of potential leaks and spills. Bulk fuel tanks will be sited and designed to minimise deleterious effects of the environment, such as ice build up on valves and fittings, and from accidental damage by operational activities. All fuel tanks will have secondary containment with the capacity to hold the full contents of the tank, as well as high level cut off valves to prevent overfilling.

Table 11. Risk assessment for fuel spill scenarios at Halley VI

Type of Spill	Probability	Maximum Spill Size (litres)	Fuel Type
Collision or grounding of BAS vessel at ice shelf	Very low	1,000,000	MGO, AVTUR and other petroleum products
Catastrophic failure of a bulk fuel tank	Low	24,000	AVTUR
Loss of transit tank through sea ice	Medium	5,000	AVTUR
Rupture/overflow of day tank	Medium	< 4,000	AVTUR
Rupture /overflow of boiler tank	Medium	< 2,000	AVTUR
Rupture/overflow of waste oil tank	Medium	< 2,000	Waste oil and lubes
Pipeline break or leak during refuelling (ship to transit tank)	Medium	1,000	AVTUR
Damaged drum during drum raising	High	205	AVTUR
Oil/fuel leak from generator	High	40	AVTUR/ Lubricating Oil
During refuelling (vehicles or aircraft) minor spills may occur from drums or bowser	High	5	AVTUR Petrol Lubricating Oil

Equipment will be of the highest standard to prevent spills. All fuel hoses will as a minimum be double wall –42°C aviation hose. Fuel pumps will incorporate nitrile rubber seals, and will be located within heated buildings. Only dry-break fuel hose fittings, made of brass or copper, will be used for bulk fuel transfer. Fuel valves will incorporate soft metal seats suitable for cold temperatures to –40°C. All fuel transfer and storage equipment will be rigorously tested before acceptance by BAS.

All staff involved in refuelling operations will be provided with appropriate training and documented procedures. The Halley Oil Spill Contingency Plan (Downie and Shears, 2005) will be updated to reflect the changes at the new station. Absorbents and oil spill clean up equipment will be provided. Staff at Halley will carry out regular oil spill response exercises during summer and winter. BAS will also undertake regular audits of its fuel handling and spill response procedures.

<u>Waste</u>

Hazardous and non-hazardous solid and liquid waste will be produced during the operation of Halley VI. If not properly stored and managed, waste may be scattered by the strong winds or become buried under snow.

No waste will be disposed of into the ice at Halley VI except treated wastewater and some sewage.

Table 12 shows the total quantity of waste removed from Halley V since 2001/02 for recycling or safe disposal

During the 2005/06 season at Halley V, a total of 462m^3 of waste was removed, of which 388m^3 (84%) including empty fuel drums was reused or recycled. A further 850m^3 of grey water/sewage was discharged to a deep ice pit and 20m^3 of food waste was discharged to a shallow snow hole.

Table 12. Total waste removed from Halley V (2002/03 to 2005/06).

Types of waste (m^3)	2001/02	2002/03[1]	2003/04	2004/05	2005/06
Hazardous waste	0	6.3	0.52	4	4
Fuels and lubes	0	3.5	2.7	3	2
Non-hazardous waste	61	164	69	80	69
Recycling	0	637	307	202	388
Total	**61**	**811**	**379**	**289**	**462**
% waste recycled	**0**	**79**	**81**	**70**	**84**

Source: Foreign & Commonwealth Office. Antarctic Treaty Exchange of Information under Article VII (5) – United Kingdom. Reports 2001/02–2005/06.
[1] No ship relief was possible at the end of 2001/02 season and remaining waste was removed in 2002/03.

BAS will continue to release some scientific equipment to the environment from Halley VI, which will not be retrieved. This includes approximately 400 meteorological balloons per annum, which are flown according to standard World Meteorological Organisation (WMO) procedures. Attached to the balloons are small cardboard packages, containing an electronic circuit board and wet cell battery. These may land up to 150km from Halley, in the sea or on the ice shelf. When the balloons burst, small quantities of helium are released to the atmosphere.

Magnetometer and riometer tunnels will be required at Halley VI for scientific research. The wood and steel used to support the access shafts and tunnels will be left in place when the station is relocated, as they will be buried deep in the snow and therefore unsafe to remove. Other material which will be left buried in the snow will include the foundations and lower sections of aerial arrays and electric cables.

Mitigating Measures

A comprehensive waste management system has been included as part of the design of Halley VI. The system will comply with the Environmental Protocol and be as energy and manpower efficient as possible. Wastes will be managed according to the BAS Waste Management Handbook (BAS, 2006). Staff will be provided with appropriate training and guidance on waste management.

Halley VI will have a dedicated facility for processing waste, located on a sledge mounted platform. All waste, other than food, sewage and grey water, will be separated at source, compacted where possible to reduce its volume, safely stored and removed from Halley VI for reuse, recycling or disposal.

Sewage and grey water from the main platform will be treated. Solid treated sludge will be incinerated and the ash removed from Antarctica for disposal. Treated grey water will be sterilised and discharged to the ice. Food waste will be incinerated and the ash removed from Antarctica.

Figure 28. Waste removal from Halley V to the resupply ship using Sno-cat and sledge.

Given the predicted decrease in station population compared to Halley V (Section 2.7.1), it is envisaged that there will be a corresponding decrease in the total volume of waste removed from Halley VI each year. BAS has also already introduced a number of measures to decrease the volume of waste produced at Halley, including reusable packing crates and packaging materials, and purchasing food supplies in catering-sized packs.

6.3.4 Impact to marine environment from the operation of Halley VI

The impact to the marine environment from the operation of Halley VI resulting from the BAS resupply vessel is as described in Section 6.2.4.

During the operation of the station all wastes will be removed and only grey water and possibly some sewage from the relocated summer accommodation building will be discharged to the ice. When the ice on which the station was situated eventually reaches the sea, the release of frozen grey water and any minor fuel spills will have a negligible impact on the marine environment.

6.3.5 Impact to science from the operation of Halley VI

<u>Light pollution</u>

Local light pollution at Halley VI can disrupt the observation of the aurora, airglow and other upper atmospheric phenomena. It can also impede cloud observations at night. Light pollution generally reduces the quality of such observations, and is particularly noticeable in marginal conditions, when observation without local light pollution would be difficult but possible. Marginal conditions for airglow observations include broken cloud or drifting snow, which act to scatter light.

Mitigating Measures

External lighting has been designed to minimise light pollution, without compromising the safety of the staff working at Halley VI. Light casings will prevent the emission of light above the horizontal. Low-pressure sodium lighting and LED lighting will be used where possible, as it can be filtered out from astronomic observations of the night sky.

Disturbance to electromagnetic observations

Science instruments at Halley make observations in the following regions of the electromagnetic wave spectrum:

VLF: 1 Hz to 30 kHz

HF: 100 kHz to 30 MHz

VHF: 38 MHz

Microwave: ~ 225 GHz

All of these wavebands require the quietest possible site conditions. Indeed, some of these observations (e.g. VLF) can only be made in remote parts of the world. At Halley, measurements are also made of the Earth's magnetic field, where the highest frequency component measured is likely to be 10Hz.

Sources affecting the science equipment may include the mains power generation (and long power supply lines running across the base site) and plant control equipment (e.g. electrical motor speed controllers, particularly those involving thyristors).

Any of the science instruments, and particularly those with sensors mounted outside, could also be vulnerable to strong radio signals. Sources of such signals include science radars and HF communication systems.

Mitigation measures

Careful site planning and zoning of activities at Halley VI will minimise the impact of the station on electromagnetic science observations. As a minimum, all electrical equipment installed at Halley VI will meet the European EMC (Electromagnetic Compatibility) standards.

The most sensitive electromagnetic measurements (e.g. VLF and Riometers at 38MHz) can only be made by moving the sensors 1–2km away from the station infrastructure, and in the case of VLF (which is very susceptible to harmonics from mains power) by not running any mains power to the antenna site. Magnetic field measurements are also made at between 1–2km away from the station, and vehicles banned from the area except for essential maintenance activities. This is to prevent large pieces of metal from disturbing the magnetic measurements.

Disturbance to meteorological measurements of the boundary layer

At Halley meteorological measurements are made of the boundary layer between the atmosphere and snow interface.

Mitigation measures

No structures or vehicles will be allowed upwind or within the measurement area. This will prevent disturbance to the snow surface and stop snow drifts.

6.3.6 Disturbance to flora and fauna from the operation of Halley VI

The site of Halley VI supports no flora or breeding fauna, and therefore has no biological significance.

Emperor penguin colony

Occasional recreational visits are made by small groups of BAS staff (usually 4 to 10 people) to the breeding colony of emperor penguins at 'Windy Creek', approximately 15km from Halley V. Such visits will continue for staff working at Halley VI.

Mitigating measures

All BAS staff and visitors are issued with the BAS Handbook (BAS, 2006). This contains guidance on preventing disturbance to wildlife, which is based on 'Guidance for Visitors to the Antarctic', Recommendation XVIII-1, adopted at the XVIII ATCM (1994). Site specific guidelines for visits made by Halley VI staff to the emperor penguin colony at 'Windy Creek' will be posted at the Windy Creek caboose and on the Halley VI intranet site. The guidelines include advice on avoiding disturbance to the breeding birds and will be available on the BAS website at www.antarctica.ac.uk/halleyvi/cee.html.

6.3.7 Impact to aesthetic and wilderness values from the operation of Halley VI

The station will be located on a flat and relatively featureless ice shelf, which is nevertheless of considerable natural beauty. This will result in a minor and local loss (within line of sight) of wilderness value on that part of the Brunt Ice Shelf. As well as the station buildings, depots, aerials and masts, there will be imprints in the snow due to the use of tracked vehicles and aircraft. These tracks create a visual impact from the air.

Mitigating measures

The design of the station is aesthetically stimulating. Station buildings and depots will be arranged to create a minimal footprint, whilst also minimising snow accumulation. Set routes will be used for tracked vehicles to reduce the disturbance of the snow surface. The station and all facilities are temporary and will ultimately be removed from the Brunt Ice Shelf.

6.4 CUMULATIVE IMPACTS

A cumulative impact is the combined impact of past, present, and possible future activities. These impacts can be cumulative over time or space. BAS has operated a station on the Brunt Ice Shelf since 1956 and certain impacts such as emissions and minor fuel spills and disturbance to the snow surface will have been continuous at this location since that time.

Over the years some materials including abandoned buildings, waste, sewage and grey water have become buried in the snow on the Brunt Ice Shelf. These materials will remain locked in the ice until they are ultimately released into the marine environment when the ice breaks off into the sea and melts.

Transport routes change over the years and therefore different areas are affected by snow disturbance and minor contamination from exhaust emissions, littering and possible minor fuel spills. This affects the overall pristine nature of the Brunt Ice Shelf and its scientific value.

Emissions due to construction and operation of Halley VI and the demolition of Halley V are detailed in Section 6.2.1 and Section 6.3.1. These emissions are cumulative and contribute to local and regional levels of pollution in Antarctica, as well as global atmospheric pollution.

6.5 IMPACT MATRICES

Table 13 and Table 14 summarise the environmental impacts of the construction and operation activities. The output and resulting environmental impact of each activity is identified. The probability, extent, duration and significance of these impacts are then ranked according to the criteria below, and finally measures that BAS will put in place to mitigate or prevent those impacts from occurring are shown.

Criteria for ranking impacts are as follows:

Probability Unlikely

	Low	
	Medium	
	High	
	Certain	
Extent	Area -specific	Small area at construction site (Halley V), at location of Halley VI , ice edge, or on traverse route between ice edge, Halley V and Halley VI
	Local	Halley V, Halley VI location, ice edge or traverse route between ice edge, Halley V and Halley VI
	Regional	Brunt Ice Shelf, including coastal area
	Continental	Antarctica and Southern Ocean south of 60°S
	Global	Earth and atmosphere
Duration	Very short	Minutes to days
	Short	Weeks to months
	Medium	Years
	Long	Decades
	Very Long	Centuries to millennia
Significance	Very low	Ecosystems or natural processes or scientific research not directly affected
	Low	Changes to ecosystems or natural processes or scientific research are less than minor or transitory
	Medium	Changes to ecosystems or natural processes or scientific research are minor or transitory
	High	Changes to ecosystems or natural processes or scientific research are greater than minor or transitory
	Very high	Major changes to ecosystem or natural processes or scientific research are significant and irreversible

Table 13. Impact Matrix – Construction of Halley VI and demolition and removal of Halley V.

Activity	Output	Predicted Impact	Probability	Extent	Duration	Significance/ Severity	Mitigating or Preventative Measure
Shipping and cargo handling at ice edge	Atmospheric emissions	Minor but cumulative contribution to local and global atmospheric pollution including greenhouse gas emissions. Local fallout of particulates and heavy metals.	Certain	Local to global	Long	Very Low to Low	Minimise distance required to re-position supply vessel to Antarctica Light refined fuel (e.g. MGO) with low-sulphur content to be used if practicable. Ships engines maintained to highest standards with fuel filtration and fuel injection systems to reduce emissions if practicable When practicable, vessels to operate on one engine only to reduce emissions
	Disturbance to non-nesting penguins and seals at ice edge	Increased energy expenditure.	High	Area-specific	Very Short	Very Low	All staff and contractors to be briefed on minimising disturbance to fauna Any disturbance would be minor and transitory
	Release of anti-fouling paint from ships hull	Toxic to marine organisms.	Certain	Area-specific	Short	Very low	Use of high quality antifouling paints on BAS ships hull which do not contain organotin compounds
	Solid and liquid waste, including sewage, grey water and food waste.	Introduction of faecal bacteria. Nutrient –enrichment and contamination of sea water by heavy metals and organic pollutants.	Certain	Area-specific (ship route in Weddell Sea)	Short	Very Low	All wastes to be managed in accordance with BAS Waste Management Handbook. Most waste stored on-board for discharge at Port Reception Facilities Food waste is macerated before discharge to sea or incinerated Sewage treated aboard supply vessel and effluent discharged at sea in accordance with MARPOL requirements
	Ballast water discharge	Transfer of non-native species. Invasive species may alter local ecosystem.	Low	Local	Short (if species dies) Long (if breeds)	Very Low (if no survivors) High (if breeds)	Exchange of ballast water to be undertaken at deep sea locations only BAS Ballast Water Management Plan to be followed
	Introduction of alien species	Transfer of non-native species to Antarctica	Low	Local	Short (if species dies) Long (if breeds)	Very Low (if no survivors) High (if breeds)	All vehicles and equipment to be cleaned before shipping to Antarctica

Activity	**Output**	**Predicted Impact**	**Probability**	**Extent**	**Duration**	**Significance/ Severity**	**Mitigating or Preventative Measure**
Use of vehicles and generators	Atmospheric emissions	Minor but cumulative contribution to atmospheric pollution including greenhouse gas emissions. Local fallout of particulates.	Certain	Local to global	Very Long	Very Low to Low	Maintain vehicles and generators to highest standards Vehicles not be left idling unnecessarily Maximum load efficiency of vehicles Vehicles to be driven at appropriate speeds Use of energy efficient measures in buildings Use of renewable energy systems (e.g. solar, wind) during Halley VI lifetime to reduce use of fossil fuels by station generators
	Minor fuel spills during refuelling and vehicle/ generator operation	Contamination of snow. Possible indirect impact on science. Possible indirect impact on construction camp or station water supply.	High	Area-specific	Long (approx. 50 year lag time before release to sea)	Very Low	Due care and attention when refuelling, reinforced through training and documented procedures Fuel transfer and storage equipment to be maintained to highest possible standards Absorbents and response equipment to be kept on site. Some spilled fuel may be absorbed by snow surface and recovered Halley Oil Spill Contingency Plan to be followed in case of incident
General construction and demolition activities	Increased quantity of solid and liquid waste (including sewage and grey water)	Contamination of snow	Certain	Local	Medium	Very Low	Site to be checked for litter at end of every day All waste to be removed from Antarctica for re-use, recycling or safe disposal Sewage and grey water to be discharged to the ice
	Increase in activities at Halley V	Loss of wilderness value	Certain	Local	Medium	Very low	Construction activities are temporary
	Irretrievable science tunnels and parts of aerial arrays	Contamination of snow Impact on marine environment when released to sea	Certain	Area-specific	Long	Low	Unavoidable impact. However, removable fixtures and fittings to be removed from tunnels
	Waste generation	Disposal of waste in UK and South Africa	Certain	Local	Long	Low	Recycle structural steelwork BAS Environmental Manager to audit waste contractor Use of licensed waste contractors
	Loss of scientific data	Reduction in science output from Halley during 2007-10	Certain	Local	Short	Medium	Use of automated systems Essential monitoring will be undertaken

Table 14. Impact Matrix – Operational activities at Halley VI.

Activity	Output	Predicted Impact	Probability	Extent	Duration	Significance/ Severity	Mitigating or Preventative Measure
Shipping and cargo handling at ice edge	Atmospheric emissions	Minor but cumulative contribution to atmospheric pollution including greenhouse gas emissions Local fallout of particulates and heavy metals	Certain	Local to global	Very Long	Low	Light refined fuel (e.g. MGO) with low-sulphur content to be used if practicable Ships engines maintained to highest standards. Fuel filtration and fuel injection systems will be used to reduce emissions When practicable, resupply vessel to operate on one engine only to reduce fuel consumption and emissions
	Disturbance to non-nesting penguins and seals at ice edge	Increased energy expenditure	High	Area-specific	Very Short	Very Low	All staff briefed on minimising disturbance to fauna
	Release of anti-fouling paint from ships hull to marine environment.	Toxic to marine organisms	Certain	Area-specific (ship route in Weddell Sea)	Short	Very Low	Use of antifouling paints on ships hull which do not contain organotin compounds
	Solid and liquid waste, including sewage	Introduction of faecal bacteria Nutrient –enrichment and contamination of sea water by heavy metals and organic pollutants from sewage	Certain	Area-specific (ship route in Weddell Sea)	Short	Very low	All wastes to be managed in accordance with BAS Waste Management Handbook. Most waste stored on-board for discharge at Port Reception Facilities Food waste macerated before discharged to sea or incinerated Sewage treated aboard supply vessel and effluent discharged at sea
	Ballast water discharge	Transfer of non-native species	Low	Local	Short (if species dies) Long (if breeds)	Very Low (if no survivors) High (if breeds)	Exchange of ballast water to be undertaken at deep sea locations only BAS Ballast Water Management Plan to be followed.
	Introduction of alien species	Transfer of non-native species to Antarctica	Low	Local	Short (if species dies) Long (if breeds)	Very Low (if no survivors) High (if breeds)	All vehicles and equipment to be cleaned before shipping to Antarctica
Bulk fuel transfer and storage	Fuel spills of > 205 litre Maximum spill size 24,000 litre	Snow contamination. Atmospheric pollution due to volatilisation No immediate	High (small spills) Unlikely (large spills) >1000 litres	Area-specific	Long (approx. 50 year lag time before release to sea)	Very Low (small spills) Medium (large spills >1000 litres)	Fuel system designed and located to minimise risk of spills Equipment and fuel tanks to be maintained to highest standards Staff trained in refuelling procedures, and spill response

Activity	Output	Predicted Impact	Probability	Extent	Duration	Significance/ Severity	Mitigating or Preventative Measure
		biological impact but possible delayed impact to marine environment Possible indirect impact on science Possible indirect impact on station water supply					Implement Halley VI Oil Spill Contingency Plan Some spilled fuel may be absorbed by snow and cleaned up. Absorbents and response equipment to be kept on site
Use of vehicles and station generators	Atmospheric emissions	Minor but cumulative contribution to local and global atmospheric pollution including greenhouse gas emissions Local fallout of particulates and heavy metals Possible direct impact of pollution on science	Certain	Local to global	Very Long	Medium (if affects CASLab research)	Implement a range of energy efficiency measures (e.g. use of passive design features and efficient power generation) Maintain vehicles and generators to highest standards Maximum load efficiency of vehicles Vehicles to be driven at appropriate speeds Vehicles not to be left idling unnecessarily If practical, install renewable energy systems (e.g. solar, wind) to reduce use of fossil fuels by station generators Site CASLab in sector minimally impacted by emissions from main station facilities
	Minor fuel spills during refuelling and operation	Contamination of snow. Possible indirect impact on science Possible indirect impact on station water supply	High	Area-specific	Long	Very Low	Due care and attention when refuelling, reinforced through education and training Equipment to be maintained to highest possible standards Absorbents and other response equipment to be kept on site. Some spilled fuel may be absorbed by snow surface and recovered Implement Halley VI Oil Spill Contingency Plan
Operation of station	Generation of hazardous and non hazardous waste	Danger to wildlife if scattered by wind Contamination of snow	High	Local	Long	Very Low	All waste to be removed from Antarctica for re-use, recycling or safe disposal Procedures outlined in BAS Waste Management Handbook to be followed

Activity	Output	Predicted Impact	Probability	Extent	Duration	Significance/ Severity	Mitigating or Preventative Measure
	Atmospheric emissions due to incineration of food, sewage sludge and waste oil	Negligible contribution to local and global atmospheric pollution including greenhouse gas emissions Local fallout of particulates and heavy metals Possible direct impact of pollution on science	Certain	Local to global	Very Long	Medium (if affects CASLab research)	Operate incinerator according to manufacturer's recommendations Restrict operation of incinerator to times when emissions will be blown away from the clean air sector Minimise production of food waste by good planning and management
	Sewage/ grey water	Contamination of snow	Certain	Area-specific	Long	Low	Sewage treatment plant to be installed at Halley VI main platform. Treated sludge to be incinerated and ash to be removed from Antarctica
	Light pollution	Loss of scientific data due to light impacting sensitive scientific cameras for imaging airglow and aurora	Medium	Local	Long	Medium	External lighting designed to minimise light pollution Use of low-pressure sodium light bulbs
	Disturbance to electromagnetic / meteorological observations due to station activities	Loss of scientific data	Medium	Local	Long	Medium	Site planning and zoning for electromagnetic observation equipment and for meteorological boundary layer measurements All electrical equipment to meet or exceed European Electromagnetic Compatibility standards
	Station buildings and human activities	Loss of wilderness value	Certain	Local	Long	Very low	Halley VI will be aesthetically stimulating and blend sympathetically into the environment. It will be decommissioned and removed from Antarctica at the end of its lifetime
Recreational visits to emperor penguin colony	Possible disturbance to breeding penguins	Increased energy expenditure	Low	Area-specific	Short	Very Low	Staff to follow 'Guidance for Visitors to the Antarctic' – Recommendation XVIII-1 Site specific guidelines to be prepared for visits by BAS staff to emperor penguin colony
Science	Scientific releases to the environment e.g. met. balloons	Contamination of snow Marine entanglement	Certain	Regional	Long	Very Low	Unavoidable impact Meteorological balloons flown according to standard international practice
	Irretrievable science tunnels and parts of aerial arrays.	Contamination of snow Impact on marine environment when released to sea	Certain	Area-specific	Long	Low	Unavoidable impact

6.5.1 Summary of predicted impacts

The environmental impacts from the construction and operation of Halley VI and the demolition of Halley V will include:

- Cumulative air pollution and particulate deposition from atmospheric emissions produced by the combustion of fossil fuels
- Large volume of demolition waste to be removed from Halley V
- Potential (and cumulative) contamination of snow and ice by fuel spills and leaks
- Short term disruption to scientific activity due to construction activities

Prevention and mitigation measures have been identified in the impact matrices to avoid or minimise these predicted impacts.

In the case of materials left buried in the ice their removal is not safe or technically practicable and removal would have a greater environmental impact than leaving them in situ.

BAS expects that the operation of Halley VI will have a reduced environmental impact compared to Halley V because of the reduced station population, improved environmental management procedures, and the introduction of new technology leading to more efficient use of fossil fuels and decreased waste production. In addition, Halley VI is being designed with a much longer design life (>25% longer) than its predecessors, and to be capable of being easily decommissioned and removed when it eventually closes, and this will contribute to reducing the overall impact.

7. ASSESSMENT AND VERIFICATION OF IMPACTS AND MONITORING

7.1 STATION ENVIRONMENTAL MONITORING

BAS will establish an environmental monitoring programme to measure the actual impact of the construction of Halley VI and demolition of Halley V. As a minimum, BAS will carry out the monitoring outlined in Table 15.

Table 15. Station environmental monitoring to be undertaken at Halley VI.

Parameter	Data recorded	Frequency recorded	Reporting
Atmospheric emissions	Emissions of CO_2 (tonnes) calculated on basis of fuel consumed by station generators and vehicles	Once a month	Total emissions each season reported in the Annual NERC Green Accounts
Fuel spills	Spills of AVTUR, petrol and lubricating oils (litres) into the environment	Case by case basis	All spills reported immediately to BAS Cambridge through Accident, Incident , Near Miss or Environment (AINME) reporting system
Wastes	Non-hazardous wastes (e.g. paper, card, metal, fuel drums) (m^3) Hazardous wastes (e.g. batteries, chemicals, paints) (m^3 or litres) Sewage sludge/ash (m^3)	Twice per season when waste removed by ship from Antarctica	Total amounts of wastes removed each season reported in the Annual BAS Waste Management Report (Antarctic Treaty Exchange of Information)

In addition, the building contractor will be given stringent environmental conditions to adhere to as part of the contract. BAS will be providing a full time Halley VI Project Manager on site during the construction phase to ensure these conditions are met. Day-to-day visual inspections of the construction site will be carried out by the BAS Project Manager, and photographs and video will be taken. If environmental conditions are not met, then the BAS Project Manager will have the authority to stop works until mitigation measures are taken and deemed satisfactory.

7.2 GLACIOLOGICAL MONITORING OF THE BRUNT ICE SHELF AND STANCOMB–WILLS ICE STREAM

A long-term glaciological monitoring programme has been implemented by BAS to measure and predict the behaviour of both the Brunt Ice Shelf and Stancomb–Wills Ice Stream. The monitoring programme was established in 2001, and is now fully operational. This wide ranging and comprehensive glaciological monitoring programme will not only provide an early warning of any possible major calving event which could impact Halley V, but also continue to improve the basic understanding of ice shelf dynamics and crack propagation in Antarctic ice shelves.

7.2.1 Daily GPS monitoring

A continuous GPS station at Halley V provides a daily recording of the position and elevation of the station. An irregular movement, for example, or unusual elevation fluctuation or jump in the latitude and longitude, could be interpreted as crack propagation.

Detection of an anomaly is investigated immediately and further investigation undertaken. At Halley, further visual observations and re-survey of the GPS network are made, whilst at BAS, Cambridge the latest satellite imagery is acquired and the raw GPS data is checked and analysed.

7.2.2 Quarterly GPS monitoring

The GPS network surrounding Halley is measured every three months to establish if there is any unusual movement in the ice which might indicate a potential calving event. It provides accurate baseline length measurements of a simple network surrounding the station. Any increase or anomalous change in a baseline length implies the onset of crack extension and would instigate visual inspection and more detailed monitoring.

7.2.3 Long-term satellite monitoring

Long term remote sensing databases for the Brunt Ice Shelf and Stancomb–Wills Ice Stream include RADARSAT, ERS–SAR and Landsat imagery from 1992, 1997, 2000, 2001, 2003, 2005 and 2006, ice front survey positions (of varying reliability) from 1915, 1956, 1958, 1959, 1968, 1978, 1986, 1997, 2000, 2001, 2003, 2005 and 2006 and an aerial photograph survey from the 2002/03 season. Furthermore, the continuous GPS station at Halley has provided latitude, longitude, elevation and ice velocity since 1999 (see Figure 18). Previous literature and archived data from prior expeditions also provide sporadic velocity measurements from 1959, 1956–70, 1960, 1966–67, 1969, 1968–71, 1972–83 and 1995–96.

7.2.4 Survey work at the proposed location of Halley VI

During the 2004/05 season, BAS glaciologists completed an extensive survey at the proposed location of Halley VI. This work included:

- Topographic survey of the station area at 2.5km resolution
- Horizontal strain measurements
- Vertical strain measurement (firn compaction)
- Density depth profiles
- Installation of two Automatic Weather Stations

In addition, during the 2005/06 season a Ground Penetrating Radar (GPR) survey was completed to provide subsurface data and images of the internal structure of the ice shelf thus detecting variations between air, ice and water. This allows the detection of internal crevassing, rifts and crack extension. Vertical and horizontal strain measurements were also re-surveyed. Two linear motion sensors were installed at known crack sites. These will provide information on crack propagation and initiation and the fracture mechanics of ice. Finally two permanent GPS stations were installed with the communication system to be installed in the coming 2006/2007 season.

7.2.5 Other glaciological studies

BAS carried out an extensive seismic survey in the 2002/03 and 2003/04 seasons to provide accurate bathymetry of the seabed beneath the Brunt Ice Shelf and an estimate of water column thickness. Also, three current moorings are presently situated in the Weddell Sea in the proximity of the Brunt Ice Shelf. These instruments have provided velocity, temperature, conductivity and sediment samples and will be used to determine the background oceanographic forces acting on the ice shelf.

7.3 SNOW AND ATMOSPHERIC CHEMISTRY MONITORING

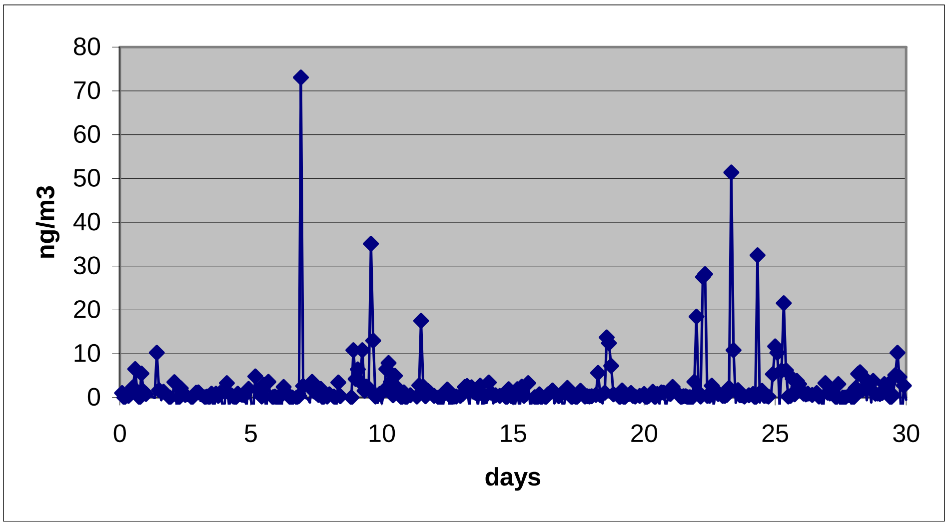
Halley is considered to be an ideal location for polar atmospheric chemistry research due to its remote location. Aerosol and snow sampling have been conducted at the station for several years.

The Clean Air Sector laboratory (CASLab) has been operational at Halley since 2003. The laboratory primarily provides a platform for conducting measurements of atmospheric chemistry, which are part of specific science programmes. Surface ozone measurements and aerosol sampling are conducted routinely. Since 1983, BAS scientists working at Halley have also contributed to ongoing greenhouse gas sampling (CO_2, CO, CH_4, SF_6), which forms part of the U.S. National Oceanic and Atmospheric Administration (NOAA) Climate Monitoring and Diagnostics Laboratory (CMDL) program. This sampling is now carried out from the CASLab.

An aethalometer is located at the CASLab and continually measures the concentration of black carbon aerosol in the atmosphere (Wolff and Cachier, 1998). The instrument has been at Halley V since 1992, and a replacement was installed in 2003, which will also be run at Halley VI. Records show a number of events of high concentrations of black carbon that are clearly due to contamination from the station generators and vehicles. Figure 29 shows data for the first two weeks in January, one of the busiest times at Halley.

The aethalometer measurements are used to indicate when local contamination of scientific samples from station activities may be occurring. Background levels of about 0.2–2ngm^{-3} are seen when the wind is not blowing from the direction of the station generators. But during contamination episodes concentrations can peak at 80ngm^{-3}, with extremes of up to 600ngm^{-3}.

Figure 29. Plot of black carbon levels (ngm^{-3}) during April 2002 at Halley V.



There will be some disruption to atmospheric chemistry monitoring at Halley during the construction of the new station. The year-round measurement campaign will continue during winter 2007, but the CASLab will be closed temporarily in January 2008 to allow for re-location and will be re-opened during the 2009/10 season.

7.4 ENVIRONMENTAL AUDIT

BAS will undertake an environmental audit of Halley VI once operational to assess and verify the environmental impacts predicted in the CEE.

8. GAPS IN KNOWLEDGE AND UNCERTAINTIES

The major gaps and uncertainties in the environmental impact assessment of the construction and operation of Halley VI and the demolition of Halley V are as follows:

- Minor changes in the project management and methodology of the construction of Halley VI and demolition of Halley V
- Natural variability of the hostile environment at Halley VI, such as weather, sea ice or ice shelf conditions. For example, in extreme circumstances it may not be possible for the resupply ship to reach Halley because of heavy pack ice, as happened to the RRS *Ernest Shackleton* in 2001/02 season
- Changes in future activities at Halley VI, for example the progressive introduction of renewable energy technology and developments in the BAS global science programme beyond 2010
- Uncertainty about predictions of the future behaviour of the Brunt Ice Shelf

9. CONCLUSION

The UK considers that the construction and operation of Halley VI Research Station and the demolition and removal of Halley V on the Brunt Ice Shelf will have more than a minor or transitory impact on the Antarctic environment. The implementation of the preventative and mitigation measures outlined in this Final CEE will reduce environmental impacts, and BAS considers the overall impact of Halley VI will be substantially less than Halley V.

The UK concludes that the global scientific importance and value to be gained by the construction and operation of Halley VI and the continued operation of the research facility by BAS on the Brunt Ice Shelf outweigh the more than minor and transitory impact the station will have on the Antarctic environment and fully justifies this activity proceeding.

10. AUTHORS OF THE FINAL CEE AND CONTACT DETAILS

This Final CEE has been prepared by Mr Rod Downie and Dr John Shears, Environment and Information Division, British Antarctic Survey and Dr Liz Pasteur, Poles Apart. The Final CEE has been approved and endorsed by the UK Government. It is available for download via the BAS website (www.antarctica.ac.uk/halleyvi/cee.html).

For further information on the Final Comprehensive Environmental Evaluation for the Proposed Construction and Operation of Halley VI Research Station and Demolition and Removal of Halley V Research Station please contact:

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- Hugh Broughton Architects – H. Broughton and S. Besly for information on the station design and comments.
- MFL – S. Gill, B. Newham and D. Mitchell for providing technical information on construction and logistics and for reviewing the Final CEE.
- Other organisations – P. Cumine and C. Dore of the UK National Atmospheric Emissions Inventory for providing conversion factors and reviewing emissions data; D. Rootes of Poles Apart for technical input and comments on the Final CEE; S. Nash of Mott McDonald Ltd. for technical comments.

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13. ACRONYMS

Acronym	Meaning
AGO	Automated Geophysical Observatories
AIS	Advanced Ionospheric Sounder
ALCI	Antarctic Logistics Centre International
ATCM	Antarctic Treaty Consultative Meeting
ATCP	Antarctic Treaty Consultative Party
AVTUR	Aviation Turbine Fuel Jet A-1
AWS	Automatic Weather Station
BDSP	Building Services Engineering Consultancy
BAS	British Antarctic Survey
CASLab	Clean Air Sector Laboratory
CEE	Comprehensive Environmental Evaluation
CEP	Committee on Environmental Protection
CFC	Chlorofluorocarbon
CHP	Combined Heat and Power
CMDL	Climate Monitoring and Diagnostics Laboratory
DEFRA	Department of Environment, Food and Rural Affairs
DHC	DeHavilland Canada
DROMLAN	Dronning Maud Land Air Network
EIA	Environmental Impact Assessment
ERS SAR	Earth Resource Satellite Synthetic Aperture Radar
ETFE	Ethylene Tetrafluoroethylene
EOI	Expression of Interest
GPR	Ground Penetrating Radar
GPS	Global Positioning System
GRP	Glass Reinforced Plastic
GSAC	Global Science in the Antarctic Context
HF	High Frequency
IGY	International Geophysical Year
ISO	International Organization for Standardization
LANDSAT	Satellite which acquires images of earth from space
LED	Liquid Electronic Display
LPM	Low Power Magnetometer
MARPOL 73/78	International Convention for the Prevention of Pollution from Ships 1973, as modified by the Protocol of 1978
MGO	Marine Gas Oil
MFL	Morrison FI Ltd
NERC	Natural Environment Research Council
OSCP	Oil Spill Contingency Plan
PV	Photovoltaic
RADARSAT	Satellite which acquires synthetic aperture radar imagery of earth from space
RIBA	Royal Institute of British Architects
RRS	Royal Research Ship
RWDI	Rowan Williams Davies and Irwin Consultants
SAR	Search and Rescue
SCAR	Scientific Committee on Antarctic Research
SHARE	Southern Hemisphere Auroral Radar Experiment
SuperDARN	Super Dual Auroral Radar Network
UK	United Kingdom
UN	United Nations
USA	United States of America
VHF	Very High Frequency
VLF	Very Low Frequency
VOC	Volatile Organic Compound
WMO	World Meteorological Organisation

APPENDICES

Appendix 1. Comments received on the Draft CEE and response to comments

A Diplomatic Note was sent to all of the Consultative Parties on 4th February 2005 to announce the availability for public review of the Draft CEE and a statement was also published in the *London Gazette*. The Draft CEE was made available for review and public comment via a website link. Comments received on the Draft CEE and the responses to those comments are presented below.

Comments were received from the following respondents:

1. United States, National Science Foundation
2. New Zealand Ministry of Foreign Affairs and Trade
3. Japanese Ministry of Foreign Affairs and Trade
4. German Federal Environment Agency
5. Antarctic Treaty Consultative Meeting (XXIII ATCM)/Committee on Environmental Protection (CEP VIII)

The comments are printed in full below and responses have been inserted below each specific comment in blue arial font, preceded by an arrowhead symbol.

The CEP advice to ATCM XXVIII on the Draft CEE is also appended at the end of this section.

1. National Science Foundation, Office of Polar Programs, USA

21/06/2005

Dear Rod,

The CEE submitted to the ATCM by the UK is well written and proposes the honorable goal of substantially reducing environmental impacts in the switch from Halley V to Halley VI. We also appreciate the helpful presentation provided at the ATCM meeting in Stockholm. We have provided several comments on the proposed activity below:

1. One serious concern we have with the program at Halley is the continued use of leaded gasoline. Lead, and its use in gasoline, is known globally for its deleterious impacts on human health and the environment. We highly recommend converting to unleaded gasoline.

    ➢ No leaded fuels are used at Halley. Lead replacement petrol (unleaded petrol with additive) is used for snowmobiles and small generators (approximately 20-50 drums per year)

2. Drip pans and spill kits are occasionally mentioned in the document; consider making use of drip pans or absorbent pads mandatory for all fuel transfers (possibly in Section 6 page 48).

    ➢ Drip trays are used when practical for refuelling operations at Halley. This is not always feasible. Further details are given in Section 6.2.2.

3. We anticipate a greater level of detail regarding the preferred design and anticipated environmental consequences in the final CEE, as the design and environmental impacts should become more clear over the next year. We suggest these details should include the removal of the station in the CEE, as it is related to the proposed activity.

- ➢ The removal of Halley V is included in the Final CEE (see Section 3).

Best wishes,

Pam Toschik and Polly Penhale

2. New Zealand Ministry of Foreign Affairs and Trade

12 April 2005 APU/GBR

APU/CV/EP/3

Dr Mike Richardson
Head, Polar Regions Unit
Overseas Territories Department
Foreign and Commonwealth Office
London SW1A 2AH
United Kingdom

Dear Mike

Thank you for the opportunity for comment on the draft Comprehensive Environmental Evaluation (CEE) "Proposed Construction and Operation of the Halley VI Research Station, Brunt Ice Shelf, Antarctica" prepared by the United Kingdom.

We have referred the draft CEE to our environmental experts. The key comments and issues they raised are provided below for your information, in advance of the eighth meeting of the Committee for Environmental Protection (CEP VIII) where the draft CEE is to be considered.

General comments

We note the challenges of preparing a draft CEE before selecting the final design for the new station, while also attempting to meet the timing requirements of Annex I of the Protocol. We also note that a key aim is to ensure that the environmental effects of Halley VI are reduced compared to Halley V. This approach is to be commended. The draft CEE indicates the actual impacts of construction are likely to be similar between the three designs set out in the draft CEE. That said, the descriptions of the environmental impacts vary between the three designs in terms of their detail, particularly around issues such as waste management (including waste water handling) and alternative energy technologies. This provides a somewhat variable impression of the likely impacts.

We also note that the "clean up" of Halley V is not covered by the draft CEE, and that no explanation as to why this decision has been made is included in the draft CEE. We assume it relates to timing. New Zealand notes that, by contrast, the draft CEE prepared by Germany covers both the construction of Neumayer III and the "clean up" of Neumayer II. While such decisions are the prerogative of the proponent, the inconsistency between the two draft CEEs does not necessarily assist the development of a consistent international approach to the drafting of CEEs.

- ➢ The "clean up" of Halley V is included in the Final CEE (see Section 3)

We recognise the UK's dedication to reducing staff numbers and thereby reducing fossil fuel use. This is commendable, especially in an environment in which most Antarctic Treaty nations are still expanding base footprints and staff numbers.

Specific comments

Section 1.3 provides excellent scientific justification for the continued operation of a station in the region.

Section 1.4 makes little reference to the fact that Halley V needs to be replaced due to the risk of the ice shelf calving within the next decade. More information could be provided here, as we understand this is a primary drive behind the need to construct Halley VI. For example, a reference to Section 5.3, where the issue is dealt with in some detail, could be provided.

- The text of Section 1.4 has been amended to provide more information on the risk to Halley V due to the potential calving of the Brunt Ice Shelf

Section 2.1 notes that the decommissioning of Halley V will be the subject of a separate EIA. Some reasoning as to why the removal of Halley V is not covered in this document would be helpful.

- The decommissioning of Halley V is included in the Final CEE (see Section 3)

Section 2.5.1 provides only limited information around the construction camp and does not cover the potential impacts of the camp. We assume this will be dealt with in detail in the final CEE.

- There will not be a construction camp at Halley VI and the existing research station at Halley V will be used to accommodate construction workers. More information on construction accommodation is provided in Section 2.6.3

Section 3 discusses the three design options for Halley VI. Although it is accepted that all three design concepts will reduce the environmental impacts compared to Halley V, the different environmental impacts of each design could have been elaborated. The design differences could have been presented in tabular format, as could the potential environmental impacts of each design (Section 6).

Section 3.1 discusses the Buro Happold and Lifschultz Davidson design, which makes no mention of wastewater treatment options. A comparison of such issues between design options would help readers ascertain the potential environmental impacts of the different deisgns.

Section 3.3.3 – delete “a vacuum toilet” from last sentence of second paragraph.

- The suggestions relating to Section 3 of the Draft CEE are no longer relevant as the final design has now been selected

Section 6.2.2 notes that an oil spill contingency plan will be developed for the construction camp. While we do not see it as essential, consideration might be given to appending this plan to the final CEE.

- The Oil Spill Contingency Plan for Halley is available on the Halley VI CEE website (www.antarctica.ac.uk/halleyVI/cee.html)

Section 6.2.2 notes that the volume of waste that will be produced at Halley VI will not exceed 500m^3, yet is unclear how this figure was reached especially with the final building design unknown.

- Section 6.2.2 has been revised to give further information on the source of this estimate

Section 6.2.4 notes that treated sewerage and macerated food waste may be discharged overboard from the supply vessels. It would be useful to mention here that the MARPOL recognises the Southern Ocean as a Special Area in relation to Annexes I (oil) and V (garbage) and that discharges will be consistent with this designation.

> - The text of Section 6.2.4 referring to MARPOL has been amended

Section 6.2.4 also notes that ballast water will only be exchanged when at deep sea. Confirmation that this will apply both to the charter vessel as well as the BAS vessel might be helpful.

> - The text of Section 6.2.4 referring to ballast water has been amended

Section 6.3.2 describes the fact that levels of pollutant gases will remain at least three orders of magnitude below thresholds set by English Air Quality Regulations. However, it should be noted in the CEE that such Air Quality Regulations do not necessarily apply in Antarctica and can only be used as a guide.

> - Section 6.3.2 has been amended to reflect these comments

Section 6.3.1 describes the impact to air from the operation of Halley VI. It is noted however, that the estimated fuel consumption amounts given in Table 7 for tracked vehicles (53,000 to 50,000), and twin otter (92,250 to 80,000), are both below the estimated values given in the previous paragraphs.

> - The numbers given in the text are in litres (volume) and those in the table are in tonnes (weight), for which a conversion is required based on the density of the fuel

Section 6.3.3 makes good use of existing data (from Halley V) to describe potential impacts of the operation of Halley IV – particularly so with respect to waste. BAS should be commended on initiatives already introduced to reduce waste, such as introduction of reusable packing crates and packaging materials.

Section 6.3.7 notes the impact to aesthetic and wilderness values from the operation of Halley VI. However, this section makes no mention of the impact (albeit temporary) of vehicle tracks around the station area. The image at the back of the draft CEE demonstrates the visual impacts that vehicular activities will have on the ice shelf area.

> - Section 6.3.7 has been amended to reflect these comments

Section 6.4 makes very little reference to the cumulative impacts associated with the construction and operation of Halley VI. There are obvious cumulative impacts that have not been mentioned in this draft CEE, including cumulative impacts from activities at Halley V. These would include transport routes, wastewater disposal into the ice shelf, visits to wildlife etc. Some mention also needs to be made of equipment left in the ice shelf and its eventual impact on the marine environment – namely equipment and materials from Halley V. Given that this issue has been high on the agenda of recent meetings of the Committee for Environmental Protection it may merit more detailed assessment.

> - Section 6.4 has been amended to reflect these comments

Conclusions

Overall New Zealand considers the draft CEE to be of a high quality and consistent with the provisions of Annex I to the Environmental Protocol. However, the variability in the operational aspects and the impacts of the CEE between the three station designs is noted. It is further noted that the final CEE will contain more detail around issues such as the construction camp and operational issues of the station such as waste management and fuel usage.

In this regard Section 1.5 notes that the final CEE will be made available for comment in the same way as the draft CEE. While this is a somewhat unusual practice, it is probably the most appropriate means of handling the uncertainties and gaps in knowledge that surround the preparation of the draft CEE.

New Zealand also agrees with the findings of the draft CEE that the construction of the new station is necessary and that the impacts of the construction and operation of Halley VI will be outweighed by the scientific advantages and benefits that are likely to be gained from the new station.

Yours sincerely

Trevor Hughes

For Secretary of Foreign Affairs and Trade

3. Ministry of Foreign Affairs, Japan

MINISTRY OF FOREIGN AFFAIRS

TOKYO, JAPAN

No. 1568/GI-GE

NOTE VERBALE

The Ministry of Foreign Affairs presents its compliments to Her Britannic Majesty's Embassy and, in reference to the latter's note No. A 39 dated 4 February 2005, has the honour to reply to the Embassy's request concerning the draft Comprehensive Environmental Evaluation (CEE), entitled "Proposed Construction and Operation of Halley VI Research Station, Brunt Ice Shelf, Antarctica", as follows:

1. It was not an easy task to implement the above-mentioned Halley VI Research Station CEE, as the detailed plan and several alternatives to consider before the final decision.
2. Generally, it is important to determine appropriate monitoring indicators for measurement and evaluation of the environmental impact of a station operation, and Halley VI Station is no exception. In considering the environmental impact on Antarctica, the draft CEE needed to clarify the indicators of annual waste from Halley VI Station. This included not only the annual waste quantity which is removed from Antarctica (see CEE page 67 Table 12.), but also the quantity, type and storage of waste which is not removed.
    - Halley VI has been designed so that no waste will be left at the station and only filtered water will be discharged at the site

The ministry of Foreign Affairs avails itself of this opportunity to reaffirm to Her Britannic Majesty's Embassy the assurances of its highest consideration to this matter.

Ministry of Foreign Affairs

Tokyo, April 28, 2005.

4. German Federal Environment Agency

German comments on the Draft Comprehensive Environmental Evaluation (CEE) for the proposed construction and operation of Halley VI research station, Brunt Ice Shelf, Antarctica, presented by the British Antarctic Survey

<u>The Facts</u>

Great Britain is planning to set up a new all-year station on the Brunt Ice Shelf in Antarctica to replace the Halley V station which is to be given up. An expert's report on its environmental impact has been prepared for the international participation in comprehensive environmental evaluation in accordance with Article 8 and with paragraph 3 of Article 3 of Annex I of the Protocol of Environmental Protection (PEP) to the Antarctic Treaty.

The Federal Environmental Agency has laid this report out publicly in accordance with paragraphs 1 and 2 of Article 16 of the PEP and provided the public with the opportunity to comment on it. The Agency will pass on the following German statement to the parties to the treaty. The German statement takes into account the statements that were submitted to the Federal Environment Agency by the Federal Nature Conservation Agency, the Federal Maritime and Hydrographic Office, and the commission of independent scientific experts in accordance with Article 6 of the PEP.

<u>Evaluation</u>

The report that has been submitted relates to the construction and operation of the planned station, the construction and operation of the required construction camp and the transport of persons and materials. The dismantling of the planned station and that of the station Halley V that is still in operation are to be considered in studies of their own (cf. sects. 2.1 and 2.8). The actions involved in the running of Halley V over the same time period are likewise not a topic of consideration in this study (cf. sect. 2.2.1). This approach deviates from the regulations laid down in paragraph 2 (f) of Article 3 of Annex 1 to the Protocol of Environmental Protection, which requires that the cumulative effects of action with regard to current and known planned activities also be included in the investigation.

- The demolition and removal of Halley V is considered in the Final CEE (see Section 3). The operation of Halley V during the construction period is also considered as Halley V will be used to accommodate the construction and demolition workers

In contrast to the Halley V station still in operation, which is designed to be staffed by 18 persons during the winter and to host maximally 70 summer visitors, Halley VI is to accommodate 16 staff over the winter and 52 summer visitors (cf. sect. 2.4). Hence there is to be a future reduction of the station staff especially in the Antarctic summer. This is a fact which is to be viewed positively, given the general tendency that is becoming apparent for increasing numbers of summer visitors at the various stations in the Antarctic. The same applies to the intention to minimise fuel consumption, to the more intensive use of renewable energy sources and to the improved environmentally sensitive waste management. The construction of the station as a building on stilts, the specific variant of which has still to be selected, ought in any case to meet high technical standards and do justice to current requirements of environmental soundness. Nevertheless, it remains to be seen what can be said with regard to the aim of minimising as much as possible the factor associated with a station in operation that has the greatest impact – i.e. its emissions – as that will depend on which of the three alternative constructions is in fact decided upon.

The intention is to construct the station on the ice shelf, which means that a contamination of the ice cannot be ruled out. This however must be weighed up against the scale of the scientific benefits of the station, which, comparatively speaking, are large, as convincingly set out by the BAS in the report. At 25 square kilometres, the size of the planned utilisation area appears reasonable for Halley VI.

The region in which the planned activities are to take place lies inland at a distance of about 30 km from the edge of the ice shelf, so that no direct effects on the maritime environment are discernable. However, in view of the local prevailing temperatures (average air temperature –18 degrees Celsius, average water temperature –1.9 degrees Celsius), we cannot understand the reasoning behind the assumption made on page 47, that in the event of an accident while fuel is being transferred or during refuelling, any hydrocarbons (e.g. AVTUR / kerosene, diesel) that are released – ultimately into the sea – would quickly disperse and evaporate. We propose that the relevant pollution control measures of the "Halley Bulk Fuel Storage and Transfer Procedures" and the "Oil Spill Contingency Plan" for avoiding contamination of the marine environment, for example, be included in the report and made public accordingly.

- The Oil Spill Contingency Plan for Halley is available on the Halley VI CEE website (www.antarctica.ac.uk/halleyVI/cee.html)

The account of supply logistics during the construction work and subsequent operation of the station could be formulated in a more detailed fashion. For instance, the report does not contain any information on the location of the planned loading /unloading site for the supply traverses. Section 2.5.1 states that the site for the unloading point should be sought as near as possible to the future site of the station. Map 5 (p.10) shows several possible traverse routes, one of which starts at the landing point at "Windy Creek", which lies directly adjacent to an existing colony of emperor penguins. In view of the major significance of the penguin colony, this variant should not be pursued any further. We assume that the protection of this colony is a matter of high priority in the planning of the BAS. The study should therefore provide details on how disruption of the colony is to be avoided. Furthermore, no concrete information is provided on the siting and directional orientation of aircraft landing strips and helipads: this includes information on any possible disturbance of groups of penguins and seals by the expected air traffic, and information on any measures planned to avoid and minimise such disturbances.

- The unloading site will either be in the area of Creek 2 or at N9 (see Figure 5). Neither of these locations is close to the Emperor Penguin colony at Windy Creek. The nearest unloading site is around 15km from Windy Creek. Windy Creek is only used for very infrequent recreational visits

To ensure that any disturbance of wildlife is avoided (see CEE, p. 59), the relevant passages from the "BAS Handbook 2004" should certainly be included as part of the study. The area-specific guidelines mentioned in the study as still to be drawn up should likewise be included in the study, so that they can be used in tables 10 and 11 "Impact Matrices" for an assessment.

- The BAS Handbook and the site guidelines for "Windy Creek" are available via the Halley VI CEE website (www.antarctica.ac.uk/halleyVI/cee.html)

To sum up: the conclusions of the draft CEE are plausible and comprehensible. The scientific significance of the Halley station and thereby the international significance of this base station for joint projects are demonstrated convincingly. It would, however, be seen as an important addition to the study if the points made above were to be taken into consideration.

5. Report of the Committee for Environmental Protection (CEP VIII, 2005)

(64) In response to a question from France on the proposed use of renewable energy at Halley VI, the United Kingdom noted that this is being addressed in the short-listed proposals, in particular the use of passive solar heating.

(65) Referring to IP 105, Japan commented that, based on experience at Syowa Station, it is important to maintain good monitoring records for waste disposed at, and removed from, Antarctic stations.

(66) Germany noted that it had forwarded comments received through its domestic consultation process on the draft CEE to the United Kingdom, and further that:

- a decision has yet to be made on which station design will be used;
- commentary on contingency planning for fuel spills may be useful; and
- the document does not contain a discussion of the supply logistics to be used during the construction phase.

(67) The United Kingdom thanked France, Japan and Germany for their comments. The United Kingdom noted that all facilities above the snow surface at Halley V will either be recycled or reused at Halley VI or will be demolished and removed from Antarctica in 2009/10. Also, all hazardous materials will be removed from the sub-surface tunnels. The demolition and removal of Halley V will be the subject of a separate EIA.

> ➢ The removal of Halley V has been included in the Final CEE for the construction and operation of Halley VI

(68) New Zealand commended the United Kingdom on the environmental criteria used in the station design competition and welcomed the novel approach to the selection of the station design. New Zealand considered, however, that this approach complicates the CEE process, and perhaps introduces some uncertainty about likely environmental impacts. New Zealand asked whether the final CEE addressing those uncertainties would be circulated for comment.

(69) The United Kingdom agreed that it had taken a novel approach and that timing of the competition had prevented the inclusion of the successful design in the document presented to the Meeting. As a result, it was the intention of the UK that the final CEE would be made available to Members via the BAS website www.antarctica.ac.uk/halleyvi/cee.html for comment before next year's ATCM.

(70) Norway congratulated the United Kingdom on their draft CEE, remarking that for continental Antarctica there is no problem of proliferation of infrastructure and that the important scientific work undertaken at Halley and other similar continental stations in relatively unexplored parts of Antarctica warrants their existence.

(71) The Chair noted the Committee's agreement that the draft CEE provides a comprehensive description and evaluation of the proposed activity and likely environmental impacts, and is therefore consistent with the requirements of Annex I to the Protocol.

(72) The CEP's advice to the ATCM on the draft CEE for 'Proposed Construction and Operation of Halley VI Research Station' is contained in Appendix 1.

CEP ADVICE TO ATCM XXVIII ON THE DRAFT CEE CONTAINED IN ATCM XXVIII-WP 19 & IP 66 (United Kingdom). From Appendix 1 of CEP Report.

The Committee for Environmental Protection,

With regard to the draft Comprehensive Environmental Evaluation for the *Proposed Construction and Operation of Halley VI Research Station, Brunt Ice Shelf, Caird Coast, Antarctica*;

Having fully considered the draft CEE circulated by the United Kingdom on 04 February 2005, as reported in paragraphs 65 to 82 of the CEP VIII Final Report, and

Having noted the comments provided by the Parties to the United Kingdom, and the response of the United Kingdom to those comments,

Provides the following advice to the ATCM:

> The draft CEE and the process followed by the United Kingdom conform to the requirements of Article 3 of Annex 1 to the Environmental Protocol;
>
> The draft CEE is well-structured and comprehensive and provides an appropriate assessment of the impacts of the proposed project;
>
> The information contained in the draft CEE supports its conclusion, that the proposed activity will have a more than minor or transitory impact on the Antarctic environment, but that the global scientific importance to be gained by the construction and operation of Halley VI outweighs the impact the station will have on the Antarctic environment and fully justifies the activity proceeding;
>
> While the draft CEE addresses the construction of a new research station based on three possible alternative designs, the Committee feels that the document nonetheless appropriately assesses the likely environmental impacts of the overall design objectives, and that whichever of the three designs is chosen, there will be a significant reduction in the overall impact compared to that at the current Halley V research station.

The CEP recommends that the ATCM endorse these views.

Appendix 2. Schedule of planned accommodation for domestic, technical and science facilities for Halley VI

Room No.	PROPOSED MAIN HABITAT FACILITIES	Room Area
	MODULE A: CENTRAL MODULE	
A-01	Ambient store	25.0
A-02	Atrium with hydroponics	30.0
A-03	Bar with bar games	52.0
A-04	Table tennis / Summer dining	58.0
A-05	Winter dining room	46.0
A-06	Kitchen	35.0
A-07	Day pantry	5.0
A-08	Hub	16.5
A-09	Upper landing	13.0
A-10	Multifunction room	46.0
A-11	TV lounge and meeting room	46.0
A-12	Office/Internet room	28.0
A-13	Plant room	25.0
A-14	Telephone booths	
A-15	Cold food store +4ºC	6.3
A-16	Freezer - meat -20ºC	5.0
A-17	Freezer - vegetables -20ºC	5.0
A-18	Bar store	5.0
A-19	Plant room	4.0
A-20	Corridor	18.0
	MODULE B1: WINTER SLEEPING MODULE	
B1-01	Bedroom Type 1 (sleeps 1 in winter 2 in summer)	9.0
B1-02	Bedroom Type 1 (sleeps 1 in winter 2 in summer)	9.0
B1-03	Bedroom Type 1 (sleeps 1 in winter 2 in summer)	9.0
B1-04	Bedroom Type 1 (sleeps 1 in winter 2 in summer)	9.0
B1-05	WC	2.0
B1-06	Showers	4.6
B1-08	Toiletries store	2.0
B1-09	Plant room	8.5
B1-10	Bedroom Type 1 (sleeps 1 in winter 2 in summer)	9.0
B1-11	Bedroom Type 1 (sleeps 1 in winter 2 in summer)	9.0
B1-12	Bedroom Type 1 (sleeps 1 in winter 2 in summer)	9.0
B1-13	Bedroom Type 1 (sleeps 1 in winter 2 in summer)	9.0
B1-14	WC	2.0
B1-15	Shower room	3.7
B1-16	WC	2.0
B1-17	Shower room	3.7
B1-18	Corridor	14.1
B1-19	Bedroom hallway	18.5
B1-20	Corridor	10.7
	MODULE B2: WINTER SLEEPING MODULE	
B2-01	Bedroom Type 1 (sleeps 1 in winter 2 in summer)	9.0
B2-02	Bedroom Type 1 (sleeps 1 in winter 2 in summer)	9.0
B2-03	Bedroom Type 1 (sleeps 1 in winter 2 in summer)	9.0
B2-04	Bedroom Type 1 (sleeps 1 in winter 2 in summer)	9.0
B2-05	Sauna	4.3
B2-06	Linen store 1	2.0
B2-07	Linen store 2	2.0
B2-08	Plant room	8.5
B2-09	Bedroom Type 1 (sleeps 1 in winter 2 in summer)	9.0
B2-10	Bedroom Type 1 (sleeps 1 in winter 2 in summer)	9.0
B2-11	Bedroom Type 1 (sleeps 1 in winter 2 in summer)	9.0
B2-12	Bedroom Type 1 (sleeps 1 in winter 2 in summer)	9.0
B2-13	Quiet room	24.4

Room No.	PROPOSED MAIN HABITAT FACILITIES	Room Area
B2-14	Bedroom hallway	18.5
B2-15	Corridor	6.5
B2-16	Balcony	5.4
B2-17	Shower and changing area	3.6
	MODULE C: COMMAND MODULE	
C-01	Lobby with ski rack	5.9
C-02	Boot room	18.7
C-03	Server	9.5
C-04	WC	2.0
C-05	Urinals	4.3
C-06	Stationery store	2.0
C-07	Plant room	8.5
C-08	Doctors consulting room	8.9
C-09	Station commander's office	10.9
C-10	Doctors surgery and pharmacy	18.0
C-13	Laundry, cleaner's store and sink	8.3
C-14	Corridor with barber shop and stretcher	11.2
C-15	Hallway with BA gear	19.2
C-16	Corridor	6.9
C-17	Communications room	16.9
C-18	Entrance Deck	3.4
C-19	Roof deck	11.0
	MODULE E: ENERGY MODULE	
E1-01	Lobby	17.5
E1-02	Water and pumps	13.9
E1-03	Fire Plant	25.7
E1-04	General workshop/store- clean	10.3
E1-05	Compactors	16.3
E1-06	Generator sets	26.1
E1-07	Lobby	7.5
E1-08	Open deck	26.1
E1-09	Roof deck	77.0
E1-10	Corridor	6.8

Room No.	PROPOSED SCIENCE FACILITIES	Room area
	MODULE H1: SCIENCE MODULE	
H1-01	Cloaks with science store	11.7
H1-02	Lab A (East)	10.8
H1-03	Science office	65.0
H1-04	Plant room	8.5
H1-05	Cleaner store	2.0
H1-06	Lab B (west)	11.7
H1-07	Wet preparation area with drench shower	10.8
H1-08	WC	2.0
H1-09	Corridor	12.5
H1-10	Corridor	10.5
H1-11	Kitchenette	3.2
H1-12	Lobby with ski rack	5.9
H1-13	Entrance deck	3.4
H1-14	Roof deck	81.0
	MODULE H2: SCIENCE MODULE	
H2-01	Science preparation area	24.4
H2-02	Mechanical workshop	11.3
H2-03	Electronics workshop	14.5
H2-04	Server	11.0
H2-05	Plant room	8.5
H2-06	Office store	2.0
H2-07	Science warm store	20.7

Room No.	PROPOSED SCIENCE FACILITIES	Room area
H2-08	Lower meteorological operations	22.7
H2-09	Corridor	6.5
H2-10	Hallway	18.5
H2-11	Balcony	5.4
H2-12	Upper met ops and Dobson spectrophotometer area	41.0
H2-13	Bin store	1.9
H2-14	Stairs	3.8
	MODULE E2: ENERGY MODULE	
E2-01	Fuel tank	7.5
E2-02	Sewage treament plant	32.2
E2-03	Omitted	
E2-04	General workshop/store	10.4
E2-05	Water and pumps	10.4
E2-06	Generator sets	32.2
E2-07	Fuel tank	7.5
E2-08	Corridor	6.5
E2-09	Lobby	17.5
E2-10	Open deck	26.1
E2-11	Roof deck	77.0

Room No.	PROPOSED TECHNICAL FACILITIES	Room Area
	MODULE K: RE-USED DREWRY BUILDING	
K-01	Lobby	4.6
K-02	Boot Room	10.0
K-03	Stair hallway	2.0
K-04	Store	12.0
K-09	Plant room	18.0
K-10	Workshops	25.7
K-11	Field GA store	62.8
K-12	Inc.	
K-13	Inc.	
K-14	Inc.	
K-15	Under stair store	2.0
K-16	Stair	9.2
K-17	Corridor	9.5
K-18	Corridor	5.8
K-19	Void over workshop	23.5
K-20	Facility Managers office	19.3
K-21	Bedroom for 4	9.5
K-22	Bedroom for 4	9.5
K-23	Bedroom for 2	6.2
K-24	Bedroom for 2	6.2
K-25	Bedroom for 4	9.5
K-26	Bedroom for 4	9.7
K-27	Female washroom	5.0
K-28	Male Washroom	14.0
	MODULE J: RE-USED GARAGE WITH ADDITIONAL SLEDGE	
J-01	Double height workshop area	84.0
J-02	Office	14.9
J-03	Plant room	11.0
J-04	Jizer bath, Melt tank, washbasin and urinal	5.2
J-05	Mezzanine parts storage	33.4
J-06	Battery store	3.0
J-07	Hazardous chemical store	2.1
J-08	Fuel tank	3.7
J-09	General storage container	14.1
J-10	General storage container	14.1
J-11	Roof rack storage	42.2

Room No.	PROPOSED TECHNICAL FACILITIES	Room Area
	MODULE L: REUSED CAS LAB	
L-01	Lobby	2.6
L-02	Flammable Gas Store	2.7
L-03	Non Fammable Gas Store	0.4
L-04	Clean Air Laboratory	25.8
L-05	Office	6.6
L-06	WC	1.0
L-07	Deck with cold gas store	60.0
L-08	Open Entrance Deck	1.6
L-09	Main lab roof deck	44.0
L-10	Stair deck	1.7

Appendix 3. Comparison between operations at Halley VI compared to Halley V

ACTIVITY	Halley V	Halley VI
Personnel	Typically accommodates up to 70 summer personnel and up to 16 winter personnel.	Will accommodate 52 summer personnel and 16 winter personnel. The reduction is all technical staff due to the change in maintenance requirements. Reducing the winter personnel to 10 or 12 will be revised.
Refueling Operations	Fuel is stored in static bulk tanks or drums. The bulk tanks are filled by smaller transit tanks traversing from the ship to the Station (20kms). Flubber tanks are filled every 3 months; fuel is decanted from a bulk tank to a transit tank and then into the flubber tank. This is labour intensive and every decanting operation provides potential for pollution.	The bulk tanks will be sledge mounted, they will be traversed to the shelf edge for refilling thus speeding up relief and reducing fuel, labour and plant usage. A single bulk fuel tank will be emptied filling all of the fuel tanks on the energy modules. The bulk fuel tank will be transported up to the energy modules once a month in the summer and once every 6 weeks in the winter. This reduces decanting operations and hence the risk of pollution.
Jacking	A team of 6 steel fixers and welders plus a structural engineer were employed all season to raise the steelwork on all of the buildings. 40 people over 2 days would then be utilised to jack the Laws building.	Requirement for less trades people; requirement for a hydraulics engineer
Stores	There is insufficient storage on the platforms at Halley V requiring a number of ISO containers to be used which requires snow management and double handling.	Provision of storage space has been an integral part of the design and two large sledges are being provided to mount ISO containers on. This will reduce snow management and double handling of stores.
Water Production	Water is limited and personnel have to dig snow twice a day in summer and once a day in winter to produce water.	Vehicles can be used to fill the melt tanks, but personnel can do so if they wish. There is sufficient water storage for 3-4 days in the summer and 10-14 days in the winter.
Waste	Food waste is buried, sewage is deposited in an “onion” below the ice and all other waste is removed for recycling or landfill.	Waste will be processed to strict environmental guidelines. Food waste and waste oil will be incinerated. Sewage from the main platform will be treated then incinerated. All other waste will be removed from site for recycling or controlled landfill disposal.
Vehicles		The number of skidoos will be reduced due to less people being on site. The number of sno-cats will be reduced being replaced by two prime movers, speeding up relief and providing more lifting capacity at the site. This will save time, spares, fuel and labour and will reduce pollution.
Renewable Energy		It is proposed to introduce solar panels and wind turbines during the first few years of operation to reduce fuel consumption and the associated logistical effort and cost.
Refuge Plan	Should an emergency occur on the Laws Platform personnel can take refuge in the Piggott building and the Drewry building (once commissioned in the winter) and	Should an emergency occur at the accommodation end of the platform, personnel can take refuge at the science end and in the Drewry and survive the

ACTIVITY	Halley V	Halley VI
	survive the winter.	winter quite easily. The Drewry will be powered all through the winter, and can easily be re-powered locally.
Relocation	Static station that cannot move if the ice shelf becomes unstable.	Relocatable enabling it to be towed to a new location if the ice shelf becomes unstable. Also, at the end of its design life it can be towed to the edge of the ice shelf for decommissioning and demolition.
Personnel Storage	The quantity of belongings personnel take has been unlimited causing storage problems on station.	Personnel will be limited in volume to two kit bags (one for BAS kit) and a storage box. Sufficient storage has been provided on station for this volume.
Masts & Towers	Masts predominate which require climbing every season to be raised, guy wire to be raised once a season and replaced every 2 or 3 seasons and a specialist team of riggers to maintain them.	Most of the masts will be replaced by towers that can be raised from the base by trained non-specialists. This reduces the need to climb (Health & Safety), the need for guy wire maintenance (time, labour, cost) and the need for the specialist team to be on site for a full season.
Building Management System		Halley VI will have a BMS that can be monitored by BAS staff in Cambridge. This will allow Building Services to provide a much improved diagnostic service during the winter.
Science	Science needs to be constantly monitored with an operator in attendance.	Science is further out in the field and is monitored remotely. Anticipated visit periods are between two weeks and one month. Science is also stationed further away from 'noisy' equipment, therefore the quality of the data will be of a higher grade. Science layout allows greater areas for future science expansion.
Field Operations Facility	No dedicated space for repairing sledges or drying tents, this is often done in the corridors.	Dedicated double height room for tents and consolidated storage in heated building has been provided.

Appendix 4. Halley V Tunnels: contents and feasibility study for removal (2003; amended 2006)

Note: Whether the following items can be removed or not will be dependent on a full and thorough Health and Safety Review.

<u>Piggott Tunnel</u>

Description	**Removable Y/N**
20,000 Ltr Fuel Flubber x 1	Y
Fuel Pumps x 2	Y
Fuel pipe network (copper)	Y
Ventilation extract ductwork in risers and through tunnel	Y
Electrical panels x 2	Y
16mm Electrical power cable	Y
500mm Cable tray through whole tunnel	Y
Old melt tank (steel) and flooring	N
Some of Wooden flooring to tunnel	Y
Armaco steel tunnelling and three exit shafts	N
Hand rails (level 3)	Y
Light fittings	Y
Signs (various)	Y
Access ladders x 3	N
Silo (melt tank) riser	N

<u>Laws – Simpson Tunnel</u>

Description	**Removable Y/N**
20,000 Ltr Fuel Flubber x 2	Y
Fuel Pumps x 3	Y
Fuel pipe network (copper)	Y
Ventilation extract ductwork in risers and through tunnel	Y
Heating pipework (Iron)	Y
Main melt tank and ancillaries	N
Heating pipework to new melt tank (rubber)	Y
Water pump x 1	Y
Electrical panels x 2	Y
16mm Electrical power cable	Y
500mm Cable tray through whole tunnel	Y
Old melt tank (steel) and flooring	N
Some of Wooden flooring to tunnel	Y
Armaco steel tunnelling and three exit shafts	N
Hand rails (level 3)	Y
Light fittings	Y
Signs (various)	Y
Access ladders x 3	N

Silo (melt tank) riser	N

Magnetometer

To be decommissioned 2007/08

Description	**Removable Y/N**
Access ladder	Y
Electrical and general science equipment	Y
Wooden tunnel and riser	N

Iris Shaft

To be decommissioned 2007/08

Description	**Removable Y/N**
Access ladder	Y
Electrical and general science equipment	Y
Wooden tunnel and riser	N

Helium/Gas Storage Tunnel

Closed 2000/01. Most services removed and now fully buried and inaccessible.

Description	**Removable Y/N**
Access ladder	N
Steel tunnel and flooring – 40 Mtrs	N
Steel fan and ductwork	N
Steel Access riser – 18 Mtrs	N