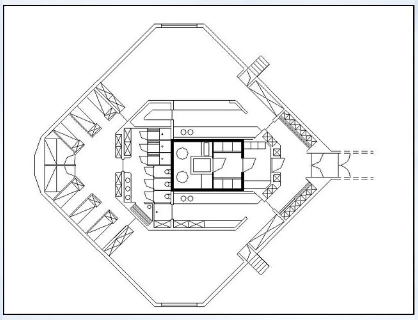

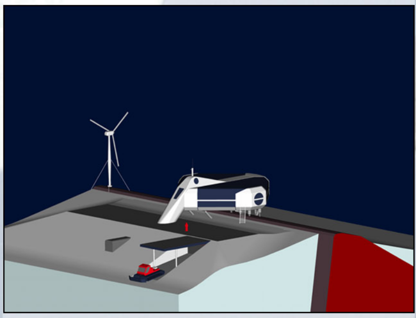

Construction and operation of the new Belgian Research Station, Dronning Maud Land, Antarctica

DRAFT COMPREHENSIVE

ENVIRONMENTAL EVALUATION (CEE)

February 2006

BELGIAN SCIENCE POLICY

THE INTERNATIONAL POLAR FOUNDATION

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CONTACT DETAILS

This draft Comprehensive Environmental Evaluation (CEE) report has been prepared by the Belgian Federal Science Policy Office (hereafter referred to as Belspo, Brussels, Belgium), with support and input from Dr. H. Decleir (CEP scientific advisor, Belgium), Johan Berte (coordinator of the station design and construction, the International Polar Foundation hereafter referred to as IPF, Brussels, Belgium), Dr. F. Pattyn (glaciology unit ULB, Belgium) and Poles Apart Ltd (environmental consultancy, Cambridge, UK).

It has been approved and endorsed by the Belgian Federal Ministries of Foreign Affairs, Environment and Science Policy. The report was circulated to all Antarctic Treaty Parties on 10 February 2006 and is available for download via the Belspo website www.belspo.be/antar.

We welcome comments and suggestions on the draft CEE.

For further information on this CEE report and its contents or if you would like to comment, please contact:

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NON-TECHNICAL SUMMARY

This CEE report, approved by the Belgian Federal Ministries of Environment, Foreign Affairs and Science Policy, covers the:

- construction, operation and maintenance of the new Belgian research station in Antarctica;
- building and operation of the temporary camp required during the construction phase and
- transport and movement of cargo and personnel to the station site south of 60° S.

The new Belgian research station will replace the former Belgian Roi Baudouin base, built in 1958 at Breid Bay in Dronning Maud Land, closed in 1967 and buried under meters of snow. The short operational period associated with the Roi Baudouin base, situated on the ice shelf, and with the nearby Asuka station (1986-1992), situated on the inland ice slope, both subject to high snow accumulation rates and strong katabatic winds, resulted in the decision to construct the new station on bedrock and in the protected western part of the Sør Rondane mountain range.

The proposed construction site is situated approximately 1 km North of Utsteinen Nunatak, on a small relatively flat granite ridge (71°57'S 023°20'E), 173 km inland from the former Roi Baudouin base and 55 km from the former Japanese Asuka station. With the closing of Asuka station in 1992, the 20-30 degrees east sector of Antarctica became again a vast territory having witnessed up to now only brief periods of systematic investigation. The new station will thus reoccupy the 1072 km empty stretch between the Japanese Syowa station (684 km) and the Russian Novolazarevskaya station (431 km).

The new platform is offered to the Belgian and international scientific community in a flexible way both operationally and with respect to research opportunities. The station will serve as a hub for field exploration in the 20-30 degrees east sector of Antarctica.

During the initial years emphasis will be placed on glaciology, earth sciences and (micro)biology. The station will also serve as a node in the network of geophysical observatories in this part of Antarctica. Apart from routine surface weather observations, the station will initially carry out observations in synergy with the earth sciences and glaciological programme. In line with guidelines set up by COMNAP, an environmental monitoring plan will be set-up to record the impacts of human activities on the Antarctic environment. Station research activities will go hand in hand with a publicity campaign and educational programme to inform the general public, students and schools about the importance and challenges of research in the Polar Regions including climate change and sustainable development.

The construction of the summer station is planned in the austral summer of 2007-2008. In this period the station will be built, the system acceptance test performed and then it will be handed over to the Belgian Science Office at the end of the season. The expected design life is 25 years minimum.

The station is designed for optimal use by 12 people with a surface area (living, technical, research, storage) of 800 m². The use of a station "extension" will make it possible to accommodate another 8 to 18 people. This extension consists of heated shelters used for sleeping only. The station's facilities (kitchen, sanitary installations, offices ...) are designed to cope with the larger occupation.

The station has a hybrid design, with the main building above ground-level and anchored onto snow-free rock area. The adjacent garage/storage building is located nearby and is mainly constructed under the surrounding snow surface. Both buildings are inter-connected by a weather protected corridor. The design and layout of the facilities will minimise snow management.

Consistent with the philosophy of the project, the station design will make best use of the terrain conditions for the integration of the buildings and will be such that it minimises impact on the environment and on the landscape during the construction, operation and removal of the station.

The system design of the station is based on sustainable technology and high energy efficiency, with a full-year monitoring and remote sensing capability. Nevertheless safety, health, comfort, functionality and cost are equally important design drivers. The facilities will use renewable energy as the primary energy source, integrating a comprehensive energy management regime, thereby minimising the use of fossil fuels. To assure a constant energy supply, two back-up generators will be installed. The amount of fuel used at the station will be mainly for vehicles.

The station will have a comprehensive waste management regime. Waste treatment will include the treatment of grey water and sewage and recycling capability for non-potable water applications. A Waste Management Plan (WMP) will be prepared that will comply with all the requirements of Annex III of the Environmental Protocol.

The station has been designed for low maintenance and recycling. Lifetime maintenance strategies will reduce the running costs. It is designed for easy repair and damage control. 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. A risk contingency plan will be developed. By design the station has extended upgrade capability. It will be easy to integrate new state of the art technologies and, if required, the station can be upgraded to a full year station with minimal effort.

The environmental impacts of the construction and operation of the proposed research station have been considered. The geographical area affected includes the route of the ship, the unloading site at Breid Bay, the traverse route from coast to station (180km), aircraft flight routes, the station area and areas visited during scientific fieldwork. Operations will generally take place within a radius of 200km of the station.

The main sources of direct impacts have been identified as:

- atmospheric emissions from the burning of fossil fuels;
- fuel spills to snow or ice and
- grey water discharge.

These impacts are likely to be higher during the construction of the station as a large amount of cargo will be transported to the site, there will be more people and the renewable energy systems will not be in place. Atmospheric emissions should be significantly reduced once the station is operational.

Direct impacts are described and summarised using impact matrices. These matrices also identify prevention and mitigation measures in order to avoid or reduce the impacts.

An Environmental Management Plan will be prepared for the construction and operation of the station. During the construction phase, the IPF Project Manager will be responsible for compliance with this Plan, including the implementation of mitigation measures set out in the CEE. During station operation the Belspo Station Manager will take over these responsibilities.

The potential environmental impacts of the station have been considered from the start of the design process, with an aim of minimising impacts wherever possible. The station has an energy efficient design, with maximal use of renewable energy. Water will be recycled and all wastes minimised. Cooperation with other nations for shipping and aircraft support will reduce the overall impact of long distance transport. Improvements in the environmental performance of the station and logistic support will be made wherever possible during the lifetime of the station.

As the station is designed to have a low environmental footprint with low energy consumption and minimal waste output, indirect impacts will be minor. Cumulative impacts may result from emissions to air, fuel spills and local discharge of grey water during the construction and operation of the station and may reduce the scientific value of the area.

Monitoring is one of the key components of the planned science at the new station and baseline monitoring work has already been undertaken during the Belare 2004 and Belare 2005 site surveys. A monitoring program will be developed to integrate with other work undertaken by national operators and in line with COMNAP guidelines.

Monitoring will be designed to investigate the potential impacts of the activities, so that adverse effects will be discovered in good time. Information on the operation of the station will be recorded, including emissions, fuel spills and wastes produced. The CEE impact assessment will be reviewed regularly to establish if the impacts are as predicted and to assess the effectiveness of mitigation measures.

Gaps and uncertainties in this draft CEE report include the unpredictability of weather and sea ice conditions which may cause delays in construction, incomplete details of the station design and logistical arrangements, incomplete information on breeding species within 200 km radius of the station and possible changes in future scientific and logistic requirements.

1. INTRODUCTION

1.1. Purpose of the new station

Aware of the increasing impact of human activities on the earth system, Belspo launched in 1997 a research programme in support of a sustainable development policy. This umbrella programme included the Belgian Scientific Programme on Antarctic Research, already in operation since 1985. The Antarctica programme resulted as legacy of the famous 1897-1899 'Belgica' expedition and Belgium's involvement in Antarctic exploration as one of the original signatories of the Antarctic Treaty.

Understanding how the earth system works is paramount in establishing a policy of sustainable development. Recent findings highlighted the importance of the Polar Regions in the global weather and climate systems, their value as a treasure house for past environmental archives and their key role in major bio-geochemical cycles. Antarctica has also proved to be ideally situated not only to study life processes in an extreme (cold) environment but also to observe geophysical and astronomical phenomena.

In order to further this challenging endeavour and to facilitate Belgian scientists in their Antarctic work, a panel of experts (commissioned by Belspo) recommended the re-opening of a Belgian scientific station in Antarctica (The Belgian Antarctic Programme 1985-2002: Findings of the evaluation panel, final report, July 2002) (http://www.belspo.be/belspo/BePoles/links/publ_en.stm). Such a station, open to all countries interested in conducting research activities in this part of Antarctica, would foster scientific cooperation with other research programmes and significantly enhance Belgium's visibility within the Antarctic Treaty System.

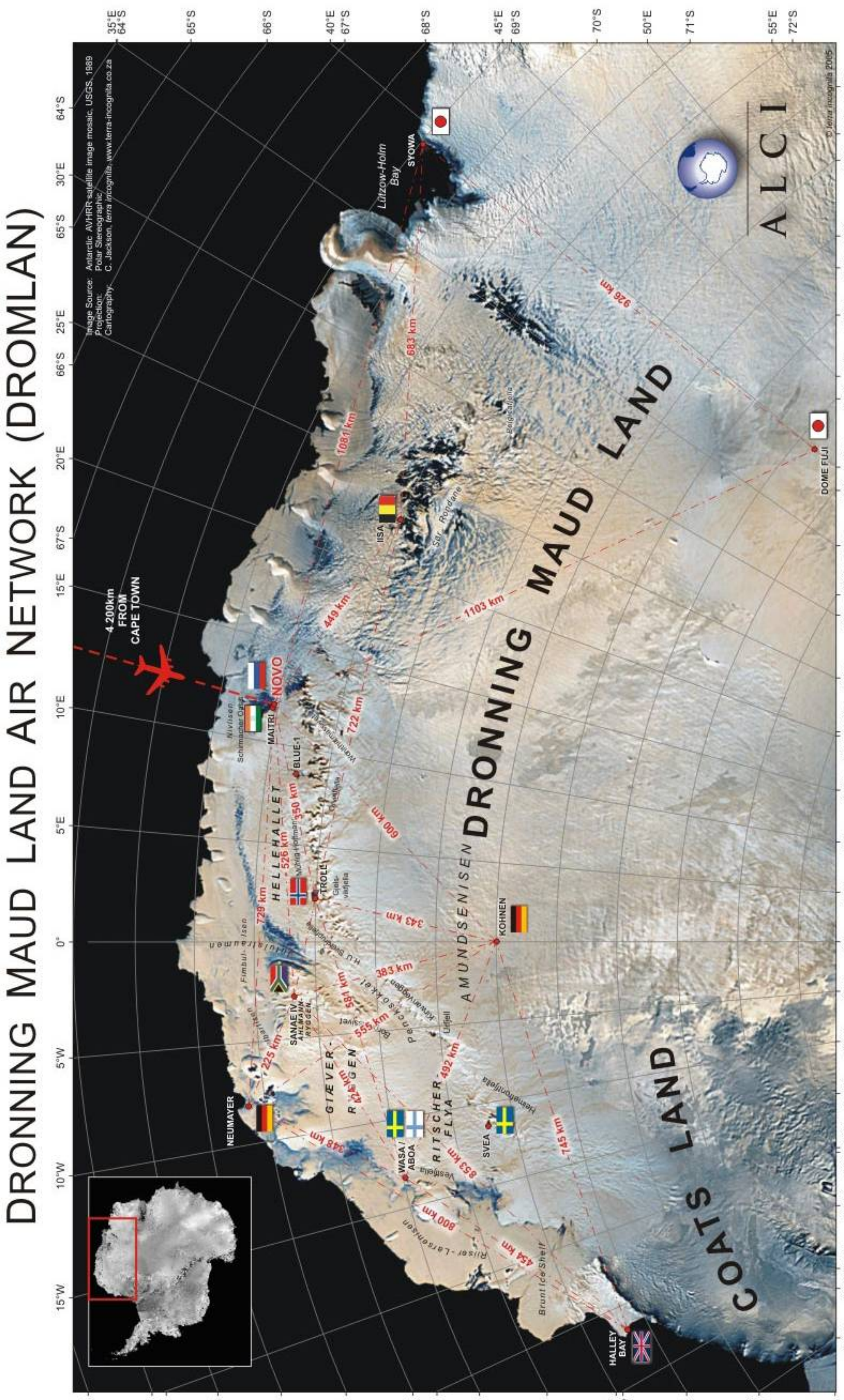
The new Belgian research station will replace the former Belgian Roi Baudouin base, built in 1958 on the ice shelf at Breid Bay in Dronning Maud Land. The new station will be erected on the Utsteinen Ridge (71°57'S; 023°21'E), situated at the foot of the Sør Rondane Mountains, Dronning Maud Land, 173 km inland from the former Roi Baudouin base (1958-1967) and 55 km from the former Japanese Asuka station (1986-1992) (**Fig. 1.1 and 1.2**). Positioned halfway between the Japanese Syowa station (684 km) and the Russian Novolazarevskaya station (431 km) it will fill in a 1072 km unoccupied stretch between these two stations in one of the least occupied sectors of Antarctica that has only been intermittently investigated since the International Geophysical Year (IGY).

Although at present designed as a summer station only, power supply will be such that continuous year-round monitoring will also be feasible, allowing the station to function as an important node in the network of solid earth and upper air geophysical observations. The station will also be situated in the exit area of the Gunnestadbreen, one of the major outlet glaciers of the Sør Rondane, giving access to the inland Plateau (Japanese Dome Fuji Station: 765 km; German Heinz Kohnen Station: 807 km).

The station therefore occupies a central position for investigating the characteristic sequence of Antarctic geographical regions (polynia, coast, ice shelf, ice sheet, marginal mountain area and dry valleys, inland plateau) within a radius of 200 km. By monitoring environmental changes, Belgium hopes to take up its full responsibilities with respect to the aspects of environmental protection in Antarctica.

The station will be designed as 'state of the art' with respect to sustainable development, energy consumption and waste disposal, with a minimum lifetime of 25 years. If dismantling of the station is required, no significant or very little remnants of the occupation will be left, in order to meet the requirements of the Environmental Protocol and relevant Belgian domestic law.

With this IPY initiative Belgium wants to contribute to a new area of high-tech Antarctic stations, offering a platform for science and exploration, open to the international scientific community.



<u>Fig. 1.1</u>: DROMLAN-ALCI map giving an overview of research stations in Dronning Maud Land and the distance to all stations from Novo Air Base.
Source: Antarctic AVHRR satellite image mosaic, USGS, 1989.

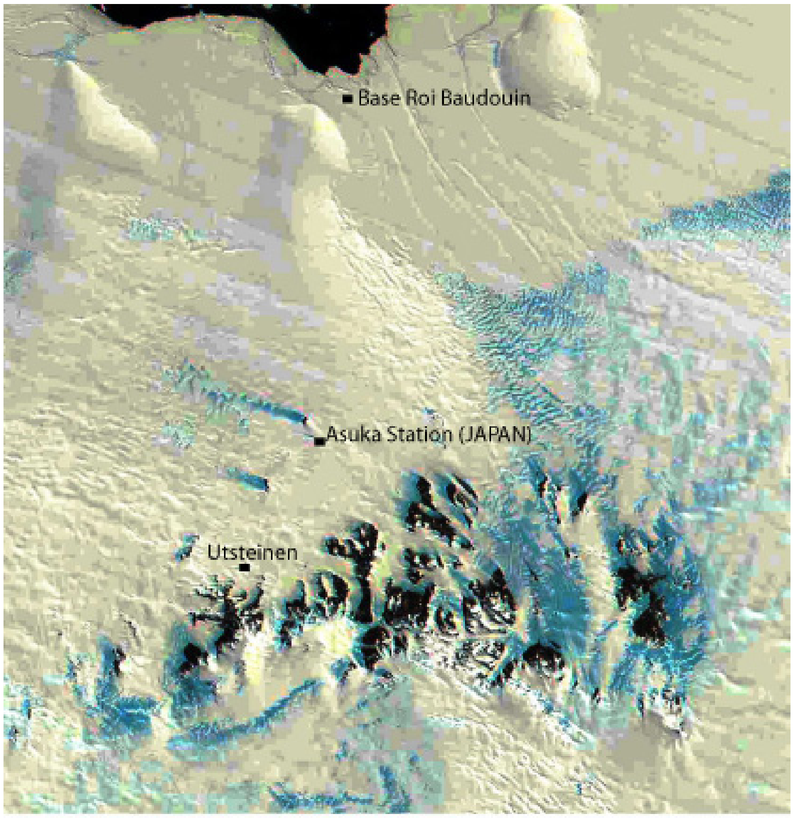


Fig. 1.2: MODIS image displaying the Sør Rondane Mountains and Breid Bay.
Situation of the former Belgian Baudouin Base, the former Japanese Asuka station and the proposed Belgian Utsteinen site.
The size of the image is approximately 250 by 250 km.

1.2. History of Belgian Antarctic research

Belgian involvement in Antarctic exploration began with the well known '1897-1899 Belgica Expedition' of Adrien de Gerlache. This expedition was the first expedition to winter in the Antarctic pack ice and is generally considered as one of the first genuine scientific expeditions to the Antarctic regions. The "Belgica Expedition" heralded the so called "Heroic Age" of Antarctic exploration which culminated in 1911 with the attainment of the South Pole by Roald Amundsen, second mate on the 'Belgica'.

In 1958 Belgium took an active part in the conception and preparation of the International Geophysical Year and, based on the legacy of the Belgica expedition, Belgium's commitment to the IGY included the establishment in January 1958 of the Roi Baudouin Research Station (70°26'S; 024°18'E) on a floating ice shelf of the Prinsesse Ragnhild Kyst in Dronning Maud Land. The Belgian base was integrated in a synoptic network of geophysical observations, carried out at more than 50 stations which contributed to our knowledge of surface weather and climate, and to our understanding of the upper atmosphere. The station also served as a base of operations for field work and geographical reconnaissance further inland. Geological and glaciological investigations were carried out for the first time in the Sør Rondane Mountains and new mountains were discovered further to the east (Belgica Mountains and Queen Fabiola Mountains). At the political level Belgium took an active part in the discussions leading to the Antarctic Treaty, one of the major outcomes of the IGY and was one of the original signatories. From 1964-1966 Base Roi Baudouin was the home of Belgian-Dutch Antarctic Expeditions. When the base was abandoned and closed in 1967, it was buried under meters of snow and was unsafe to inhabit.

After the closure of the Roi Baudouin base, a period of discontinuous activities followed. In 1985 Belgium resumed its Antarctica activities at the scientific level with a multi-annual research programme, while at the political level Belgium took active part in the development of the Protocol on Environmental Protection to the Antarctic Treaty (referred to hereafter as the 'Environmental Protocol') in 1991.

The scientific programme started with nine 4-year projects, financing 10 scientific teams for about 2 MEUR. Today, 15 scientific teams are financed within five 4-year network research projects for about 6.5 MEUR. The programme has evolved from a 'stand alone' programme within Belspo, to a part of a more general programme of sustainable development, positioning as such the Antarctic research and the role of Antarctica within the global environmental system. The major current research themes are climate change and biodiversity. At present Belspo supports high quality research teams, internationally recognised within the fields of ice-dynamics modelling, biogeochemical modelling, food-web dynamics, shelf slope dynamics and marine biodiversity.

Since closing Roi Baudouin base in 1967, Belgian scientists have depended solely on the hospitality of other nations to invite them to participate as guests in their scientific campaigns. Although this situation has led to a number of important and sustainable collaborations with other countries, this was not a long lasting situation as Belgium couldn't give an adequate return for the support, while it limited the selection of favourable sites for specific research activities.

1.3. Planned science

The new platform is offered to the Belgian and international scientific community in a flexible way both operationally as with respect research opportunities. It means that the research will be able to adapt not only to the evolution of science and technology but also to increased environmental concern. Initially the station will be open the summer only (November-February) but if required at a later stage the station can - without major modifications - be used as a wintering station.

(i) *The New Belgian Research Station as a hub for field exploration in the 20-30 degrees east sector of Antarctica*: access to the station is feasible throughout the whole summer season via the DROMLAN air network, allowing maximum use of surface transport vehicles for multiple field trips to the Sør Rondane and the coastal area. During the initial years emphasis will be placed on glaciology, earth sciences and (micro)biology. The glaciers flowing around and in the Sør Rondane are among the least investigated glaciers in Antarctica. The ice-dynamic surveying of the glaciers will be coupled with ice modelling and geochemical-isotopic studies, fields in which Belgian research teams excel. The study of rock outcrops in the Sør Rondane, belonging to the East Antarctic basement shield, was initiated by Belgian geologists and further explored by Japanese scientists in the period 1986-1992. It is clear that the Sør Rondane (together with Enderby Land) forms a key area in Antarctica for investigating the crustal evolution of Gondwana Land and international research teams will carry out such investigations from the new Belgian station. In the past, the blue ice fields characterizing the hinterland of the Sør Rondane (Nansenisen) have been successfully used by Japanese scientists to collect meteorites and cosmic dust. Using the gateway to Nansenisen via the Gunnestadbreen a new period of search for meteorites will contribute to the study of fundamental planetary processes. The dry valleys in the Sør Rondane will allow study of the waxing and waning of glaciers in the mountain area, as well as the periglacial (permafrost) environment. Finally, the different landscapes from the coast to the inland plateau represent varying environmental conditions for microbial habitats. Physiological experiments as well as molecular-genetic and genomic approaches are planned to gain a better understanding of which biological and environmental processes have shaped microbial communities and which factors are likely to be important in the context of future climatic change.

(ii) *The New Belgian Research Station as a node in the network of geophysical observatories*: the addition of a new node in the network of geophysical observatories will significantly complete the coverage of stations in this part of Antarctica. Apart from surface weather observations, the new Belgian Research Station will initially carry out observations in synergy with the earth sciences and glaciological programme. A broad-band seismometer will help to improve understanding of intra-plate seismic activity and the lithospheric structure. The combination of absolute gravity measurements each year and continuous GPS measurements (surface deformation measurements) will allow scientists to estimate the change in ice load and hence the regional mass balance in this region. At the same time, GPS dual frequency measurements can be used to reconstruct ionospheric disturbances and ionospheric scintillations. Such measurements in the upper atmosphere would significantly benefit from continuous monitoring of the geomagnetic field. The continuous monitoring of the geomagnetic field with an absolute accuracy is, at present, considered part of a second phase of geophysical measurements at the new station. The same applies for experiments to monitor the D-region of the ionosphere by passive and active electromagnetic sounding.

(iii) *The New Belgian Research Station as a monitor of environmental change in Antarctica*: in line with guidelines set up by COMNAP, standard measurements will be carried out to record possible impact of human activities on the pristine Antarctic environment. This will be done not only by samples of air, water, soil, snow and ice in the immediate vicinity of the station but a more ambitious plan will be set up for eco-toxicologic research of lichens and birds in a broader environment to monitor the introduction of non-native biota, diseases or toxic substances caused by increased human activities elsewhere and/or global warming.

(iv) Education and outreach: Belgium's decision to take up its share of responsibilities with respect to Antarctica will go hand in hand with a publicity campaign and an educational programme – set-up in collaboration with the IPF, in order to inform the general public, students and schools about the importance and challenges of research in the polar regions, climate change and sustainable development.

Scientific projects at the new station will be financed separately from the scientific projects funded within the Belgian multi-annual research programme and thus will not necessarily be part of the multi-annual programme. This will allow the continuation of multi-annual research projects such as marine biodiversity, marine biogeochemistry, terrestrial research in other specific regions of Antarctica, independent of the new station's activities.

The first scientific projects at the station will commence at the end of the construction season 2007-2008. The first field campaigns will start in the 2008-2009 season. Apart from the monitoring programmes, requiring continuous measurements, the plan is to start-up with a number of core projects and to expand gradually.

1.4. CEE preparation and submission

The CEE report has been prepared to meet the requirements of Article 8 and Annex I of the Protocol on Environmental Protection to the Antarctic Treaty and the provisions of the Belgian Law in execution of the Protocol on Environmental Protection to the Antarctic Treaty (Official Journal 19 May 2005).

The draft CEE was circulated for comments and approval to the Belgian Federal Ministries of Environment, Foreign Affairs and Science Policy. The draft CEE was circulated by the Belgian Government to the other Antarctic Treaty Consultation Parties not less than 120 days before the XXIX

Antarctic Treaty Consultative Meeting (ATCM) to be held from 12-23 June 2006 in Edinburgh, UK. The draft CEE will be considered by the Committee for Environmental Protection (CEP).

Following the XXIX ATCM, Belspo will prepare the final CEE. After circulation to and approval by the three Belgian Federal Ministries involved, the Belgian Government will submit the final CEE to the XXX ATCM in June 2007.

1.5. Permits, applications etc.

Belgian activities in Antarctica are regulated by Belgian law implementing the Protocol of the Antarctic Treaty on the protection of the environment (Belgian law of 19 May 2005). It contains provisions on permit requests, regulations regarding the protection of indigenous fauna and flora, the elimination and management of waste, Specially Protected Areas and the prevention of marine pollution. It describes general obligations in case of environmental emergency situations.

Belgian law states that no Antarctic activity by Belgian citizens can take place without a written permit, except in the case of scientific activities authorised by another Treaty Party. The permit can only be delivered if the activity conforms to the provisions of the Environmental Protocol.

The Belgian Federal Ministry of Environment oversees the execution and follow up of Belgian law implementing the Protocol. It sets permit conditions, reviews environmental impacts of the authorised activity and may impose additional obligations and conditions.

The Ministry has permitted the two site survey visits "Belare 2004" and "Belare 2005" in the Sør Rondane region in the framework of the preparations for the construction of the Belgian Antarctic research station. End of Mission Reports including the impact on the environment of the visits were transmitted to the Federal Ministry of Environment 6 weeks after the expedition.

The draft CEE report was approved in January 2006 by the Belgian Federal Ministry of Environment.

1.6. Legislation, standards and guidelines

The Antarctic Treaty (1959), which came into force in 1961, has been developed by the adoption of measures, resolutions, decisions and the negotiation of further international agreements. It is known collectively as the Antarctic Treaty System and includes the Convention for the Conservation of Antarctic Seals (CCAS 1972), the Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR 1980) and the Protocol on Environmental Protection to the Antarctic Treaty (Environmental Protocol, 1991).

The Environmental Protocol sets out environmental principles, procedures and obligations for the comprehensive protection of the Antarctic environment and its dependent and associated ecosystems. Belgium ratified the Environmental Protocol in May 1995 and the law implementing the Protocol of the Antarctic Treaty on the protection of the environment was published in the Belgian Official Journal on 19 May 2005.

Additional relevant laws, in line with the sustainability philosophy of the project, include international environmental agreements such as the Convention on Biological Diversity (1993) and the Kyoto Protocol on Climate Change (2005). Ship and aircraft operations fall under a number of international and national regulations including the Convention on International Civil Aviation (Chicago Convention) and the International Convention for the Prevention of Marine Pollution from Ships (MARPOL 73/78). Ships and aircraft will be fully certified in their country of registration.

Relevant resolutions will be followed including Resolution 2 (2004) on Guidelines for the Operation of Aircraft near Concentrations of Birds in Antarctica. Documents and guidelines produced within the Antarctic Treaty System by COMNAP have been used in the preparation of this document. These include guidelines on monitoring and on the preparation of environmental impact assessments (COMNAP, 2005a and b).

1.7. Project management structure

The Belgian government commissioned the International Polar Foundation (IPF-www.polarfoundation.org) to coordinate the design and construction phases of the new Belgian research station between 2005 and 2007, under the supervision of the Federal Ministry of Foreign Affairs and Science Policy. The IPF was also commissioned to find the necessary private funding for the concept and building phase.

The use of sustainable technology as the primary energy source, without compromising functionality, comfort or safety demands, implies an integrated design methodology similar to the one used in applied technology projects (cfr. industry & space). The project management has been structured according to this method.

In the first phase of the project an extensive analysis of Antarctic construction history, including the latest projects that will emerge during the IPY, was conducted. A technology survey identified new and proven technologies appropriate for the project. The outcome of these studies, lessons learned and proven solutions were integrated in the requirements and specifications of the new station.

On the conceptual design level a verification method with four major lines of approach (environment, human factors including safety, technology and cost) is used to evaluate and steer all conceptual decision making. All prime project partners work together from the start of the iterative design process thereby guaranteeing that the different fields of interest are taken care of in a homogeneous way.

The construction and inauguration of the station is foreseen in 2007-2008, on the occasion of the fourth "International Polar Year" (IPY), at the same time being the 50^{th} anniversary of the construction of the former Roi Baudouin base (1957-1959).

Once the station is in place, Belspo will be in charge of management and maintenance of the station and the follow-up of station activities.

2. DESCRIPTION OF THE PROPOSED ACTIVITY

2.1. Location

The new station will be built in Dronning Maud Land, at the foot of the Sør Rondane Mountains. It will be situated 173 km inland from the former Roi Baudouin base, Breid Bay (1958-1967) and 55 km from the former (1986-1992) Japanese Asuka station (**Fig. 1.1 and 1.2**). The nearest stations will be the Japanese Syowa station (684 km) and the Russian Novolazarevskaya station (431 km).

The proposed construction site is situated approximately 1 km north of Utsteinen Nunatak, on a small relatively flat exposed granite ridge (71°57'S 023°20'E). The Ridge - oriented in a north-south direction - is 700 m long, approximately 16 m wide and protrudes 20 m above the surrounding snow surface.

Utsteinen Nunatak is a few kilometres north of the Sør Rondane Mountains. This granite rock consists of two peaks with maximum elevation of 1564 m a.s.l. Around the Nunatak there are some blue ice fields and some surface lakes, which are frozen at the beginning of summer. The SE side of Utsteinen has a large wind scoop.

The construction site is also situated in the exit area of the Gunnestadbreen, one of the major outlet glaciers of the Sør Rondane, giving access to the inland Plateau (Japanese Dome Fuji Station: 765 km; German Heinz Kohnen Station: 807 km).

Once the station is operational, station personnel and scientists will use the DROMLAN air link to access the station and the Sør Rondane region and to bring in small items of equipment. The annual re-provisioning of the station will take place via ship unloading at Breid Bay and overland tractor transport via Romnaesfjellet.

Monitoring research will take place in the vicinity of the station and field research will be carried out at a maximum distance of 200 km from the station, the limit for logistic support. Within this radius one can visit the whole mountain range, up to the polar plateau (Nansenisen) and down the inland slope to Breid Bay (the grounding line and the ice shelf of the continental margin).

2.2. Site selection

2.2.1 Utsteinen selection

Belgian research activities in Antarctica started with the installation of a research station during the IGY in 1957. At that time, the Roi Baudouin base (1958-1967) was situated at the coast in Breid Bay (Eastern Dronning Maud Land) on the ice shelf. Large accumulation rates and ice shelf motion made the construction of a new base necessary in 1964. This second station was eventually closed in 1967. Research activities were concentrated on the coastal zone, but also on the Sør Rondane Mountains, that were extensively studied during that period.

The interest in the area was revived two decades later by the Japanese who, in 1986, installed Asuka Station at the foot of the Sør Rondane Mountains, 173 km inland from the Roi Baudouin base. This station was also built on the snow surface and due to high accumulation rates and strong katabatic winds the base was only active for a period of 6 years before it had to be closed. The strong katabatic winds were coming from major outlet glaciers in the eastern part of the Sør Rondane Mountains. Mean wind speed at Asuka was 12 m/s, creating a constant snow drift, even in summer. At that time, research was primarily focussed on the area near the station and the nearby Sør Rondane Mountains.

Renewed interest in the area, relatively far away from any other research station in Antarctica, revived the idea of a new research station within proximity of the Sør Rondane Mountains. However, in view of the short operational period associated with the Roi Baudouin base and Asuka station, a sustainable solution was sought, i.e. to have a construction on bedrock and not on a snow surface so that it would last longer. Furthermore, the area should be protected from strong katabatic winds. However, from a sustainability point of view, the use of alternative energy as a major power source was preferred. Therefore, the site should have relatively low wind speeds (at least lower than Asuka), but preferably constant and from a more or less constant direction.

It was clear from the beginning that the western part of the Sør Rondane mountain range would be the most suitable area as it is more protected from the fierce katabatic winds and offers an easy and safe access to the polar plateau via Gunnestadbreen, one of the many outlet glaciers through the mountain range.

Prior to the Belare 2004 site survey a number of potential sites were selected within the western sector of the Sør Rondane mountains on the basis of terrain knowledge, satellite imagery, topographic maps and aerial photographs collected by the Japanese Antarctic Research Expedition and on the basis of a number of characteristics, such as accessibility (both by small aircraft and overland traverse), presence of water (either abundance of snow or the presence of supra-glacial lakes), exposed and flat bedrock to enable a stable construction (and not on frozen regolith), protection from katabatic winds.

Utsteinen was found to be a likely candidate. The immediate surroundings of the Nunatak itself are not suited to build a station due to difficult accessibility and a large wind scoop. However geologic field work demonstrated the existence of a small ridge north of this Nunatak that was relatively flat and consisted of exposed granitic bedrock.

Fig. 2.1: View of Utsteinen ridge from Utsteinen Nunatak. Picture looking to the North. The small dots to the left of the ridge are the Belare 2004 expedition camp.

Fig. 2.2: Close-up view of the Utsteinen Ridge and Utsteinen Nunatak in the back. Picture is looking to the South.

During the site survey the Utsteinen site was found to be particularly favourable because of the following features:

- **Site stability**: the site itself is relatively flat, consisting of weathered granite (no moraine deposits). There is no wind scoop;

- **Local accessibility**: the rock itself protrudes only a few meters above the snow surface and is therefore easily accessible by vehicles. The surrounding area is relatively flat and consists of soft snow; good conditions for small aircraft operations.

- **Global access**: because of its northern position compared to the mountain range, its is closer to any other access route from the coast and Asuka Station, and in the proximity of potential landing sites for bigger aircraft (blue ice fields);

- **Water**: the presence of soft snow guarantees a large supply of water;

- **Wind**: the site receives significantly less wind than the central or eastern part of the Sør Rondane or Asuka Station. The wind direction is constant, although more wind variability might have been expected in such a protected area; the constant direction is an important factor with respect to the use of wind energy as a power source.

- **Access to the Sør Rondane region**: the site lies within the Sør Rondane Mountains and only 5 km from Gunnestadbreen, a major outlet glacier of the Sør Rondane that offers easy and safe access to the polar plateau.

The Utsteinen Ridge has been chosen as the site for the new station because it meets the requirements of the proposed research activities, site conditions and environmental and safety considerations.

An overview of the other potential sites surveyed during the Belare 2004 expedition is given in **Section 3.2.**

2.2.2 <u>Construction site selection</u>

Consistent with the philosophy of the project, solutions are preferred that make best use of the available terrain conditions therefore minimizing impact on the environment during construction (and removal) of the station. The ridge was subdivided in 3 sections: Northern, Middle and Southern:

- **The Northern section** (furthest away from the Nunatak) is more exposed to the wind and has a less favourable orientation versus the prevailing wind. For anchoring, the terrain conditions are similar to the Southern section.

- **The middle section** is the lowest part of the ridge. Only few rock outcrops rise above the surrounding snow. Due to its low position the wind speed in this area is lower compared with the other sections, but the area accumulates more snow. Anchoring conditions are uncertain and the geological characteristics of the ridge are less favourable (highly eroded area). The ridge geometry at the east side (steep slope) would result in very deep sub-surface anchoring points.

- **The Southern section** of the ridge has similar terrain conditions as the Northern section but it has a better alignment versus the prevailing wind (approximately 90°) and is in general more protected against the wind.

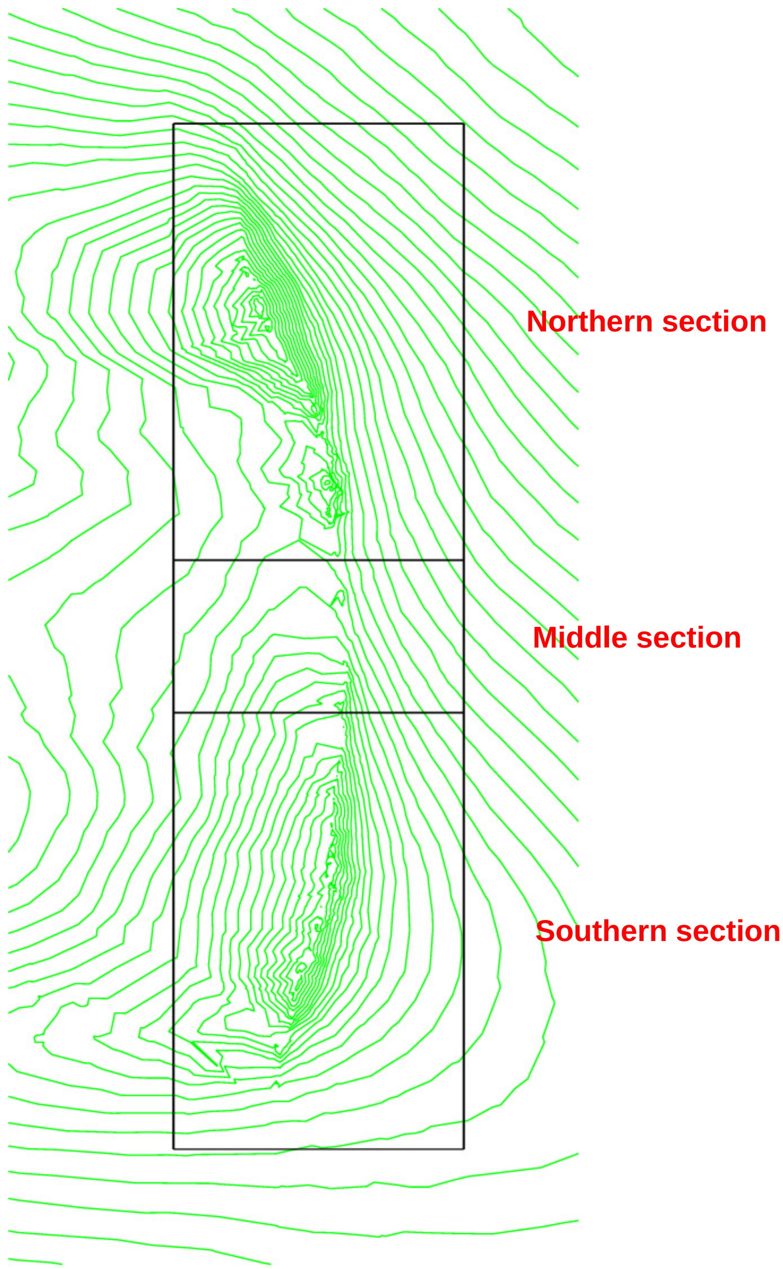


Fig. 2.3: Overview of the different ridge sections (Northern, Middle and Southern section)
(contour interval of 1 m)

Taking into account the parameters mentioned above the decision was taken to focus the survey on the Southern section of the ridge.

A number of possible station areas were identified in the Southern section, which was therefore divided from North to South into 3 sectors (01-03) of 100 m each. All sectors have good anchoring conditions, with sector 03 being slightly less favourable due to its "mixed character": while sectors 01 and 02 consist mainly of big bedrock granite slabs, sector 03 has more permafrost patches and loose material. Sector 02 is best aligned to the prevailing wind direction, has the lowest wind speed and best accessibility due to the regular shaped lee-side and less steep snow surface.

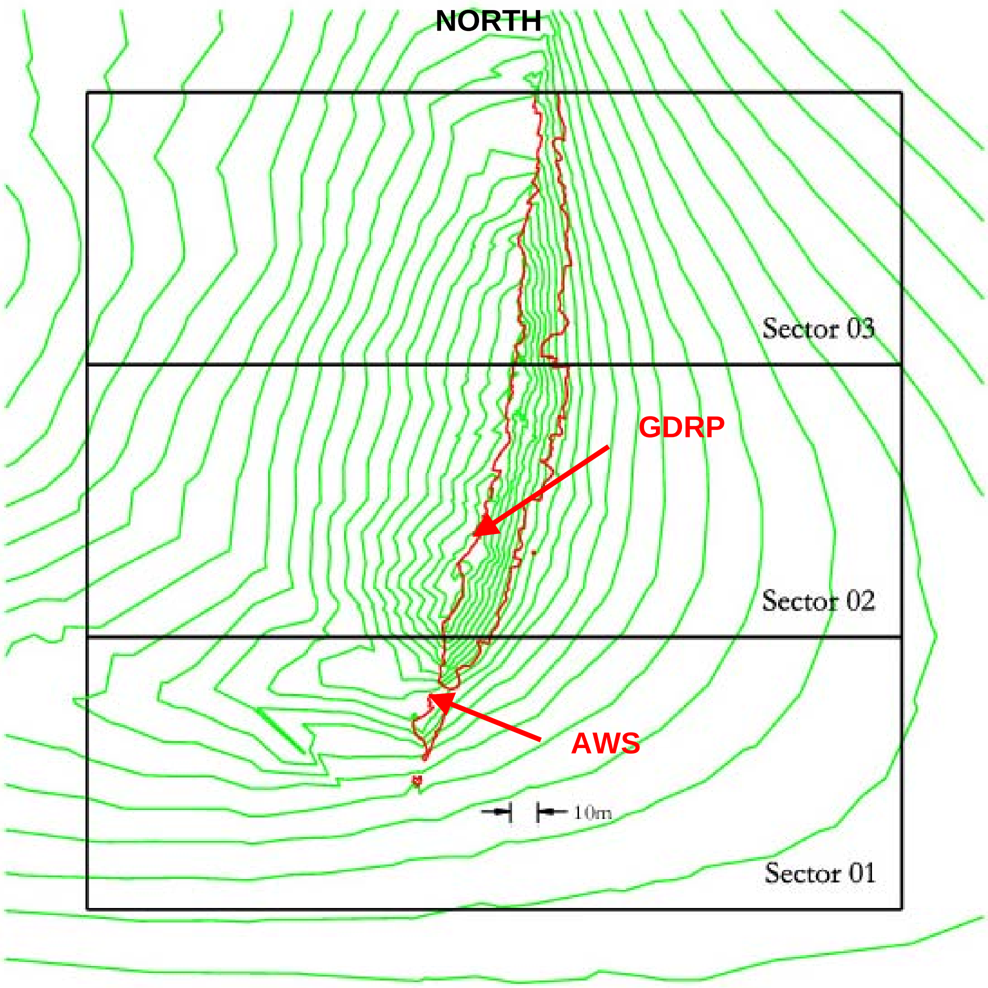


Fig. 2.4: Overview of different ridge sectors in the Southern section.
Ridge building integration study area: sectors 01 to 03 (contour interval of 1 m).
(GDRP = Geodetic Reference Point); (AWS = Automatic Weather Station)

The Northern half of Sector 02 was selected as the preferred station area; it is the best compromise between the major influential parameters:

- Good alignment versus the prevailing wind direction (best available incoming airflow characteristics)
- Wind speedup is less extreme than alternative positions.
- Excellent snow-clearing characteristics will prevent snow accumulation on the building
- Good anchoring conditions with a majority of anchoring points directly on the granite bedrock
- Anchoring points are easily accessible and in the snow-free area (sufficiently big)
- Installing (and removal) of the anchoring points will have minimum impact on the terrain.

2.3. Principal characteristics of the proposed activity

The activities covered by the draft CEE are:

- construction, operation and maintenance of the new Belgian research station,
- building and operation of the temporary camp required during the construction phase,

- transport and movement of cargo and personnel to the station site south of 60°S.

Note that the DROMLAN air-link has not been included in the evaluation and that regarding scientific activities, each scientific project will be subjected to EIA before being allowed to progress.

2.3.1. General specifications of the station

The project consists of the construction, operation and maintenance of the new Belgian station at the Utsteinen Ridge as a station for scientific research and monitoring.

The construction of the station is planned in the austral summer of 2007-2008. In this period the station will be built, system acceptance test will be performed and finally it will be handed over to the Belgian Science Office at the end of the season.

Characteristics of the station:

- Austral summer station: open from November to February.
- Full-year monitoring and remote sensing capability.
- The station is designed for optimal use by 12 people accommodated in the main building.
- The use of a station "extension" will make it possible to accommodate another 8 to 18 people. This extension consists of heated shelters used for sleeping only.
- The station's facilities (kitchen, the sanitary installations, offices ...) are designed to cope with the larger occupation as mentioned above.
- Expected design life: 25 years minimum.
- Accommodation (living, technical, research, storage): 800 m².
- There will be laboratory facilities as well as mobile units to be used for field work
- The station has a hybrid design: the main building is above the ground-level and anchored into snow-free rock area. The adjacent garage/storage building is mainly constructed under the surrounding snow surface. Both buildings are inter-connected by a weather protected corridor.
- The activities (construction, operation and decommissioning) will comply with the requirements of the Environmental Protocol. The environmental impact will be minimal.
- The system design of the station is developed based on sustainable technology and high energy efficiency. Nevertheless safety, health, comfort, functionality and cost are equally important design drivers.
- The facilities will use renewable energy as the primary energy source thereby minimising the use of fossil fuels.
- The station will have a comprehensive energy management regime.
- The amount of fuel to be transported to the station will be mainly for vehicles only having a positive effect on logistic operations.
- To assure a constant energy supply 2 back-up generators will be installed.
- The station will have a comprehensive waste management regime.
- The waste treatment will include the treatment of grey and black water and recycling capability for non-potable water applications.
- By design the station has extended upgrade capability. It will be easy to integrate new state of the art technologies. The station will be upgradeable to a full year station with minimal effort.
- The station has been designed for low maintenance.
- Recycling and lifetime maintenance strategies will reduce the running costs.
- The design and layout of the facilities will minimise snow management.
- The building will be designed for easy repair and damage control; a risk contingency plan will be developed.
- 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.

Four staff personnel will be present during the whole summer season. Some scientists will occupy the station for some weeks every summer for servicing and maintaining the monitoring equipment and for environmental sampling; others will use the station as a hub for scientific expeditions in the field.

Logistic functions and tasks of the station will grow depending on the needs of the research work.

2.3.2. Shipping and logistics

Once the station is operational, station personnel and scientists will use the DROMLAN link for access to the station and the Sør Rondane region in general. The yearly station provisioning by ship (Ice class) - via unloading at Breid Bay - will be as much as possible co-organized and shared with the other nations active in Dronning Maud Land.

An air and oversnow reconnaissance survey of Breid Bay and ice shelf area during Belare 2005 was carried out to assess the local situation. Breid Bay was used as a ship loading/unloading area during the Belgian (1958-1960) and Belgian-Dutch (1964-1966) expeditions to Base Roi Baudouin and during the Japanese Antarctic Research (JARE) expeditions to the now abandoned Asuka station (1986-1991).

Fig 2.5 : Fast ice in Leopold III Bay (Breid Bay) with ice cliff and ramp to ice shelf in the back. (Picture taken in 1966)

The reconnaissance team mapped the approximately 200 km access route and identified a preferred and a back-up unloading site (see **Fig. 2.6**). The east route (1) is the preferred route and consists in an almost straight line from BEL-L0 (see **Table 2.1** for coordinates) to the station site. BEL-L0 was the preferred unloading site for helicopters, used by the Japanese expeditions. Although there are no crevasses or other obstacles in the last 80km of the route, due to the occurrence of large sastrugi some surface preparation will be required prior to the actual transports. For the east route a new (BEL-L0 NEW) reference point was established closer to the preferred unloading site. At point BEL-RAMP access to the fast ice is possible by means of a local recess in the terrain which forms a stable and gentle slope.

Alternative unloading sites and access routes were also identified. For the east route this is the Polarhav Bay (point BEL-LD) where unloading can be done directly on the ice shelf (the ice cliff being less than15m high). Satellite images show that typically the fast ice completely disappears in this area. Another unloading area can be found to the west (point BEL-LC) where a few ramps were detected. In this case, a more western route using the former Japanese L0 point (indicated as BEL L0) will be used. The west route (2) would provide the shortest way to the construction site. The terrain conditions are similar to the ones that can be found on the east route. Between both east and west options a large crevasse area was found near the edge of the ice shelf. This area was also surveyed. The closest point the routes come to the crevasses is at point BEL-CREV E, which is still at a distance of more than 2km.

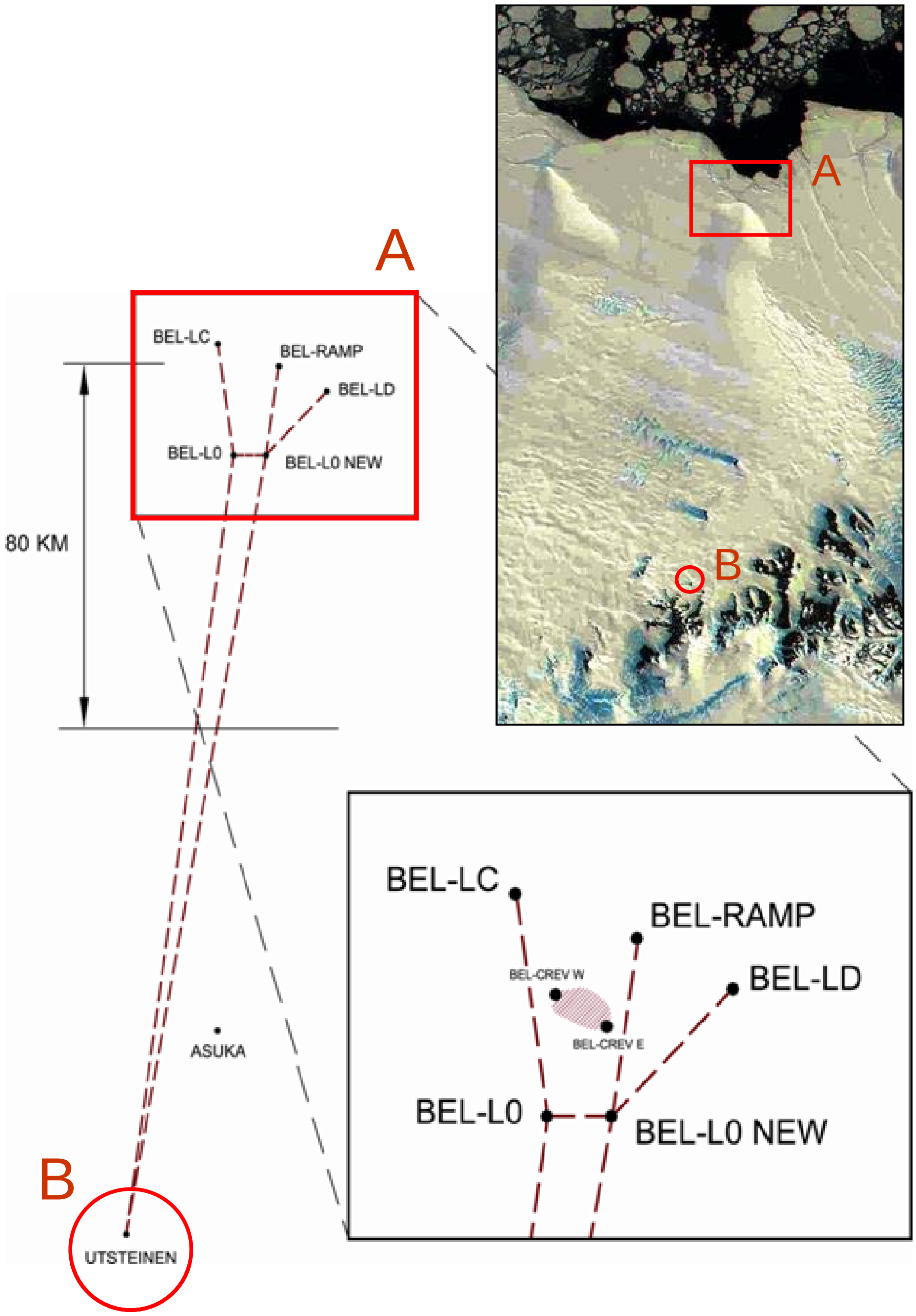


Fig 2.6: Overview of access routes (eastern and western) from Utsteinen to Breid bay and unloading site.

BEL-L0	S 70°29′50″	E 24°00′37″
BEL-L0 NEW	S 70°30′00″	E 24°12′00″
BEL-RAMP	S 70°20′26″	E 24°14′18″
BEL-LC	S 70°18′25″	E 23°52′32″
BEL-LD	S 70°23′06″	E 24°31′47″
BEL-CREV E	S 70°25′04″	E 24°10′43″
BEL-CREV W	S 70°23′08″	E 24°01′08″

Table 2.1 : Coordinates of major survey points

To limit the number of lay-days of the ship for unloading (for budget and safety reasons) an inland depot area has been located at a safe distance from the edge of the ice shelf. Transport containers will weigh maximum 8 ton for safe movement across the sea ice and easy handling. Fuel in bulk will be transferred in tank sledge-based containers.

After collecting the full cargo load on the inland depot site (which will have a base camp facility) the transport to the actual site will start. The estimated unloading time to the inland depot area is 5 days while the first load arriving at the construction site will be approximately 7 days after ship arrival (weather conditions permitting).

1	Logistics Support Equipment (LSE)	Large vehicles, sledges, snowmobiles … to be used for the building and operational phases. Some of this equipment will become redundant when the building is finished and will be removed from Antarctica.
2	Construction Support Equipment (CSE)	Equipment specifically for the building process (shelters, tools, generators, lifting equipment…) except for vehicles (see 1). Some of this equipment will become redundant when the building is finished and will be removed from Antarctica.
3	Construction Support Supplies (CSS)	Spare parts, food … Except for fuel (see 5) specifically foreseen for the building process itself.
4	Operational Support Equipment (OSE)	Work shop tools, spare parts, appliances … required to run the station.
5	Operational Support Supplies (OSS)	Spare parts, food … except for fuel (see 5) needed to support the first period of the operational phase of the station.
6	Fuel (FL)	Different kind of fuels (octane 95, JET A1 …) needed for the vehicles, emergency generator, powered tools and snowmobiles.
7	Building Construction Materials (BCM)	All construction materials that are part of the buildings and its auxiliaries.
8	Waste (W)	All kinds of waste resulting from the activities (human waste, food waste, packaging materials …).
9	Scientific Equipment (SE)	Instruments and other equipment for initial science projects
10	Excess Material (EM)	Equipment and material redundant when the building is finished. Will be removed from Antarctica.

Table 2.2: Categories of transport needs

Category		Transport Volume (m^3)	Net weight (kg)	N° ISO containers (20′)	Weight containers (2300kg)	Total Weight (kg)
CSE	Used for all constructions	76	10000	2	4600	14600
CSS	Belare 2006-2007 period	115.5	20000	3	6900	26900
OSE	Garage building	154	21000	4	9200	30200
	Main building	383	60000	10	23000	83000
	Stand-alone facility 1/2	38.5	2000	1	2300	4300
	Emergency shelter	38.5	1500	1	2300	3800
	Wind turbines	115.5	20000	3	6900	26900
OSS	Minimum 2 years period	152	15000	4	9200	24900
FUEL	JETA1/gazoline oct. 95	76	20000	3 units (tank version)	15000	35000
	Gasoline oct. 95	38,5	4400	1 (drums inside)	2300	6700
BCM	Garage	270	42200	7	16100	58300
	Main building	536	96200	14	32200	128400
	Stand-alone facility 1/2	38.5	5000	1	2300	7300
	Emergency shelter	38.5	5000	1	2300	7300
TOTALS		**2070.5**	**322300**	**55**	**134600**	**457600**

Category		N°
LSE	Heavy snow Tractors	3
	20′ Sledge 01	12
	Lifting crane	2
	Bulldozer/tractor	1
	Snowmobiles	2

Table 2.3: Ship cargo transport needs for construction (incoming goods 2006/2007/2008)

Belare 2006 Expedition
Objective: Preparation of building site camp

- Ship => January 2007: in: 5 ISO-norm containers 20″ + 2 Vehicles (2 tractors) + 4 big sledges (250m^3) + 2 people
- Air => January: Team of 8 people + 2 extra snowmobiles (already at Novo) flies in from Novo
- Air => February: Team of 8 people flies out via Novo

Belare 2007 Expedition
Objective: Building the station

- Air => November: A team of 12 people flies in
- Ship => December/January: in: 45 ISO-norm containers 20″ + 4 Vehicles (1 tractor, 1 bulldozer and 2 cranes)+ 8 big sledges (2000 m^3) + 2 people
- Air => January : A team of 20 people flies in+ 8 people out
- Air => February: 26 people out

Belare 2008 Expedition
Objective: Remove redundant equipment, waste and containers + first scientific activities

- Air => November: a team of 8 staff people + scientists (number unknown) flies in
- Ship => December/January: 2 people + 5 ISO containers 20″ => 200m³ IN + containers + 3 vehicles (1 tractor and 2 cranes) OUT (1600m³)
- Air => January: 6 staff people out
- Air => February: 4 staff people out
- Air => period unknown: scientists out

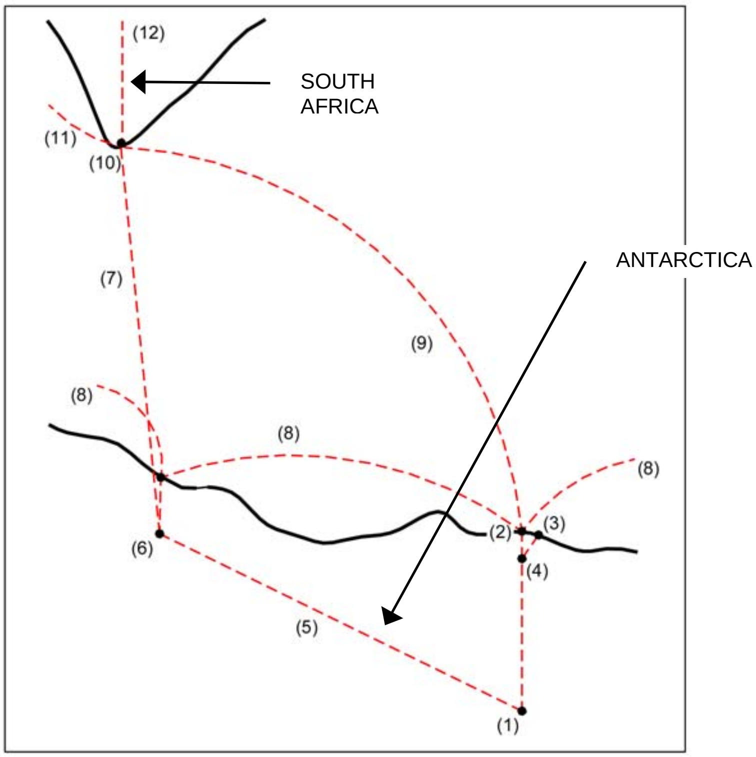


Fig 2.7: Scheme of different transport routes for the proposed activity (cargo discharge at coast, construction, operation and science): (1) Utsteinen construction site; (2) Preferred unloading site (Breid Bay); (3) Alternative unloading site in Breid Bay (Polarhav Bay); (4) L0 point (Ice rise); (5) Flight-route from Novolazarevskaya station; (6) Novolazarevskaya; (7) Flight-route from Cape Town; (8) Supply shipping combined with other stations; (9) Direct sea route from Cape Town; (10) Cape Town; (11) Cape Town sea route to Europe; (12) Cape Town air route to Europe.

2.4. Station description

The station concept presented in this section is the baseline design selected for further development. This will be carried out during the last part of the concept validation phase of the project (due end of February 2006). This means that some modification will be possible depending on the final outcome of tests and calculations.

As already said the new Belgian station is a compact and efficient facility to support the scientific field work. Key features are its low-emission character and the low demand on resources to operate it. The station has been designed to anticipate the evolution towards automated scientific experiments and logistic support to field work in the wide area.

2.4.1. Station programme

User scenarios

Prior to the actual design process of the station a comprehensive study covering the wide spectrum of characteristics typical to the Antarctic building tradition was done. This study, with the valuable support and feedback of different polar institutes and individuals experienced in the field, led to an exhaustive specification and requirement list including guidelines and lessons learned. The approach, as for the whole of this project, was fourfold: environment, human factors, technology and cost. A key-element to define the programme (and energy needs) were the user scenarios. These gave a detailed insight on how people will live and work in and out of the station.

Building surface and basic layout

The extensive study of the user scenario's resulted in a building programme that foresees in a total building surface of ± 800 m². Taking into account the requirements of the building programme and the terrain conditions it was decided to construct two major building units separate from stand-alone facilities for specific scientific activities.

The air-conditioned main building is the living area of the station and has a usable floor space of approximately 300 m². The "garage/storage" building accommodates secondary functions such as work shops and storage of supplies and spare parts. The station will provide an efficient and pleasant living/working environment for the crew but the programme is also developed according to energy efficiency needs and the specific technical demands imposed by the winter close-down of the station.

Main building

The main building has a concentric architecture laid out around a "technical core" (see **Fig. 2.8**). All temperature-sensitive installations and equipment, such as the waste water treatment system, are concentrated in this area of the building. A second concentric layer around the technical core consists of space for active systems such as the kitchen, sanitary, laundry and the station's energy management system. It also has storage for fragile office equipment during winter. A third concentric layer consists of "passive" areas, for example, the living and sleeping rooms. Temperature buffer spaces are included below the floor and above the ceiling. The fourth and last of the containment levels is the outer shell. This structure consists of a number of passive and active elements such as insulation materials, air-gaps for buffering and energy-related systems.

The core-based architecture allows a "feed-through-the-wall" concept for water supply, drainage and other services resulting in compactness and a high level of system integration. This has positive repercussions on key-features such as energy preservation, reliability, maintenance and cost. From an energy point of view all "internal gains" of the building are centralized in the building layout thereby reducing the additional heating load required (note that for most of the summer the building simulations performed so far indicate that no additional heating is required).

The building will be optimised for typical summer season conditions but also for winter close-down. Close-down preparation work will be practical and easy. For example drainage of the water tubes will be very straightforward. For winter each individual layer is "sealed" thereby creating a number of temperature-controlled buffer zones against the cold exterior environment. This makes it possible to maintain all layers at a guaranteed minimum temperature with minimal energy supply, protecting installations and whole year active systems located in the technical core as well as the appliances located in the second layer. The "passive" area (third layer) acts as an additional buffer zone. All building zones will be monitored for temperature routinely.

The building layout will guarantee good acoustic comfort. The distribution of noise sources and the layout of the functionalities and storages (acting as buffer-zones) in the building have been reviewed for compatibility with the user scenarios to assure there is minimal disturbance caused by the activities. Wind-induced noise (turbulence areas on the building) has also been studied and a number of noise limiting measures will be used in the detailed design phase of the project.

The entrance has a lock with self-closing doors that can only be used consecutively. The aim is to reduce heat loss through the entrance. Once through the lock, people enter an area where exterior clothing equipment or supplies can be left. This zone gives access to different parts of the building, including:

- the storage area (after having recovered the equipment left in the transition zone),
- the sanitary facilities,
- the laundry (integrated in the wardrobe area),
- the lab/office area,
- the sick bay and
- the living area.

A demountable wall section and over-head rail system will allow heavy equipment or spare parts to be carried directly from the entrance lock to the technical core.

The sanitary facilities include toilets, bathroom with showers and, eventually, a sauna. The sleeping area has a flexible layout but there are also a number of dedicated rooms for the station crew. Care has been taken to group the communication room, the station control room and the station manager's office. The technical core is a crew-only area and during normal conditions no access is required.

Very important to the building concept is the common living space with annexed kitchen. Here people meet and eat together. This room, as most of the third layer, has a multifunctional and flexible character. It can be used as a "quite corner" for reading but can be transformed into a meeting space. In general flexibility is a key-element in the design. While some areas of the building have dedicated functions there still is a lot of flexibility in sub-dividing the building space for alternative layouts to cope with changing needs.

A dedicated area near the building entrance, with easy access for a stretcher, can rapidly be transformed into a sick bay in case of illness or injury. If required this area can easily be upgraded into a small and well equipped hospital room. The room will be designed following best practice guidelines for sterility and efficiency.

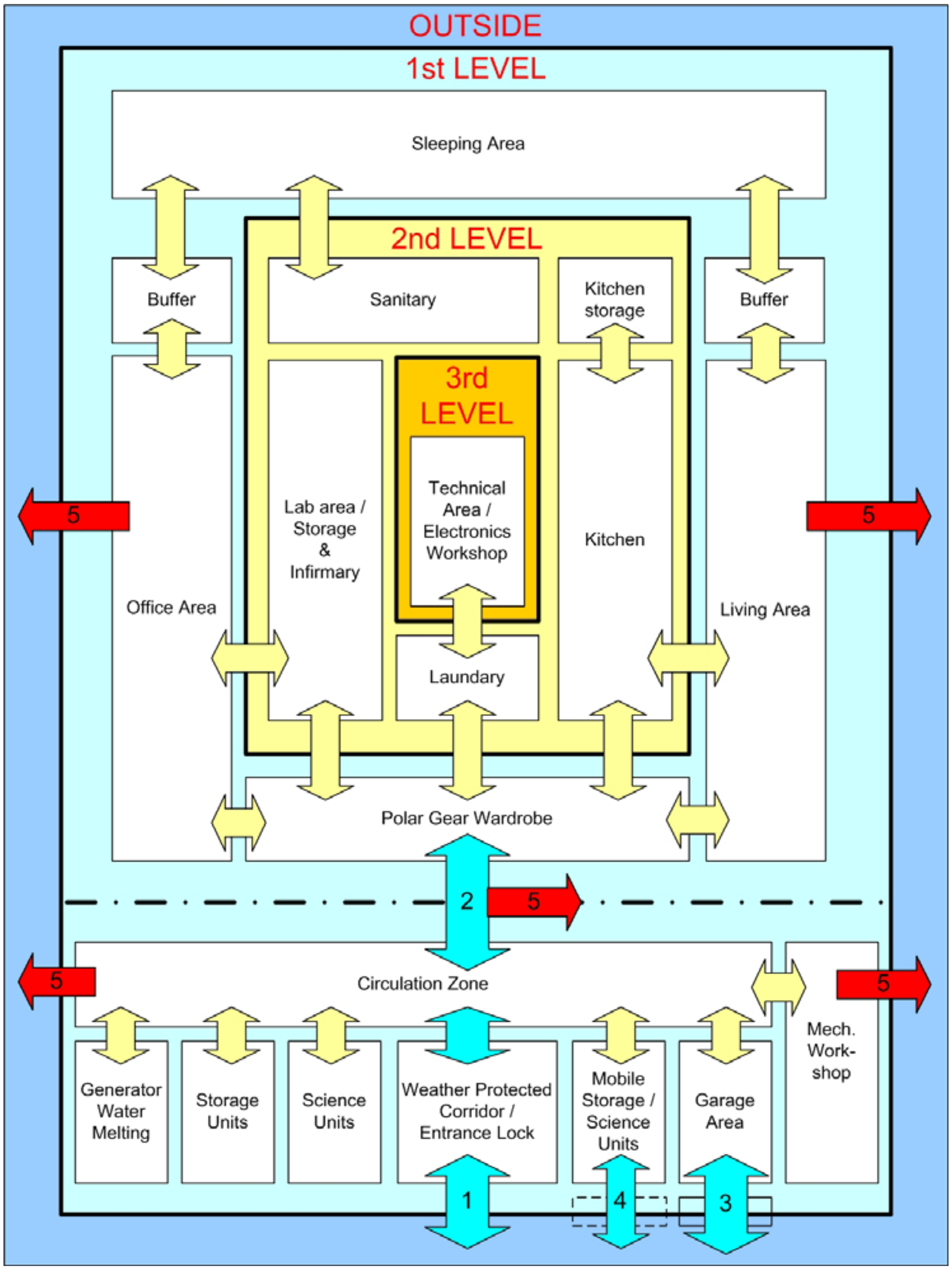


Fig 2.8: Building programme - functional relations and thermal layers (abstract)
(1) Entrance (no vehicles); (2) weather protected connection corridor between building volumes; (3) Entrance vehicles; (4) access removable units; (5) Emergency exits

The garage/storage building

This building is an under-snow surface construction connected by an aerodynamically shaped and weather-protected staircase to the main building, and follows the design philosophies of minimal environmental and visual disturbance, best comfort and energy efficiency. This construction protects the crew against bad weather conditions (note that there is increased wind speed in this part of the site) and minimises walk distances. All tubing and cabling between both building units will be integrated, minimising the heat load required for water tubing and facilitates maintenance. A simple lift system will help to carry heavy loads from garage/storage to the main building.

The garage/storage building has a minimum height of 4 m. Most of the building is below the snow surface and the roof is used as an airflow diffuser (see **Section 2.4.5** Aerodynamics). The garage/storage building will contain stores, workshops and field support facilities. It will house the two emergency back-up generators and the water melting system. The building has a very simple construction. The main open area which is basically only a roof will house a number of 20′ ISO-norm containers on sledges for most of the functions including transportable science lab. Part of this open area will be used to repair vehicles and for vehicle storage during winter. Under the roof construction there are three building units that are supported independently from the roof supports. The middle one interfaces to the staircase and has some sanitary and workshop facilities requiring temperature control. One unit at the north side of the building has the generators and snow melting system. The unit to the south contains the mechanical workshop. These units are well insulated from the environment for energy efficiency but also to deal with potential stability problems that could occur by melting of the ground surface.

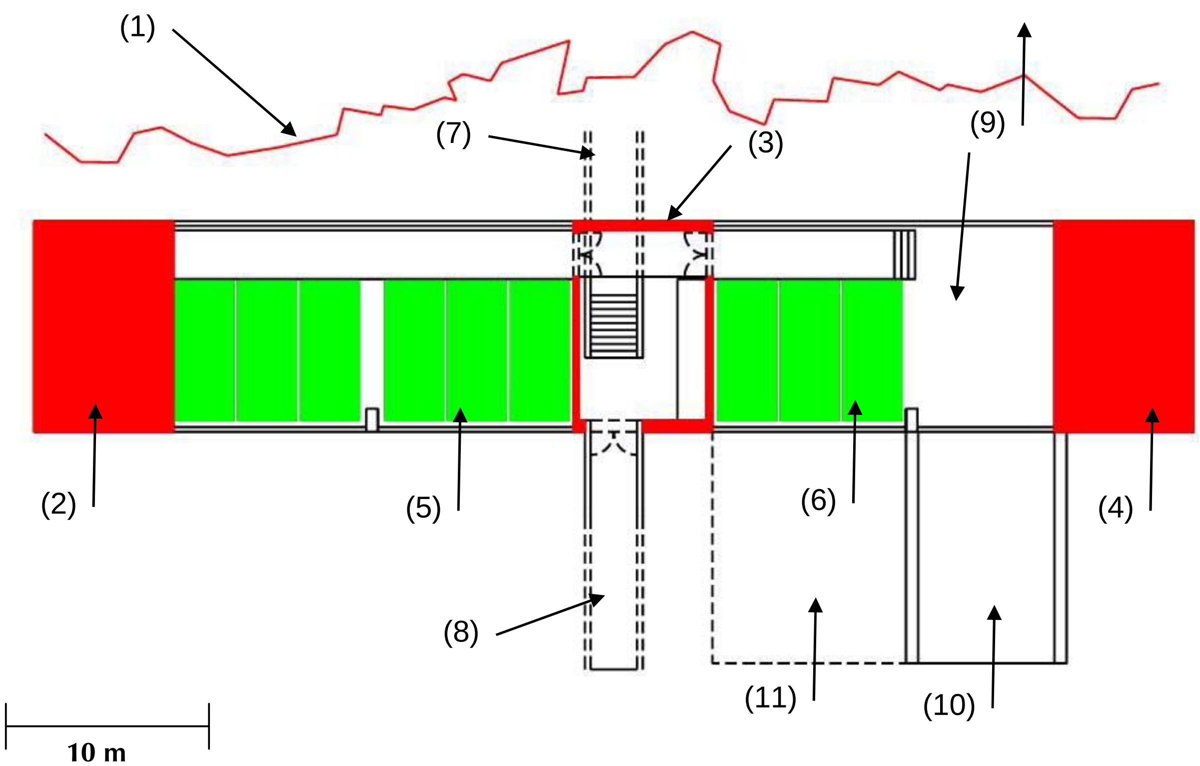


Fig 2.9: Garage/storage building (under-snow)
(1) Utsteinen ridge – granite bedrock; (2) Snow melting/emergency power unit (north-side); (3) Entrance lock unit; (4) Mechanical workshop unit; (5) Storage/lab units (ISO-norm containers); (6) Removable storage units (ISO-norm containers); (7) Staircase to main building; (8) Entrance to west (people only); (9) Garage area (repairs/maintenance); (10) Entrance ramp garage (regular use); (11) Access ramp to removable units (sporadic use)

Accessibility

Emergency exits on the north and south side of the main building assure good evacuation possibilities. The normal entrance of the station is located at the west side of the garage building and consists of a small people entrance (8) used on a daily basis and a large vehicle entrance (10). Removable panels will allow access for sledge units (11) that will be removed every few years, for example full waste containers. During the summer season vehicles will remain outside except for maintenance or other practical reasons. The use of the large entrance therefore is limited. Both entrances are located to make best use of the aerodynamic characteristics of the site in order to keep them snow-free. The garage/storage building also has two emergency exits.

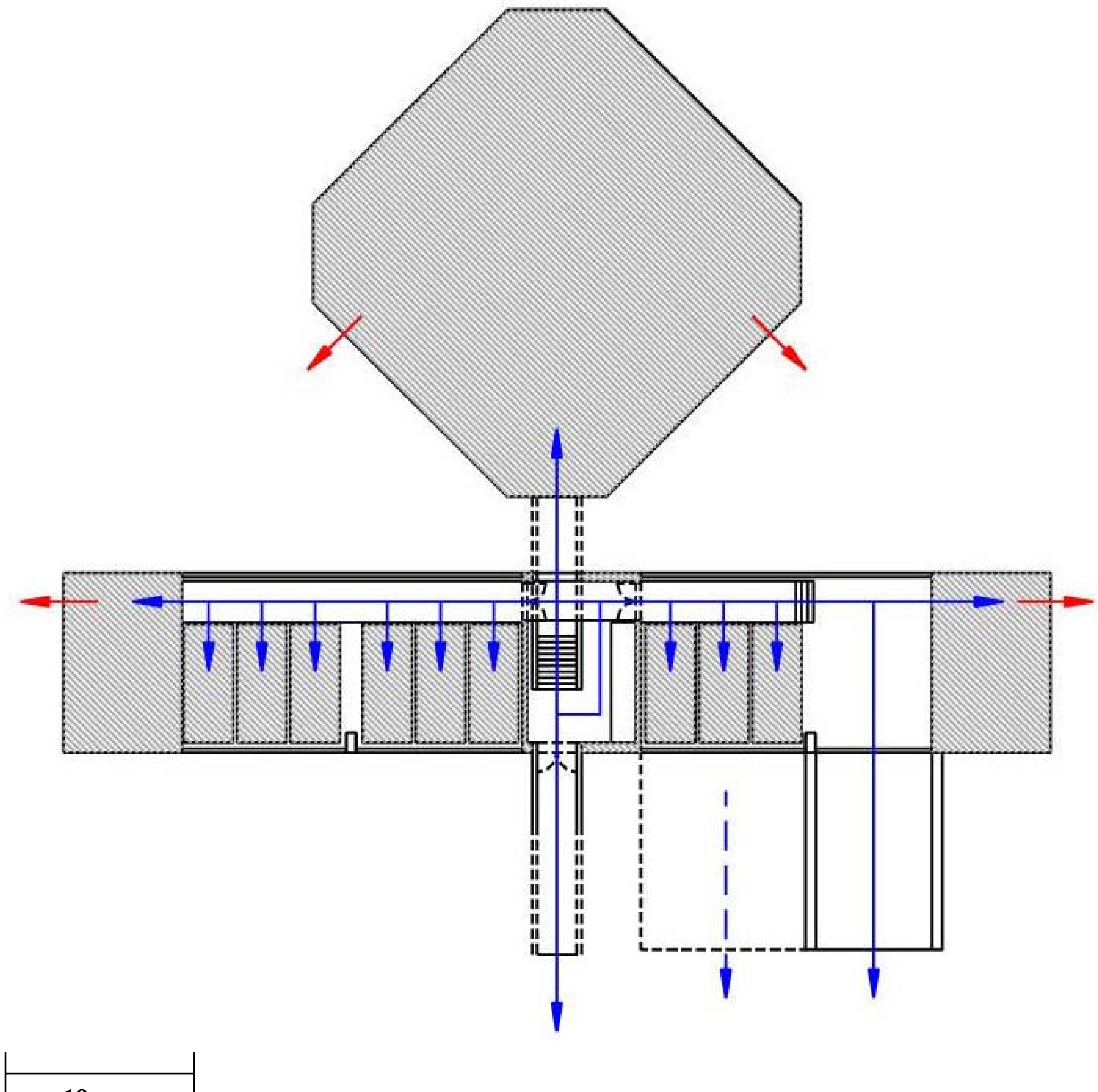


Fig 2.10: Accessibility of garage and main building
(Emergency exits shown in red)

Psychological aspects

The building will have excellent natural light conditions but also the contact with the environment from inside the building is considered very important to create a good living atmosphere. It is no coincidence that the site survey teams (Belare 2004, 2005) were struck by the sheer beauty of the area and recommended good visual contact with the surrounding landscape and, especially, with Utsteinen Nunatak and the Sør Rondane mountains beyond. Preliminary energy calculations predict a maximum of 30% glassed surface on each side of the building, giving passive solar gains. Design of the window layout will take the panoramic view into consideration. A triple glazed window system is under evaluation. In addition to the main glazed surfaces an additional array of small "portholes" located at eye-height for a seated person will allow visual contact with the environment from separate rooms regardless the building's internal organisation. This concept will not compromise the integration of energy related systems in the outer building surface.

Fig 2.11: Contact with the environment
(looking to the South - approximately from station's living room)

Staff

The main station building is designed for use by 12 people. This number optimises the energy efficiency of the building. The use of a station "extension", however, will make it possible to accommodate another 8 to 18 people. The extension consists of stand-alone heated shelters used for sleeping only. The station's main facilities such as kitchen, sanitary installations and offices are designed to cope with the larger numbers. The minimal support team will be 4 people, including:

- Station leader/physician
- Electrical engineer/electrician
- Mechanic/cook
- Field support guide

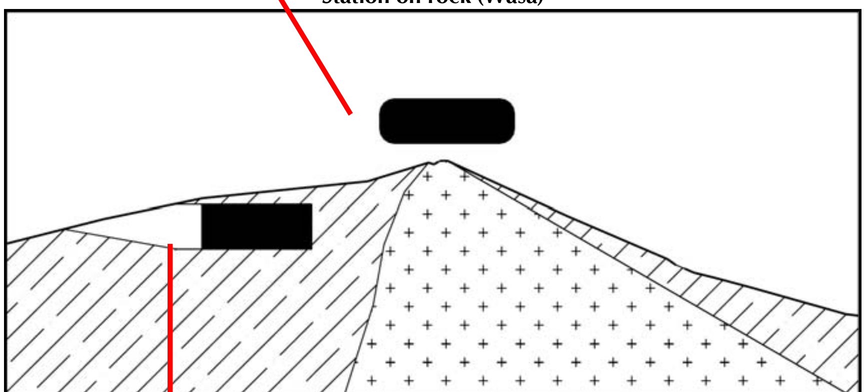
Visitors will receive a briefing on arrival on the guidelines and rules of the station. The typical visitor may stay a week or more. In this period they may leave with a field party or remain at the station.

2.4.2. Station design

Development of building type

The combined characteristics of rock anchoring, natural snow-free conditions and nearby snow-covered surfaces, all present on the Utsteinen North ridge, make it possible to have under-snow surface facilities very close to the station's above-ground main building; the result being a hybrid design maximally exploiting the on-site potential.

Station on rock (Wasa)



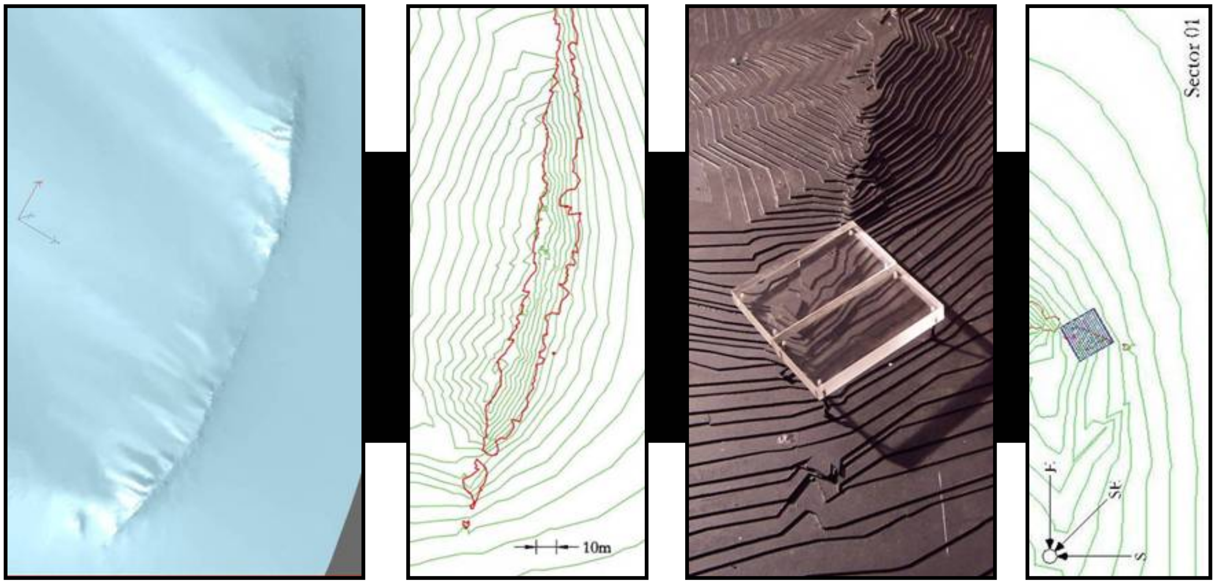
Hybrid design Belgian station

Station on ice/snow (Neumayer II)

__Fig 2.12:__ Hybrid concept of the proposed new Belgian station:
a combined design of a rock anchored station and a station built directly on the snow/ice surface.

In the process of defining possible building designs for the main building 11 alternatives were identified (both integrated on and above the ground). All the designs answered the minimum requirements as defined by the programme. For these proposals a total of 37 options were mapped and evaluated using a trade-off concentrating on accessibility for construction and dismantling, anchoring conditions, orientation versus prevailing wind, orientation versus sun, compactness, energy efficiency (based on preliminary simulations), operational accessibility and expected snow accumulation. From this first study six solutions were selected for further evaluation, mainly focusing on the snow accumulation characteristics of the buildings that were assessed by means of wind tunnel simulations (models at 1/100 scale). The prevailing wind at Utsteinen is from the sector E-SSE (see **Section 4.4.2**). The prevailing direction for wind speeds higher than 15 m/s, lies within the sector E-

ESE. The wind tunnel test showed that symmetrical building designs with above-ground integration gave the best overall performance, and three building designs were selected. Since these designs mainly differed in the use of one or two storeys and were almost symmetrical, further selection concentrated on the orientation of the building versus the prevailing wind and the number of storeys to be used.



3D D-GPS Model   Snow boundary   Position   Orientation

Fig 2.13: Development of building type study.
The step by step approach identified 11 building designs and 37 terrain integration alternatives.

The overall building concept is also defined by the integration of the energy systems. A solution was found in a 1.5 storey type of building with an almost symmetric footprint. This design incorporates the principal characteristics of the remaining proposals. The final alignment of the building (45° orientation) will be the outcome of the final wind tunnel testing. Regardless of these test results the final selection of the building geometry is a design that provides an answer to various often contradictory requirements and is unavoidably a compromise.

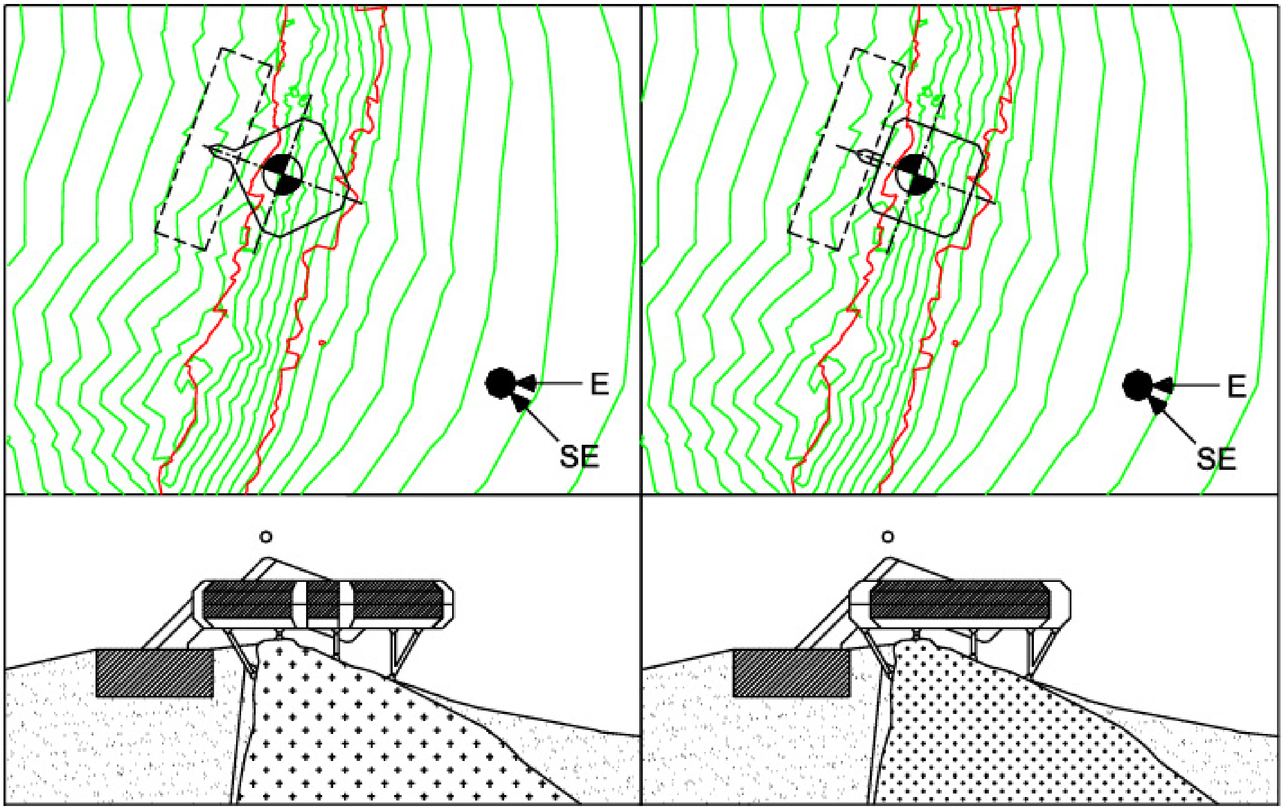
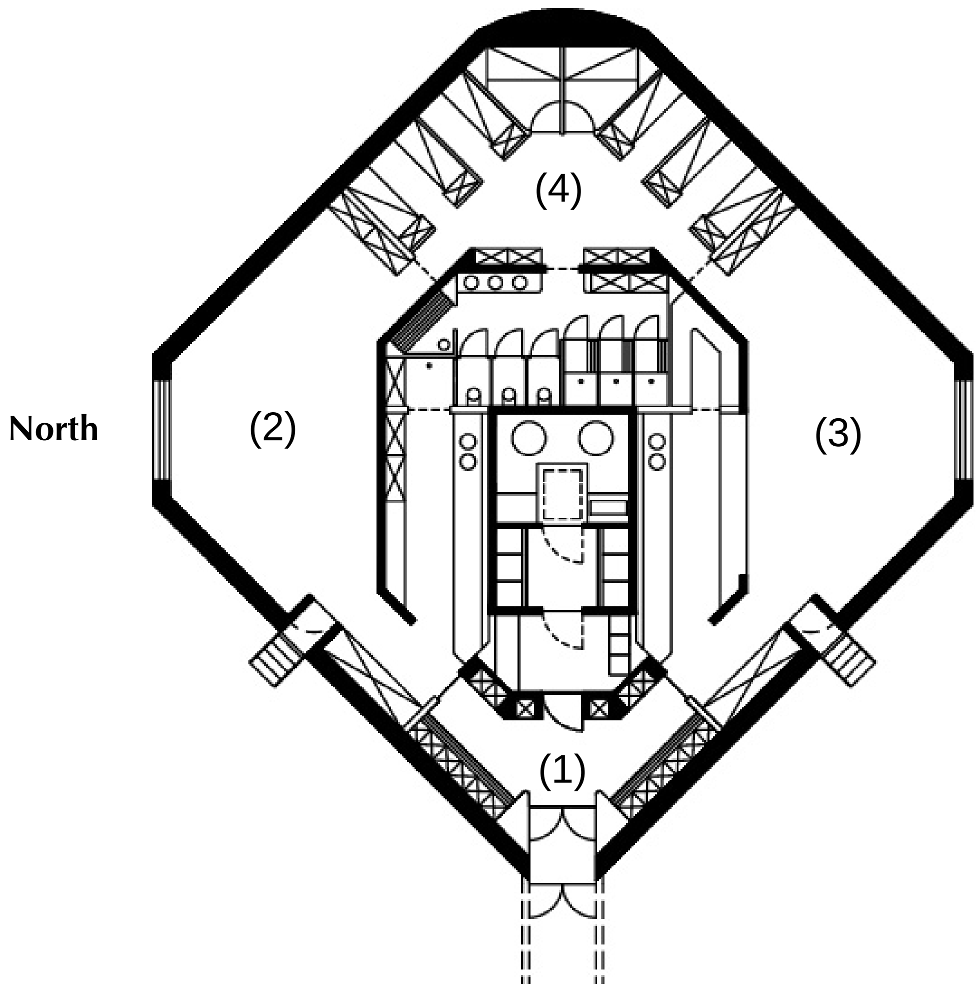
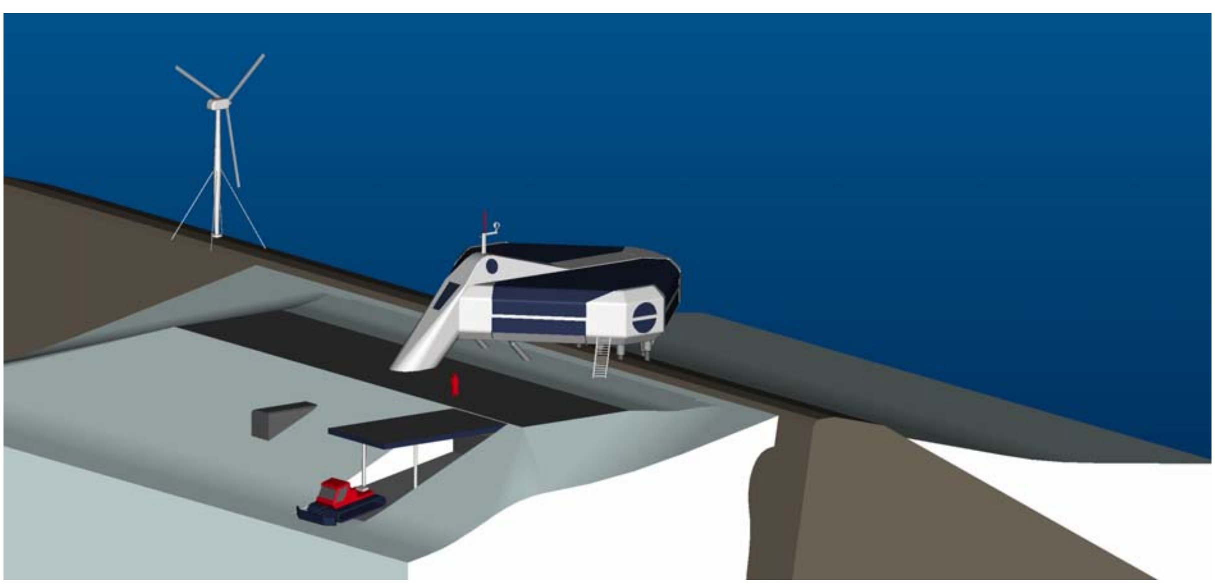


Fig 2.14: Main building integration variants.
The variant with 45° angle versus prevailing wind (left) is the preferred solution.



<u>Fig 2 15</u>: Main building programme – preliminary layout for 45° integration variant garage/storage building (under-snow): (1) Entrance wardrobe and laundry + access to technical area; (2) Office area + lab; (3) Living area with kitchen; (4) Noise-buffered sleeping area + bathroom.



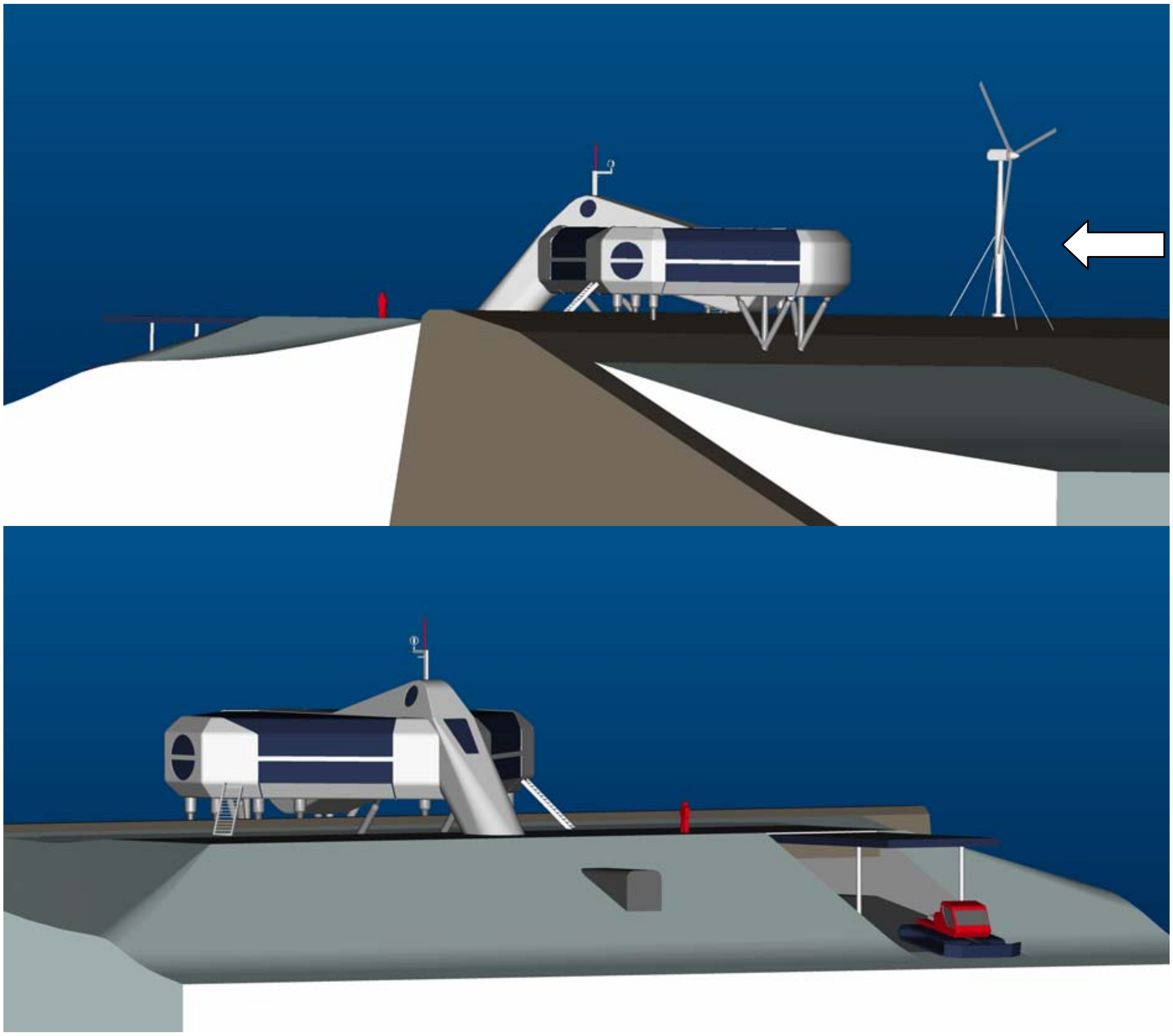


Fig 2.16: Building concept: impression of buildings integrations on-site.
Black areas on the main building are solar collector areas combined with windows
(arrow indicates prevailing wind direction)

2.4.3. Anchoring the building

A detailed survey of the selected construction area was conducted during Belare 2005 (see **Section 2.2.2**) to map the site for anchoring. **Fig. 2.17 and 2.18** show the boundary of the exposed rock surface and a typical cross section through the ridge and adjacent snow/ice area. Consistent with the sustainable character of the project the baseline for selecting anchoring points was to favour direct anchoring in the bedrock making best use of the available exposure. Making use of 3D measuring equipment - with 5 mm precision - the team identified 74 bedrock anchoring surfaces. These articulated surfaces are integrated into a 3D CAD system to define definitive anchoring points and minimising as much as possible the impact on the terrain (**Fig. 2.19**).

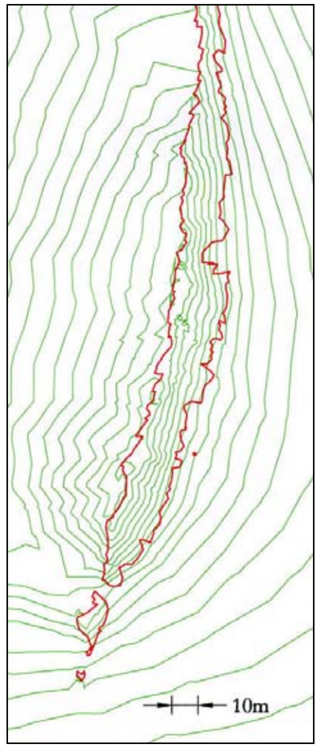


Fig 2.17: Topographic model: snow-free area (Snow boundary = red)
Contour interval of 1 m.

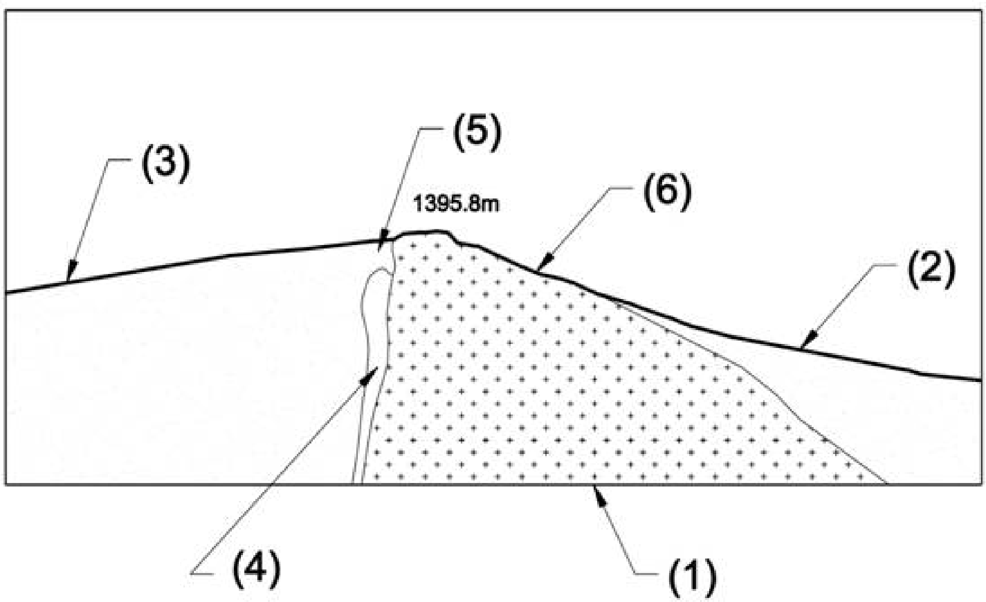


Fig 2.18: Utsteinen ridge characteristics:
(1) Utsteinen ridge – granite bedrock; (2) Compacted snow (west-side); (3) Compacted snow (east-side); (4) 'randkluft' (gap); (5) Snow-bridge; (6) Exposed rock surface

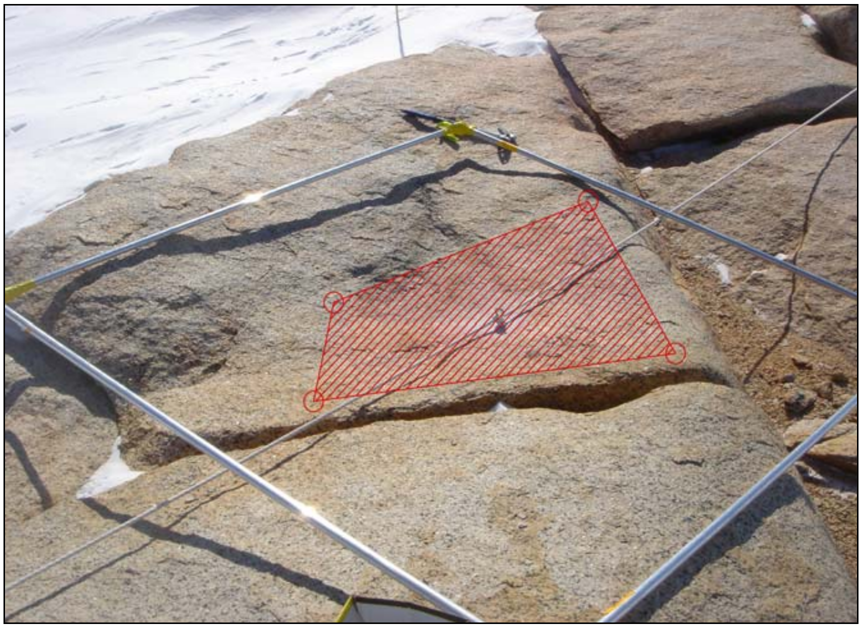
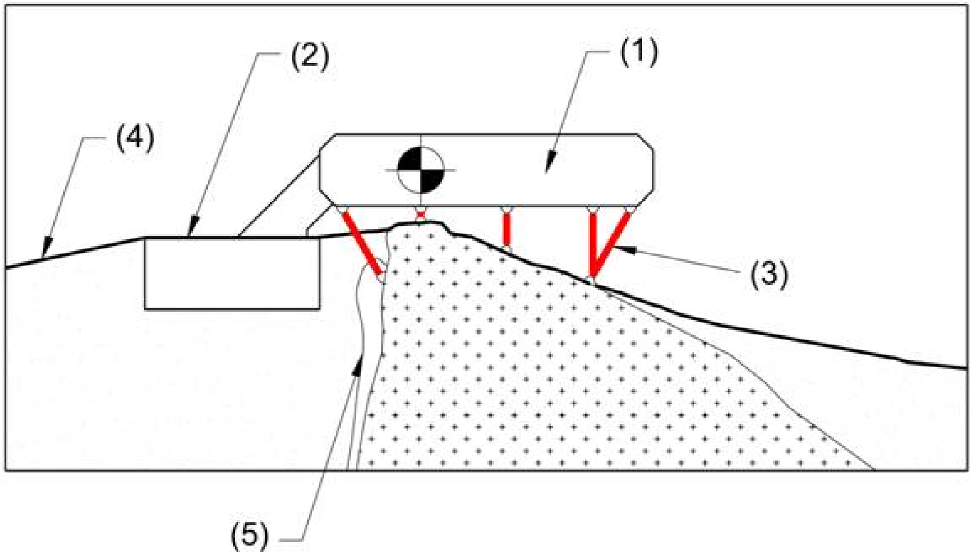


Fig 2.19: Anchoring points survey: 3D surface measurements
(red area corresponds to flat rock surface)

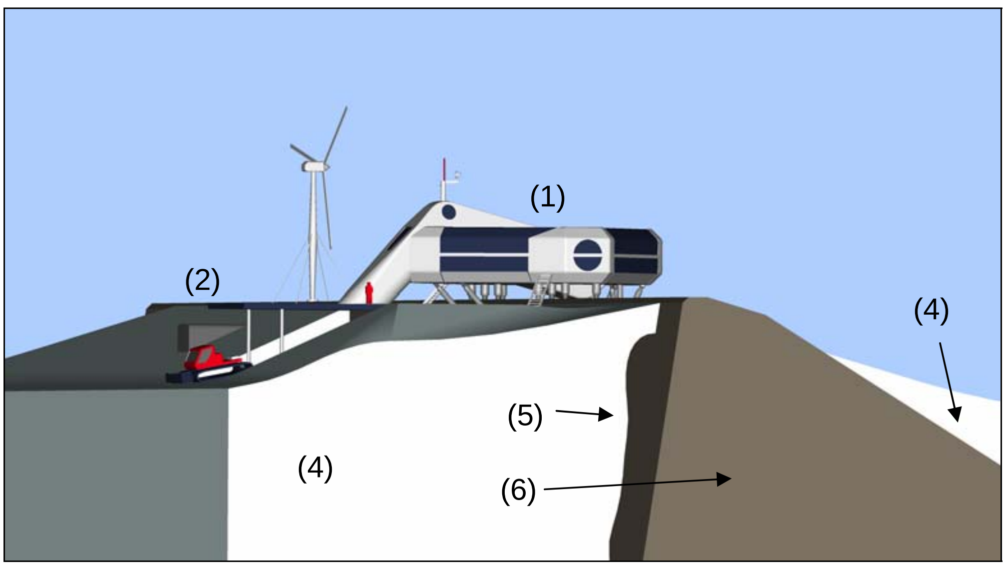
2.4.4. Building support concept

The integration of an above-ground building on the ridge implies that there is a considerable difference in support post height. In the proposed design the building centre of gravity is located near the ridge summit in the area where the support posts are the lowest (a 1m high air gap was defined by wind-tunnel testing). These support posts form a rigid N-S axis under the building and act as a stability point around which the rest of the building is laid out. The building extends to the west where it is supported by articulated posts to the bedrock's relative vertical surface on the west side of the ridge. To the east side the building has a number of articulated support posts that become gradually longer. Both east and west side supports are interconnected with a rigid beam structure.

This construction provides a number of benefits: Although the building has been shaped to reduce wind-induced lifting forces it is impossible to completely avoid this effect due the variability of the wind. Furthermore the thermal dilatation transfers (in W and E directions) originating from the high temperature difference is limited in length and thus in effect. This approach will make it possible to optimize the overall building-support concept resulting in less airflow disturbance underneath the building (porosity), a crucial parameter to enhance the building's aerodynamic performance for snow accumulation as well as to reduce wind-induced noise and vibrations.



view from the South



view from the South-West

<u>Fig 2.20</u>: building support concept:
(1) Above-the-ground building; (2) Under-surface building; (3) Articulated posts for support; (4) Compacted snow (terrain adaptation; (5) 'randkluft' (gap); (6) Ridge.

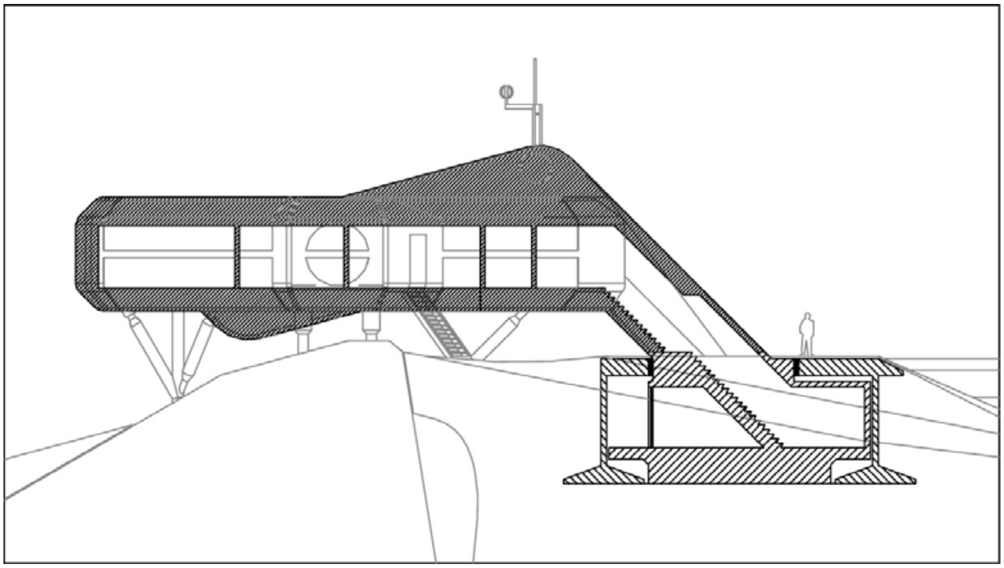


Fig 2.21: Building concept: main building and connection to garage/storage building. Floor level of insulated units is at entrance height of containers

2.4.5. Aerodynamic studies carried out at the von Karman Institute

Wind conditions have a major impact on the structural aspects of the building but also heavily influence operations, comfort and energy efficiency. Aerodynamic testing is used to:

- limit the expected snow accumulation in the lee of the building;
- prevent snow accumulation upwind of the building;
- control wind-induced forces on the building;
- set mechanical engineering specifications;
- enhance the comfort inside (and outside) the building by reducing noise and vibrations;
- validate the numeric wind model to assess wind power potential;
- assign positions for stand-alone facilities.

Overview test planning:

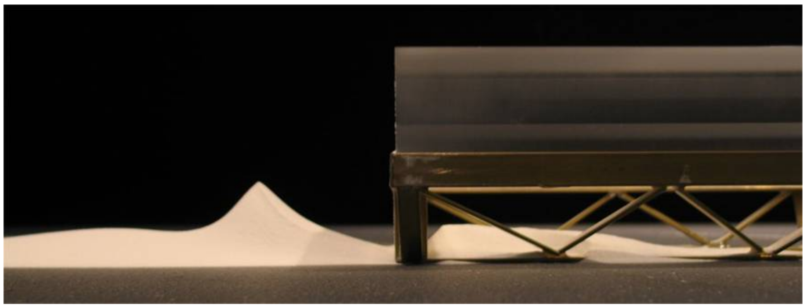
- Wind Tunnel Test Session 1 (WTT-1): Snowdrift testing validation.
- Wind Tunnel Test Session 2 (WTT-2): Building Free Model and numeric wind model.
- Wind Tunnel Test Session 3 (WTT-3): Development of building configuration.
- Wind Tunnel Test Session 4 (WTT-4): Instrumented tests.

The WTT-1 and WTT-2 tests are validation tests on the aerodynamic test method to assure the realistic simulation of snow drift, snow accumulation and snow erosion in the wind tunnel. A good correlation between the building free model used in the wind tunnel, the computer model and the field measurements was found and from this the testing parameters were identified. In WTT-3 the concept proposals were tested mainly with respect to snow accumulation properties. From this result a final building design was selected. In WTT-4 the forces on the structure are measured in detail,

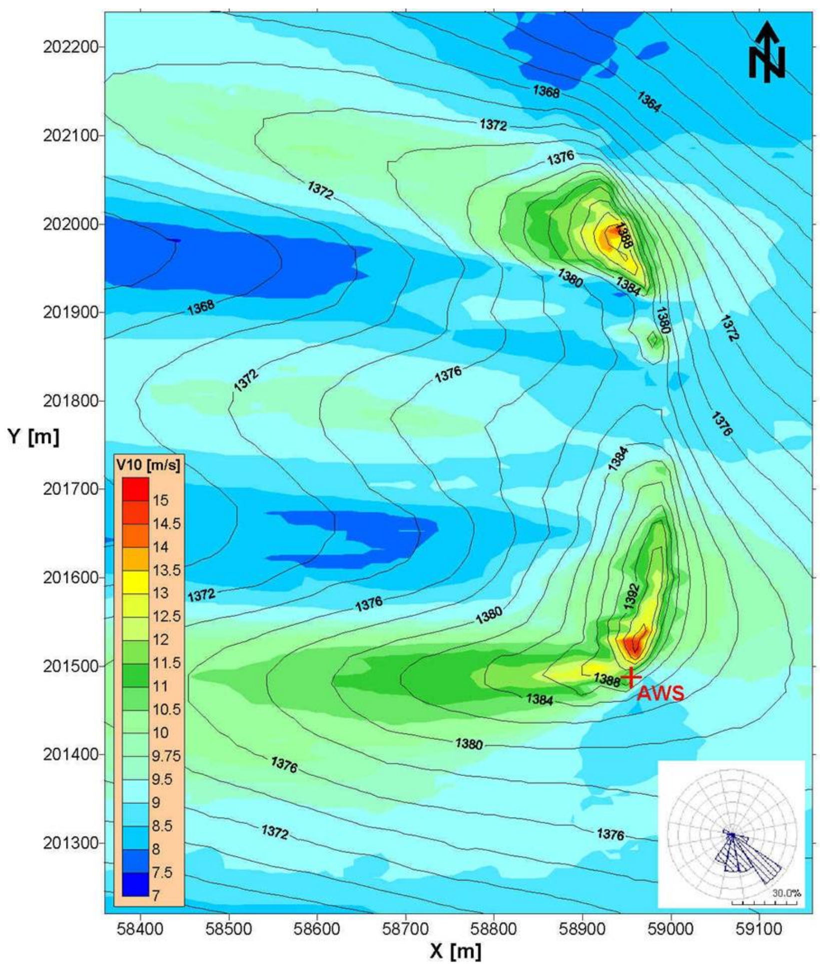
The selected design generates manageable snow accumulation and erosion features for the prevalent wind direction. It also prevents snow build-up on the windward side of the building. Such a snow build up would continuously change the incoming airflow characteristics creating unpredictable behaviour in terms of long term snow accumulation.

The worst case testing (blocked air gap) proved the robustness of the design: it will take a long time before the resulting accumulation compromises the functionality of the base allowing the station staff enough time to intervene. The geometry of the garage roof creates an almost horizontal snow-free surface at the lee side of the station, that will result in the snow accumulation zone to recede away from the base.

The vortex path generated by the building has positive and negative side-effects depending on the relative position of the garage building and its entrance. The erosion regions are exploited enabling a low maintenance entrance.



<u>Fig 2.22:</u> WTT-1 - Snowdrift model validation



<u>Fig 2.23</u>: Terrain model (contour lines in m a.s.l.) and simulated wind field (m/s)

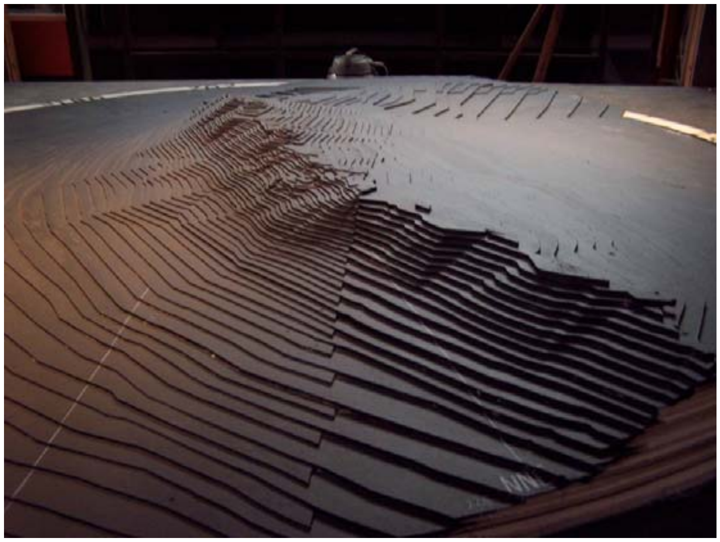
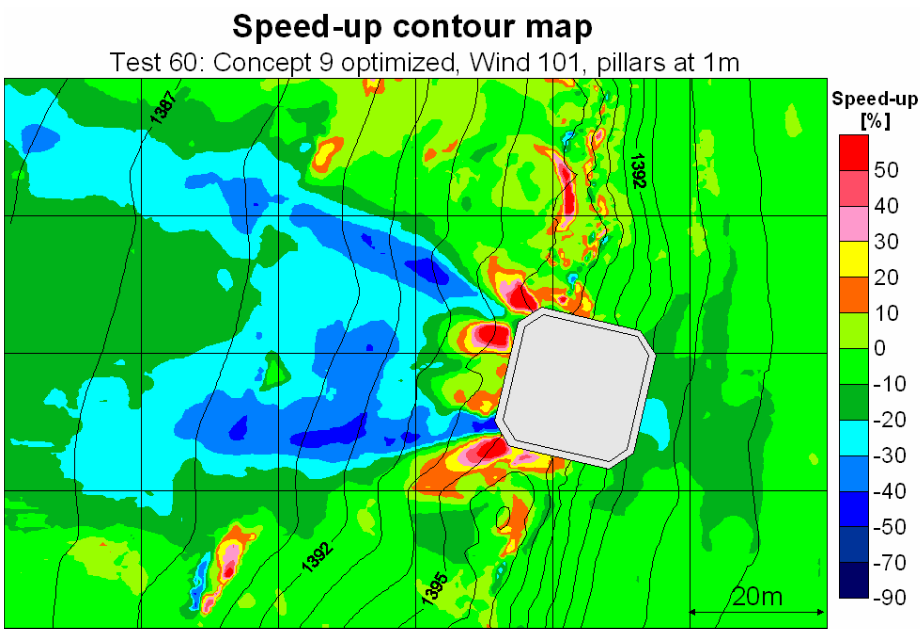


Fig 2.24: WTT-2 - Building free scale model of the terrain



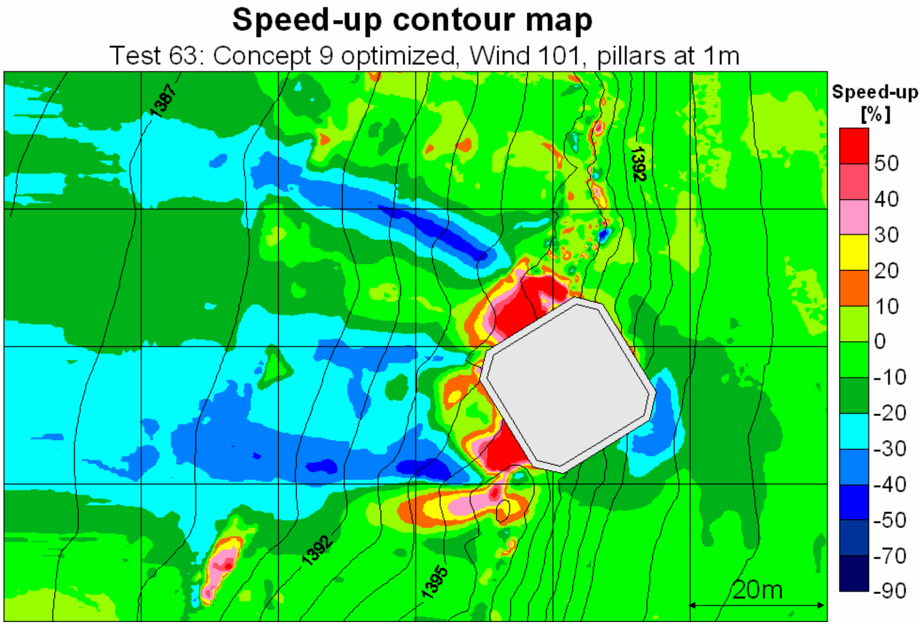


Fig 2.25: Wind speed up map (in %) due to building integration showing accumulation zones (blue) and erosion areas (red). Both integration variants are shown, (geometries not optimised) without garage/storage building.

Fig 2.26WTT-3: Sand erosion testing with garage building integrated.

2.4.6. Station surroundings

The diagram below shows the organization for the different elements to be integrated in the base vicinity. This layout illustrates the relation of the base main building(s) versus the areas with a designated function.

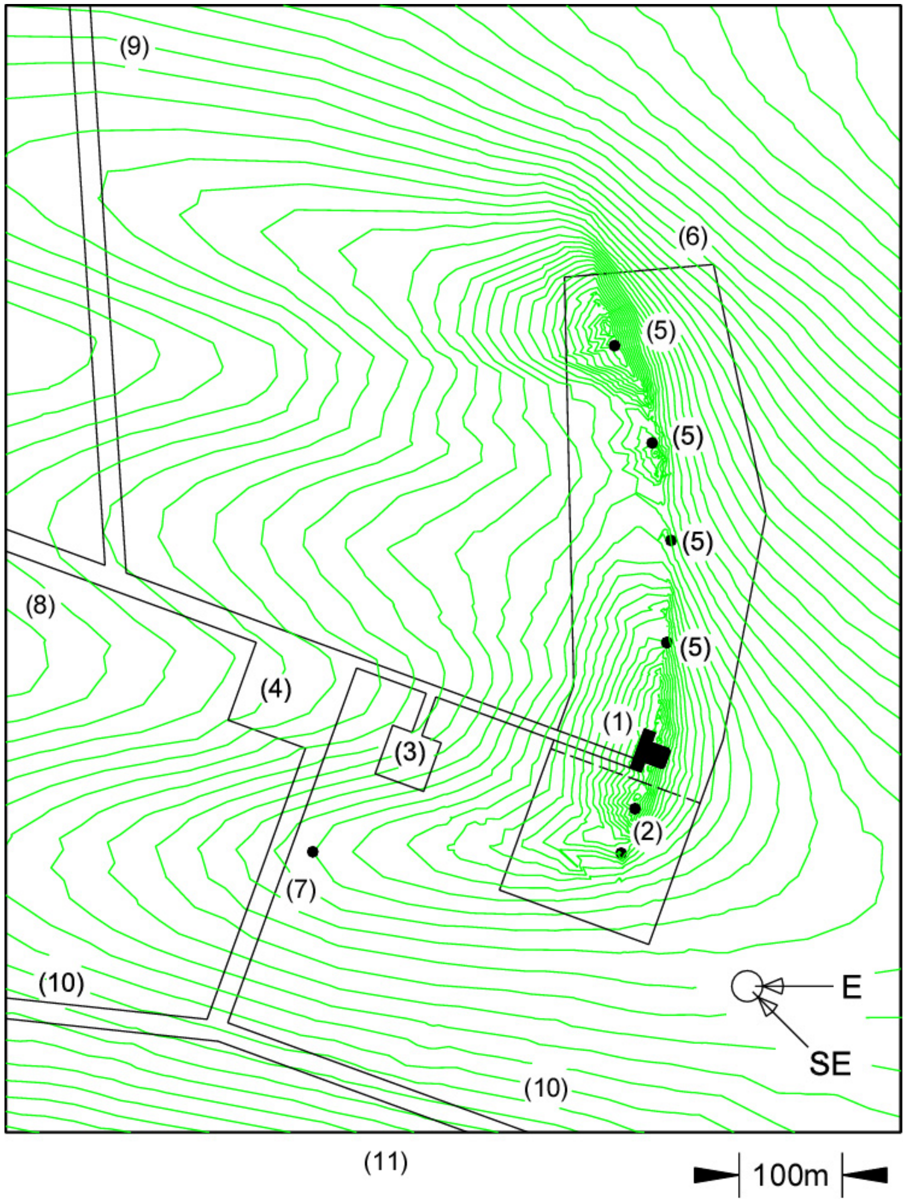


Fig 2.27: Boundaries of construction area, station operation, landing strip:
(1) Station; (2) "Stay-out" zone with stand-alone scientific facilities & AWS; (3) Snow collecting zone;
(4) Parking outside; (5) Wind turbine positions; (6) Access allowed zone; (7) Emergency shelter;
(8) Access to fuel depot (at 1000m) and small Nunatak (2000m); (9) Access to snow runway (2000m N-W);
(10) Access routes to various areas (Gunnestadbreen, coast route, mountains east, mountains west, Utsteinen Nunatak);
(11) Utsteinen Nunatak.

Fuel depot

Storage of fuel and oils in the garage/storage building will be kept to a minimum and will have secondary containment. The fuel depot is located on a safe distance and out of the main wind direction to the lee-side of the ridge (West). The baseline for fuel storage will be the use of 4 sledge-based double skin (bunded) fuel tanks of 12 m³ capacity each. They will store fuel for the back-up generators and transport. These bulk storage tanks are proven technology (used on Concordia) and appear to be safe and reliable. The handling of the fuel will be limited to the displacement of the tanks to avoid too much snow accumulation. When practical the fuel tanks will be equipped with automatic monitoring system. The number of fuel transfers will be reduced. The use of drums on site will be limited but there always will be a minimum quantity on site. At the refuelling points located in designated positions measures will be taken to avoid and eventually retain spills.

Estimated fuel consumption per year (construction):

Jet A1:

- Back-up generators: 8,000 litres => tank capacity 12,000 litres
- Overland transport => 17,000 litres
- Aircraft 8,000 litres

Gasoline (unleaded 95):

- Snowmobiles and other equipment: 2,000 litres

White gas (stoves)

- To be defined

Estimated fuel consumption per year (operational):

Jet A1:

- Back-up generators: 100-2,500 litres => tank capacity 12,000 litres
- Overland transport => 5,000 litres
- Aircraft 4,000 litres

Gasoline (unleaded 95):

- Snowmobiles and other equipment: 2,000 litres

White gas (stoves)

- To be defined

Emergency shelter

The under-snow emergency shelter will be stand-alone (food-power supply-communications) and will be designed for 12 people. The site is out of the wind path versus the station at the lee-side of the ridge.

Stand-alone scientific facilities

Small stand alone facilities are foreseen to the south of the station. The ridge provides good accessibility and anchoring conditions over about 200 m. This is up-wind versus the station and might cause some disturbance. There is an alternative position a small unnamed nunatak 2 km to the west of the ridge.

2.4.7. Water generation and disposal

Water generating

Efficient water housekeeping required water consumption to be kept under control. This will be done by means of using water-efficient end-user equipment (for example toilets).

The water supply for the station will result from a combination of solutions. The initial system will use snow drift and the (resulting) snow accumulation caused by the building and the ridge. The collected snow is automatically dumped into (the lower positioned) snow collector located in the garage/storage building.

Solar thermal panels will be used to melt the snow thereby limiting the use of electrical energy to pumping the water. This system may be very economic but it will only be viable when fresh water is recycled in a secondary network. As a bonus there will be less energy needed to melt snow and less waste water to dispose of. In addition electrical heating, eventually backed-up with waste heat originating from co-generation (multiple sources possible), can be used in the system. A water buffer tank in the main building will accommodate five days supply and the hot water storage will also be inside the main building. Both water storage systems are part of the thermal buffer mass of the building.

Grey and black water

The waste water treatment plant consists of a grey and black water system (black water includes urine and human solid waste). The proposed design minimises water demand by reducing fresh water consumption. Water coming from the snow melting facility, stored in a buffer tank, will be used for all potable functions, including showers and cooking. Other building functions will use recycled water. This has been designed as a modular system that can be extended in future. In an initial configuration there will be:

- An influent buffer collecting all grey and black water produced;
- An anaerobic reactor with ultra-filtration unit;
- A Membrane Aerobic Bioreactor;
- A chlorine unit;
- Active carbon treatment unit;
- UV-treatment unit; and
- Buffer hygienic water.

Future extension could include a reverse osmosis unit (giving up to 90% recycling).

In the current configuration the low quantity of surplus grey water will be released into the 'randkluft', a natural formed gap between rock and snow/ice mass at the west side of the ridge. This backup solution will use an insulated and heated sewage pipe. Note that this can be done north and south of the station and that the water will never be disposed at the snow surface or onto exposed rock. An overview of the expected effluent quality of the grey water is given in **Section 12**, **Table 12.3.**

Air exchange (venting) will use bacterial filters on the outlets adding an additional level of containment to the system. Very low quantities of CO_2 will be produced by the waste water treatment system. The production of methane is avoided in the bioreactor. This will create a higher output of residue but the surplus is very acceptable. The residues will be dried, sealed and stored in sterile containers together with the other waste that will be removed from the site during ship re-supply.

Water consumption

All obvious measures will be taken to keep the water usage as efficient as possible. An important element in this is the selection of low water use equipment. For example the use of latest technology laundry and dishwasher machinery will reduce water demand but also measures such as the use of recycled water for dish washing combined with fresh water for rinsing in the same machine will be beneficial.

2.4.8. Energy

Reliability

The use of sustainable technology as the primary energy source without compromising functionality, comfort or safety requires a cautious approach in the system engineering. Making best use of co-generation and enhancing energy efficiency implies a high level of integration but this could have a major disadvantage: vulnerability of the whole system for partial break-downs. Therefore in the conceptual design the following approach has been used:

- Reliability: where possible subsystems are composed of modules built up from proven technology extended to (relatively) new technology for highest efficiency. The minimum functionality of the subsystem is assured by the core system.
- Independency: the interaction (e.g. co-generation) of subsystems does not compromise the functioning of the individual subsystems.
- Redundancy: detailed Failure Mode Effect Analysis (FMEA) of the whole building is used as an input to the design process. Safety measures, maintenance and other applicable strategies are tailored according to this.

Prior to the concept phase of the project an extensive technology survey was conducted looking at potential solutions for energy generation, distribution, storage and sustainable energy system in general. Such a survey was also applied for most aspects of the building physics such as Heating, Ventilation, Air Conditioning (HVAC)... Brainstorms for possible solutions were backed-up by preliminary energy simulations taking into account the on-site weather data (wind/sun/temperature), user (consumer) profiles, user scenarios, materials used, the building geometry and orientation.

User profiles

Base energy "modes" identified for energy consumption, basic overview:

	Profiles	**Days**	
1	Winter	215	Remote sensing & monitoring
2	Unmanned start-up	30	Remote waste water system start-up + gradual heating of building
3	Manned start-up	5	Staff arrives (+ visitors) - air transport available
4	Summer high 1	25	Science activities (nominal use) - air transport available
5	Summer low	60	Science activities (nominal use) - air transport NOT available
6	Summer high 2	25	Science activities (nominal use) - air transport available
7	Manned close down	5	Preparing for over wintering - air transport available

Table 2.4: Base energy "modes" identified for energy consumption

The number of people on the base will vary depending on the time of the season and the scientific activities planned. There will be a minimum support staff of 4 people. This number may increase depending on the support required for the scientific work. In a season with a high level of activity the average number of people stationed at the base is estimated to be approximately 50% of the total number because many of them will be performing field research. In November and February when most air transport is available the occupation is highest. In these periods most people will stay for a maximum of 1 month at the base. Also during summer the weather conditions can force the crew to stay inside the buildings. In the energy budgets these "events" have been taken into account.

Energy generation system overview

The energy generation side of the system consists of different elements that function separately or combined depending on the demands and circumstances. The station site has a sheltered nature (see **Section 4.4** for weather data) but the site still provides sufficient wind to use wind energy as a major electrical energy source.

The concept currently studied consists of a number of relatively small wind turbines positioned on the ridge in (N-S direction) with an interval of 100 m. All the wind turbines are located north of the station (the first at 100 m) and are supported by a guy wire system for robustness and minimal-impact anchoring. These turbines can be lowered without the assistance of heavy equipment. From a technical point of view this is not obligatory but this option can be envisaged to minimize the risk of damage during winter. Furthermore this will facilitate maintenance and repairs. The mechanical modifications are limited to few reinforcements and better sealing to counter snow drift intrusion. Additional to these turbines a small "winter turbine" will be installed at a natural lower point of the ridge (speed-up). This turbine will provide extra power to the station during the winter thereby reducing the required battery capacity needed for monitoring (building & science) and to maintain the buildings inside temperature under control.

On the building different solar power systems are used. They are solar thermal and photovoltaic panels. For solar passive energy there are, apart from the strategically positioned glazing, also "solar transparent" insulation panels on the roof used for pre-heating ventilation air and to warm up the thermal masses situated in the building roof buffer zones. The distribution of the different panel types is defined by the user profiles (energy needs) and the position of the sun during the day. The photovoltaic system will be capable to provide up to 10 % of the electrical load and mainly will reduce the storage capacity in batteries as much as possible.

Although power supply at the station is based on renewable energy, wind and solar radiation studies show that both are reliable energy sources; it may happen that occasionally the power supply can be insufficient. Therefore a number of measures are taken:

The station is equipped with two back-up generators. Jet A-1 consumption is estimated at 50-100 litres fuel per day depending on the load. A double-walled fuel tank can store 12000 litres which will provide sufficient autonomy for a full season at 100 % use. Excess heat from the generators will be reused into the hot water system which itself supplies the passive snow melting circuit, the building active heating system or preheating for appliances which use hot water. In nominal conditions the generators are expected to be used at a very low rate as the systems mentioned do not rely on the generators to be operational. The use of redundancy in the generator park adds another safety level and allows maintenance to be done during operations; also it provides flexibility to cope with energy use variations.

Installed power overview

1. Wind energy:

- 3 positions used for 15kW wind turbines (summer)
- 1 spare position for upgrade (upgrade)
- 1 position for the integration of the "winter" wind turbine of 7kW

2. Solar electric energy:

- 100m² in photovoltaic panels (10kW)

3. Solar thermal collectors:

- Water melting: 20m²
- Sanitary hot water production: 20m²

- Building heating: 40m²

4. Solar passive energy:
- 30% of building vertical and roof surfaces

5. Emergency power supply:
- Uninterrupted Power Supply (UPS) by means of fly-wheel and 1 conventional system (5kW for 10 minutes)
- 2 generators 20kW running on Jet A1

6. Not taken into consideration here:
- Power facilities for stand-alone scientific facilities.

Heating, ventilation and air conditioning

Most of the heating and ventilation as well as the snow melting and water heating are done with passive solar energy and waste heat recovery. Solar thermal collectors supply almost all the necessary heat for snow melting and sanitary hot water production.

The HVAC is composed of a balanced ventilation system and a central heating via floor and wall heating. The ventilation group is provided with a high efficiency heat and moisture recovery in the form of a hygroscopic wheel or accumulation block.

Buffer zones optimised for passive solar thermal gains will reduce to a large extent the need of additional heating in the comfort zones. This small amount of additional heat will be provided partly by solar thermal collectors, the rest will be recovered from the electricity generation (co-generation) or by fuel boilers. The heat will be distributed at low water temperatures using floor and wall heating.

Energy storage

Electricity storage

A (typical) problem with renewable energy is its intermittent character. The energy stored in the buffer battery pack will be reduced as much as is reasonably feasible by the following measures:
- It has been decided to rely on photovoltaic as well as wind energy production as primary electricity sources.
- A fly-wheel will be installed that will buffer fast variations in the consumption and electricity production of the wind turbines. This will also help to level out energy input variations and it can be used as an Uninterrupted Power Supply (UPS) providing an emergency back-up system.
- Electricity consumption will be matched to electricity production by demand side management.

Heat storage

It is essential to enhance the heat-storage capacity of the building since by nature the thermal mass of the building will be very small. One possibility studied is to use the rock (granite) found on site. Special care will be taken to assure that the stones will not collect lasting contamination so that after the decommissioning of the building they can be left on site.

Furthermore, heat storage tanks will be placed in the inner core of the building, guaranteeing the recuperation of the convection losses of the storage tanks for space heating. Depending on the impact on the building volume, phase change materials will be introduced to reduce the volume of the storage tanks within the building volume.

Demand side management

An intelligent and robust control system (industrial type) will monitor the building and, according to demand, will steer the different processes in the building. The system will keep energy use coordinated as much as possible with energy supply. One of the measures the system will be able to take to anticipate power peaks will be to use short 15 minute 'switch-off or power-on' sequences for non-critical items e.g. battery chargers, freezers, heating equipment.

Reducing energy usage

All building elements are studied with energy efficiency in mind. Equipment selection and the use of passive systems will be maximised. Some examples:

- External light will be captured using photon collectors or "solatubes" to provide light in technical rooms and other building spaces.
- The selection of low energy-use equipment.
- The use of water-efficient spray water taps.
- "Presence detector" systems for unoccupied rooms.
- Self closing doors in the entrance area.
- Aerodynamic studies to identify high thermal losses on building skin (more insulation required).

Alternative systems under evaluation

- Propane for water heating (as a backup-system) and the kitchen stove.
- Hydrogen production and storage plant linked to the wind turbines (excess wind power used to generate hydrogen by electrolysis and storage for later use instead of higher buffer battery capacity).

2.4.9. Emissions

In normal operation the station will generate very low emissions. Even in the exceptional case when the emergency generators are used for powering the whole station the emission will be relatively low thanks to the very energy efficient nature of the building.

Very low quantities of CO_2 will be produced by the waste water treatment system. The aerobic bioreactor is tuned to avoid production of methane.

Most emissions will originate from vehicles. Thanks to the very compact layout of the station's different buildings and the direct connection between the main building and the garage/storage vehicle movements are limited and mainly needed for logistic supply and science related tasks.

The vehicle park will be diverse and focussed on over-snow scientific missions. In the operational phase the number of heavy vehicles dimensioned for transporting heavy loads will be limited. Currently a number of vehicle types are being evaluated. An economical-to-run vehicle to be used for scientific missions is sought-after since this will be used intensively. The programme foresees in the relative near future snowmobiles with 4-stroke engines. These machines consume significantly less than 2-stroke machines and are getting more common on the market. Most field missions to the mountain area will probably use this equipment.

2.4.10. Communications

Today's standard communications will be used including satellite telephone, satellite data-link and radio (VHF) for small distances. Field parties will get individual satellite phones (Iridium).

2.4.11. Testing and validation

The main building will be pre-assembled in Belgium where a comprehensive testing programme will be conducted to validate the station's performance and robustness. The fact that the main building will be erected in an almost identical manner as on site will allow running a test programme that not only looks at the mechanical aspects but also tests the functionality of all active subsystems. Furthermore break-down scenario's identified in the FMEA of the building and its subsystems will be validated, by simulating as realistic as possible, the emergency response and damage control scenarios identified. By doing this the project team intends to limit the time needed for debugging on site (where not all specialised staff will be present). Another aspect judged to be important is that most of the delicate assembly and construction tasks will be possible in best conditions rather than on site where weather conditions and human factors are more critical.

2.4.12. Transport

After the testing in Belgium, the building will be disassembled and packed for shipment. The units remain partially assembled and will be dimensioned for easy handling and to meet transport requirements. The pre-assembled building units will be mounted in the ISO-norm containers in such a way that transport damage caused by shocks and vibrations of the over-land transport over the ice-shelf will be avoided.

2.4.13. Construction on site

As a baseline, the assembly on site will be done using mechanical (bolted) interfaces only, thereby avoiding on-site welding or the use of adhesives as much as possible. This will also facilitate the decommissioning and recycling of the different components in a later phase. Pre-assembled building units dimensions and weight will favour easy and safe handling rather than size. Construction techniques will be rationalised using a minimum of different tools. The construction method will be studied to cope with the extremely short time period available for on site assembly.

2.4.14. Materials

Material selection will be done according to environmental and safety parameters established along ecological building guidelines. In the material selection process the following parameters will get priority:

- maximum durability (station lifetime)
- materials suitable for recycling

Exceptions to this baseline will only be allowed after thorough analysis has demonstrated that the material has major technical advantages enhancing the overall efficiency of the building.

No environmentally harmful substances will be used. Special attention will be paid to the off-gassing characteristics of the materials used in the building in order to create a clean and healthy environment. Also in the context of fire protection the building materials will not emit toxic fumes. The station has a light-weight construction that will facilitate transport and construction. The light structure however has also a low thermal mass and thus the built-in heat buffering capacity is limited. A solution to this is the use of on site material such as small granite stones that can be found in plenty on the construction site. No contamination of the stones will be allowed to make sure they can be returned to the ridge during decommissioning.

2.4.15. Upgradeability

Studying different Antarctic stations and the way they evolved in time has helped in the design and to set up upgrade strategies for the building and its facilities. In the retained philosophy there's no extension in floor space of the main building foreseen. The building is not only designed for a specific integrated energy concept but also it is not the intention of the Belgian government to enlarge the station. The building design allows an easy upgrade to a full-year station (this will have hardly have an effect on the hardware) and the flexible design allows to accommodate more people inside the building if required. An essential part of the upgrade capability are measures to update the equipment and the facilities with minimal impact on the required construction and resources (reference industrial facilities). This is applicable for example to the cable management concept, the modular architecture of active systems and the thorough standardization of mechanical interfaces throughout the building. In a nutshell: improving the existing building without enlarging it.

2.4.16. Best practice strategies

The different systems in the building will be designed according to best practice guidelines. These will, for example, include measures to assure that no disturbance is caused for communication and for scientific equipment in and near the building. There will be down-time management plans; a maintenance and a spare part strategy will be in place.

2.4.17. Documentation

A key-factor in safe and efficient operations is documentation. To manage the station, a technical data-package, following standard industrial procedures, will be applied. The data-package will consist among other things of user and maintenance manuals, assembly drawings and instructions, spare part lists and emergency procedures. Two identical sets, both on paper and electronic, of this data-package will be kept on the station as well as in Brussels to assure easy communication on technical issues.

2.4.18. Decommissioning

The station will be designed as 'state of the art' with respect to sustainable development, energy consumption and waste disposal, with a foreseen lifetime of minimum 25 years. The station is also designed so that it can be easily decommissioned, disassembled and removed. If dismantling of the station is required, no significant remnants of the occupation will be left, in order to meet the requirements of the Environmental Protocol and relevant Belgian domestic law. The eventual clean-up of the removed station will be subject to an EIA.

2.4.19. Minimum Impact Objectives

Design Criteria

The station design has a maximum target energy load of 40 kW, excluding research equipment and support vehicles. The station is designed to be constructed, operated and decommissioned using:

- fossil fuels for transport and construction only
- solar / wind for building functions and scientific equipment (operational)
- other (under evaluation)

The facilities are designed to minimise use of fossil fuels and to maximise the use of renewable energy where practical. The station has been designed to have a minimum environmental impact during construction, operation and decommissioning.

Construction and Operation

The method of construction, operation and decommissioning have been planned to meet the requirements of the Environmental Protocol and relevant Belgian domestic law.

A waste management regime that includes the treatment of human waste will be implemented.

Construction, operation and decommissioning will be managed under the framework of an Environmental Management Plan.

The station construction, operation and decommissioning has been planned to minimise health and safety risks during all stages. Belspo, IPF staff and contractors will have relevant training and will be provided with the necessary equipment and personal protection to reduce the likelihood of major health or safety incidents.

The construction team and any contractors will be managed by the IPF Project Leader. The key-construction team will already be involved in the pre-construction in Brussels in order to become acquainted with the construction itself. Staff and contractors will be briefed prior to departing for Antarctica to ensure that they understand and fully comply with the relevant provisions of the Environmental Protocol, its Annexes and Belgian law that might affect them or their work.

2.5. Area of disturbance

2.5.1. Area of operations

The area of operations around the new station will include the buildings, (research) facilities and cargo depot within the station perimeter. This area will be about 0.5 km^2 excluding the 600 m x 50 m snow runway and access routes (see also **Fig. 2.27**: boundaries of construction area, station operation, landing strip)

The scientific field activities during the period November-February are in a range of maximum 200 km from the station, up to the polar plateau and down to coastal Breid Bay.

There will be an additional disturbance by the yearly movement of station personnel and small amounts of cargo to and from the station using the DROMLAN air-network and the annual re-provisioning of and waste removal from the station using ship transport to Breid Bay, (un)loading at the ice shelf and the transport of cargo via tracked vehicles. See also **Fig. 2.7**: scheme of different transport routes for the proposed activity (cargo discharge at coast, construction, operation and science).

2.5.2. Duration & Intensity

The construction of the new station is likely to take 4 months, depending on weather conditions and transport availability. It will include the main building, a garage/storage building, an emergency building and the huts for geophysical observations.

The construction will then be handed over to Belspo, who will supply other necessary scientific equipment as of 2008-2009, the first planned scientific and logistic operations season. Scientific equipment will be installed at the station as required by the scientific demand and evolution of the research programme.

A minimum lifetime of the station of 25 years is foreseen.

2.5.3. Standard Procedures

A number of policies and standard procedures are being developed to manage operations in Antarctica. The policies and procedures are integral to safe and efficient operations and include minimum standards for staff, equipment and working conditions.

Policies will be designed to lessen inherent risks of working in Antarctica and to minimize environmental effects.

The Station leader in Antarctica, in close cooperation with Belspo, will oversee Search and Rescue (SAR), medical response and other emergencies in accordance with an Emergency Response and Contingency Plan. The plan includes among other things:

- responsibilities and chain-of-command;
- Health and Safety issues;
- medical support and evacuation procedures;
- emergency communications procedures; and
- route marking and navigation.

2.5.4. Fuel Caches and Fuelling

A fuel depot consisting of 12 m³ sledge-based fuel tanks is located near the station. See also **Section 2.4.6:** Station surroundings.

For the construction of the station emergency fuel depots along the access route to the coast will be installed near Seal (Selungen) nunatak at approximately 53 km from the station as well as on the coastal depot area (BEL-L0 or BEL-L0 NEW) at approximately 165 km from the station.

2.6. Description of Construction Camp

Belare 2007 Expedition

- By air in November: a team of 12 people in
- By ship in December/January: cargo + 2 people in
- By air in January: A team of 20 people in + 8 people out
- By air in February: 26 people out

The construction camp will be installed on the same spot as the base camps of the Belare 2004 and 2005 expeditions. During these expeditions a covered trench was made to store the equipment used by the survey expeditions in winter. A Weatherhaven tent is currently available on site. The camp will be extended with additional Weatherhaven shelters. All procedures will be in place as described elsewhere in this document. The early team that flies in beginning of November will install the base camp. A weather protected work shop will be installed using the equipment on site from the Belare 2006 expedition. Note that this is only equipment and no construction material. The team will prepare the site and start to install the mechanical anchoring points on the ridge as well as the validation of the traverse route to the coast route and organize the coast camp and emergency fuel depots.

Sea-ice conditions allow ship arrival and unloading in the first week of January. At this moment a new construction team will fly in (although a group may come with the ship depending on the possibilities) and 8 early team members will be evacuated by airplane. The construction team will be responsible for the logistics (unloading and over-land transport) and the construction of the building. The construction camp will be extended to accommodate the larger group using the emergency building unit that will come in by ship and will be pre-assembled. An additional Weatherhaven shelter will provide sufficient sleeping accommodations.

Kitchen/eating room	Weatherhaven shelter
Office/briefing/meeting room	Emergency building
Sleeping accommodations	Weatherhaven shelter
	Weatherhaven shelter
Sanitary facilities	ISO-norm container 20′
Food storage (construction)	ISO-norm container 20′
Weather protected workshop	ISO-norm container 20′
	ISO-norm container 20′
	ISO-norm container 20′
Waste collecting	ISO-norm container 20′
	ISO-norm container 20′

Table 2.5: Overview of the construction camp facilities

2.7. Waste collection and disposal

A Waste Management Plan (WMP) will be prepared that will comply with all the requirements of Annex III of the Environmental Protocol. The plan will comprise aspects of the reduction of waste generated, handling and storage of waste in Antarctica, disposal of waste removed from Antarctica, and education and training of staff.

There will be two parts to the WMP. The first part will cover the construction of the station and associated activities. The second part will be the plan for the ongoing operation of the station and will be regularly reviewed and updated.

The following elements will form part of the Waste Management Plan:

- Management and Responsibilities
- Minimisation of Waste
- Waste Storage and Handling
- Waste Equipment
- Waste Disposal
- Prohibited Products

Waste

On the station all wastes will handled and stored according to Belgian law safety, environment and health guidelines. All waste will be removed from the station for appropriate reuse, recycling, treatment or disposal in Cape Town South Africa.

In both main building and garage/storage buildings the wastes will be collected in designated areas. There will be different types of rubbish bins (or other appropriate receptacle) to separate the wastes at the source. Successively the bins will be emptied in larger transport boxes located in a 20' ISO-norm container located in the garage/storage building. This container will be removed from the building when a ship re-supply is organized. The full container can be exchanged for an empty one when unloading on the sea-ice or the ice shelf. Also the transport boxes are designed to be taken out of the container in order to transport them by cargo-sling (helicopter unloading at the ice shelf will always be an option). In the logistic preparation of the station's supply a first logical step is to get rid of packing material as much as possible. The incoming goods will be stored in the transport boxes mentioned above. The empty boxes already on site will be reused. A garbage compactor can be used to compact the solid waste if required.

Fuel drums

The quantity of fuel drums on site will be limited. The empty drums will be reused on site or taken out of Antarctica but they will not be compacted so that they can be recycled in Cape Town. It is not the intention to use fuel drums for storing solid waste. This would contaminate the waste with fuel/oil (processing issue), furthermore it would require more time and effort from the crew on site.

Hazardous products

Procurement guidelines will be used to make sure that the most appropriate products are selected, limiting the quantity of hazardous products to the strict minimum. The products and their empty packaging will be stored in specific areas according to best practice standards. This storage will also be monitored by the building safety system.

Mitigation measures

The recovery of energy by burning waste is not considered in order to keep emissions low (adequate process control).

Also during the construction the amount of waste will be minimised (see **Section 2.6**: Description of Construction Camp).

3. ALTERNATIVES TO PROPOSED ACTIVITY

Several alternative locations and designs have been examined for the construction of the new station, taking into account scientific, environmental, logistical, engineering, health and safety requirements.

3.1. Do not go alternative

The Belgian Science Policy, guided by the conclusions of the Evaluation panel of foreign Experts ('The Belgian Antarctic Programme 1985-2002: findings of the evaluation panel, final report') takes the view that there are compelling scientific and logistical grounds for the construction of a new station.

With the construction of Base Roi Baudouin on a floating ice shelf near the Breid Bay Polynia in 1958 at the occasion of the IGY, Belgium joined a number of countries (Norway, Japan, South Africa and Russia) in opening this part of Eastern Antarctica (Dronning Maud Land) for exploration and scientific research. Conceptually these expeditions followed the footsteps of the famous Norwegian-British-Swedish Antarctic Expedition (1949-1952) at Maudheim (71°03'S; 010°55'W) which pioneered modern scientific research and international collaboration in Antarctica. After the withdrawal of Belgium in 1967 and the closing of the Roi Baudouin base, its role was temporarily taken over by Japan with the establishment of Asuka Station (1986-1992). Although this station was situated 122 km inland from the Belgian station, the Breid Bay Polynia was still used as access area to this part of the Southern continent. With the closing of Asuka station in 1992, the 20-30 degrees east sector of Antarctica became again a vast territory having witnessed up to now only brief periods of systematic investigation.

In 1985 Belgium resumed its scientific activities with emphasis on Antarctica's role in the earth system. Since then Belgian research projects have been run for many years in conjunction with other National Operators, usually based at their facilities and utilizing their logistics. Although this situation led to a number of important and sustainable collaborations with other countries, this was not a comfortable situation as Belgium could not give an adequate return for the support, while it limited the areas of research to those of the host countries.

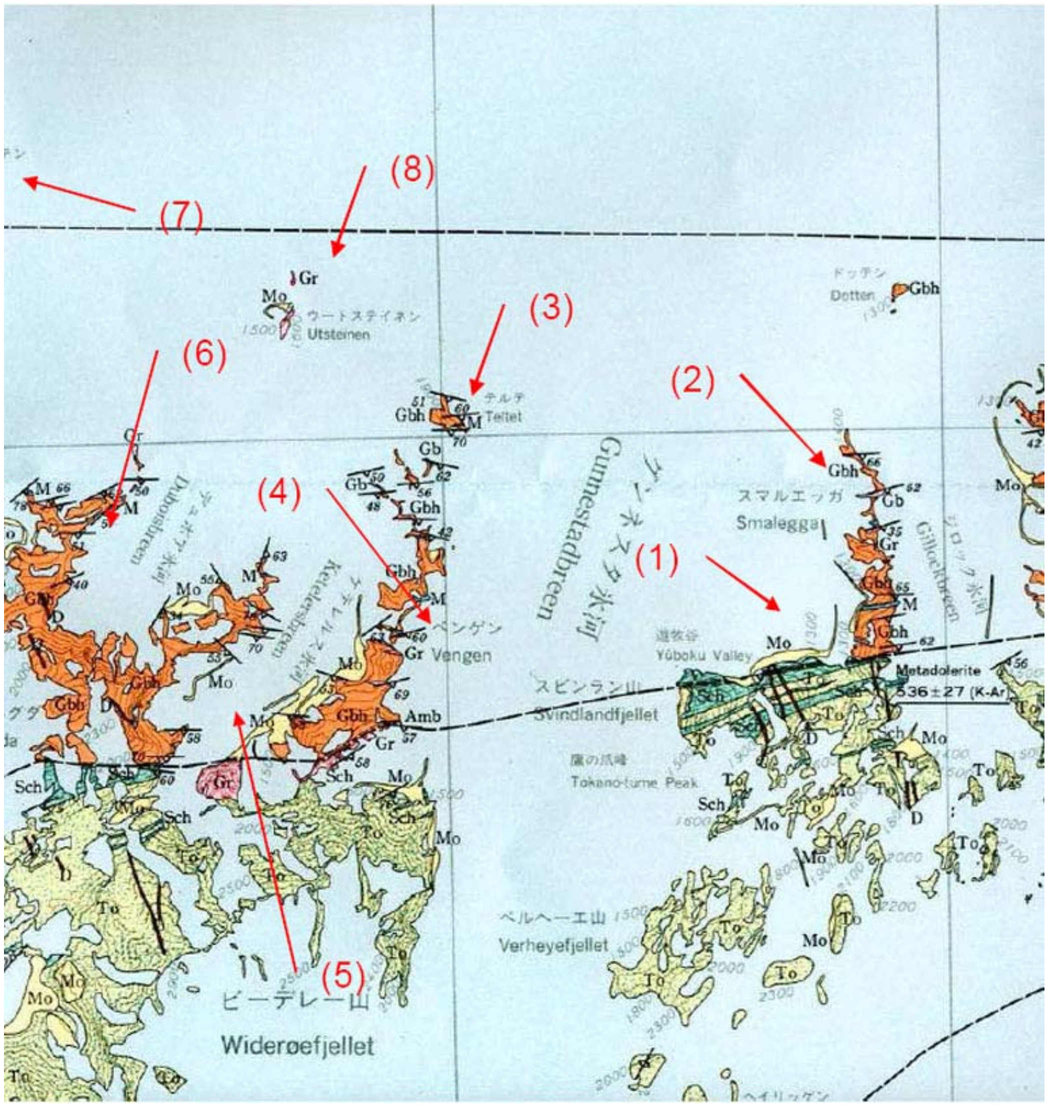
With the realisation of the DROMLAN Network an instrument became available for multiple visits to Dronning Maud land during the summer season and to optimize the use of a scientific platform in this region. Making use of modern technology to reduce energy consumption and waste disposal as well as technical staff, Belgium decided to offer to the international scientific community a new state of the art Antarctic research station allowing geophysical monitoring and field research in an area where the closest permanent research stations are situated at a distance of 684 km (Syowa) and 431 km (Novolazarevskaya). With the realisation of this new research station Belgium also wants to take up its full responsibilities with respect to environmental monitoring and protection of Antarctica.

It is very unlikely that there will be increased activity by the Belgian scientific research community if the project does not happen. The use of existing research stations, such as Novolazarevskaya and Syowa, could be an option, but the distance of these facilities from the proposed area of research would implicate a greater use of flight or over-snow vehicles to gain access to research sites. The proposed technologically advanced station, benefiting from modern efficient and low energy technologies, will likely have no more impact than using existing facilities.

Belgium considers this decision in line with its position as one of the original signatories of the Antarctic Treaty. The "Do not go alternative" is considered as opposed to the philosophy of growing importance of Antarctica's key role in Global Change and increased concern about the state of its environment.

3.2. Alternative locations

Next to the Utsteinen Nunatak site (see **Section 2.2.1**), several other possible construction sites were identified from aerial photographs and surveyed during the Belare 2004 expedition (**Fig. 3.1**):



<u>**Fig. 3.1:**</u> Part of the geological map in the vicinity of Utsteinen, with Gunnestadbreen lying in the central and giving access to the polar plateau. Overview of the alternative sites and Utsteinen:
(1) Jan Valley - Southern Smalegga; (2) Northern part of Smalegga; (3) Teltet; (4) Vengen - South of Teltet; (5) Valleys inside the mountain range; (6) Northern part of Vikinghøgda; (7) Pingvinane; (8) Utsteinen.
(Source: NIPR, Tokyo, Japan, 1997)

Jan Valley

Situated in southern Smalegga it is the most eastern site visited, lying protected from the wind within a small valley. Some supraglacial lakes are present but frozen over early in the season (as is the case with Utsteinen). There is no exposed and flat bedrock in the vicinity, only moraines and ice-cored moraines. The site is more protected than Utsteinen from the wind, but the wind direction changes frequently. The latter prevents the use of wind as an energy source for the station. Accessibility is more difficult, as the ice is sloping and very slippery and dispersed rocks are found; there is a good access for small aircraft.

Vengen
Situated south of Teltet; a small ridge of exposed bedrock was present. Access is more difficult due the presence of large wind scoops. Wind direction varies frequently and gusts are quite common. The ridge is very small and cannot sustain large building facilities.

Northern part of Vikinghøgda
This site consists of a flat surface of exposed bedrock and is easy accessible. The site has one major inconvenience, i.e. the snow surface surrounding the site is an erosional surface (with a lot of sastrugi). The latter hampers the use of snow for water production. The erosional surface also points to major action of katabatic winds and wind gusts in particular.

Other valleys
Valleys that are within the mountain range suffer from similar problems to those encountered with the sites at Jan Valley or Vengen, i.e. poor accessibility and the lack of exposed bedrock (and not moraine). Another factor remains the lack of wind for energy use through summer.

Analysis of the alternative sites indicates that substantially more work will be required to construct a station, consequentially, there is likely to be a greater environmental impact during construction and possibly during operation. The alternative locations for the site of the new station have been rejected because there are no scientific, operational or environmental benefits.

3.3. Alternative designs/technologies

Within the design constraints outlined in **Section 2.4**, several designs for the station were considered. Each design was evaluated for environmental effect, logistic implications for construction and operation, decommissioning and ability to meet the planned scientific programme. In order to evaluate alternative design proposals a number of key parameters were used (see also **Section 2.4.2:** Station design):

1. Accessibility for construction
2. Anchoring conditions
3. Orientation versus prevailing wind
4. Orientation versus sun
5. Compactness
6. Energy efficiency
7. Accessibility operational
8. Expected snow accumulation
9. Compatibility with program

In the process a weighted trade-off table was used.

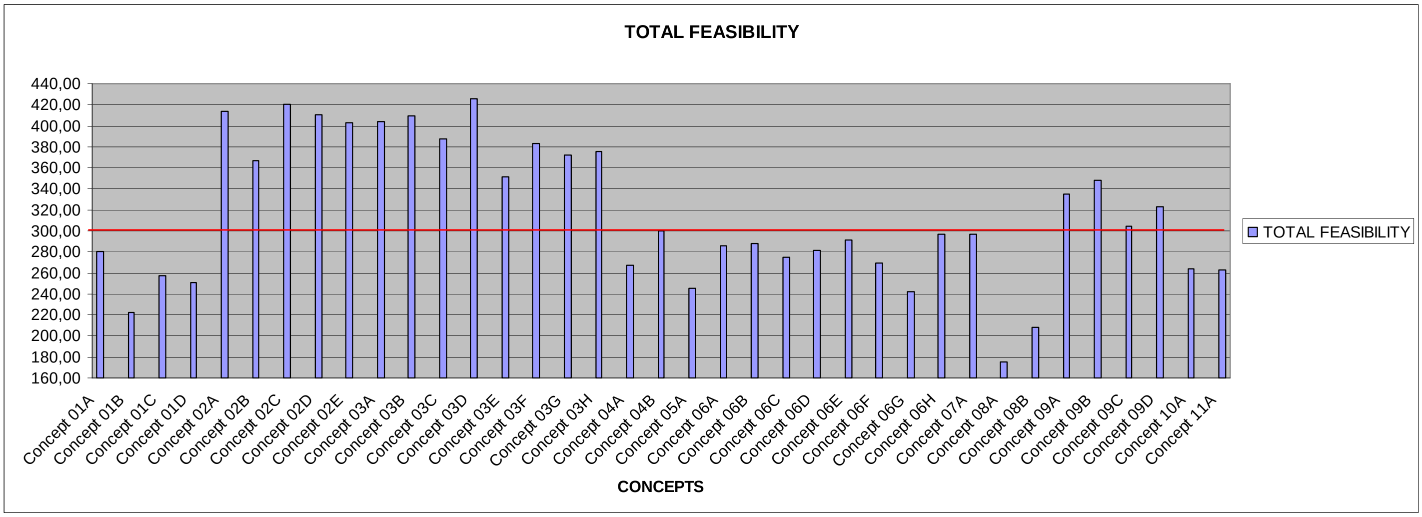


Table 3.1: Design trade-off

The overall performance (total feasibility) of the different concept proposals is summarised in **Table 3.1** above. Note that with the outcome of this study no less than 6 alternative designs were selected for further elaboration. Further analysis reduced the choice to three designs, and the best features of these were combined into the final layout. Aerodynamic tests (see **Section 2.4.5**) were used in the final choice to determine which design had the least effect on snow accumulation, consistent with operating and maintaining the station.

The final three designs had, in all other respects, similar environmental costs and benefits and had no significant environmental advantage over the chosen design.

3.4. Alternative transport

The construction site can be accessed by different means; the diagram below illustrates the possibilities.

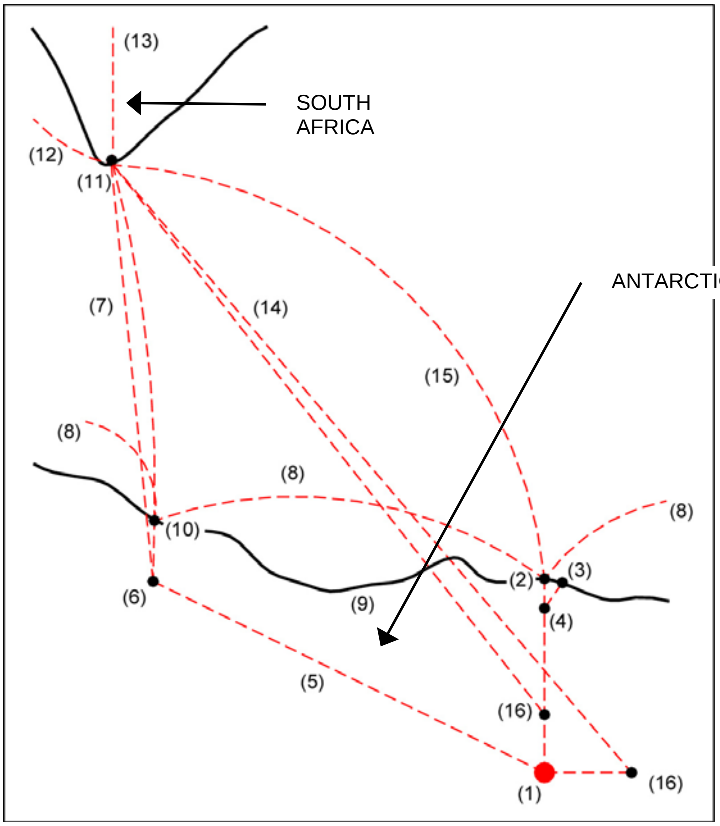


Fig. 3.2: Overview of accessibility options:
(1) Utsteinen (building site); (2) Preferred unloading site at coast; (3) Alternative unloading site at coast (Polarhav Bay); (4) Inland depot area (former Japanese L0 point); (5) Connection to Novolazarevskaya (+/- 430km), by air or over land; (6) Novolazarevskaya; (7) Intercontinental flight and ship route to Cape Town; (8) Ship access from other stations to the East and West; (9) Ice Shelf edge (coast line); (10) Novolazarevskaya coast unloading site (at 60km); (11) Cape Town; (12) Intercontinental ship route Europe-Cape Town; (13) Intercontinental flight route Europe-Cape Town; (14) Intercontinental flight route Cape Town-blue ice fields; (15) Intercontinental ship route Cape Town-Breid Bay; (16) Blue ice fields.

All transport will transit in Cape Town South Africa. Both goods and passengers can be flown in or go by ship. The following list summarizes the different possible scenarios:

Air transport only

1. Cape-Town => Novolazarevskaya => Utsteinen

Air transport + over land transport

2. Cape-Town => Blue ice field => Over land transport to Utsteinen
3. Cape-Town => Novolazarevskaya => Over land transport to Utsteinen

Ship transport + over land transport

4. Cape-Town => Breid Bay => Over land transport to Utsteinen
5. Cape-Town => Other stations => Breid Bay => Over land transport to Utsteinen
6. Cape-Town => Coast at Novolazarevskaya => Over land transport to Novolazarevskaya => Over land transport to Utsteinen

Ship transport + air transport

7. Cape-Town => Coast at Novolazarevskaya => Over land transport to Novolazarevskaya => air transport to Utsteinen

Feasibility of the proposed scenarios:

1. Feasible but costly and the highest limitations on volume and weight. Best use for passengers unless long transition time on ship is acceptable.
2. This is not a short term option since a possible blue ice field runway has not been validated for the time being.
3. Vehicles and sledges can be flown in but the over-land route needs validation (has not been done before), this will take time. This could be an interesting option to bring in small amounts of heavy goods such as vehicles and transport sledges. Bringing in the bulk of the building materials is not feasible because of the high cost and long transition time to the building site. Furthermore apart from the obvious safety issue the longest over-land route means more risk of damaging building materials (vibration and shocks).
4. Feasible and essential for the future viability of the station. It is advisable to build up experience in unloading at this area.
5. As 4 but may be more economical. Good option when transport volumes are not too big and timing is flexible.
6. Cheaper than scenario 3 but remarks on over-land route remain.
7. Feasible but costly and highest limitations on volume and weight but nevertheless probably less costly then scenario 1. Can not be used for transport heavy equipment (vehicles, sledges, etc.).

Preferred scenario:

Scenario 1 is for passengers, scenario 5 is for cargo.

Environmental issues:

The various scenarios present different environmental issues. All the overland components will produce more emissions than the shortest route, from Breid Bay to the proposed site. The operation phase will not normally require a dedicated vessel to service and where possible, sharing of logistics will be used, such as during ship transport to Antarctica.

The alternatives to the proposed ship-overland route to the site for station construction will not bring any environmental benefits and these have been rejected.

4. INITIAL ENVIRONMENTAL REFERENCE STATE OF THE SØR RONDANE

4.1 Location

The proposed site (Lat.: 71°57'S; Long.: 23°21'E; alt.: 1397 m) of the Belgian Antarctic station lies in the Western part of the Sør Rondane Mountains in Dronning Maud Land. It is situated at the foot of the mountains, approximately 1 km north of Utsteinen Nunatak on a small relatively flat granite ridge ('Utsteinen Ridge'), sticking out of the snow. The ridge – oriented in a more or less N-S direction – is 700 m long and a few meters large and elevates 20 m above the surrounding snow surface in the accumulation zone, although a number of blue ice fields occur in the vicinity as summer meltwater lakes. Utsteinen Nunatak is a few kilometres north of the Sør Rondane Mountains. This granite rock consists of two peaks and culminates at an elevation of 1564 m a.s.l. The SE side of Utsteinen has a large wind scoop. The area has been briefly visited by Belgian (1958-1967) and later by Japanese (1987-1991) field expeditions and more recently by the site survey expeditions in preparation of the new station, in 2004 and 2005. Although the Utsteinen area itself is pristine, a small number of depots and litter can be found elsewhere in the Sør Rondane, left by field parties during the pre-Madrid Protocol period. Drawing up an inventory and clean up of these artefacts of previous human activities will be on the agenda of Belgian activities, once the base is installed.

Fig 4.1: Field depot and litter left behind by previous expeditions.

The ice sheet to the north of the Sør Rondane rises smoothly from the grounding line situated a few tens of kilometres South of the coastline of Breid Bay towards the first nunataks, where the surface attains 900 – 1000 m a.s.l. This inland slope area is well known and relative crevasse free due to the damming effect of the mountains and has been used in the past by Belgian and Japanese expedition members as main route from the coast towards the interior. It is entirely situated in the accumulation zone (average mass balance of 0.4 m of ice, Pattyn et al., 1992)

Breid Bay is a prominent feature on satellite images, situated over a – for Antarctica – relative shallow continental shelf (200-300m). It is also the place of a coastal polynia, characterised by the frequent occurrence of open water or low ice concentration between the fast ice and the pack ice during the whole year (Ishikawa, 1996). In summer an open water lead along the coast allows ice strengthened cargo ships to reach the coastline. Breid Bay is composed of several smaller inlets, in which the fast ice frequently stays until January.

The ice shelf to the south of Breid Bay moves in a NW direction at a relative slow speed of some 50 m/yr. Base Roi Baudouin was situated on this ice shelf at a distance of 11 km from one of the inlets (Leopold III Bay) and at an altitude of 38 m. Further to the east, where the sea floor has a depth of 400-700 m, the movement of the ice shelf is much greater reaching values of 200-350 m/yr (Pattyn et al., 2005), between the Roi Baudouin ice shelf and the ice rise further to the east (Derwael ice rise).

4.2 Geology

4.2.1 Geology of the Western Sør Rondane

Geological and geomorphological surveys of the western part of the mountains including the site area of the new base were performed by Belgian expeditions during 1958 to 1967 (Van Autenboer, 1969). Following the reconnaissance survey in 1984, Japanese expeditions conducted field surveys until 1991 (Kojima and Shiraishi, 1986; Shiraishi et al.,1991,1992) (see also **Fig. 3.1**).

The Sør Rondane Mountains are underlain by the late Proterozoic to Paleozoic igneous-metamorphic complex which is related to the formation of the Gondwana Super-continent. Outcrops in the western part of the Sør Rondane Mountains are represented by various kinds of metamorphic and plutonic rocks and minor mafic (dolerite) dykes. Amphibolite-facies gneisses derived from semi-pelitic and volcanic rocks are the dominant metamorphic rocks. Thin layers and lenses of calcareous and mafic rocks also occur in many places. Plutonic rocks which range from granite to diorite are sporadically distributed as masses and stocks of km size. Foliation of the gneisses generally strikes E-W and dips monoclinally to the south. The most remarkable major structural feature in the surrounding area is a pronounced E-W trending shear zone (Main Shear Zone). All rock types except for some granites and dyke rocks in the surrounding area show various degree of mylonitization.

4.2.2 Geology of the proposed station site

The outcrop of the proposed new station site is a northern extension of the Utsteinen Nunatak in the south (Van Autenboer and Loy, 1966). The outcrop, approx. 700 m long and 20-30 m wide, is predominantly composed of massive coarse-grained granite with minor xenolithic blocks of metamorphic rocks covering less than 10% of the outcrop. Exotic rocks and sediments (till and moraine) are negligible on the surface of the outcrop. In general granitic rocks tend to be easily weathered chemically and mechanically. However the granite in the present site is rather fresh suggesting recent (probably Holocene) exposure on surface. A set of joint system trending NNW and NE is dominant and the long and narrow outline of the outcrop is controlled by the NNW joint.

The granite is a part of the "Pingvinane granite" which is typically distributed in the Pingvinane Nunataks 10 km west of the site (Shiraishi et al., 1992). The granite is a typical alkali granite with coarse-grained equigranular texture. Mafic schlieren of 10-20 cm long are found in some places. The granite is composed mainly of K-feldspar (35-50 vol.%), quartz (20-45 vol.%), plagioclase (20-45 vol.%), hornblende and biotite (2-5 vol. %) with or without clinopyroxene (Li et al., 2003 a, b). Accessory minerals are Fe-Ti oxides, titanite, apatite and zircon. The Pingvinane granite generally has low magnetic values (3 to 8 10-4 SIU) corresponding to the ilmenite series (Shiraishi et al., 1992). The intrusive age of the granite is considered to be ~500 Ma estimated by the similar rock type in Pingvinane Nunataks. The granite contains xenolithic blocks and lenses up to several meters long in places. The boundary to the granite is sharp. They are quartz-feldspathic hornblende gneiss and amphibolite with banded and migmatitic structure.

Most of the granite along the ridge is relatively fresh and weathering only occurs over the top few centimetres. However, in some areas along the ridge the granite is more deeply weathered. These weathered zones can easily be observed from the three-dimensional view of the topography of the ridge as well, as they occur in these areas that are lying much lower. Here, the wind has weathered a large part of the rocks away. Due to the deeper weathering, the lower zones of the ridge can not support a construction without a lot of anchoring efforts. The building site is thus confined to the higher lying areas which have much better anchoring conditions (see **Section 2.2.2**).

4.3 Glaciology

Glaciological investigations were carried out by Belgian (1958-1967) and Japanese (1987-1991) field parties both on the ice shelf as in the mountains. They allowed among other things to estimate the total mass flux of ice through the mountain range (Van Autenboer and Decleir, 1974, 1978) and to map the subglacial topography of the central Sør Rondane (Pattyn and Decleir, 1995) but many parameters for a physical understanding of the glacier behaviour in the mountain range - as well as with respect to the adjacent ice shelf - are still unknown. This is even more so for the large and fast flowing ice streams contouring the damming mountain range, making the 20-30 degrees east sector one of the least known areas of the Antarctic ice sheet.

Since most of the ice flow coming from the polar plateau is blocked by the mountain range, many sheltered areas exists that are characterised by slow ice movements, as is the case with the proposed construction site. However, only a few measurements with respect to ice dynamics and mass balance have been carried out in the immediate vicinity of the Utsteinen site.

Table 4.1 lists accumulation rates and displacements measured between 2004 and 2005 for stakes set up close to the Utsteinen ridge (within 300 m). Since snow density measurements were not carried out, values are given in cm snow depth. Highest accumulation rates are found east and west from the ridge, around 45 cm/year (stakes I, II and IV). At the northern part, accumulation is half this value (20 cm/year), while in the South (stake V), ablation rules at a rate of approximately 10 cm/year. Here the snow layer is relatively thin and the stake lies in the proximity of a blue ice field.

Stake nr	Accumulation (cm snow/year)	Displacement (cm/year)
I (West)	42	5.5
II (West)	43.5	14.1
III (North)	24.5	8.7
IV (East)	47	26.2
V (South)	-9	8.0

Table 4.1: Snow accumulation and horizontal displacement obtained for the 5 stake positions near Utsteinen ridge.

Minimum displacement is found to be 5 cm/year (stake I), maximum displacement amounts to 26 cm/year (stake IV). These low values indicate that the whole area around the ridge is stable and hardly influenced by the overall ice sheet motion.

Ice thickness measurements were carried out along an East-West transect across the ridge. Ice thickness rapidly increases to 200 m in depth away from the ridge over a horizontal distance of 500 m. Furthermore, the ridge is asymmetric in shape. The western part is deeper than the eastern side at a same distance from the ridge. Such asymmetry is also observed near the ridge extending from Utsteinen Nunatak. Further away from the nunataks previous Belgian measurements (Van Autenboer and Decleir, 1978) indicate ice thicknesses of more than 1000m and a subglacial bedrock close to or even below sea level.

4.4 Climate

4.4.1 Air temperature

The temperature record from the AWS, installed during 2005 at the site of the new station (**Fig. 4.2**), is analogous to the 1987-91 series from Asuka station, situated 55 km further north-east and 466 m lower in height. Average temperature amounts to -18°C, varying between -8°C (December) and -25°C (September). This implies that the daily maximum does not exceed zero in summer, while the daily minimum reaches -36°C in winter (**Fig. 4.3**). Although this temperature regime is relatively mild as compared to the lower lying Asuka Station and to the temperatures observed at Base Roi Baudouin (-15°C, close to sea level and 173 km further north), the yearly variation of the temperature curve shows already the typical coreless winter character of the more continental stations. It is characterized by a rapid drop in temperature in fall, a first minimum in May, a second (more important) minimum in August-September and a very steep rise towards the December-January maximum. This coreless winter results from the specific radiation conditions during the polar night. At the new site the sun stays permanently below the horizon from May 16 to July 28 (73 days) but some twilight remains around noon, even at Midwinter.

Month	Pst (hPa)	Tm (degC)	Tx (degC)	Tn (degC)	Vm (m/s)	Vx (m/s)	D (deg)	D
Jan-05	**834.7**	**-8.7**	**-3.0**	**-16.8**	**4.9**	**19.2**	**99.5**	**E**
Feb-05	**825.0**	**-12.3**	**-7.0**	**-20.2**	**6.6**	**28.6**	**105.9**	**ESE**
Mar-05	**827.1**	**-15.5**	**-7.2**	**-24.1**	**5.8**	**26.7**	**123.1**	**ESE**
Apr-05	**824.4**	**-19.7**	**-11.8**	**-29.1**	**5.6**	**31.1**	**134.9**	**SE**
May-05	**824.2**	**-22.0**	**-15.2**	**-31.4**	**6.2**	**23.2**	**125.3**	**SE**
Jun-05	**831.0**	**-21.0**	**-13.9**	**-32.4**	**8.2**	**28.9**	**118.3**	**ESE**
Jul-05	**823.5**	**-23.2**	**-15.8**	**-30.8**		**32.9**		
Aug-05	**821.0**	**-23.3**	**-15.4**	**-34.0**	**5.1**	**18.8**	**122.5**	**ESE**
Sep-05	**818.2**	**-24.4**	**-16.8**	**-33.0**	**5.9**	**30.7**	**113.2**	**ESE**
Oct-05	**823.1**	**-21.0**	**-14.5**	**-35.5**	**5.2**	**26.5**	**124.3**	**SE**
Nov-05	**832.9**	**-15.0**	**-9.9**	**-20.9**	**4.5**	**20.9**	**99.4**	**E**
Dec-05	**842.1**	**-8.4**	**-1.4**	**-17.5**	**4.5**	**18.3**	**98.1**	**E**
2005	**827.1**	**-18.0**	**-1.4**	**-35.5**	**5.9**	**32.9**	**116.2**	**ESE**

Table 4.2: Meteorological observations from the Utsteinen automatic weather station (AWS) in 2005. Monthly mean air pressure (Pst), air temperature (Tm), monthly maximum (Tx) and minimum (Tn) air temperatures, monthly mean wind speed (Vm) and wind direction (D), and monthly maximum wind speed (Vx). Mean wind speed in July is not given due to lack of measurements (temporary instrument failure).

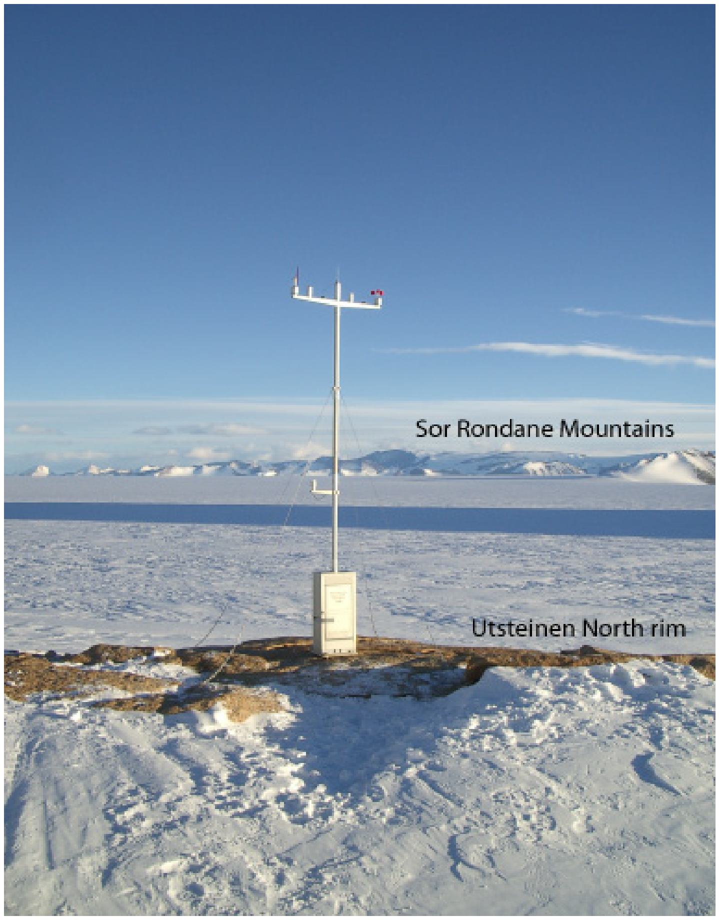


Fig 4.2: Automatic Weather Station, installed during the Belare 2005 expedition on the Utsteinen Ridge, with the Sør Rondane Mountains in the background.

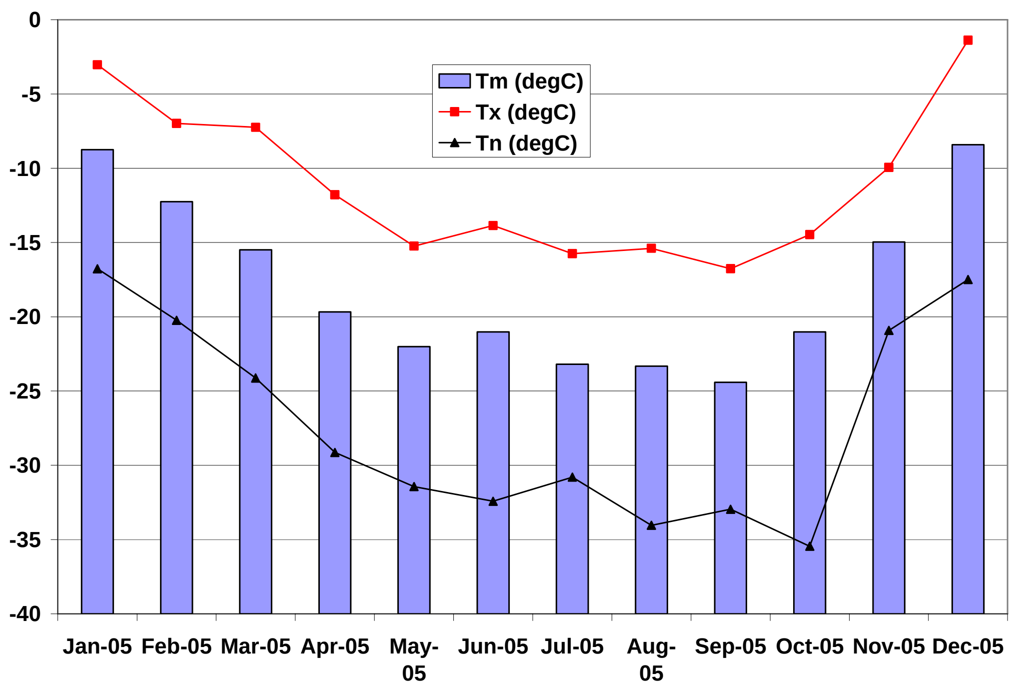


Fig 4.3: Monthly mean air temperature (Tm) at Utsteinen in 2005.
Monthly minima (Tn) and maxima (Tx) are given as well.

4.4.2 Wind speed and direction

Utsteinen ridge benefits from the protection of the mountains and is, due to its position at the western side of the range, less influenced by high katabatic wind speeds. Nevertheless, the site is not over-protected as it protrudes northwards from the northern rim of nunataks and therefore benefits from a more constant wind flow that might be useful from an energetic point of view. The mean wind speed recorded at Utsteinen amounts to 6 m/s, which is half the value of the mean wind speed recorded at Asuka Station, situated at 55 km to the Northeast. Mean summer wind speeds are around 4.5 m/s (**Fig. 4.3**).

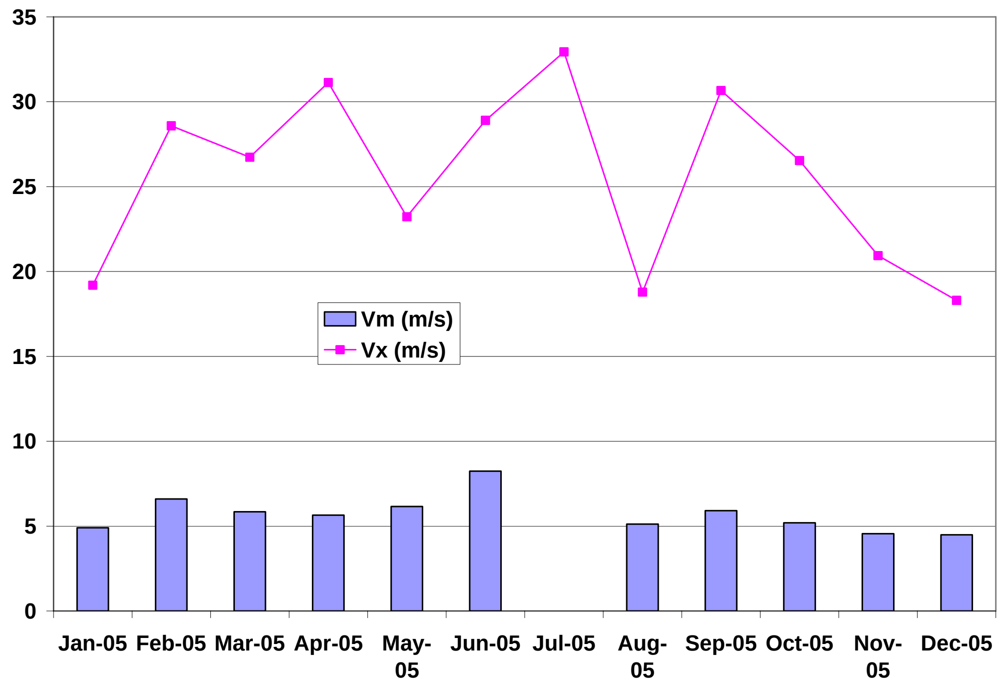


Fig 4.4: Monthly mean wind speed (Vm) at the Utsteinen site in 2005. Maximum recorded wind gusts (Vx) are given as well.

The main wind direction at Utsteinen is from the East, which is a katabatic wind regime coming from Jenningsbreen, one of the major outlet glaciers that cut through the range. Somewhat less frequent are winds from the SE direction, coming from Gunnestadbreen, the outlet glacier that lies closest to the site (**Fig. 4.5**). The whole sector E to SSE accounts for more than 90% of winds at Utsteinen. More variable winds occur only at very low wind speeds, which shows that the katabatic wind regime is dominant. Higher wind speeds (> 15 m/s) mostly come form the E and ESE (80%) The near absence of a northerly component indicates that near the surface the climate is seldom reached by cyclones or air masses associated with the low pressure trough bordering Antarctica.

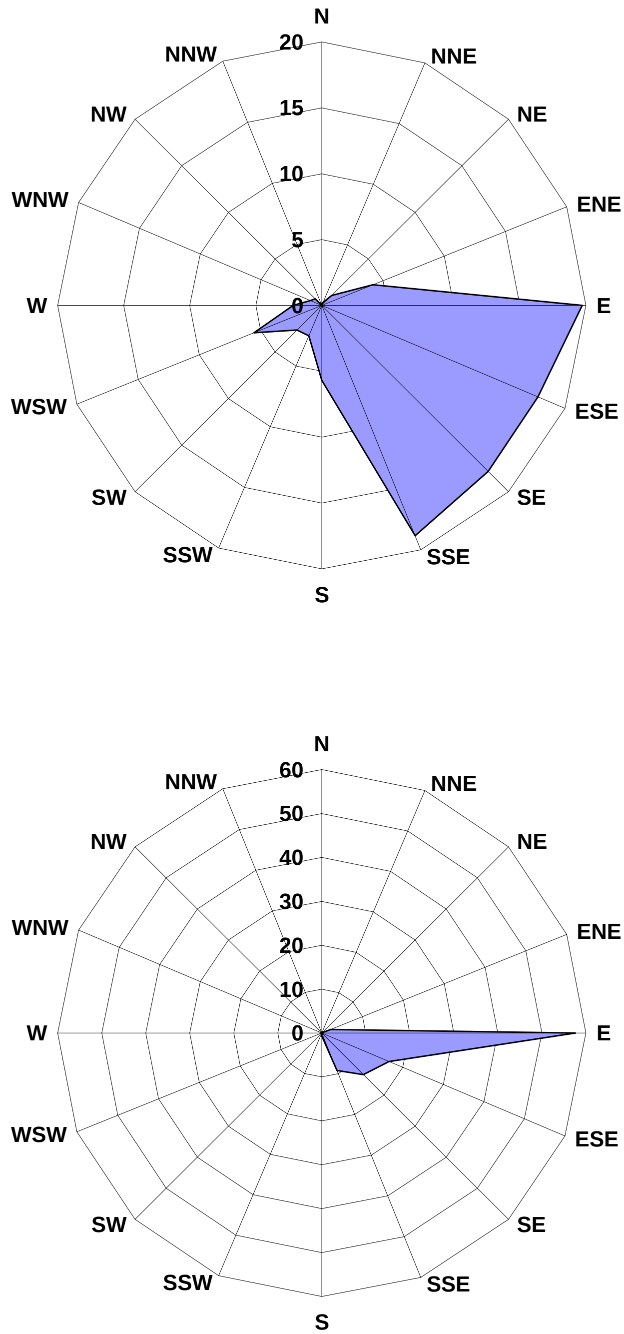


Fig 4.5: Frequency of winds (upper panel) and winds stronger than 15 m/s (bottom panel). Values are given in %.

4.4.3 Atmospheric pressure

Atmospheric pressure variations at Utsteinen are relatively constant in time while oscillating around a mean value of 827 hPa, which underscores the fact that coastal cyclonic activity hardly influences the site. With exception of low pressure values in August and September, all variations are within 20 hPa. The yearly pressure curve lacks the double minima observed at most coastal stations.

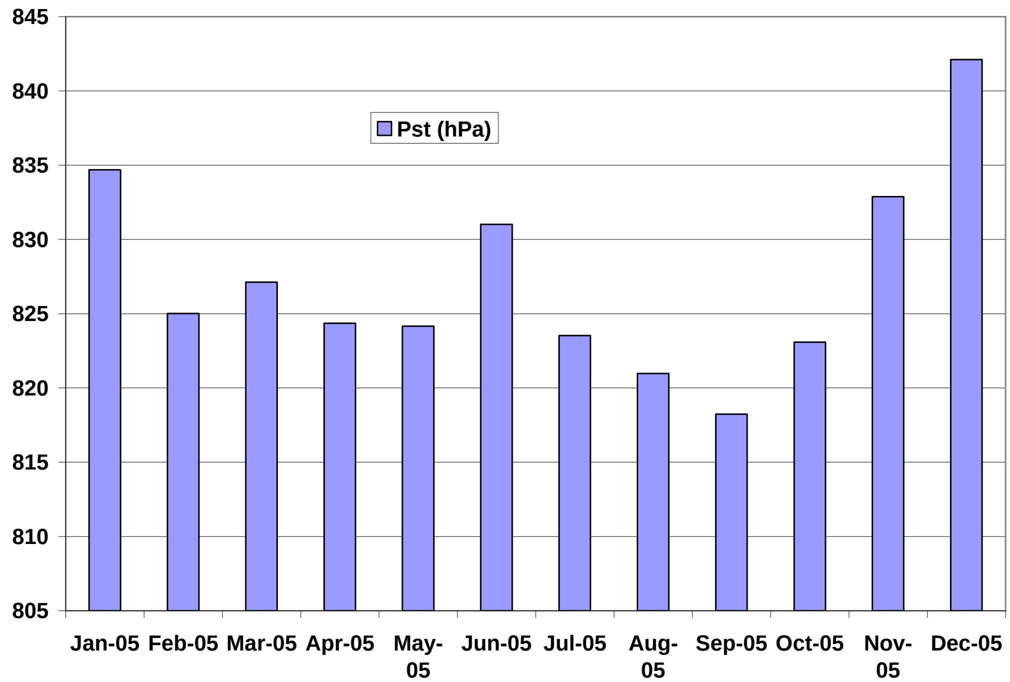


Fig 4.6: Monthly mean atmospheric pressure observed at Utsteinen during 2005**.**

4.4.4 Conclusion:

The one year record of the AWS at Utsteinen confirms what was already known from reports of field parties in the past, i.e. the relative mild climate (high temperature and low wind speed) of the Western part of the Sør Rondane, being optimal for field work in summertime. The yearly variation of the climatic elements on the other hand points towards the continental character of the climate. Considering the very few stations in the continental interior, the climatic record of the new Belgian station will contribute to a better understanding of the East Antarctic climate.

4.5 Baseline monitoring information

The Environmental Protocol includes requirements to undertake regular and effective monitoring of the impacts of ongoing activities and verification of the predicted impacts. Environmental monitoring is also required to facilitate early detection of possible unforeseen effects of activities.

A baseline study was performed on soil, snow/ice and lichen samples taken from the Utsteinen Ridge during the Belare 2004 and Belare 2005 site survey expeditions, in order to obtain reliable data about the initial clean state of the environment and to establish the "footprint" of the station.

Sampling was performed following the guidelines from the COMNAP and SCAR "Antarctic Environmental Monitoring Handbook" and analysed for the following indicators:

- Soil: total carbon, organic and inorganic carbon; total petroleum hydrocarbons (TPH); metals (Al, Cr; K, Sb, Co, Se, As, Cu, Ag, Ba, Fe, Na, Be, Pb, Tl, Cd, Mg, V, Ca, Mn, Zn, Ni, S, Hg); polycyclic aromatic hydrocarbons

- Snow/ice: metals (Al, Cr; K, Sb, Co, Se, As, Cu, Ag, Ba, Fe, Na, Be, Pb, Tl, Cd, Mg, V, Ca, Mn, Zn, Ni, S, Hg); total petroleum hydrocarbons (TPH); particulates

- Lichens: metals (Al, Cr; K, Sb, Co, Se, As, Cu, Ag, Ba, Fe, Na, Be, Pb, Tl, Cd, Mg, V, Ca, Mn, Zn, Ni, S, Hg)

An overview of the soil and snow samples and preliminary analyses results are given in **Tables 12.4, 12.5 and 12.6**.

Sample results show that the Utsteinen site is indeed pristine, with no indication of previous human impact. These baseline analyses results can therefore be used as reference values within the environmental monitoring program that will be set-up once the station is operational. The general objectives of the monitoring program will be:

- detect, measure and monitor future environmental changes,
- verify predictions on the effect of human activities,
- detect possible unforeseen effects of human activities,
- assess the consequences of regulatory mechanisms and operating and managing facilities,
- establish the environmental status of the Antarctic environment.

4.6 Flora and Fauna

Biological research studies conducted in the Sør Rondane area are limited in number and studies at the construction site are non-existent.

4.6.1 Flora

On the Utsteinen Ridge, only a few Lichens were found, however, they are quite abundant on the Nunatak itself.

Three different species were detected, the same on both the Ridge and the Nunatak:

- *Umbilicaria aprina* Nyl.
- *Candelariella* sp. (indeterminable in absence of apothecia)
- *Caloplaca regalis* (Vain.) Zahlbr.

Fig 4.7: Lichen *Umbilicaria aprina* Nyl.

Fig 4.8 : Lichen *Candelariella* sp.

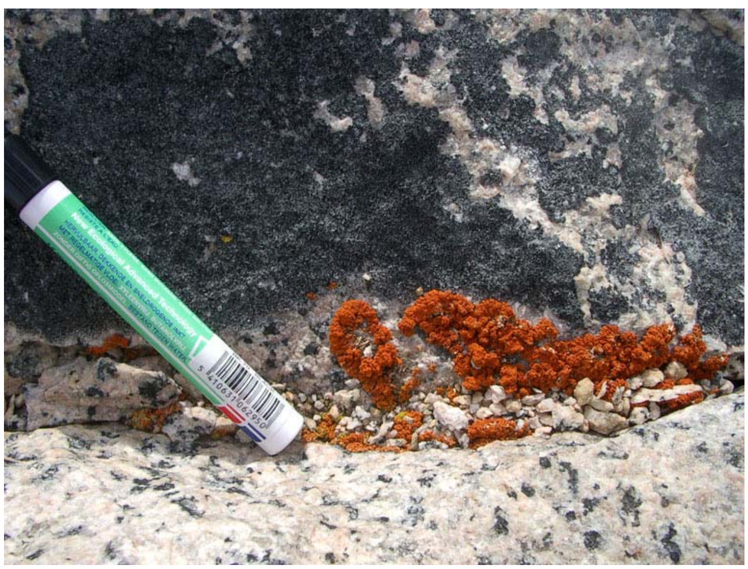


Fig 4.9: Lichen *Caloplaca regalis*

4.6.2 Vertebrate Fauna

Published data on the breeding distribution of Antarctic (sea)birds in the Sør Rondane region are very limited. The vertebrate fauna in the vicinity of the station consists of birds only: snow petrel (*Pagodroma nivea*) and Antarctic skua (*Catharacta maccormicki*).

There may be breeding colonies of Weddell seals (*Leptonychotes weddellii*) at various locations on the fast ice beside the ice front of Prinsesse Ragnhild Kyst. The offlying pack ice may support breeding populations of crabeater seal (*Lobodon carcinophaga*), Ross seal (*Ommatophoca rossii*) and leopard seal (*Hydrurga leptonyx*). During summer, coastal waters may be visited by baleen whales and toothed whales. These whale species do not breed in the region but visit the area to feed.

There are no observations of Penguin rookeries at Breid Bay, neither from all the working years of the Roi Baudouin base nor during the Belare 2005 expedition.

Snow petrel (Pagodroma nivea)

Very few data on breeding sites of snow petrels in Antarctica are available from literature. In general, colony sizes seem to range from single pairs to an estimated 20.000 pairs. Snow petrels breed amongst others on areas of exposed rock which may be as much as 300 km from the open sea during the breeding season. The colony farthest inland is in the Tottanfjella, Dronning Maud Land. The colony closest to the construction site recorded in the literature is at Pingvinane (72°00'S, 25°00'E), estimated at about 100 breeding pairs in 1959-1961 (Croxall et al, 1995).

Some snow petrel pairs are breeding on the steep slopes of Utsteinen Nunatak, at a distance of about 1 km from the new station construction site. It is extremely difficult to get an accurate census of breeding pairs. During the two site survey expeditions it was estimated that the small colony is made up of no more then 50 pairs. Most of the nests are high up the Nunatak slopes and thus difficult to access.

Snow petrels return to the nest sites in November about the time of the proposed start of station activities. One egg is laid in late November to mid-December and incubated for 41-49 days. The chick remains in the nest for an additional 7 weeks. Snow petrel chicks leave the nest in late February to mid-May, when the proposed station will have closed for the winter.

In order to complete and update the database on breeding distribution of the snow petrel for the SCAR Bird Biology Expert Group, additional relevant data from the Utsteinen Nunatak breeding site will be forwarded to the Expert Group. The breeding site will not be visited unless related to approved scientific research.

Fig 4.10: Snow petrel at Utsteinen Nunatak

Weddell seal (Leptonychotes weddellii)

During the over-land survey of the coast and access route to Utsteinen (Belare 2005), a breeding colony of Weddell seals was spotted at Breid Bay, the future unloading site for construction and yearly provisioning.

The number of individuals was estimated at about two hundred, including females and pups basking on the ice, next to openings through which they could slide into the water.

Females give birth to one pup per year in October. Mothers care for them for six weeks, after which they are weaned and on their own. Ship operations for the station at Breid Bay, including construction operations, will take place end of December to beginning of January and will thus not interfere with the breeding season of the seals. Adult and juvenile seals may haul out onto sea ice at any time of year, and will typically bask near tide cracks or the ice edge. Their usual response to noise or activity is to return to the water.

Fig 4.11: Weddell seal mother and pup at Breid Bay

4.6.3 Invertebrate Fauna

During Japanese Research Expeditions (JARE), several terrestrial invertebrate species were discovered living in the western and central part of the Sør Rondane Mountains, including one springtail and several mite species (Hiruta and Ohyama, 1995). Most of these areas supported rookeries of snow petrel, indicating a relationship between the rookeries, plant communities and soil animals.

At the construction site, no invertebrates were recorded, but may possibly be found near the small Snow Petrel breeding site at the Utsteinen Nunatak.

4.7 Tourism

There has been very limited non-governmental activity in the Sør Rondane region. One or two expeditions have visited, notably a four man expedition in 1996–1997 to climb peaks lying to the west of Byrdbreen in the eastern Sør Rondane. The expedition was serviced by a non-government organisation that also searched for alternative blue-ice runways in the Sør Rondane region. The mountains of the Sør Rondane continue to have an interest for expeditions, however, the costs associated with reaching the area tend to restrict activity.

4.8 Protected Areas and Historic Sites and Monuments

There are no Antarctic Specially Protected or Managed areas (ASPA's or ASMA's) or Historic Sites and Monuments in the region of the proposed Belgium Station. The nearest ASPA's being ASPA Nr 142 (Svarthamaren, Mühlig-Hofmannfjella (71°54'S; 05°10'E)) to the West and ASPA Nr 141 (Yukidori Valley, Langhovde, Lützow-Holmbukta (69°14'S; 33°45'E)) to the East.

The DROMLAN link has been used for access to the Sør Rondane region for preliminary studies. The link may be used for some of the building crew during the construction phase or scientists and station staff during the operational phase. The following Historic Site and Monument is situated near to the Novolazarevskaya airfield used by the DROMLAN link:

Historic Site and Monument No. 44: A plaque erected at the temporary Indian station, Dakshin Gangotri, 70º45'S 11º38'E, marks the First Indian Antarctic Expedition.

4.9 Prediction of the future environmental reference state in the absence of the proposed activity

The site of the new station is on the north ridge of Utsteinen Nunatak. There has been previous human activity in the area resulting from survey and research programmes run at Asuka (Japan) and Roi Baudouin (Belgium) stations. There have also been two recent visits to the area undertaken by Belspo/IPF in order to identify likely sites and to collect baseline data.

Although there are some records of previous operations at the proposed station area, no signs of such human activities were recorded during the 2004 and 2005 visits.

In the absence of the proposed activity, the near pristine state of the regions will be maintained and the aesthetic and wilderness values will be unaffected. It is likely that periglacial processes will continue at the site shaping the geomorphology of the region and breeding bird species will continue to occupy suitable nest sites.

The ice shelves of Prinsesse Ragnhild Kyst, where unloading of construction materials will take place, are an active ice front that continually refreshes itself.

5. LIKELY IMPACTS, ASSESSMENT, MINIMISATION AND MITIGATION OF THE PROPOSED ACTIVITIES

The following section identifies the direct effects on the environment of the proposed station construction, operation and logistic support activities described in **Section 2**. The Source–Pathway–Receptor process has been used to assess origins and outputs of activities and their likely environmental effects. Minimisation and mitigation measures to reduce these impacts are then described. The assumption is made that the minimisation and mitigation measures described will be applied. Finally, a summary of the impacts and mitigating measures is given in the impact matrix **Table 5.4** in **Section 5.13**.

The main sources of direct impacts are:

- construction activities
- emissions and fuel spills
- grey water
- noise
- impacts resulting from visitor disturbance

Indirect impacts are described in **Section 6**.

5.1 Methodologies

Likely Impacts are assessed qualitatively in **Sections 5.3-5.12** using the criteria outlined below. These criteria are used in the impact matrix in **Section 5.13**.

Nature
The nature of the impact caused by the activity on potential receptors.

Scope
The geographical area affected by the impact in local, regional or continental terms.

Persistence
The duration of the impact and whether it is likely to be short-term (minutes–hours), medium-term (days–weeks), long-term (months–years), permanent or unknown. There may be a lag time between when the output occurs and the time of the impacts.

Intensity
The overall severity of the impact is assessed in relative terms (low, medium or high).

Probability
The likelihood of the impact occurring. This is assessed as low (<25% probability), medium (25–75% probability), high (>75% probability).

Importance
The overall importance of the impact is assessed in relative terms (low, medium or high).

Description of effect.
This categorises qualitatively the direct, indirect and cumulative effects of the specific impact. Three types of impact categories are specified in Article 3 of Annex I of the Environmental Protocol and the CEP (2005) definition of each category is adopted for this CEE.

(1) *Direct Effects*: Any first order effect, impact or consequence that may be associated with an activity. For example, acute toxicity effects (mortality) in marine birds, or in intertidal limpets, or in pelagic krill caused by exposure to toxic constituents of petroleum products spilt at sea.

(2) *Indirect and Second Order Effects*: Any second order effect, impact or consequence that may be causally associated with an activity. For example, particulate emissions from combustion leading to melting of ice or snow that subsequently causes loss of ice or snow algae habitat.

(3) *Cumulative Impacts*: Effects, impact, or consequences that may come from similar or varied sources, but that are additive, antagonistic or synergistic in their effect, impact or consequence. For example, disturbance to nesting skuas caused by existing scientific use and by a proposed use.

5.2 Source, Pathways and Receptors

The Source-Pathway-Receptor principle has been used for the identification and likely result of impacts resulting from activities. This is in accord with the Environmental Protocol, which recognises that impacts may be greater, for example, where waste products are carried to areas of high ablation (Environmental Protocol Annex III, Art 4(2)).

The proposed location of the station is in an area of limited rock outcrops, where there is the possibility of waste produced or emissions generated in one area, flowing along a pathway to another. The Protocol recognises ice as a pathway but here are also transient pathways such as seasonal melt water that may carry pollutants between sources and receptors.

5.3 Atmospheric Emissions

The station has been designed for minimum energy requirement and maximum use of renewable resources. The fossil fuel requirement for operation of the station will, therefore, be kept as low as possible. There may be greater fossil fuel requirements during the construction phase until the station becomes operational.

Fuels used will include:

- Aviation kerosene, Jet A1 (air transport, tractors, heating)
- Unleaded gasoline (snowmobiles, generators)
- White gas (small stoves)
- Propane(larger stoves)
- Lubricants and hydraulic oils (mechanical equipment and vehicles)

Atmospheric emissions during the construction of the station will come primarily from the combustion of fossil fuels during the transport of materials and the construction of the station. A minor amount of fugitive emissions will occur during fuelling activities. During the operational phase transport and fuel spills will be the main source of emissions.

The geographical area affected will include the route of the ship, the unloading site at Breid Bay, the traverse route, aircraft flight routes and the station area. Areas visited during scientific fieldwork will also be affected.

Estimate of fuel usage

The major use of fuel during the construction phase will be for transport. Fuel will be used for ship transport to the ice edge, by the tractors to transport materials to the station, and, locally, at the station by vehicles and generators. Fuel will also be used for flights for the input of personnel.

The operational phase will require fuel for the annual re-supply of the station by ship, local transport from the ship to the station (by helicopter and/or tractors) and for local and scientific field transport. It is envisaged that the fuel requirements for station operation (excluding transport) will be minimal and the ultimate aim is to operate the station using only renewable energy sources.

There are limited data available to estimate fuel use for the above activities. Figures from other station construction activities by other national operators have been used to estimate fuel consumption:

Fuel type and use	Construction (litres)	Operation (litres) per year
Jet A1 (Flight within Antarctica)	8,000	4,000
Jet A1 (Land transport)	17,000	5,000
Jet A1 (Power Generation)	8,000	100-2,500
Unleaded Gasoline (Land Transport)	2,000	2,000
White gas / propane (Cooking and heating)	Not known	Not known

Table 5.1: Estimates of fuel use for construction and operation of the station (litres)

Fuel amounts are relatively low compared to other Antarctic operations because of the small scale of the proposed station and the philosophy to minimise fuel requirements.

Fuel consumption for shipping has not been included as it is not yet known which ship will be used for construction or operational phases, and to what extent that ship might be deviating from its usual operational activities. However, it is acknowledged that shipping accounts for significant air emissions due to the high amount of fuel burnt.

Fuel use during intercontinental flight has also not been included. Fuel consumption during these flights will be reported by the DROMLAN operator to the relevant authority.

Air and ship transport to Antarctica

Ship and air transport used in the construction and operation of the Belgian research station will be negotiated on a year by year basis, using the facilities of existing operators in the area. For shipping, the environmental impacts will therefore be based on the additional amount of cargo carried and the deviation from the ship's normal itinerary. The impact of air transport (DROMLAN and local) depends on the amount of people and cargo transported, but the use of existing facilities has environmental benefits.

Emissions during passage to Antarctica by ship and aircraft will be rapidly dispersed and are unlikely to have any significant impact on wildlife, marine or air quality.

Coast

The time the supply ship will spend berthed at the coast during unloading operations will depend on a variety of factors including sea ice and weather conditions, and the speed at which construction materials can be moved to the station location. Emission calculations have been based on an estimated period of 10 days during which there will be ship and vehicle activity at the coastline.

In the operational phase, re-supply of the station by ship should take around 1–2 days only.

Emissions at the coastline will be rapidly dispersed and are unlikely to have any significant impact on wildlife, marine systems or air quality.

Traverse route

Fuel will be used by vehicles in transporting construction materials, stores and personnel between the ship and the station location. There will be emissions to air along the route to the station that will be repeated each year but at a reduced level once the station is operational. Emissions to air will be rapidly dispersed although there may be local areas of increased concentration where tractors stop, fuel or are allowed to idle for long periods.

Ship unloading during the operational phase may be assisted by helicopter depending on the facilities available on the ship.

Station

Emissions to air at the station location will be greatest during the construction phase due to increased vehicle activity and the use of fossil fuels by the construction camp. Once operational, emissions to air will reduce significantly, although there will continue to be limited vehicle and flight activity at the station in support of scientific work and to re-supply the station. Very low quantities of CO_2 will be produced by the waste water treatment system.

Fall out from combustion products generated at the station locality may result in impacting the flora and breeding bird colonies on Utsteinen Nunatak and the surrounding snow and ice. There is the possibility of cumulative impacts to these systems during the lifetime of the station. The Sør Rondane are noted for frequent and persistent winds. At Utsteinen Nunatak they are from an E to SSE direction (see **Section 4.4** Climate) so emissions to air will normally be dispersed away from the Nunatak and the Sør Rondane generally.

Heavy particulates, such as carbon soot, may deposit a short distance down-wind from the station and may have an impact on future ice-related research. Studies at other stations have shown that downwind contamination of snow and ice rapidly reduces to background levels within 10 km of the origin (Suttie and Wolff, 1993).

Predicted atmospheric emissions

Based on the estimates of fuel use given above and in **Table 5.1**, atmospheric emissions have been calculated and are shown in **Table 5.2**:

Emission	Construction (tonnes)			Totals (tonnes)
	Air transport	Land transport	Generators	
CO_2	20.317	49.841	17.46	87.618
CO	0.033	0.421	0.005	0.459
NO_x	0.013	0.592	0.02	0.625
N_2O	0.0014	0.0034	0.0014	0.0062
SO_x	0.038	0.082	0.038	0.158
CH_4	0.0006	0.0035	0.0004	0.0045
VOC	0.005	0.084	0.004	0.093

Total calculated atmospheric emissions for the construction phase

Emission	Operation (tonnes per year)			Totals (tonnes per year)
	Air transport	Land transport	Generators	
CO_2	10.159	17.404	5.456	33.019
CO	0.017	0.147	0.002	0.166
NO_x	0.04	0.207	0.006	0.253
N_2O	0.0007	0.0012	0.0004	0.0023
SO_x	0.019	0.024	0.012	0.055
CH_4	0.0003	0.0013	0.0001	0.0017
VOC	0.003	0.029	0.001	0.033

Calculated annual atmospheric emissions for the operation of the station

Table 5.2: Calculated atmospheric emissions
Notes: Weight fraction of Sulphur in fuel used for SOx calculation = 0.3% by weight for Jet-A1 and 0.02% by weight for unleaded gasoline ; Density of Jet-A1 = 0.795 kg l-1; Density of unleaded gasoline = 0.735 kg l-1 (Emission factors from Shah and Pope, 1994)

There is a high level of uncertainty in the estimation of emissions from the above activities and emissions will vary depending on temperature and specific fuel and engine characteristics.

Impact of emissions

Use of fossil fuels will generate combustion products including CO_2, SO_2, NO_x and particulate matter. The impacts from these emissions will depend on the location at which they are generated. As most of the emissions will be from transport, they will be rapidly dispersed.

Impacts will only occur during the summer months, and are of a relatively low intensity. The predicted impacts are contamination of snow, ice and rock surfaces which may affect biota. This may result in a loss in scientific value of the affected areas. Particulate matter may remain in the snow/ice for thousands of years and could affect a down-stream environment on release to the ocean. Measurements at the proposed site indicate that there is relatively little ice movement (see **Section 4.3**).

Atmospheric emissions are cumulative and certain gases emitted may contribute to regional and global atmospheric pollution.

Minimisation and Mitigation

When negotiating the use of shipping and aircraft, environmental considerations will be taken into account. For example, a supply vessel which uses Marine Gas Oil (not heavy fuel oils) and which complies with MARPOL Annex VI on air emissions would be preferred. The overall environmental impact of 'sharing' shipping and aircraft facilities is very much reduced compared to having dedicated facilities.

During the unloading and construction phase the quantity and quality of emissions to air will be minimised by the use of energy conservation practices, including minimal use of vehicles and aircraft, not leaving vehicles and aircraft idling for long periods, and use of clean fuels where ever practicable (such as low sulphur fuels).

During the construction phase it is planned to use twelve sledges and six vehicles - of which 3 tractors - to transport materials from the ship to the construction site, so that the tractors can run almost continuously during the operation. Sledges will be pre-loaded at the coast ready for pick-up and a loaded sledge can then be exchanged for an empty sledge at the construction site without any delay. This will also give plenty of time for the loading and unloading of sledges, thus reducing the probability of accidents and mistakes. In addition, it will reduce idling time and will reduce the potential for increased concentrations of emissions at loading and unloading points.

Vehicles will be chosen based on their fuel efficiency and environmental performance where possible. They will be maintained to high standards and serviced regularly. Where practical, catalytic converters will be fitted to reduce output of contaminants. Only two heavy vehicles will be used during the operational phase.

The station has been designed with a low energy requirement with a focus on using solar or wind generation wherever possible to minimise the use of fossil fuels during operation. There will be a continuous process during the operation of the station to reduce its energy requirement by the use of energy conservation measures and investigation of alternative energy solutions to further reduce the use of fossil fuels.

The station site is also being designed to minimise the requirement for mechanised transport for station operations.

5.4 Fuel and Oil Spills

A variety of fuels and lubricating and hydraulic oils will be used during the transport, construction and operation of the station. The type of fuels and oils include aviation kerosene (Jet A1), unleaded gasoline, white gas, propane and minor quantities of oils.

Most fuels will be transported in bulk in $12m^3$ sledge-based bunded bulk fuel tanks. Some fuel and oils will also be transported in UN classified 205 litre tight-head drums. Small cans (20 litres) will be used at the station and during field work for storage and transportation of smaller quantities of fuel.

Fuel and oil spills may occur during maintenance and fuelling of aircraft, vehicles, generators, stoves and heaters, and by leakage from bulk fuel tanks, depoted drums or small cans. Fuelling of vehicles and leakage from damaged drums are the most likely sources of fuel spills.

Most spills are likely to be less than 5 litres and the maximum risk is the loss of a bulk fuel tank. Damage to the supply vessel at the coast could lead to a large fuel spill.

Fuel is relatively volatile and spills will rapidly evaporate but a waxy residue may remain. There will be some fugitive emissions dependent on the scale of the spill. Fuel spills on snow will migrate downwards to an ice layer where the fuel will be encapsulated and remain in the ice until point of release. Released contaminants could, therefore, affect a downstream environment, most likely marine, in the future. Once released in the ocean, the fuel would rapidly disperse.

Spills on rock exposures may have a biological effect on cryptogamic flora. Fuel spills may also lead to contamination of any soil layer. Spills during the transport and construction phases may have an indirect effect on the scientific value of the area during the operational phase. Over time, fuel spills will contribute to the cumulative effects of the station.

Minimisation and Mitigation

Standard procedures will be developed for the transport, handling, transfer and use of fuels (see also **Section 2.4.17**: documentation). The underlying structure of these procedures will be the prevention of fuel spills by use of the correct equipment, minimising handling and transfer of fuels, secondary containment and staff training.

Fuel tanks will be sited where they are least likely to be damaged and fuel drum depots will be clearly marked to avoid loss of fuel or collision with drums.

Minimisation of spills during fuelling activities, the most likely time for minor spills, will be managed by identifying fuelling points that have suitable absorbent mats, spill containment and clean-up equipment. Proprietary secondary containment drum stands will be used for fuel transfers, for example when fuelling snowmobiles and stoves.

An Oil Spill Contingency Plan will be prepared for the transport and construction phases, and a separate plan prepared for operation of the station. Staff involved in refuelling operations will be trained appropriately and spill response exercises will be held. Fuel handling and spill response procedures will be regularly audited. All spills will be reported to the Project Manager (construction) or Station Manager (operation) and will be recorded for monitoring purposes.

5.5 Domestic Waste Water ('Grey' water)

Domestic waste water (grey water) will result from washing, food preparation and ablution activities. It does not include any solid waste from human, food, or garbage wastes.

There are limited data for grey water output at stations. Mäkitalo (1992) and Markland (1990) recorded average waste water output of 60 litres per day per person at Wasa Station, Basen Nunatak, a seasonally occupied permanent facility with sauna, showers and low-water consumption dishwashers and washing machines. Neumayer II station (Germany), Ekström Ice Shelf, estimated an average of 117 litres per day per person (Enss, 2004). Neumayer II is a year-round station with a winter population of 10–12, rising to 25–30 in summer. The year round US Amundsen–Scott South Pole station estimates 95 litres per day per person (summer population of 230–235; NSF, 2004).

The proposed station will be designed to minimise generation of grey water with a further objective of no grey water output. It is accepted, however, that during construction and initial operation there may be some grey water discharge.

Grey water will be discharged to a designated area on the lee-side of Utsteinen Ridge where there is a naturally formed fissure between the rock outcrop and permanent ice (randkluft). Discharge sites will be marked and the locations recorded. Care will be taken that no grey water discharges are made in the vicinity of wildlife or onto ice-free surfaces.

All grey water will be filtered at the station before disposal to remove solid material. Residues from filtration will be collected and removed from Antarctica. Due to the use of the 'randkluft', there will be no surface discharge of grey water either to the snow surface or to exposed rock outcrops. Discharging grey water into the 'randkluft' will contain it in a restricted area where it will freeze. **Section 4.3** shows that there is limited ice movement and discharged grey water is unlikely to be transported to other areas. An overview of the expected effluent quality of the grey water is given in **Section 12**, **Table 12.3.**

The direct effect of grey water disposal will be contamination of the underlying snow and ice. Grey water will have a local scope and low intensity but a long-term persistence and is therefore assessed to be of low–medium importance. Contaminated ice may eventually flow to the coast over a period of tens of thousands of years, where it will be diluted and dispersed as it enters the marine environment. The indirect and cumulative effect will be the spread of the contaminated area and a reduction in scientific value of the contaminated ice.

Minimisation and Mitigation

The station design will specify no grey water output. This will be achieved by two processes. The first is to reduce the water requirement of the station by only using consumer units that have low to extremely low water needs. Second, all grey water output will be collected, treated and, as far as practicable, recycled. The recycled water will be used for non-potable applications.

It is recognised that technologies for zero grey water output are still relatively unproven. During construction and the initial period of operation, all grey water will be collected, filtered and treated as far as practicable but there will be a limited grey water discharge. The construction camp will be organised so that grey water is collected at designated locations for filtering and treatment before disposal.

5.6 Solid Waste

Construction phase

Substantial quantities of non-hazardous solid waste will be generated during the construction of the station. The largest part of this will be packaging and construction materials, including metals, plastics, glass and wood.

Construction will also generate limited quantities of hazardous waste, such as adhesives, batteries, solvents, oily wastes and paints. Solid sewage and food garbage will also be generated. Estimates for the amounts of wastes that may be generated will not be possible until details of the design and construction methods have been finalised.

If not securely contained, waste materials may be blown away by strong winds, buried by snow fall or scavenged by skuas. If not properly managed, solid waste may have a direct effect as litter or have a biological effect on fauna. Solid waste may also have an indirect effect on the future scientific value of the area.

Minimisation and Mitigation

Minimisation will be achieved by
- Prefabrication of structures before shipping to Antarctica.
- Reduction of packaging where practicable.
- No prohibited products (listed in Annex III of the Environmental Protocol) brought to Antarctica.
- Sorting and labelling of all waste and putting into a designated shipping container ready for removal and to prevent wind dispersal or scavenging.
- Removal from Antarctica and reused, recycled or correctly disposed by licensed contractors.
- Weekly inspections will be made to retrieve any litter around the construction area or blown downwind.
- Solid sewage waste and food waste will be stored securely and removed from Antarctica.

A Waste Management Plan will be prepared for construction activities.

Operational phase

Solid wastes will be generated during the operational phase and will fall into the following categories as defined in Annex III (Art. 8) of the Environmental Protocol:

- Sewage (Group 1)
- Garbage (Groups 3 and 4: metals, plastic, paper, wood, glass, etc.)
- Fuel drums (Group 4)
- Food waste (Group 3 or 4)
- Hazardous or special waste (Group 2: oils, oily rags, etc.; Group 4: batteries.)
- Scientific waste

Data from year round stations indicate an annual solid waste output of 2–3 m^3 per person (Enss, 2004; NSF, 2004; BAS, 2005). The likely output from the proposed summer only station will be less than 1 m^3 per person.

If not correctly managed, some waste may be scattered by winds or buried by snowfall. Wastes could be scavenged by the local avian population or contaminate exposed rock surfaces and flora if not contained.

Activities at remote scientific sites will generate human waste that may, occasionally, be disposed of locally.

Minimisation and Mitigation

A Waste Management Plan (WMP) will be prepared to document the procedures for the collection, storage, reduction, recycling and disposal of wastes (see **Section 2.7**). A principle measure in the WMP will be minimisation of packaging brought to Antarctica as this has been shown to be a primary source of solid wastes (Enss, 2004; BAS, 2005). Waste items will be re-used and recycled as much as possible. The WMP will also deal with the disposal of wastes outside Antarctica, which is likely to be through a licensed waste contractor in Cape Town.

The amount of hazardous materials brought to the station will be kept to an absolute minimum.

The proximity of breeding bird species requires that food wastes are managed particularly carefully. Only certified poultry food products will be brought into Antarctica and all food wastes will be stored in secure containers prior to removal.

Solid sewage waste will initially be shipped out of Antarctica. However, it is planned that a treatment system, which is integrated with the water recycling system, will be used in the future. Wherever practical, human waste generated at remote scientific camps will be returned to the station for correct disposal.

All waste will be sorted and stored in a shipping container at the station. A member of each summer team will be designated as Waste Management Officer, responsible for implementing correct waste procedures. All station personnel will be briefed on waste management procedures and there will be regular inspections to collect any litter around the station and identify any potential sources of litter.

5.7 Noise

Noise will be generated by:

- Ship and cargo activity at the ice shelf
- Station operation
- Scientific activity

- Aircraft operation
- Land transport
- Wind turbines

Breeding bird species that nest in the Sør Rondane nunataks and seals breeding on the fast ice adjacent to the ice shelf may be disturbed by noise. The coastal lead may be used by feeding birds, seals and whales. Disturbance may result in a temporary increase in metabolic rate and consequent energy expenditure.

Breeding birds in the Sør Rondane nunataks are at the extreme edge of their range. Noise (or physical) disturbance resulting from the station, wind turbines, transport or scientific activity may result in loss of eggs or chicks through abandonment of nests, raiding by skuas and general disturbance. In severe cases noise can lead to the mortality of entire breeding communities. The nearest breeding birds are on Utsteinen Nunatak, around 1 km away from the station.

General activity and, in particular, vehicle use may generate noise in the station area. Scientific activities that require generators or other mechanical equipment may also generate noise. A wind farm at 350 metres has a noise level around 35–45 dBA. This is slightly more than a quiet bedroom at 20 dBA and slightly less than a busy general office at 60 dBA (WWF, 2000). It is unlikely that there will be significant disturbance to the birds from activities at the station.

Minimisation and Mitigation

Disturbance by ship and cargo activity at the shelf front is unavoidable. Selection of the unloading site should take account of known seal haul-out locations, especially if these are breeding sites, and the seasonality of breeding activity. Vehicle and helicopter movements at the ice edge should be kept to a minimum.

Aircraft noise will be minimised by using aircraft only when required and by keeping to minimum height and spatial separations unless weather, mechanical or operational changes during a flight require descent to lower altitudes for safety.

Resolution XXVII-2 provides recommended spatial and height distances for over flight of wildlife and guidance for crossing coastlines. Flight approach plans will be prepared for the station to avoid over flight of any of the nunataks which have known breeding bird sites. Flight plans will be abandoned and modified for future use if there is any indication of disturbance caused by flight activity

By avoiding over flight and maintaining minimum height and spatial separations when in the vicinity of wildlife, there is a low probability of disturbance to wildlife caused by aircraft noise.

The station will be designed to operate from renewable resources, and generator use will be minimal. Other activities will be conducted in such a way as to minimise noise. Vehicles will be routinely serviced to minimise noise output. Noise from the workshop and garage will be attenuated as these facilities will be sited underground.

The larger wind turbines will be collapsed during the winter and there will just be one small turbine close to the station while it is unoccupied.

5.8 Light Pollution

The construction and operation of the station in a previously unoccupied area will generate light. For most of the operating season, the station will be in 24 hour daylight and there will be no impact. If the station is open during periods of dark there is the possibility of disturbing breeding bird species or affecting light-sensitive scientific programmes.

Minimisation and Mitigation

External lighting will be designed to minimise stray light emission, particularly above the horizontal. Station windows will have blinds fitted if the base operates during dark periods to prevent disorientating returning snow petrels.

5.9 Flora and Fauna

There are very few lichen growths on the rock exposure where the proposed station will be sited, but they are more abundant on the main Nunatak (Belare, 2004). The few growths on the station site are likely to be affected by construction, but this and the subsequent operation activities will not affect the flora on the Nunatak itself, except for possible uptake of emissions to air.

Activity at the shelf ice edge from ship and cargo operations may have a minor impact on seals. At the likely ship arrival time in January, the Weddell seal breeding season will have finished. However, there may be seals hauled out on the ice that may be disturbed by noise and general activity.

The colony of breeding snow petrels on Utsteinen Nunatak may be impacted by the construction of the station but this will be transitory. Activity will be less during operation of the station and breeding petrels are less likely to be disturbed. Birds have been known to fly into the blades of wind turbines, but it has been shown that strikes are highly unlikely to occur in good visibility conditions and in poor visibility birds are less likely to be in the vicinity of turbines. Most birds fly over or around turbines (WWF, 2000). During the field visit in 2005, birds were observed to fly on either side of the rock ridge where the turbines will be sited, rather than above it (personal observation).

Minimisation and Mitigation

Noise and physical activity at the station during the most sensitive petrel breeding periods will be kept to a minimum. Aircraft will not over fly the station and the skiway will be sited at least 1 km from the Nunatak.

Visits to the Nunatak by station staff will be restricted during breeding periods and all staff will be given guidance on minimising disturbance to the petrel colony, any skua nest sites and lichen growth.

Ship, cargo handlers and construction staff will be instructed in minimising disturbance to seals, birds or penguins that are hauled out or feeding at the ice edge.

The wind turbines will be monitored to see if they have any effect on birds, and if they do then bird deterrent devices may be used.

5.10 Physical Disturbance, Aesthetic Values

The construction of a station on the ridge at Utsteinen Nunatak, an area of outstanding wilderness, will have a minor visual impact in the locality but only within line of sight.

There will be some disturbance to the rock ridge as the station legs and wind turbines will be anchored to the rock. Also there may be some local disturbance to loose rocks which may be used for heat storage. These will be left unaltered at the site after the station is decommissioned.

Station construction and operation will require an amount of snow management. The garage building will be located below the snow surface and this will necessitate significant snow moving during the construction phase. Introducing a new above surface structure to the ridge at Utsteinen Nunatak may cause minor local changes to snow deposition and wind effects but these will be temporary for the duration of the station.

The use of vehicles will leave tracks and a skiway will be maintained during the summer months. Water will be from melting snow and this may require some stockpiling of clean snow during some periods. The likely effect of the presence of the station on the snow/ice environment is likely to be minor and transitory.

Minimisation and Mitigation

The station is being designed to have a minimal visual impact. Extensive wind tunnel testing has been conducted to find the optimal situation for the station with respect to snow management. The layout of fuel tanks and other equipment at the station site will be designed to keep visual impact and effect on snow accumulation to a minimum. Marked vehicle routes will be used to minimise the amount of tracks made.

5.11 Introduction of alien species and translocation of diseases

Construction and operation of the station, linked to support by rapid inter-continental air transport, presents a moderate risk of the introduction of alien species or translocation of diseases into Antarctica. Introduction may occur through imported food or contaminated packaging and equipment entering the environment.

Scavenging of unsecured food wastes by skuas is a simple pathway for alien species or diseases to enter the system. Soil and seeds may be introduced by unclean footwear or equipment, resulting in the accidental transfer of non-native organisms to the Antarctic.

Antarctic bird populations are susceptible to infection by disease. Highly contagious viral diseases, such as morbillivirus, Newcastle disease and influenza, immunosuppressant diseases, such as infectious bursal disease, morbillivirus and retrovirus, and agricultural and zoonotic diseases, such as brucellosis, tuberculosis and leptospirosis are considered to be the greatest potential risk to the health of Antarctic wildlife.

Minimisation & mitigation

Strict observation of Environmental Protocol Annex II Art. 4(5)-(6) and Appendices will ensure the prevention of introduction and translocation of species and disease. The following practices will be implemented to minimise the introduction of alien species and diseases:

- poultry products must be certified clear of Newcastle's and other contagious diseases;
- proper food handling and secure storage procedures at the station and in field camps;
- poultry waste separated and contained in secure storage for disposal at an appropriate reception facility outside the Antarctic Treaty Area;
- as far as practicable, all clothing (particularly foot wear), scientific instruments, mechanical and field equipment to be cleaned before importing into Antarctica.
- tracked and wheeled vehicles in particular to be steam cleaned before importation.

The probability of introducing alien species will therefore be extremely low.

5.12 Adjacent and Associated Ecosystems

Two features of the proposed activities are likely to impact associated ecosystems:

- Emissions to air (see **Section 5.3**): contribution to regional and global air pollution burdens.
- Removal of waste to South Africa (see **Section 5.6**): increased landfill in Cape Town; indirect effect of contamination of soil and groundwater; and disease transfer during sewage handling.

5.13 Impact Matrix

An impact matrix (**Table 5.4**) has been prepared to summarise the environmental impacts of the construction and operation of the proposed station at Utsteinen Nunatak. Activities which will have an impact are identified and the duration and output of the activity are stated. The scope, persistence, intensity, probability and importance are ranked according to the criteria described in **Section 5.1**. These criteria are summarised in **Table 5.3** below.

Heading	*Content*	*Detail*
Activity		
Nature	Type of activity	
Duration	Time period of activity	Listed in days, weeks, months etc.
Output		
	Description of potential results of activity that may cause impact	
Impact		
Scope	Geographical area affected	Local, regional, continental (L, R, C)
Persistence	Duration of impact	Short (minutes–hours), medium (days–weeks), long (months–years), permanent, unknown (S, M, L, P, U)
Intensity	Severity of impact	Low, medium, high (L, M, H)
Probability	Likelihood of impact occurring	Low (<25%), medium (25–75%), high (>75%) (L, M, H)
Importance	Importance of impact	Low, medium, high (L, M, H)
Effects		
Direct	Qualitative description of what is directly, indirectly and cumulatively impacted by the Activity/Output.	
Indirect		
Cumulative		

Table 5.3: criteria for ranking scope, persistence, intensity, probability and importance of the activity

The final two columns in the impact matrix describe the predicted impacts and indicate the measures that will be put in place to mitigate or prevent them from occurring.

Table 5.4: Impact matrix, showing preventative or mitigating measures

Nature	*Duration*	*Output*	*Scope*	*Persist.*	*Intens.*	*Prob.*	*Imp.*	*Predicted Impacts*	*Mitigation*
Shipping									
Shipping and cargo handling	10 days for construction; 1–2 days per year during operation	Atmospheric emissions	L	M–L	L	H	M–H	Cumulative contribution to regional and global air pollution; contamination of snow / ice and biota	Minimise ship movements; use ship which uses MGO; maintain engines to high standard; shared use of ship
		Noise / physical disturbance of wildlife	L	S	M	L	L–M	Disturbance of wildlife decrease in colony size; loss of biodiversity	Staff briefed on minimising disturbance of fauna
		Grey water, food, solid waste, human waste	L	S–L	L	H	L	Contamination of local marine environment; potential introduction of alien species and diseases	Prepare Waste Management Plan; poultry products retained on-board; wastes stored or discharged according to MARPOL
Aircraft									
Aircraft flight and landing	Repeated during season (Nov-Feb)	Atmospheric emissions	L	M–L	L	H	M–H	Cumulative contribution to regional and global air pollution; contamination of snow / ice and biota	Minimise flight operations; minimal ground running.
Fuelling	Repeated during season (Nov-Feb)	Fuel spill: <200 litre. Oil: <5 litre	L	M–L	H	M–H	M–H	Cumulative contamination of snow and ice; reduction in scientific value	Care and attention during fuelling Use of spill mats; Oil Spill Contingency plan prepared
Over flight of bird or seal breeding colonies	<1 hr per flight	Noise	L	S	M	L	L–M	Cumulative if repeated. Disturbance of wildlife decrease in colony size; loss of biodiversity	Aircrews to follow Resolution XXVII-2 Aircrews to follow local wildlife avoidance guidelines
Vehicles									
Running snow vehicles / generator / stoves	Repeatedly throughout season	Atmospheric emissions	L	M–L	L	H	L–M	Cumulative contribution to regional contamination of local ecosystems (lichens) & snow	Maintain equipment to high standard; minimal use; do not leave vehicles idling

Nature	*Duration*	*Output*	*Scope*	*Persist.*	*Intens.*	*Prob.*	*Imp.*	*Predicted Impacts*	*Mitigation*
		Noise	L	S	M	L	L–M	Cumulative if repeated. Disturbance of wildlife decrease in colony size; loss of biodiversity	Minimise vehicle activity in vicinity of wildlife; maintain minimal distances so that wildlife not disturbed
Fuelling	Repeated during season (Nov-Feb)	Fuel spill: <200 litre. Oil: <5 litre	L	M–L	H	M–H	M–H	Cumulative contamination of snow and ice ; reduction in scientific value	Care and attention during fuelling Use of spill mats ; Oil Spill Contingency plan prepared
Station									
Snow clearing	<100 hr per season	Physical disturbance	L	S–M	L	H	M	Aesthetic; cause of ablation; loss of scientific value	
Waste generation	Throughout season	Grey water and sewage	L	S–L	L	H	L	Contamination of snow and ice; loss of scientific value	Primary treatment and filtration before disposal; record disposal site
		Hazardous and non-Hazardous waste	L	M–L	L–M	H	M–H	Indirect effect of waste disposal outside Antarctica; contamination of snow if not stored securely	Prepare Waste Management Plan; remove waste from Antarctica; minimise packaging; recycle / reuse where possible.
		Introduction of alien species	L–R	P	H	L	H	Spread of alien diseases; loss of biodiversity	Clean equipment and clothing prior to departure; use certified poultry products; poultry waste stored securely.
Wind turbines	Throughout season; small turbine in winter	Noise	L	S–M	M	L	L–M	Disturb birds; decrease in colony size	
		Bird strikes	L	L	H	L	H	Damage or death of birds	Use bird deterrents
Light	Periods of darkness (minimal)	Disturbance of birds	L	L	L	M	L	Disturbance and disorientation of birds; decrease in colony size	Use blinds; minimal use of outside lights; lights to be angled below the horizontal
Science									
Site visits	Throughout season	Litter/waste	L–R	M–P	L	L	L–M	Spread of waste; expansion of 'footprint; loss of scientific value	Staff briefed on minimising impacts
		Trampling (rock)	L	M–P	L	L	M	Damage to lichens; disturbance of breeding birds	Staff to follow Recommendation XVIII-1

6. INDIRECT & CUMULATIVE IMPACTS

The station will be designed to have a low environmental footprint with low energy consumption and minimal waste output. It is therefore unlikely to have any significant indirect impacts.

All impacts if repeated, however, have the potential to become cumulative. The only significant cumulative impacts that may result from the construction and operation of the station are emissions to air (**Section 5.3**), fuel spills (**Section 5.4**) and local discharge of grey water (**Section 5.5**).

These cumulative impacts may affect the biota in the region and reduce the scientific value of the area. Outputs that lead to cumulative impacts, such as emissions to air or discharge of grey water, can be measured but it may only be possible to gauge their cumulative impact by measuring deviation from baseline data over time.

7. MONITORING AND VERIFICATION

Baseline data was collected during the Belare 2004 and 2005 site survey expeditions, in order to obtain reliable information about the initial clean state of the environment and to establish the "footprint" of the station (see **Section 4.5**).

Monitoring is one of the key components of the planned science at the new station (see **Section 1.3, iii**). A monitoring program will be developed to integrate with other work undertaken by national operators and using the Practical Guidelines for Developing and Designing Monitoring Programmes in Antarctica (COMNAP, 2005b). Monitoring activities may include the following:

- Collection of air, water, soil, lichen, snow and ice samples in the immediate vicinity of the station for analysis
- Investigation of bacteria of human origin in Utsteinen Nunatak
- Changes in breeding population of spp (snow petrel or Antarctic skua)
- Changes in snow deposition characteristics
- Effect on breeding seal population due to ship activity (Weddell seal)
- Introduction of non-native biota, diseases or toxic substances

Monitoring will be designed to investigate the potential impacts of the activity, so that adverse effects will be discovered in good time, allowing for modification of the activity to remove or reduce the impact. This work will also increase knowledge about human interaction with the Antarctic environment.

Information on the operation of the station will also be recorded for monitoring purposes. This includes fuel consumption data, fuel spills, station population, waste generation, waste disposal routes etc. This information will be used to validate the CEE and establish if the impacts are as predicted. Recommended mitigation measures will be reviewed as information about the extent and intensity of impacts becomes available.

8. GAPS IN KNOWLEDGE AND UNCERTAINTIES

The following major gaps and uncertainties in the assessment of the environmental impacts of the construction and operation of the Belgian research station are:

- Unpredictability of sea ice extent at Breid Bay and local weather conditions during construction of the station. May lead to delay in completion of construction.
- Exact conditions at unloading site.
- Incomplete details of final station design.

- Incomplete details of logistic operations for the construction of the station, i.e. which ship and aircraft will be used.
- Location of breeding species in a 200 km range – birds, penguins, seals.
- Changes in future scientific and logistic activities.

9. ENVIRONMENTAL MANAGEMENT PLAN

An Environmental Management Plan (EMP) will be prepared prior to the start of construction that will contain the following elements:

- Statement of Intent to follow Belspo environmental policies and procedures.
- Definitions of roles and responsibilities of parties involved in carrying out the proposed transport and construction activities and for specified project personnel.
- Description of general environmental management activities which will provide the framework for implementation of the recommended mitigation measures.
- Plan for implementation of recommended mitigation measures for specific environmental impacts.

Statement of Intent

Standard policies and procedures will be developed for the various activities including waste management, fuelling operations, field operations and operation of equipment (see also **Section 2.4.17**). The underlying structure of these procedures will be to ensure safety and the prevention of environmental impacts by correct use of equipment, proper maintenance and safe operation.

Roles and responsibilities

Protection of the environment is a management responsibility that starts with senior personnel in Belspo/IPY and is implemented by personnel in the field.

Senior managers at Belspo/IPF will be identified as responsible for overall environmental performance during the transport and construction phases. Senior management control may change for the operational phase. A member of the Antarctic field team will be identified as having overall responsibility to monitor implementation of environmental requirements in the field.

General Environmental Management Activities

This section outlines recommended environmental management activities before and during the transport and construction phases. Belspo will be in charge of environmental management during the operational phase.

Before the project commences

- Belspo will obtain all relevant clearances and necessary approvals from authorities prior to commencing the operation.
- IPF will brief all contractors and crew on sensitive aspects of the environment and expected environmental conduct.
- IPF will brief all contractors and crew on the requirements of the EMP.
- IPF will be responsible for the training of all personnel involved in the activities on emergency procedures and implementation of the EMP.

During transport and construction

- IPF will report environmental incidents or accidents to Belspo.
- The IPF Project Manager will ensure that the Environmental Management Plan is implemented by the Antarctic field team.

After transport and construction phases have been completed

- IPF will complete a report summarising environment, health and safety issues, incidents/accidents and observations.

- IPF shall ensure that any contractual requirements, including any reporting or follow up activities required, are completed to Belspo's satisfaction.

Plan for Implementation of Mitigation Measures

The IPF Project Manager will be responsible for implementing the mitigation measures identified in **Sections 5.3–5.12** and in the impact matrix in **Section 5.13** during the construction of the research station. During station operation the Belspo Station Manager will be responsible for the implementation of mitigation measures.

Implementation is not a static process and the Managers will be responsible for reviewing and updating minimization and mitigation measures during the construction and operational phases as conditions change.

10. CONCLUSION

Belgium considers its decision to reconstruct a new research station in Antarctica in line with its position as one of the original signatories of the Antarctic Treaty. The "Do not go" alternative is considered as opposed to the philosophy of growing importance of Antarctica's key role in Global Change and increased concern of the state of its environment.

The station will be situated at the foot of the Sør Rondane Mountains, Dronning Maud Land, having access to all geographical regions (polynia, coast, ice shelf, ice sheet, marginal mountain area and dry valleys, inland plateau) within a radius of 200 km.

The station concept is unique in several ways. Situated on a small exposed rock surface completely surrounded by snow, the station will have a hybrid design exploiting maximally this 'island' effect. The main building will be anchored on the snow-free granitic ridge, while the garage/storage building will be constructed under the adjacent snow surface.

The design of the station is based on sustainable technology and high energy efficiency, using renewable energy as the primary energy source, thereby limiting the use of fossil fuels to transport and field work.

The main building has a concentric architecture laid out around a "hot technical core" for temperature-sensitive installations and equipment. Second and third concentric layers will contain respectively the active and passive living spaces. When closed down for winter each individual layer will be "sealed" thereby creating a number of temperature-controlled buffer zones against the cold exterior environment.

The CEE has identified and evaluated potential impacts that may be generated during construction and operation of the station. Due to its 'Island' position and the remarkable constant wind direction, fall out from emission products at the station will be dispersed away from the nunatak and mountain areas. This and the sustainability concept of the station assure a low environmental footprint with minimal waste output.

Belgium therefore concludes that the global scientific importance and value to be gained by the construction and operation of the new Belgian station in the 1072 km empty sector between the Japanese Syowa station and the Russian Novolazarevskaya station outweighs the more than minor and transitory impacts the station construction and operation will have on the Antarctic environment and fully justifies the launch of this project.

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12. APPENDICES, TABLES ETC.

ATCM	Antarctic Treaty Consultative Meeting
AWS	Automatic Weather Station
Belspo	Belgian Federal Science Policy Office
Belare	Belgian Antarctic Research Expedition
CEE	Comprehensive Environmental Evaluation
CEP	Committee for Environmental Protection
COMNAP	Council of Managers of National Antarctic Programs
EIA	Environmental Impact Assessment
EMP	Environmental Management Plan
EOMR	End of Mission report
FMEA	Failure Mode Effect Analysis
GDRP	Geodetic Reference Point
HVAC	Heating, Ventilation, Air Conditioning
IPF	International Polar Foundation
MEUR	Million Euro
SCAR	Scientific Committee on Antarctic Research
UPS	Uninterrupted Power Supply
VHF	Very High Frequency
VOC	Volatile Organic Carbon
WMP	Waste Management Plan

Table 12.1: Acronyms used in the Draft CEE

Site	*Latitude*	*Longitude*
Basen Nunatak	73º05'S	014º30'W
Belgica Mountains	72°35′S	031°15′E
Breid Bay	70º15'S	024º15'E
Byrdbreen	71°45′S	26°00′E
Derwael ice rise	70°15′S	026°30′E
Ekström Ice Shelf	70º37'S	008º22'W
Enderby Land	60°30′S	53°00′E
Gunnestadbreen	72°03′S	23°50′E
Jenningsbreen	71°57′S	24°22′E
Leopold III Bay	70°20′S	024°13′E
Nansenisen	72°40′S	024°00′E
Novolazarevskaya Station (Russian Federation)	71º46'S	011º50'E
Pingvinane	72°00′S	25°00′E
Polarhav Bay	70°18′S	024°40′E
Prinsesse Ragnhild Kyst	70º30'S	027º00'E
Queen Fabiola Mountains	71°30′S	35°40′E
Roi Baudouin Research Station (Belgium)	70º26'S	024º18'E
Romnaesfjellet	71°28′S	023°56′E
Sør Rondane	72º00'S	025º00'E
Seal or Selungen Nunatak	71°32′S	024°04′E
Syowa Station (Japan)	69º00'S	039º35'E
Utsteinen Nunatak	71°57'S	023°20'E
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Table 12.2: Site Coordinates

Parameter		
CODt	g/l	45
EC	mS/cm	2,5
pH	-	8,3
TOC	g/L	0
Sulphate	mg/L	80
Phosphate	mg/L	24
Ammonium	g/L	0
Fluoride	mg/L	0.5
Chloride	mg/L	96
Nitrates	mg/L	78
Mg	mg/L	4
K	mg/L	125
Ca	mg/L	11
Na	mg/L	95
Turbidity	-	5,0
Total coliform		<100
E.Coli		0
Enterococci		<10

Table 12. 3: expected effluent quality of the bio membrane reactor after final ozone, peroxide and chlorine treatment

Sample ID	Date sampling	Latitude (S)	Longitude (E)	Altitude (m)
1	28/11/2004	71°57.027′	023°20.478′	1373
2	28/11/2004	71°57.013′	023°20.492′	1382
3	28/11/2004	71°56.586′	023°20.508′	1385
4	28/11/2004	71°56.561′	023°20.513′	1372
5	28/11/2004	71°56.529′	023°20.505′	1365
6	28/11/2004	71°56.533′	023°20.509′	1363
7	28/11/2004	71°56.491′	023°20.486′	1367
8	28/11/2004	71°56.481′	023°20.469′	1372
9	28/11/2004	71°56.468′	023°20.447′	1377
10	28/11/2004	71°56.449′	023°20.423′	1369
1	22/11/2005	71°57.033′	023°20.802′	-
2	22/11/2005	71°57.023′	023°20.821′	-
3	22/11/2005	71°57.016′	023°20.822′	-
4	22/11/2005	71°57.006′	023°20.828′	-
5	22/11/2005	71°57.005′	023°20.847′	-
6	22/11/2005	71°57.002′	023°20.843′	-
7	22/11/2005	71°57.000′	023°20.845′	-
8	22/11/2005	71°56.997′	023°20.852′	-
9	22/11/2005	71°56.994′	023°20.847′	-
10	22/11/2005	71°56.981′	023°20.844′	-
11	22/11/2005	71°56.972′	023°20.842′	-

Table 12.4: Overview soil samples

Sample ID	Date sampling	Latitude (S)	Longitude (E)	Altitude (m)
1	28/11/2004	71°56.705′	023°20.838′	1365
2	28/11/2004	71°56.789′	023°20.930′	1366
3	28/11/2004	71°56.852′	023°20.978′	1363
4	28/11/2004	71°56.984′	023°21.181′	1374
5	28/11/2004	71°57.100′	023°20.845′	1381
6	28/11/2004	71°57.015′	023°20.569′	1381
7	28/11/2004	71°56.854′	023°20.743′	1372
8	28/11/2004	71°56.773′	023°20.651′	1382
9	28/11/2004	71°56.699′	023°20.536′	1380
10	28/11/2004	71°56.817′	023°19.150′	1359

Table 12.5: Overview snow samples

Table 12.6: Preliminary analyses results baseline monitoring

Snow													
Dissolved fraction (filtration after storage, filtered on 0.45µm))													
	Be	**Mo**	**Ag**	**Cd**	**Sn**	**Sb**	**Hg**	**Tl**	**Pb**	**Al**	**V**	**Cr**	**Mn**
	µg/L	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**
snow 1	0,002	0,014	0,072	0,011	0,028	0,010	0,007	<0.001	0,070	1,330	0,008	0,033	0,252
snow 2	0,001	0,011	0,009	0,006	0,030	0,005	0,004	<0.001	0,015	1,370	0,006	0,029	0,095
snow 3	0,004	0,014	0,012	0,018	0,041	0,008	0,002	<0.001	0,028	1,217	0,006	0,037	0,115
snow 4	0,002	0,037	0,016	0,013	0,021	0,005	0,008	<0.001	0,032	1,680	0,006	0,043	0,205
snow 5	0,001	0,035	0,015	0,038	0,024	0,011	0,007	<0.001	0,037	1,299	0,007	0,109	0,097
snow 6	0,001	0,014	0,020	0,025	0,018	0,008	0,005	<0.001	0,040	0,970	0,008	0,048	0,420
snow 7	0,002	0,013	0,018	0,015	0,015	0,007	0,007	<0.001	0,069	0,740	0,004	0,022	0,435
snow 8	0,001	0,011	0,013	0,012	0,023	0,003	0,005	<0.001	0,052	1,000	0,005	0,022	0,131
snow 9	0,001	0,006	0,013	0,015	0,013	0,004	0,004	<0.001	0,037	0,470	0,007	0,010	0,093
snow 10	0,004	0,007	0,013	0,009	0,019	0,004	0,004	<0.001	0,030	1,981	0,008	0,027	0,453
	Fe	**Co**	**Ni**	**Cu**	**Zn**	**As**	**Se**	**Ba**	**Ca**	**K**	**Mg**	**Na**	**S**
	µg/L	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**
snow 1	0,543	0,009	0,089	0,234	2,832	0,006	0,020	0,0001	0,0689	0,0435	0,0276	0,1788	0,1204
snow 2	0,646	0,006	0,038	0,035	1,066	0,004	0,020	0,0001	0,0348	0,0100	0,0197	0,0990	0,0459
snow 3	0,350	0,005	0,056	0,147	2,325	0,004	0,010	0,0001	0,0461	0,0395	0,0128	0,0940	0,0412
snow 4	0,350	0,006	0,064	0,118	1,299	0,004	0,020	0,0004	0,0655	0,0100	0,0267	0,1931	0,0429
snow 5	0,520	0,006	0,100	0,261	3,012	0,013	0,024	0,0005	0,1242	0,0624	0,0228	0,1322	0,0450
snow 6	0,410	0,007	0,080	0,216	3,193	0,013	0,026	0,0002	0,0883	0,0035	0,0284	0,1854	0,0514
snow 7	0,340	0,015	0,137	0,107	2,280	0,014	0,010	0,0002	0,0780	0,0100	0,0203	0,1508	0,0271
snow 8	0,360	0,005	0,082	0,125	1,750	0,001	0,022	0,0002	0,0487	0,0397	0,0197	0,1307	0,0555
snow 9	0,210	0,005	0,056	0,093	2,880	0,009	0,025	0,0001	0,0250	0,0038	0,0129	0,0744	0,0334
snow 10	0,396	0,014	0,074	0,101	1,441	0,002	0,010	0,0001	0,0679	0,0564	0,0173	0,0837	0,0353
Acid leachable fraction (unfiltered, acidified 0.5% HNO3)													
	Be	**Mo**	**Ag**	**Cd**	**Sn**	**Sb**	**Hg**	**Tl**	**Pb**	**Al**	**V**	**Cr**	**Mn**
	µg/L	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**
snow 1	0,002	0,014	0,071	0,023	0,165	0,011	0,011	<0.001	0,203	8,62	0,022	0,033	0,442
snow 2	0,001	0,011	0,009	0,006	0,039	0,006	0,004	<0.001	0,038	5,49	0,009	0,030	0,136
snow 3	0,040	0,011	0,013	0,023	0,060	0,008	0,002	<0.001	0,074	4,55	0,014	0,060	0,205
snow 4	0,004	0,023	0,020	0,013	0,038	0,005	0,017	<0.001	0,036	4,79	0,020	0,048	0,380
snow 5	0,002	0,050	0,015	0,041	0,042	0,011	0,010	<0.001	0,093	5,30	0,014	0,137	0,142
snow 6	0,002	0,045	0,020	0,026	0,031	0,011	0,005	<0.001	0,068	3,37	0,011	0,065	0,577
snow 7	0,003	0,047	0,018	0,017	0,017	0,007	0,01	<0.001	0,095	3,88	0,010	0,022	0,526
snow 8	0,003	0,017	0,013	0,013	0,023	0,003	0,005	<0.001	0,074	7,83	0,016	0,026	0,222
snow 9	0,004	0,019	0,015	0,016	0,018	0,004	0,004	<0.001	0,064	3,03	0,013	0,063	0,121
snow 10	0,004	0,031	0,015	0,009	0,020	0,004	0,002	<0.001	0,035	9,16	0,025	0,042	0,605

	Fe	Co	Ni	Cu	Zn	As	Se	Ba	Ca	K	Mg	Na	S	Particulates
	µg/L	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**
snow 1	6,200	0,013	0,092	0,281	3,290	0,014	0,020	0,0002	0,0728	0,0442	0,0251	0,1788	0,1204	6
snow 2	1,590	0,006	0,054	0,036	1,086	0,004	0,025	0,0001	0,0333	0,010	0,0177	0,0990	0,0459	4
snow 3	2,670	0,008	0,056	0,154	2,325	0,005	0,010	0,0005	0,0433	0,0313	0,0121	0,0940	0,0412	5
snow 4	3,190	0,010	0,086	0,121	1,322	0,006	0,024	0,0007	0,0678	0,0658	0,0268	0,1931	0,0429	3
snow 5	5,190	0,010	0,133	0,261	3,074	0,015	0,024	0,0004	0,1209	0,0735	0,0234	0,1322	0,0450	3
snow 6	2,650	0,014	0,095	0,220	4,743	0,017	0,047	0,0004	0,0878	0,0174	0,0246	0,1854	0,0514	6
snow 7	3,860	0,020	0,171	0,129	2,300	0,016	0,010	0,0002	0,0730	0,0157	0,0185	0,1508	0,0271	9
snow 8	4,440	0,008	0,097	0,128	1,799	0,003	0,022	0,0002	0,0491	0,0612	0,0212	0,1307	0,0555	4
snow 9	3,170	0,013	0,098	0,119	3,010	0,010	0,024	0,0001	0,0255	0,0181	0,0126	0,0744	0,0334	3
snow 10	9,205	0,020	0,064	0,117	1,478	0,003	0,010	0,0003	0,0613	0,0573	0,0174	0,0837	0,0353	7

Soil															
samples	**Be**	**Mo**	**Cd**	**Sn**	**Sb**	**Hg**	**Tl**	**Pb**	**V**	**Cr**	**Co**	**Ni**	**Cu**		
	µg/g	**µg/g**	**µg/g**	**µg/g**	**µg/g**	**µg/g**	**µg/g**	**µg/g**	**µg/g**	**µg/g**	**µg/g**	**µg/g**	**µg/g**		
soil1	0,43	14,59	0,17	1,96	0,010	0,035	0,64	10,1	80,8	39,7	12,7	20,8	38,1		
soil7	0,32	3,15	0,27	1,55	0,014	0,054	0,41	10,7	67,2	31,4	10,6	17,3	29,2		
samples	**Zn**	**As**	**Se**	**Al**	**Ba**	**Ca**	**Fe**	**K**	**Mg**	**Mn**	**Na**	**P**	**S**	**Sr**	**POC**	**PIC**
	µg/g	**µg/g**	**µg/g**	**mg/g**	**mg/g**	**mg/g**	**mg/g**	**mg/g**	**mg/g**	**mg/g**	**mg/g**	**mg/g**	**mg/g**	**mg/g**	**%**	**%**
soil1	73,0	1,40	0,38	26,0	0,2	10,3	51,9	12,4	15,4	0,616	1,505	3,07	2,00	0,092	1,19	0,003
soil7	44,1	1,96	0,43	19,0	0,1	11,6	35,6	7,0	11,9	0,412	0,922	3,88	1,88	0,107	3,89	0,030

Lichens															
samples	**Be**	**Mo**	**Cd**	**Sn**	**Sb**	**Hg**	**Tl**	**Pb**	**V**	**Cr**	**Co**	**Ni**	**Cu**		
	µg/g	**µg/g**	**µg/g**	**µg/g**	**µg/g**	**µg/g**	**µg/g**	**µg/g**	**µg/g**	**µg/g**	**µg/g**	**µg/g**	**µg/g**		
lichens1	0,01	4,67	0,06	0,06	0,004	0,340	0,02	0,39	0,85	0,63	0,20	0,72	5,55		
lichens2	0,17	1,49	0,13	0,41	0,014	0,116	0,14	3,33	10,99	7,24	2,45	4,67	4,79		
lichens3	0,04	0,32	1,01	0,17	0,008	0,008	0,04	1,46	2,64	1,18	0,38	0,78	7,61		
lichens4	0,04	2,14	0,07	0,02	0,002	0,234	0,06	1,31	2,50	1,85	0,45	0,96	5,57		
lichens5	0,00	0,35	1,19	0,02	0,008	0,017	0,01	0,05	0,16	0,07	0,05	0,30	12,32		
samples	**Zn**	**As**	**Se**	**Al**	**Ba**	**Ca**	**Fe**	**K**	**Mg**	**Mn**	**Na**	**P**	**S**	**Sr**		
	µg/g	**µg/g**	**µg/g**	**mg/g**	**mg/g**	**mg/g**	**mg/g**	**mg/g**	**mg/g**	**mg/g**	**mg/g**	**mg/g**	**mg/g**	**mg/g**		
lichens1	21,4	0,68	0,98	0,252	0,003	1,06	0,48	4,56	0,48	0,017	0,140	2,46	2,26	0,010		
lichens2	21,1	0,57	0,23	4,852	0,029	3,43	10,66	2,00	2,57	0,158	0,145	1,05	0,88	0,024		
lichens3	19,4	0,50	1,02	1,121	0,007	8,86	2,84	1,09	0,59	0,038	0,331	2,95	0,81	0,064		
lichens4	18,4	0,95	1,15	1,220	0,006	0,94	2,99	5,58	0,83	0,050	0,078	2,84	2,84	0,006		
lichens5	11,6	2,49	3,85	0,018	0,002	4,91	0,06	5,53	1,36	0,004	3,874	8,78	5,37	0,089		