Final Comprehensive Environmental Evaluation of New Indian Research Station at Larsemann Hills, Antarctica

NATIONAL CENTRE FOR ANTARCTIC AND OCEAN RESEARCH

(MINISTRY OF EARTH SCIENCES, GOVERNMENT OF INDIA)

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FINAL COMPREHENSIVE ENVIRONMENTAL EVALUATION

OF NEW INDIAN RESEARCH STATION AT LARSEMANN HILLS, ANTARCTICA

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Table of Content

List of Tables

List of Figures

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NON-TECHNICAL SUMMARY

INTRODUCTION

This Final Comprehensive Environmental Evaluation (CEE) has been carried out by the National Centre for Antarctic and Ocean Research (NCAOR), an R&D wing of Ministry of Earth Sciences, Government of India, which is mandated to coordinate and manage all the activities of India in the Antarctic region. The CEE has been prepared for establishment of the proposed new Indian research base in the Larsemann Hills of the East Antarctica (69°24' to 69^0 25'S latitude and 76°10' to $76^0$13'E longitude) at an unnamed promontory referred in some journals as Grovnes. The document has been prepared in accordance with Annex I of the Protocol on Environmental Protection to the Antarctic Treaty (Cohen, 2002) and the Guidelines for Environmental Impact Assessment in Antarctica (Resolution 4, XXVIII ATCM, 2005). This document deals with the following:

a) *History of Indian Antarctic programme and scientific activities planned at the new base*
b) *Description and need of the proposed activity*
c) *Design and construction criteria*
d) *Alternatives to proposed activity*
e) *Initial environmental reference*
f) *Identification, prediction of impacts and mitigation measures*
g) *Gaps in knowledge and uncertainty to define activity or impacts.*

This CEE is based on final design of the proposed station which will be built using the latest technology to minimize the environmental impact due to the structures and planned scientific and logistic activities.

DESCRIPTION OF THE PROPOSED ACTIVITY

The proposed station, which is to be built on an unnamed promontory between Stornes and Broknes peninsula in the Larsemann Hills area (69°24'-69^0 25'S latitude and 76°10'-$76^0$13'E longitude) is an ice-free coastal oasis fringing the Prydz Bay. It is located approximately midway between the eastern extremity of the Amery Ice Shelf and the southern boundary of the Vestfold Hills.

The proposed location is of interest on account of scientific and logistic reasons, ice-free terrain and easy access from the sea. This area, including the islands and promontories offers an excellent scope for extensive studies on geological structures and tectonics with special reference to Gondwanaland, palaeoclimatology, solid earth geophysics, space-weather and meteorology, oceanography, marine biology, microbiology, environmental science etc.

The proposed research base is planned to have a life span of 25 years. It will accommodate 25 people during summer and 15 people during winter. The station is designed to withstand extreme environmental conditions prevailing at Larsemann Hills, meeting the environmental standards as provided under the Madrid Protocol (Cohen, 2002). Emphasis will be on use of alternative sources of energy i.e. wind and solar power to reduce fossil fuel consumption.

STATION DESIGN AND CONSTRUCTION CRITERIA

The Station has been designed as an ergonomic entity in harmony with the prevailing environment at the Larsemann Hills. It is proposed to build a self-contained double-storey structure on stilts capable of accommodating a maximum of 25 persons. To facilitate the planned scientific studies, including environmental monitoring, the base will have state-of-the-art laboratory facilities.

The conceptual design of the station has been obtained through global tenders for innovative ideas. Overall 32 design proposals were received from around the world out of which four entries were short listed for providing a detailed concept on design and construction of the station. The architect/consultants were selected based on their experience to build environment friendly stations in Antarctica by a committee of experts, drawn from national organizations and academic and technological institutions, involved in building design, construction and environmental engineering.

The selected conceptual design meets the Madrid Protocol requirement. Once the approvals of the CEP and ATCM are obtained, the construction of the station will be initiated during the subsequent austral summer. The station is expected to be commissioned in two years time from initiation of construction activity. The scientific activities and work for collection of base data, which was started in the austral summer of 2003-04, when the first Task Force landed at Larsemann Hills, and continued to gather more information on the gap areas and to improve upon the design parameters so to further reduce the environmental impact.

SITE SELECTION AND ALTERNATIVES

Initially, three regions in Antarctica were recommended to the Government of India by an expert committee in 1996, for more comprehensive research by the Indian scientists by establishing an additional research base in Antarctica. The probable areas were:

- *a) Antarctic Peninsula,*
- *b) Filchner Ice Shelf and*
- *c) Amery Ice shelf – Prydz Bay area*

The site for the new Indian base at the Larsemann Hills was selected after a thorough study and examination of various options available along the East Antarctic coast.

The Antarctic Peninsula being overcrowded by the existing stations did not find much favor. The Filchner Ice Shelf poses logistics constraints in maintaining a research facility. After a thorough consideration of various options available along the East Antarctic coast, since it offers enormous scope for initiating long term scientific experiments in Antarctica and the Indian Ocean region between India and Antarctica, the third option emerged as the most favorable choice.

In the Amery Ice shelf-Prydz Bay area, many sites were visited to find out a suitable location. Considering various environmental factors and avoiding areas of wildlife concentration and critical natural values, the Larsemann Hill region was found most suitable. In Larsemann Hills, three locations were visited, but finally the present site was selected based on:

- *the availability of a flat terrain for station construction*
- *the relative ease of cargo discharge operations,*

- *the availability of freshwater lakes in case of emergency, and*
- *the open sea approach to the site.*

As bathymetry of Prydz Bay along the approach route was not available, a detailed multi-beam bathymetry survey was carried out during the austral summer of 2006 and 2010 to identify a suitable channel for ship/barge movement. The route selected was found to be deep enough for vessel movement and would provide a safe sea access to the station site. Main environmental factors that favored to short list of present site are:

- *No penguin rookeries or nesting site of birds exist on the promontory*
- *No designated ASPA exists nearby*
- *Treated waste disposal to the sea rather on land or ice*
- *Relatively open sea access for about a month during austral summer*
- *Availability of flat terrain*
- *Proximity to sea water for station use (potable purpose by desalination, flushing purpose) rather than totally depending upon fresh water lake*

The information on the selection of the new site was provided to the ATCM through IP 80 at XXVIII ATCM in Stockholm and in the WP 20 at XXIX ATCM in Edinburgh.

DESCRIPTION OF THE AREA AND ENVIRONMENT

The Larsemann Hills area is marked by persistent, strong katabatic winds that blow from east to southeast during austral summer. Daytime air temperatures from December to February, at times, exceed 4˚C, with the mean monthly temperature a little above 0˚C. Extreme minimum temperature recorded in the region so for is -40^{0} C (Turner and Pendlebury, 2004). Annual mean wind speed of 7 m/s and maximum wind speed 50 m/s have been recorded at the nearby Zhongshan station. Annual mean gale days are about 171 (47%). Precipitation occurs as snow and is unlikely to exceed 250 mm water equivalent annually (Hogdson et al., 2001). Pack ice is extensive in north-eastern side during early summer and the fjords and embayment are rarely ice-free. Snow cover is generally thicker and more persistent on Stornes Peninsula than on Broknes Peninsula. The sea ice grows steadily during March – September, with maximum during April – June.

Lakes present in the Larsemann Hills area are mostly fresh water in nature (Gillieson et al, 1990) and are characterized by low microbial diversity (Burgess and Kaup, 1997). However, the promontory supporting the proposed site has small fresh water lakes and a saline lake at the upper reaches. The area adjoining the proposed site does not support any population of breeding penguins or seals.

Data on hydro-chemical properties of 13 lakes in the proposed site indicate that Na^+ and Cl^- are predominant ions in the water, but no CO_3^{--} is present. Hence, all lakes belong to Na^+ group. The concentrations of nutrient substances (N, P, SiO_2) are rather low; inorganic nitrogen exists mainly in the form of NH_4^+-N, both in water and in the snow. The relatively high concentrations of Na^+, Cl^- and SO_4^{--} suggest that the precipitation in the Larsemann Hills is dominated by marine conditions. Nutrient parameters such as PO_4 and NO_3, though varied marginally between lakes, showed lower values, suggesting that the lake in Larsemann Hills are not subjected to organic or inorganic pollution.

These lakes were also found to harbor a large number of manganese oxidizing bacteria (10^5 – 10^6 CFU/l), predominantly belonging to the genera *Shewanella*, *Pseudomonas* and an unclassified genus in the family Oxalobacteriaceae (Krishnan et al., 2009)

Results showed the range of black carbon concentration as 26.5±16.2 ng/m^3 during 27th ISEA. During 28th ISEA average concentration of black carbon aerosol recorded was 13±5 ng/m^3 (Chaubey et al. 2010).

IMPACT ASSESSMENT AND MITIGATION MEASURES

Assessment of impact of the proposed station has been carried out keeping in view various activities pertaining to the logistics of transportation, construction and subsequent operation of the proposed station. Experience of about 25 years in maintaining Dakshin Gangotri and Maitri stations in Antarctica has been the main strength of the Indian scientists and engineers in assessing the environmental impacts and taking mitigation measures in the proposed CEE.

A matrix was prepared to identify the impacts and define appropriate practical mitigation measures. The main environmental disturbances during construction and operational phases pertain to:

- *air pollution due to emissions from the vehicles, vessels, helicopters, generators and incinerators*
- *ground impact due to vehicular and human movement*
- *noise pollution*
- *contamination of lakes*
- *disposal of treated wastewater and solid waste*
- *accidental oil spill*

The environmental impact assessment matrix indicates, by and large, low to medium category impacts. Proper preventive and mitigation measures have been proposed for strict implementation during the construction and operation phases. There will be an overall attempt to keep the environmental impact due to waste generation at minimum. Wastewater generated in the station from various sources will be treated by biologically activated sludge technology using membrane filter. Deep pipe encased with trace heating element will be used to discharge treated wastewater at safe distance from the water intake point. Effluent water characteristics will meet EU bathing water quality. Wastewater will be discharged in sea after proper treatment. Electromagnetic disturbance due to operation of the electrical equipments and vehicles is not ruled out, but all the equipments placed in the area will meet Electro Magnetic Compatibility standards. To reduce the fossil fuel consumption, renewable energy (solar and wind) shall supplement fuel based power generation. The thermal energy from the water cooled generators will be used for station heating purposes.

Since the mitigation measures are defined and all construction and operational activities at the proposed station shall comply with the provisions contained in Madrid Protocol using appropriate technologies, the environmental impact will be kept at minimum and close to the existing level of the parameters.

GAPS IN KNOWLEDGE AND UNCERTAINTIES

Gaps and uncertainties in this final CEE report include:

- *Uncertainty of sea ice extent during the period January-March each year.*
- *Impact matrix and evaluation have been done according to expert judgment which is based on the predicted values and are subjected to change depending on the environmental conditions.*
- *During the long life span of the station, need-based scientific activities and energy scenario may change with the advancement in technologies.*

CONCLUSIONS

India plans to have a new research base in the Larsemann Hills of East Antarctica for carrying out long-term research in various domains of polar, ocean and atmospheric sciences for complementing the existing studies at Maitri and adjoining areas. India considers that construction and operation activity of the proposed Indian research base shall have more than minor or transitory impact on the Antarctic Environment. Suitable mitigation measures have been proposed based on impact assessment matrix to minimize the impact.

The draft CEE Report was submitted for consideration by the Committee for Environmental Protection (CEP X) at the XXX Antarctic Treaty Consultative Meeting (ATCM) held from 30th April to 11th May 2007 in New Delhi, India. Final CEE has been prepared incorporating suggestions, received by various member countries and fully justifies the activity proceeding.

FURTHER INFORMATION

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INTRODUCTION

1.1 HISTORY OF INDIAN ANTARCTIC RESEARCH

1.1.1 DAKSHIN GANGOTRI

The importance of Antarctica as a pedestal for front-ranking scientific research was recognized by India in 1981, when the first Indian Antarctic Expedition was launched. Since then, India has made great strides both in Polar Sciences and related logistics, through a judicious and harmonious blend of multi-institutional expertise, brought together under the umbrella of the Ministry of Earth Sciences (earlier Department of Ocean Development). This has paved the way for the country to sustain its scientific endeavor in the icy continent on year-round basis ever since 1983, when the first permanent Indian Antarctic Base “Dakshin Gangotri” (70^{O} 5’ 37”S: 12^{O} E) was commissioned on the ice shelf, off the Princess Astrid coast in Central Dronning Maud Land (Figure 1).

The station, made of wooden huts and built in a record time of an austral summer, continued to host the members of Indian expeditions to Antarctica till 1989, when it had to be decommissioned due to excessive snow accumulation (Figure 2 and 3). The area has since been designated as historical site, HSM 44.

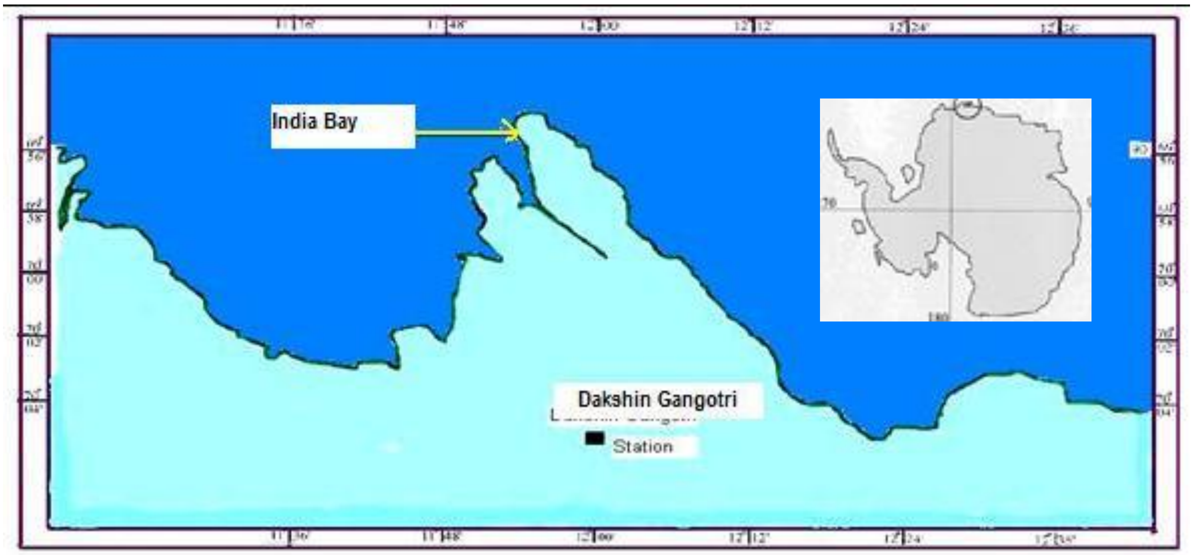

FIGURE 1 : DAKSHIN GANGOTRI STATION

FIGURE 2: DAKSHIN GANGOTRI STATION IN 1983

FIGURE 3 : STATION BURIED UNDER SNOW AS IN 1990

1.1.2 MAITRI

In the austral summer of 1987-88 an ice free, rocky area on the Schirmacher oasis was selected to build the Second Research Station "Maitri (70°45'52"S: 11°44'03"E). The building (Figure 4) was erected on steel stilts, and has since stood the test of time. The infrastructure available at the station has enabled the scientists to conduct research in various disciplines such as Atmospheric Sciences & Meteorology, Earth Sciences including Glaciology, Human Biology & Medicine, Biology and Environmental Sciences etc. Maitri also serves as a gateway to one of the largest mountain chains in central Dronning Maud land, located south of Schirmacher. About 20,000 sq. km. area in Wohlthat, Orvin, and Muhlig Hoffmann Ranges have been geologically mapped by Indian scientists, making Maitri as their base Station. Several research programs initiated by India in the Schirmacher oasis and its environs have also contributed directly to global experiments mounted under the aegis of the Scientific Committee on Antarctic Research (SCAR). Maitri has also provided a platform for collaborative studies with some Antarctic Treaty nations i.e. Germany, Italy, France, Poland and the United States of America. It has also facilitated scientists from Malaysia, Columbia, Peru and Mauritius to work in Antarctica. A collaborative research is also being planned with Norway, Brazil, South Africa and AFOPS member countries.

FIGURE 4: MAITRI STATION AT SCHIRMACHER OASIS, EAST ANTARCTICA

1.2 SCIENTIFIC STUDIES IN ANTARCTICA

Ever since 1981, the Indian endeavors in the icy continent have continued uninterrupted and annual scientific expeditions to Antarctica have remained one of the high priority activities of the National Centre for Antarctic and Ocean Research (NCAOR). Till date, twenty-nine expeditions have been successfully launched. In addition, a special expedition to Weddle Sea in 1989-90 and four expeditions to the Southern Ocean have also been undertaken. These expeditions have provided an avenue for over 1800 scientists and logistics personnel from more than 60 national laboratories, universities, and research institutes of India to conduct experiments/studies in some of the frontier areas of polar sciences. The studies have contributed significantly to a better understanding of the state of the Antarctic environment, in general and the central Dronning Maud Land, in particular. Many of the scientific studies have continued uninterrupted since 1985 and have produced important results and generated a substantial database.

Salient highlights of the Indian scientific activity in Antarctica are as follows:

EARTH SCIENCE

Indian geologists have systematically mapped about 20,000 sq km of the area in central Dronning Maud land on a 1:50,000 scale. Three geological maps of Schirmacher Oasis, Wohlthat and Orvin Mountains (GSI, 1991, 1999, 2006) and a geomorphological map of Schirmacher Oasis (GSI, 2006) have been released so far. Monitoring of glacier snout and the continental ice margin, on a regular basis has revealed significant retreat of the ice margin in the last two decades (Chaturvedi & Ravindra 2001, 2005). A detailed bibliography on the geological work accomplished in Central Dronning Maud Land is mentioned in References.

A permanent GPS station at Maitri is contributing to the understanding the inter-plate motion and crustal deformation between India and Antarctica (Ravikumar and Malaimani, 2000). The station has been tied up geodetically with other ITRF reference stations. The Seismological Observatory at Maitri is a part of the Global Seismological Network and contributes the data to USGS, ISC (UK) and AnSWeR. Absolute gravity measurements too have been initiated to address the crustal deformation studies in conjunction with GPS for complementary verification, determination of geode, glacial rebound and determination of sea level rise.

Ice cores drilled from the continental ice, south of Maitri, have been analyzed to evaluate the temporal changes in environmental characteristics during past few centuries. Results show that temperatures at the beginning of this period were about 2^0 C cooler than today (Nizampurkar et al., 2002). The ice core studies also indicate that the sulfate aerosol deposition is related to the volcanic eruption (Thamban et al, 2006). The nitrate profile reveals a systematic negative shift since mid 18^{th} century, suggesting a possible change in the zonal wind transport and an apparent solar modulation of the same (Laluraj et al., 2010).

UPPER ATMOSPHERE, ASTRONOMY AND METEOROLOGY

Ozone profile by Laser heteorodyne and Radio spectrometer has shown 3 to 68% depletion in ozone concentration in the height range of 13 to 40 km. Effect of planetary wave on dynamical behaviour of the polar vortex has also been established (Jain et al, 2004). Sun photometer, UV related studies and optical aeronomical experiments have been conducted for monitoring auroral emission. Regular monitoring of the greenhouse gases such as CO_2, CH_4 and CO is also being done at Maitri. The results have shown that there is an increase of 1.3 ppm of CO_2, whereas CH_4 concentration is relatively stable with an average value of 1.699 ppm.

During the total solar eclipse over Antarctica on 23 November, 2003, shadow-band activity resulting from the illumination of the turbulent atmospheric boundary layer was studied. The results reveal that the average width of the bands was in the range of 20-50 cm with comparable separation between bands and the speed of their movement at about 5-10 meters per second (Bagare et al., 2005).

Micrometeorological data are being recorded hourly and transmitted on real-time basis. Indian station Maitri is included in the WMO network of synoptic stations and has been assigned the index number 89514. Ozone monitoring has been continuing since 1987.

GEOMAGNETISM

Interaction of sun's atmosphere with earth magnetic field and magnetic storms that are produced by the solar activity, affect the technical aspects of satellite operation and communication systems. Instruments like Riometer/Flux gate Magnetometer have been installed to observe the geospace interaction. Statistical occurrence of storms and sub storms with intensification of auroral electro jet currents is being studied. It has been established that during quiet time, the Indian station occupies a sub-auroral position (Rajaram et al., 2002). Since Antarctica is recording a greater drop in the Total Magnetic Field Intensity than the global average, and Maitri falls in a 'region of Reverse magnetic Flux', continuous monitoring of 'F' values recorded here is of significance.

ENVIRONMENTAL SCIENCE AND BIOLOGY

Psycrophilic bacteria play an important role in sub zero activity in Antarctica. So far, around 125 new species have been discovered from Antarctica of which India has contributed around 20 new species. (Shivaji et al., 1989; Reddy et al., 2002a, b, 2003 a, b, c, d). Two new species, *Arthobacter Gangotriensis* and *Planococcus Maitriensis*, have been named after Indian station Dakshin Gangotri and Maitri, respectively (Alam et al., 2003; Gupta et al., 2004).

1.3 PLANNED SCIENTIFIC ACTIVITIES AT THE NEW BASE

The proposed research base is expected to cater to myriad scientific activities in some of the frontier areas of atmospheric, earth, ocean, biology and environmental sciences. The close proximity of the base to the Australian, Chinese, Romanian and Russian stations would go a long way in fostering significant collaboration and co-operation in polar sciences.

1.3.1 METEOROLOGICAL AND ATMOSPHERIC STUDIES

Meteorological data acquisition will be with real time data transmission capability to be used worldwide for various studies. A high resolution multi-parameter Automatic Weather Station (AWS) will be installed to acquire the data. Other atmospheric studies to be conducted are as follows:

- *Aerosol Radiative Flux estimation using Sky Radiometer*
- *Aerosol size distribution using multi-channel sun-photometer for solar terrestrial effects and transportation of aerosols*
- *Establishment of a geomagnetic observatory and installation of instruments like DFM, DIM, PPM*

1.3.2 EARTH SCIENCE STUDIES

The Prydz Bay is considered as a key in the India-Antarctica link during Gondwanaland as this area of Antarctica and the Eastern Ghat Mobile belt of India once formed a contiguous landmass. Geologically, the area offers possibilities of detailed correlation between the rocks exposed all along the eastern coast of India (high grade granulite, charnockites, khondalites) with rocks of Prydz Bay area (Kanao et al., 1994, Rao et al. 1995, Yoshida et al., 1999, Brauo and Kriegsman, 2003, Ghosh et al 2004, Mishra et al 2006). Apart from this:

- *Integrated geophysical–geological studies will help in further understanding the India-East Antarctic rifted margins and its role in the crustal evolution during Grenvillian and*

Pan African events.

- *The study of Lambert Glacier, the fastest moving glacier in Antarctica, opens an exciting new vista in glaciological studies.*
- *The movement of the continental ice margins along the Ingrid Christensen coast as also the accumulation and ablation pattern of the snow on the coast will be monitored.*
- *Late Quaternary glaciations in the Vestfold and Larsemann Hills areas remain a topic of intense academic interest.*
- *The studies on the sediment records available in the lakes of the area will supplement the research pertaining to palaeoclimate by earlier workers (Gillieson et al., 1990; Hodgson et al., 2001, 2005, 2006) beyond Holocene.*
- *The new research base offers an ideal location for yet another geomagnetic observatory in Antarctica, linking it with the Maitri research station as well as India. GPS will be operated for studies of crustal deformation and atmospheric sciences such as TEC, Scintillation and water vapor content. Studies on the measurement of current drift of the Indian sub continent with respect to this region of Antarctica will complement similar studies being undertaken by the Indian scientists at Maitri. The GPS station operational at Maitri, which contributes to the International Earth Rotation Services (IERS) for the realization of ITRF 2000, will be linked to this GPS station as well as with the one existing at Davis, under the SCAR-GPS campaign.*
- *Stornes and Brattnevet are unique for the variety of phosphorus and boron minerals, some of which are found in spectacular specimens, and others of which are not found elsewhere. Minerals discovered in these areas are; Stornesite-(yttrium), Tassieite and Boralsilite. In addition to the rare minerals listed above, Stornes is noteworthy for the spectacular development of the ferromagnesian aluminosilicate minerals cordierite and garnet, which are also index minerals providing information on the pressure-temperature conditions under which they crystallized (Australia, 2009). Similar study carried out by scientists as mentioned above, will be extended to other parts of Larsemann Hills using station as platform.*
- *Oceanographic studies*

Physical, chemical and biological oceanographic studies in the Indian Ocean sector of Southern Ocean will receive impetus. A long term and systematic approach regarding the time series observations of hydrographic parameters at different locations in the Prydz Bay area will be carried out to understand the quantity, causes and year to year variability of freshwater input in the Prydz Bay area.

1.3.3 ENVIRONMENTAL STUDIES

Supplementing the ongoing studies at the Maitri station to understand the impact of anthropogenic activities on the pristine Antarctic environment, similar studies would be initiated at the new site referring to earlier studies carried out at Larsemann Hills on nutrient pollution of lakes, introduction of alien organisms, dispersal of wind-blown debris and aerosol and erosion from road construction (Burgess et al., 1992; Ellis-Evan et al., 1997; Goldsworthy et al., 2002; Kaup and Burgess, 2002; Goldsworthy et al., 2003). Impact not only due to local activity but also due to land-based anthropogenic impact will be studied, as Antarctic coast is becoming a sink for the aerosol deposition. Aerosol spectrometer, Aethalometer and Multistage Impactor will be operated around the new site to collect long-term data. Study of particulate matter in water and sediment will provide useful tool to assess the environment.

Determination of other environmental indicators, i.e. studies of flora and fauna, their population trends and anthropogenic impacts on other biotic and abiotic factors on the coastal Antarctic ecosystem will be carried out. These studies will thus generate a spatial spread of data in two widely separated coastal oasis of Antarctica.

1.3.4 BIOLOGICAL STUDIES

Biological studies at the new site have potential to explore new vista in:

- *Biodiversity study of sea-ice microbial community*
- *Conservation of terrestrial & aquatic biota (fungi, lichens, bryophytes, micro fauna like protozoans, nematodes, tardigrades), aerobic bacteria*
- *Monitoring of wild life population and behavioral studies*

Even while using Antarctica as a platform for conducting scientific research, India has always recognized the importance of preserving the pristine nature of the continent, which modulates the intricate global climate processes. To uphold these commitments, India ratified the Protocol on Environmental Protection to the Antarctic Treaty in April 1998. All the principal activities pertaining to the proposed base, inclusive of design, transportation of men, materials and machineries during construction and operation have been considered in development of this report. The proposed scientific studies have also been taken into consideration, while formulating the CEE.

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DESCRIPTION AND NEED OF THE PROPOSED ACTIVITY

2.1 NEED FOR THE STATION

The need to have an additional station in Antarctica is justified in view of the following scientific and logistic factors:

India, through its sustained presence in Antarctica since 1981, has been conducting scientific experiments in various parts of central Dronning Maud land covering diverse disciplines. In view of the emerging trends in Antarctic research, India now intends to broaden the scope of its scientific research in Antarctica by complementing the existing studies from an additional location, so that the studies become regional and comprehensive rather than site-specific.

Antarctica plays a significant role in global science by providing a platform for observing and measuring several natural parameters like global warming, nature of upper boundary layer, fluctuations in total magnetic field of the Earth, geological evolution of the crust and movement of crustal plates, fluctuation of continental ice margin etc. Understanding the complexities of monsoons and the effect of polar climatic regime in its generation, has been one of the most sought after objectives of climatic and meteorological research being undertaken in Antarctica by India, as it has direct implication on the predominantly agriculture based societal needs.

The present Indian Antarctic station Maitri, is located in a sub auroral zone, while the proposed site at Larsemann Hills is located in auroral zone. The data obtained from the two stations would be complementary to each other and would help in understanding the development and movement of longitudinal propagation of localized auroral current systems in a unique way.

The magnetic field lines originating from Maitri pass over oceans and end up near Greenland. There is no magnetic station under the footprint of this field line to conjugate area studies. On the other hand, the field lines originating from Larsemann Hills pass over Middle East and Europe (close to Hungary and Denmark). Both the countries have operational magnetic observatories and the combined data can be used to conjugate area studies.

India launched a polar sun synchronous satellite - OCEANSAT-2 with a payload of Ocean Color Monitor (OCM), Scatterometer, and Radio Occultation Sounder for Atmosphere (ROSA) for monitoring global ocean chlorophyll, ocean-surface winds and sea ice characteristics, and accurate measurements of the atmospheric refractive indices to derive, atmospheric vertical profiles of temperature, pressure and humidity, profiles of electron content in the ionosphere, respectively. "India (24°N, 76°E) & Larsemann Hills (69°S, 76°E) are located almost on the same longitude. It is possible to establish a communication link between these two locations through an Indian GEO stationary communication satellite with ground station elevation angles better than 10°. For other far locations, simultaneous visibility of the Indian GEO stationary satellite is not possible for this elevation angle."

Since satellite is visible for around 10 passes a day, over the proposed site the data can be transmitted to the Ground Station in every orbit. This site is also useful to collect the data from CARTO-1, CARTO-2A, and CARTO-2B, which are already in the orbit and also will be useful to receive data from RISAT-1.

The proposed Earth station at Larsemann Hills (76^{o} E), when established, would be extremely useful for having an extended coverage over the Indian Ocean sector of the Southern Ocean, as also the online transmission of data to archival centers in the mainland. The *in situ* data collected over the oceans near Larsemann Hills will help in validating ocean circulation models in the near future.

The Mahanadi Graben located on the Eastern Ghat Mobile Belt of India exposes an entire sequence of rock types ranging in age from middle/late Proterozoic to Permian. A similar sequence is found to be present along the Lambert Graben. The correlation between the two distant locations with respect to lithologies, structure, tectonics, P.T.t., and other geological constraints would help in fine-tuning the Gondwana fit (Figure 5). The significance of this region is best explained by Reading (2006) in following lines;

"Although there is reasonable outcrop exposure around the Antarctic coastline, the mountain ranges surrounding the Lambert glacier are the only outcrop in the interior of East Antarctica and thus provide a window into understanding the assembly of Gondwana and earlier super continent".

There are very few locations available along the east Antarctic margin like Larsemann Hills that are free of ice shelf and are easily accessible.

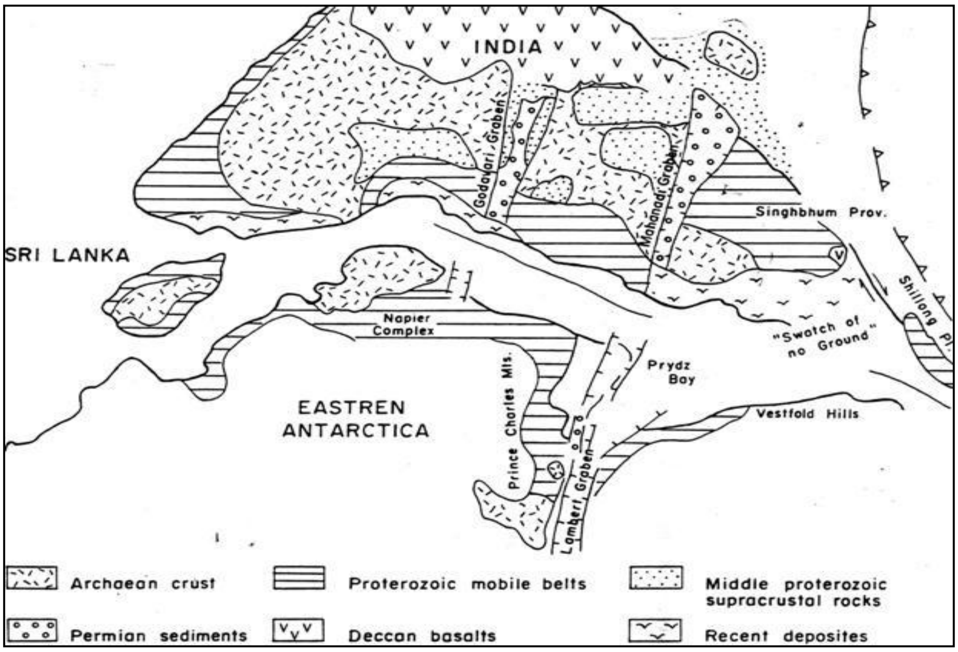

FIGURE 5 : INDIA-GONDWANA FIT

2.2 ADDITIONAL SUPPORT TO SOUTHERN OCEAN STUDY

Southern Ocean, especially the Indian sector remains least understood in terms of physical, chemical and biological oceanography. Since expeditions to Larsemann hills would cruise through the Southern Ocean it would provide an opportunity to collect XCTD, XBT, SST and other relevant data by the same team. India has launched several programs on microbial diversity, physical oceanography and atmospheric sciences, biological productivity, biogeochemistry etc. in the Indian Ocean sector, through regular oceanographic expeditions (Vyas et al., 2003, 2004, Anilkumar et al., 2005; Bhandari et al., 2005; D'Souza et al, 2006; Luis et al., 2006; Mathur et al., 2006). Similar research in the Antarctic- Southern Ocean sectors, undertaken between 2007 and 2010 would be of interest to supplement and enrich the existing database (Khare et al., 2007; Srivastava et al., 2007; Luis and Ravindra, 2008; Mohan et al., 2008; Rajan and Khare, 2008;,Khare et al., 2009; Luis and Sudhakar, 2009; Jasmine et al., 2009). Having the new scientific station at Larsemann Hills would also facilitate systematic surveys and continuous monitoring of the Southern Ocean for climatic changes, biogeochemistry and other related areas that may also have an impact on the environment and biota of Antarctica. Under the Southern Ocean Programme, India is planning to position Argo floats, 20^{o} S onwards to cover the major fronts of Indian sector of Southern Ocean. The new station will be the end point of the long traverse in the Southern Ocean Expedition.

2.3 LOCATION OF SITE

The proposed location for new research base is at Larsemann Hills of Prydz Bay area. The Prydz Bay represents an embayment along the Eastern Antarctic margin, lying between the East Longitudes 66^{0} and $79^{0.}$ The Amery Ice Shelf on the southwestern side and Ingrid Christensen Coast on the southeastern end define its limits. Isolated islands, promontories, peninsulas and nunataks occurring along the continental ice, describe the rocky terrain exposed in the area, which, from north-east to south-west, fall under Vestfold Hills, Rauer Group, Svenner Island, Larsemann Hills and Bolingen Islands (Figure 6).

The Larsemann Hills (69^{o}20’S to 69^{o}30’S Lat : 75^{o}55’E to76^{o}30’E Long), named after Mr. Larsemann Christensen, is an ice-free coastal oasis fringing the Prydz Bay and is located approximately midway between the eastern extremity of the Amery Ice Shelf and the southern boundary of the Vest fold Hills .

There are two main peninsulas on the two extremities of the Larsemann Hills, namely the Broknes and the Stornes Peninsulas (Figure 8). In between these two, there are a number of islands and some unnamed promontories of varying dimensions. Westwards, the Clemence Fjord separates Broknes Peninsula from Stinear Peninsula and Fisher Island. The area north and westwards is marked by islands, namely Harley, Easther, Breadloaf, Butler, Betts, McLeod, Jeason, Solomon and Sandercock. Geomorphology of the area has been described in detail by Gillieson et al.,(1990), Burges et al., (1994), Hodgson et al., (2001, 2006), Ravindra et al., (2004) and several others.

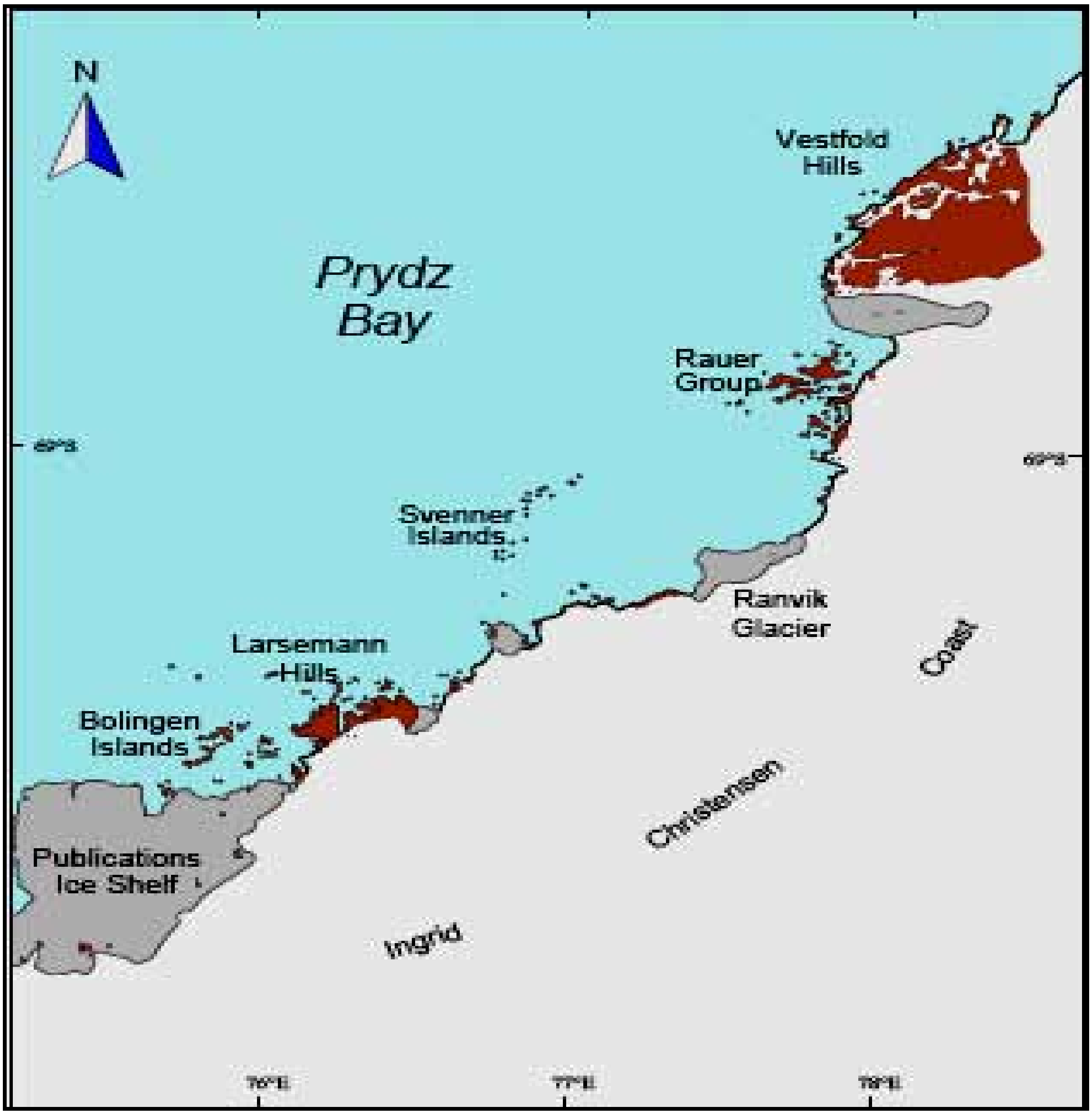

FIGURE 6 : PRYDZ BAY AREA

The area exposes Late Proterozoic rocks comprising gneisses with intrusive granite bodies (Stuwe and Powell, 1989; Beg et al., 2005). The physiographic disposition of rocks exhibits low rising strike ridges, lying between the heights of 65 to 85 m above msl. However, the hills close to the continental ice rise to more than 105 m. The highest elevation in Larsemann Hills is observed to be 153 m above msl in the Broknes peninsula. The hills are dissected by steep valleys. One such feature represented by the western margin of Thala Fjord, is a N-S running lineament (fault) that runs for a distance of about 5 km. The landscape is controlled by the lithologies and geological structures, particularly joints and lineaments. Wind, snow/ice and chemical processes have been the main agencies responsible for the weathering and erosion.

The selected site (69°24’28.8”S: 76°11’14.7”E) is an unnamed pear shaped promontory (in some literature it is mentioned as Grovnes), trending NE-SW that has its wider end facing the sea (Figure 6). The northern and western slopes have a high gradient with the edge being exposed in the form of a steep cliff. The southern margin merges with Polar ice. The western part has ice upto 50 m thick at places and hence hills are inaccessible from this end. The area is fairly undulating, and encased by Thala fjord and Quilty bay, and remains ice-free during most of the summer months. Water is available in one big lake and five smaller lakes. The lake-LGR (numbered as 37 by Gillieson et.al, 1990) holds water that is oligo-saline in characteristics with a salinity of 1.4% (Verleyen et al., 2003). LH 37 and LH 36 are located to the south of Grovnes (Gillieson et al., op. cit.). Smaller lakes, however, have been found suitable for drinking purpose. The site is accessible from open sea through a passage between McLeod and Sandercock Island. A suitable landing site at the northeastern corner of the promontory is an area of low gradient, where landing can be made by barges. With some effort, a flat surface can be carved out of the sloping rocky ground for off -loading cargo on to the land. The area being rocky, an approach path has been made from the landing site up to the proposed site of the station. The flat ground available at the location is suitable for construction of the base.

2.4 SCOPE OF CEE

All the principal activities pertaining to the proposed base, inclusive of design, transportation of men, materials and machineries, during construction and operation, have been considered in development of this report. The proposed scientific studies have also been taken into consideration, while formulating the CEE.

The CEE has been prepared in accordance with Annex I of the Protocol on Environmental Protection to the Antarctic Treaty (Cohen, 2002) and the Guidelines for Environmental Impact Assessment in Antarctica (Resolution 4, XXVIII ATCM, 2005). Environmental monitoring during construction and operational phases will adhere to the Practical Guidelines for Developing and Designing Environmental Monitoring programs in Antarctica (COMNAP, 2005), with regard to various aspects of pollution indicators.

Since the site is situated within Antarctica Specially Managed Area (ASMA-6), due consideration has been given to environmental management plans before carrying out any construction activity. During construction too, proper care will be taken as India is a member of the Larsemann Hills Management Group comprising Australia, China, Romania and Russia that are committed to maintain environmental health of the area. India’s commitment in this regard is documented by the submission of IEE for three activities viz. placement of shelter huts (IP 2 XXX-ATCM), installation of 6 kW wind turbine generator (IP 21, XXXII-ATCM) and development path (IP 001, XXXIII-ATCM) to the ATCM/CEP before starting of activities.

2.5 PROPOSED FACILITIES AT THE STATION

The Station is being designed as an ergonomic entity in harmony with the local environment. It is proposed to build a self-contained thermally insulated three-storey structure on stilts including air conditioning system on terrace which is referred to as third floor. The first floor will house the general facilities like, storage, laboratories etc., second floor will be used for living accommodation, kitchen, lounge, offices, recreation facilities, medical room etc. *(Appendix 1)*. The sate-of-the-art communication facilities as well as laboratories will be established at the station. As the building is proposed to be constructed at around 50 m above msl, the structure will be visible while approaching the area from north. The designed life span of the station has been envisaged as 25 years. Footprints and different views of site location are shown in Figure 7, 7a, 7b.

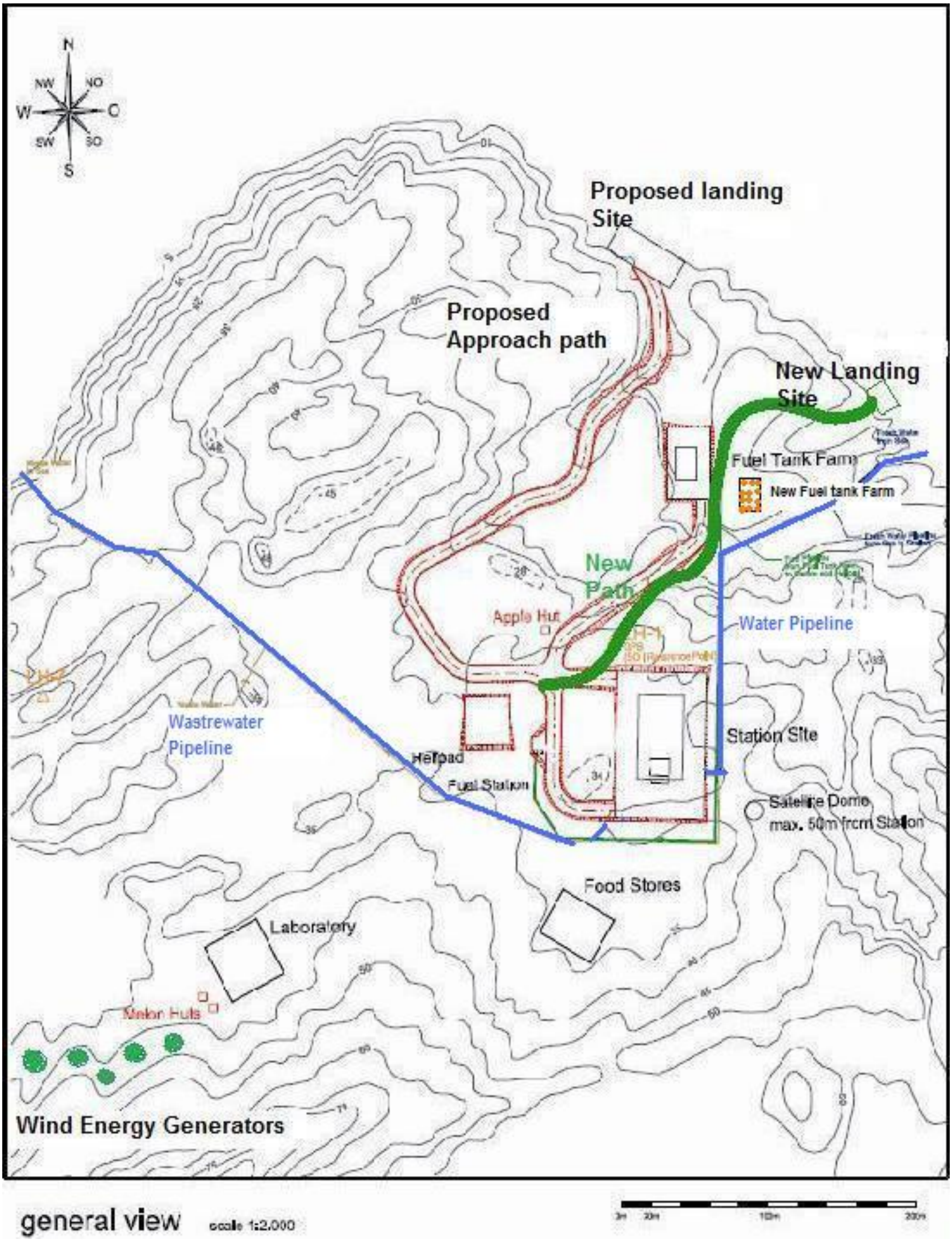

FIGURE 7: LAYOUT PLAN OF THE STATION BUILDING AND OTHER INFRASTRUCTURE

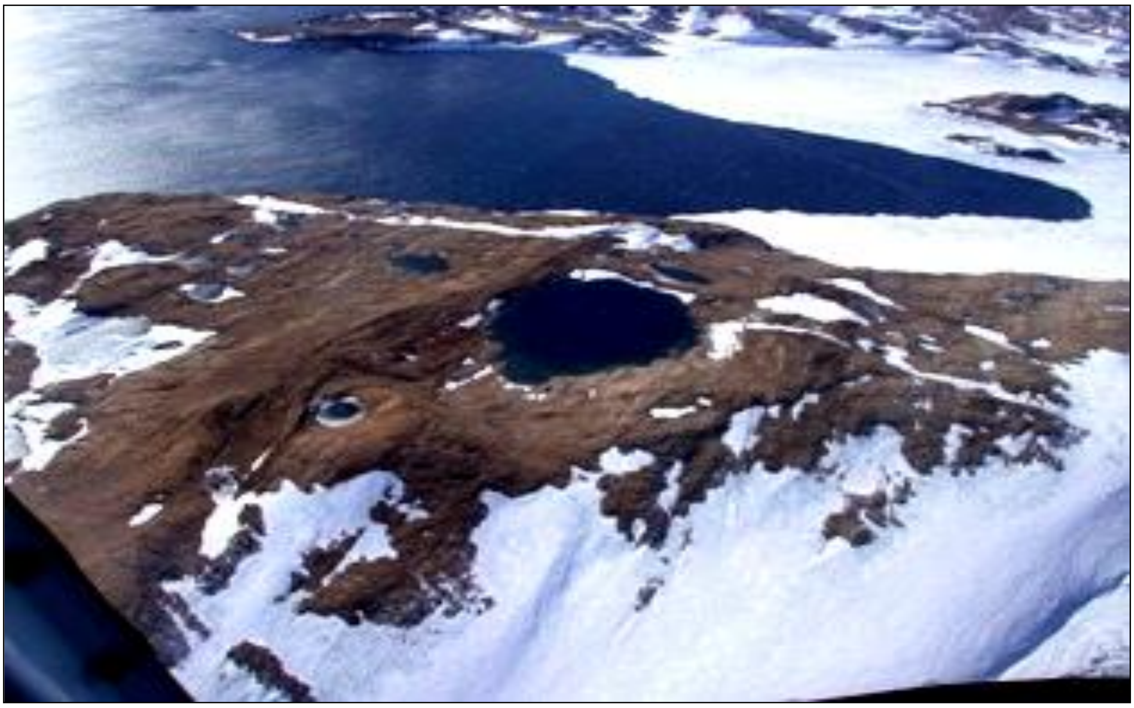

Figure 7 (a): Overview of Station Site and Lakes

Figure 7 (b): View Wind Energy Generator Site along with Igloo Huts

2.5.1 LIVING ACCOMMODATION

The Station is being designed to accommodate 25 people during summer (provision is also being made for additional accommodation for 15 people in case of need) and 15 people during winter period with all the facilities to carry out routine as well as scientific work. The proposed summer team composition will be 15 scientists and 10 maintenance staff, and the winter team composition will be ten scientists and five logistics personnel.

2.5.2 LABORATORIES

The Station will have well-equipped laboratories on the ground floor which will cater to earth and biological sciences as well as environmental studies. Some laboratories such as meteorology, astronomy, geomagnetism and seismology will be located outside the main station in separate modules away from each other to avoid radio interference, manmade noise and other disturbances (Figure 7). An environmental monitoring laboratory will be among the first facilities to be established to monitor the environmental parameters.

2.5.3 MEDICAL FACILITIES

The sick bay and medical room will be housed on the second floor and will have all the modern facilities and amenities including an operation theatre. The facility will be designed as per the best practice guidelines for sterility and efficiency. Proper health care and safety measures will be enforced to minimize any risk.

2.5.4 KITCHEN AND DINING

Kitchen and dining, both adjacent to each other on the second floor, have been designed to foster the concept of group living in the harsh conditions of Antarctica. The lounge and auditorium will be multifunctional in scope, providing facilities for group meetings, discussions and indoor recreation.

2.5.5 GARAGE, WORKSHOP AND STORES

It is proposed to provide these facilities on the ground floor, which would be easily accessible. This structure will comprise pre-fabricated modules with an emphasis on keeping the noise levels to the minimum.

2.5.6 WASTE MANAGEMENT

A well designed wastewater treatment system and a comprehensive solid and liquid waste management plan will be implemented with minimum waste generation at source. There will be an overall attempt to keep the environmental impact due to waste generation at minimum. Wastewater generated in the station from various sources will be treated by biologically activated sludge technology using membrane filter. Deep pipe encased with trace heating element will be used to discharge treated wastewater at safe distance from the water intake point. Effluent water characteristics will meet EU bathing water quality as shown in Table 1.

TABLE 1 : EFFLUENT CHARACTERISTICS

S. No	Parameters	Concentration
1	BOD	5 mg/l
2	COD	80 mg/l
3	Temperature	App. 20^{o}C
4	Coliform	E.Coli< 500 cfu/100 ml Intestinal enterococci <200 cfu/100 ml

2.5.7 WATER MANAGEMENT

Drinking water demands will be fully met mainly by drawing water from sea and desalinization through reverse osmosis. The small fresh water lakes, which get their recharge through snow accumulation, will be used only in case of emergency. The option for water source is accounted from snow accumulation over the small lakes situated nearby the station named as L1 and L3 as shown in Figure 36. A conservative annual recharge over 11000 m^2 with 10 cm of snow accumulation will generate a yield of 176 m^3 equivalent water. However, this option is only kept for emergency purpose. A provision of water production through snow melting will also be kept as standby system.

Domestic water demand is estimated to be 60 liters per person per day, apart from water needed for toilet flushing. Grey water collected from showers will be recycled in recovery plant and used for supplementing the water requirement in toilets etc. Total water requirement during summer will be around 2400 liters per day for 40 persons, out of which 20% of water (500 liters) will be recycled to use for toilet flushing. During winter around 900 liters will be utilized by 15 occupants and around 200 litres will be recycled for toilet flushing per day.

After filtration, desalination and mineralization drinking water will be stored in two storage tanks of 12 kL each. These tanks can store water for continuous use for 11 days for 15 persons during winter and for 5 days for 40 persons during summer. Hot water supply in the station will be met through two tanks, fitted with heating elements.

2.5.8 ENERGY MANAGEMENT

While the fuel based power generation system will remain the main source of energy, attempts will be made to supplement the power demand with alternate sources like wind and solar energy. The heat generated from the generators will be utilized in heating the station using Combined Heat and Power (CHP) concept. These provisions will reduce the environmental impact of the fossil fuel. Maximum electrical load of the station is envisaged to be around 153 kW. Three CHP of 100 kW (operated with ATF) will be installed in the station. Only two CHP units will be run simultaneously to meet the basic demand of station of 96 kW and additional peak load of around 57 kW. In addition to contribution of electrical load, total 155 kW of thermal energy requirement will also be met through these units. All the CHP units will be augmented with exhaust system to emit the waste gases and particulates.

The shift from fossil fuel based power supply to alternate source will be achieved in a phased manner. In the beginning wind turbine will be installed for 15/25 kW power generation. The type and design is under finalization. Solar panels will also be installed to produce around 20 kW in the initial stage, which will require approximately 400 m^{2}of panels.

2.5.9 APPROACH PATH

It was proposed to have a path connecting the landing site to station site as well as fuel storage area. The approach path was necessary to connect the landing site to the fuel dump and station to transport the materials using sea and land routes. The width of the path according to earlier design was six to eight meters for easy movement of vehicles and materials to the station and other storage units. Later, according to ground conditions, landing site was shifted from the earlier decided point to further eastern location. This has reduced the length of the path from 800 meters to 500 meters and thus has resulted in reducing further the overall footprints. Since it was initiated before construction of station, Initial Environmental Evaluation (IEE) Report for development of approach path, at Larsemann Hills in Antarctica was prepared in agreement with Article 2 of Annex 1 to the Protocol on Environmental Protection to the Antarctic Treaty. Probable impacts due to development have been carried out as per the guidelines of the Council of Managers of National Antarctic Programs (COMNAP, 2005) for Environmental Impact Assessment addressing the environmental issues and their management. The IEE was submitted to XXXIII-ATCM held in Uruguay as IP1.

The initial development work pertaining to the path was completed in phases during austral summer of 2009-10. At the beginning, necessary equipment weighing about 2 to 3 tons such as rock drill, splitters and air compressor were transferred from ship to the site by helicopter (Figure 11). In the second phase, landing zone was prepared for offloading the machineries such as bulldozer, excavator, piston bully vehicles etc. These items were driven on the fast ice after ascertaining the thickness of fast ice for safe movement of the machinery etc. In the third phase, a 50 ton crane was transported to site over fast ice, while ship was berthed around 100 meters away from the edge of the promontory (Figure 12). Thereafter, cutting and filling of the rock was undertaken along the path, leading up to the station and fuel storage area.

2.5.10 PLATFORM FOR EARTH STATION

Three sets of antenna and radome of remote sensing earth station will be mounted on three platform of 16 m x16 m size. Platform will be anchored with rock, with minimal disturbance to adjoining area (Figure 7).

2.6 SHIPPING AND LOGISTICS

2.6.1 ACCESSIBILITY FROM THE OPEN OCEAN

The promontory is accessed through the gap between the McLeod and Sandercock Islands (Figure 8). This area of the sea was found to be open during early February (observed since 2004-05) with presence of some isolated icebergs on the outer periphery. An isolated iceberg was found berthed between the McLeod and the Sandercock Islands but comparison of imageries of past few years have shown that the said iceberg is firmly grounded and is getting destroyed (Inset Figure 8).

(Source AAD)

FIGURE 8 : LARSEMANN HILLS AND SURROUNDINGS

In Prydz Bay area, bathymetry data was available only up to McLeod Island in navigational charts. During late February 2006, preliminary multibeam swath bathymetric surveys *(Appendix 2 and 3*) were undertaken along a corridor from the grounded iceberg to the western face of the Larsemann promontory to define an approach channel for the ship. The NW-SE trending corridor from the grounded iceberg to the promontory measured about 6 km and had a width of about 2.5 km. Bathymetric data totaling 122 line km was collected along 22 survey lines within the corridor. The minimum depth recorded in the channel was 25 m and the maximum was 460 m. The bathymetry data was further supplemented during 2009-10 austral summer by undertaking small tug boat (Figure 9). Bathymetry data shows that channel is free of any obstruction and has sufficient depth to navigate any ship/boat and berth close to promontory. This study facilitated berthing of ship around 100 meters from the edge of promontory of station site (Figure 10).

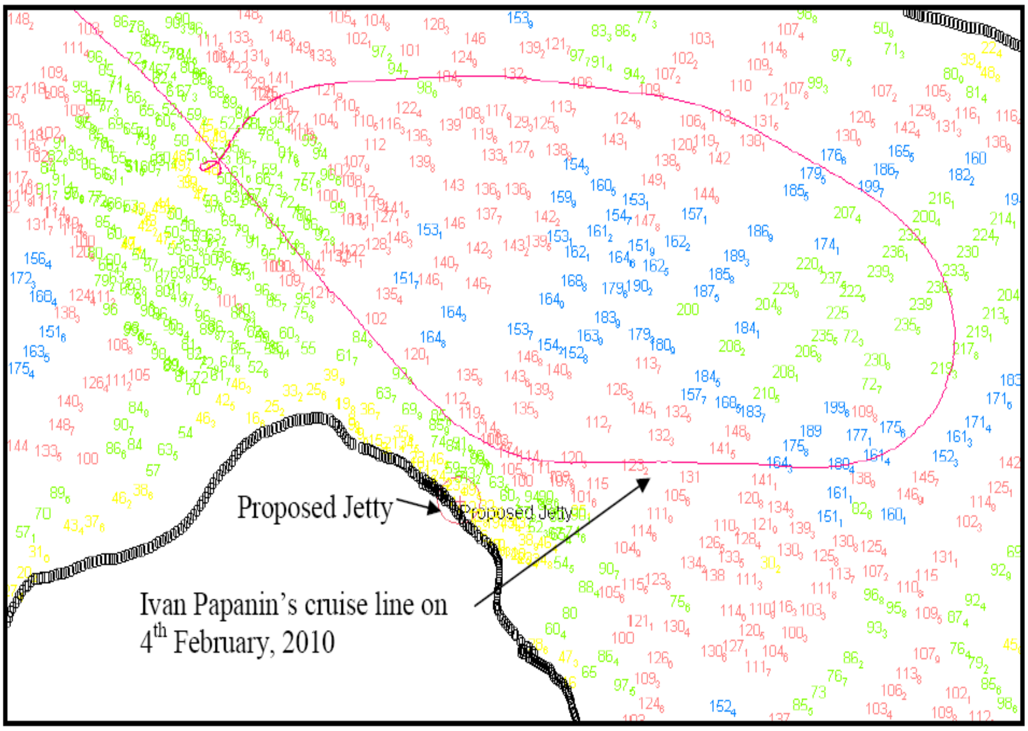

FIGURE 9 : BATHYMETRY MAP CREATED DURING 2009-10 AUSTRAL SUMMER

FIGURE 10 : BERTHING OF SHIP VERY CLOSE TO PROMONTORY

2.6.2 TRANSPORTATION AND MOVEMENT

The men and material will be transported through an ice class ship and helicopters. A heavy–lift helicopter (Kamov) will also be used. The weight of various components of the station will be modulated to conform to the lifting capacity of the helicopter so that transportation of container/modules will be possible by helicopter from ship to site. In addition, barge may also be used for movement of odd-size and heavy equipment/machinery. A Russian airstrip exists about 6 km away from the proposed site and this may also be used as an option to send men and material if need arises. The fuel will be transported using flexible pipes by pumping directly from the ship to the shore. The approach to Russian air strip from Thala fjord will be worked out during successive years, jointly with Russian Antarctic Programme personnel.

FIGURE 11 : HELICOPTER DROPPING OF MACHINERIES AT SITE

FIGURE 12 : TRANSPORTATION OF HEAVY CRANE OVER FAST ICE

2.7 CONSTRUCTION OF STATION

Construction of the station is proposed to be initiated in the austral summer season of 2010-11. It is planned to complete the construction activity during two austral summers, by using pre-fabricated structures/modules. In the first phase during austral season of 2010-11, erection of foundation, fuel farm preparation, pipeline laying, construction of radome foundation and landing site will be completed while in the second phase during austral summer season of 2011-12, superstructure will be erected. A dedicated work force of 25-30 men will be involved in the construction activity at the site. One Igloo hut, already placed at the site during 2004-05, was supplemented by placing another four living modules during 2009-10 austral summer, to act as emergency shelters.

Different stages of design development are scheduled as follows:

Basic requirement framework	*April-June 2006*
Expression of Interest	*August-September-2006*
Concept Proposal	*November 2006*
Selection of Architect	*Early December 2006*
Design Development and Tendering	*May- 2007-2010*
Path development	*Austral Summer of 2009-10*
Construction	*Austral Summers of 2010-11 and 2011-12*

2.8 INSTALLATION OF WIND TURBINES AND SOLAR PANELS

It is proposed to supplement the energy requirement through wind and solar energy. The wind turbines will be installed near the station on the hills, while the solar panels will be placed over the walls and the roofs of the station. A Wind Energy Generator (WEG) of 6 kW was installed (Figure 13) at western side of proposed station, during austral summer of 2008-

09, on experimental basis for which an IEE was submitted to XXXII-ATCM/CEP as IP021, including potential impact of bird strike on wind turbine. It was also observed through study that birds were not present in that area and were not flying over the site. Installation on experimental basis of a WEG was needed to provide uninterrupted power supply to the instruments, which have to be left unattended during the winters as the shelter huts placed at proposed site was unoccupied during winter. Additional WEGs of higher capacity i.e. 15/25 kW will be installed near the existing WEG after construction of the station.

FIGURE 13 : WIND ENERGY GENERATOR (6KW) INSTALLED AT SITE

2.9 DECOMMISSIONING OF STATION

The station is designed for a total life span of 25 years. Every five years, strength of the station will be assessed through inspection and material testing. Any strengthening or replacement of a particular block or a portion would be carried out without disturbing adjacent structures. The decommissioning of the station will depend upon the health of the structure and/or completion of the objectives of the planned scientific activities.

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STATION DESIGN

3.1 STATION DESCRIPTION

The Station design has been drawn based on logistic needs, operational demands, trouble free supply and maintenance of life support systems. To reduce the footprint on the ground, design and placement of the module is conceptualized to keep minimum movement of men and material in and around the station.

An experts committee of India, comprising specialists from School of Planning and Architecture (New Delhi), Central Building Research Institute (Roorkee), Structural Engineering Research Centre (Chennai), Mormugao Port Trust (Goa), and a Civil Engineer with experience of building construction in Antarctica, selected the design offered by M/s IMS Ingenieurgesellschhaft mbH, Germany. This German company (selected out of the four short listed firms) was involved in general planning for the new German Antarctic research station Newmayer III at Ekstron ice shelf, west of Atka Bay. The selected conceptual design (Figure 14, 14a, 14b, 14c) is environmental friendly and commensurate with the Environmental Protocol *Vis-a-vis* objectives and requirements of the base.

The station building is an elevated three-storey structure supported on columns at base. Garage is located at back side of the building in ground level and is part of the main structure. The three-storey building is aligned in north-south direction. At the site, main wind direction is from east and north-east direction, which strikes transversely to the station. Apart from access through the garage, the building also has two entrances from eastern and western sides of the building. The station complex comprises main building, helipad, fuel tank farm etc. In view of the extreme climatic conditions in Antarctica and the short working window time available, pre-fabricated modules will be used keeping, the environmental impact to the minimum.

FIGURE 14 : ARTIST'S IMPRESSION OF THE STATION

Figure 14 (a): Perspective View

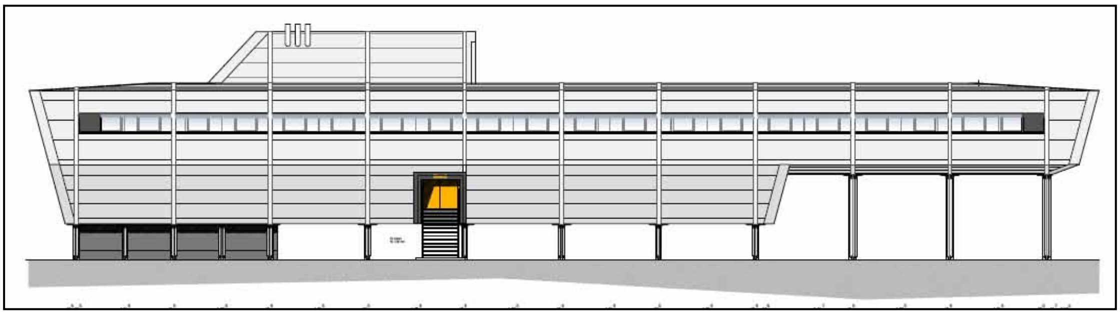


Figure 14 (b): Side View

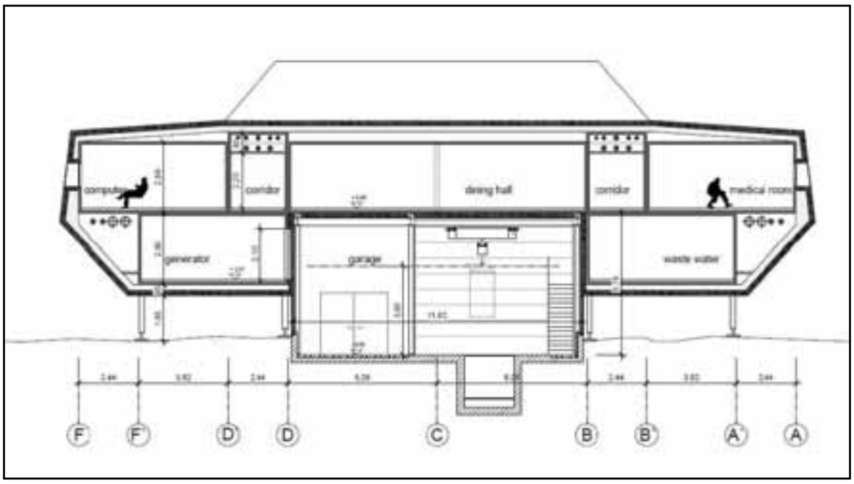


Figure 14 (c): Sectional Front Elevation

3.2 STRUCTURAL DESIGN

3.2.1 BASE FOUNDATION AND STABILITY

The structure conceptualizes a compact design by placing customized containers (ISO 668) on a platform and uses their load carrying capacity and stability for load transfer to the foundation. The containers will be fitted with standard fixing elements (stacking cones and bridge fittings), friction-locked together and will make a 3D-sheet type bearing system. The foundation platform will be designed as an elevated girder-grid construction which will be supported on columns (Figure 15).

The foundation of the building rests on firm rock base. Considering the high wind loads coming on the building and the low dead weight of the structure, additional anchors will be arranged under the footings to avoid up lift of the columns. To avoid thermal bridge, columns will have additional insulation. Superstructure will be supported on micro-piles (GEWI-piles) system. The micro-pile system consists of a pressure-grouted single steel bar in a borehole up to 30 cm in diameter. The temperatures in the ground are assumed to be equivalent to the air temperature (down to -40 °C in winter). To reduce the number of equipments and spares in the installation of the piles was decided to stick to a uniform GEWI bar size of 50 mm throughout the foundation of the structure. Three groups of two piles each are required for the heavily loaded vertical columns under the staircase in the three-storey part of the building and six groups of three piles each are required under the Y-shaped columns. Single vertical pile will be provided at all other foundation locations.

All steel members will be protected against corrosion by robust galvanizing. Since the columns will be exposed to snowdrift and thus to stronger abrasion, an additional coating will be applied on these higher strained members.

The structural elements of the platform will be prefabricated and assembled on site by friction grip screws. Welding on site is not planned. The elements of the platform structure will be fabricated from rolled steel sections of ordinary structural steel. Only for the elements exposed to higher loads and extreme weather conditions like the columns, steel with low temperature grade will be used. Various steel members to be used in the structure will be having the specifications as given below:

- *GEWI type : steel S 500/550 grade*
- *Columns : steel S 355 NL*
- *Garage steel members : steel S 355 NL*
- *Container frames : steel S 355*
- *Primary structure : steel S 355 N*
- *Façade substructure: steel S 355 N (N: normalized/normalized-rolled steel, L: low temperature).*

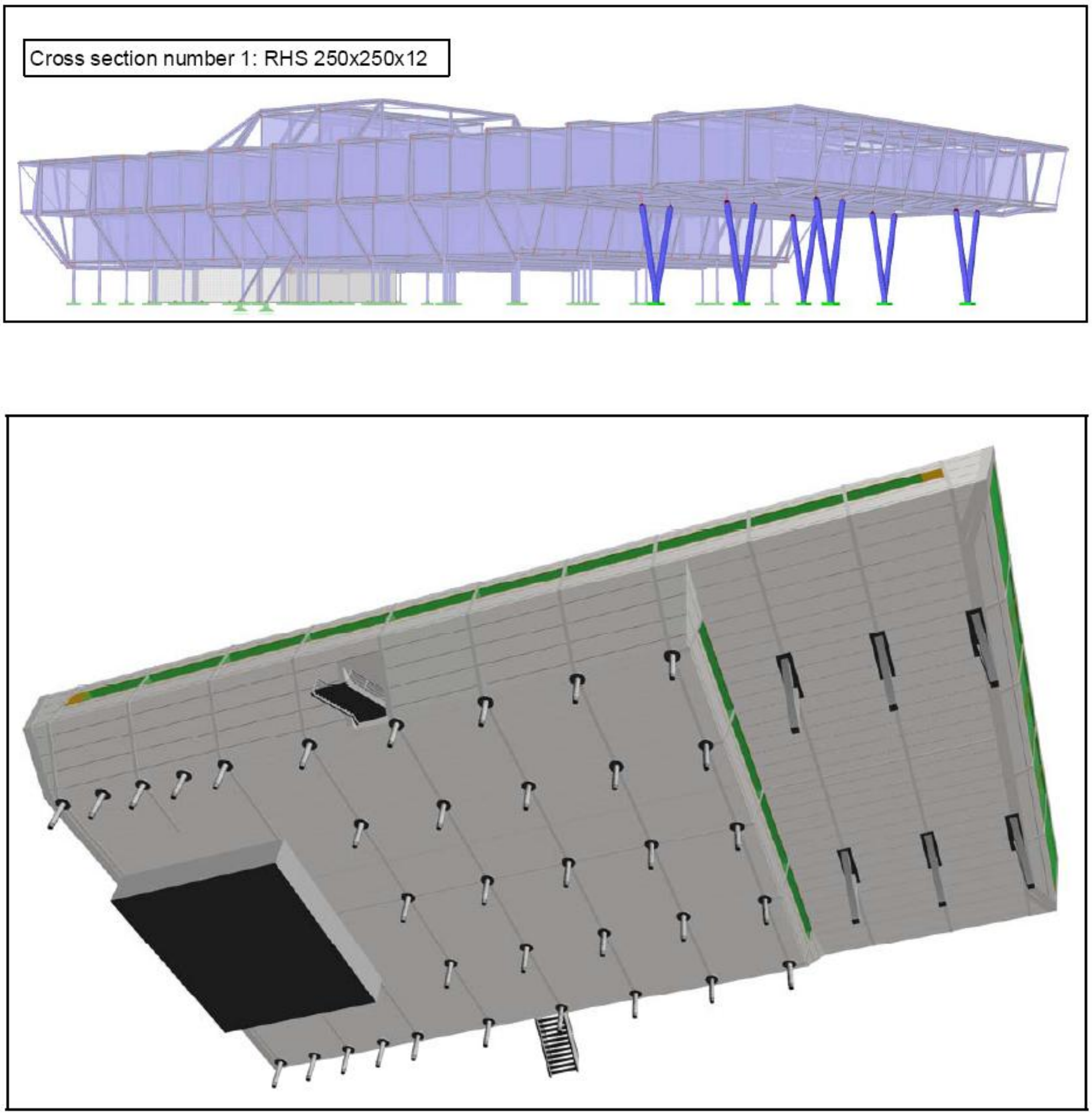
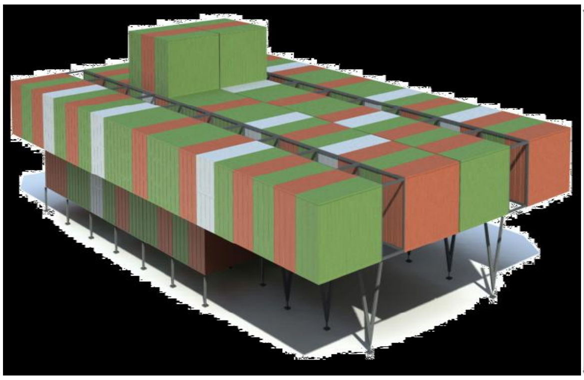
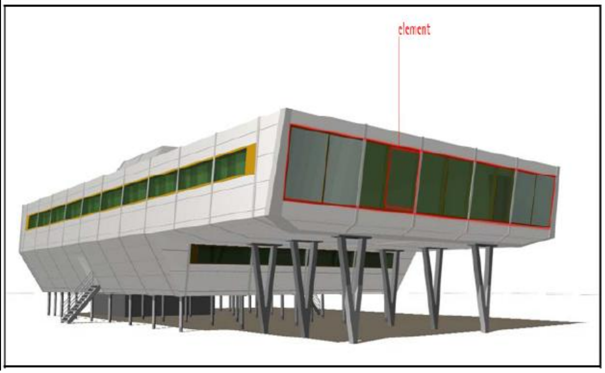


FIGURE 15 : BASE STRUCTURE AND COLUMN OF THE BUILDING

3.2.2 OUTER SHELL

An additional exterior jacket (outer shell) will be erected around the containers. It will protect the internal space from wind, precipitation and radiation. This exterior jacket will form the visible face of the station. The facade system is constructed of sandwiched elements comprising a PUR-core between steel sheet covers. The panels will be of special construction that combines the standards for cold stores and for façade systems (Figure 16). A special locking system for the splices will be used, so that they do not loosen due to wind-inducted vibrations.





Inner base of containers facade

FIGURE 16 : INNER BASE OF CONTAINER AND FACADE

By providing a PUR-core, the elements will have a high shear resistance to withstand the wind forces, good temperature performance to withstand low temperature up to -45^{0}C and to eliminate vibrations which are higher than that of elements with a mineral-wool core. Due to corrosion protection provided by Al-Zn, the covering steel sheets will give a longer life and a higher radiation resistance. All the external joints will be sealed against wind and snow by special gaskets and locking.

The panels at the roof will be coated with waterproof membrane and additional covering of coated metal sheet will be provided at the edge. Glass façade at the front and sides will be triple glazed with sun protection. The façade will be made of standard steel insulation panels. Approximately 80% of the panels are designed as standard galvanized panels with coating of Polyvinylidene Fluoride (PVDF) enamel which shows high strength durability and resistant to solvents.

3.2.3 AERODYNAMIC STABILITY

Since the site of the station represents a region of katabatic winds, following design criteria have been given due consideration:

- *Providing free passage for wind to pass above and under the structure*
- *Positioning the station in such a way that winds pass by the structure perpendicularly*

A wind tunnel test was performed on the model of the structure at the Indian Institute of Technology Kanpur (IITK), a premier institute in the field of engineering and technology in India, by providing vital statistics on wind flow and wind pressure measurements (Poddar and Saxena, 2009).

Determination of wind load on the building structure has been carried out using met data obtained from neighbouring stations and considering European code for wind loads as well as wind tunnel test. Computerized Fluid Dynamics (CFD) analysis has been done and the same is shown in Figure 17. The sandwiched panels are designed to withstand a characteristic wind load of 2.338 kN/m^2, based on a wind velocity pressure of 1.67 kN/m^2 and a maximum surface pressure coefficient of cp = 1.4. However, at some surface areas, especially at the building corners and edges, higher surface pressure coefficients occur. Pressure coefficients of up to 2.0 have been determined at these surface areas, where additional beams support the sandwiched panels at intermediate locations.

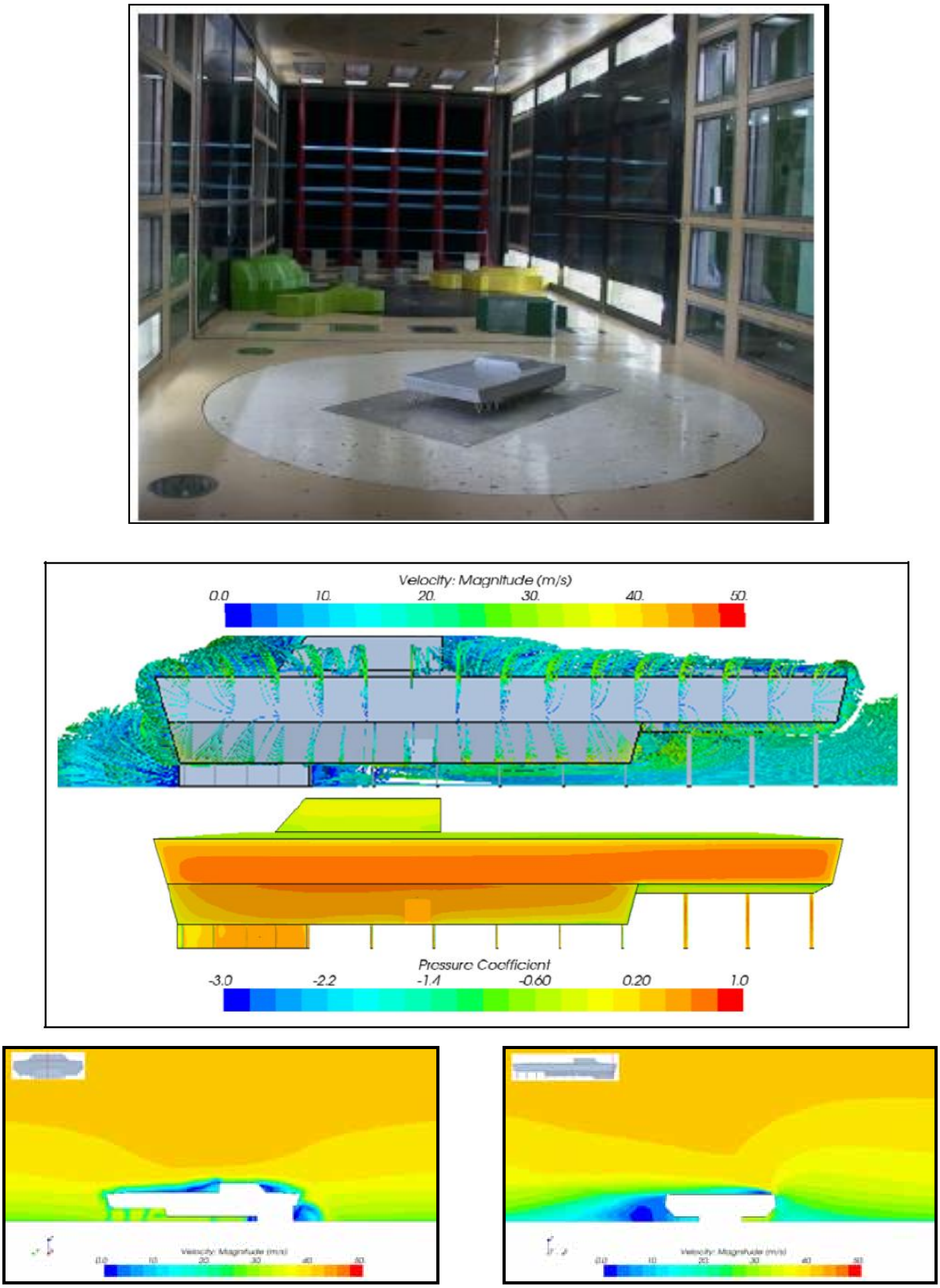


FIGURE 17 : WIND TUNNEL SET-UP AND CFD ANALYSES ON BUILDING STRUCTURE

CFD analysis has been carried out to understand and ensure operational safety of the persons who would be working at nearby station, under high wind condition, for identification of the structural elements subject to high noise-and-vibration, and possible areas of accumulation of snow around the station. Taking into consideration the above effects the design and orientation of the building have been established. Considering the wind direction from East to North with prevailing wind directions North, North-East, East, South-East and South, the orientation of the building has been kept North-South direction, facing North. Passage height below floor of the building varies from 1.83 meter to 4.33 meter.

3.3 FLOOR AND ROOM SYSTEM

The proposed station is a three-storey structure (Figure 18, 19, 20). Garage is placed on the back side of the building, at ground floor. First floor has been designed approximately 1.83 meters above the ground and will consist mainly of service rooms i.e. generator, wastewater treatment unit, water storage, various storages rooms, and laboratories. Living rooms, entertainment room, library, office, kitchen, dining hall, offices, prayer room, communication room, computer room, washroom, sauna, hypothermia bathtub and medical room etc. are placed in the second floor of the structure. Third floor will accommodate air-conditioning system and access to terrace. There will be two side entrances to the building, one each from eastern and western sides of the building. All the three storeys will be connected with two hatches for emergency exit.

The rooms of the research station have been designed to be built up in modular construction using standard containers (20’ long, 8’ wide and 9.5’ high). The advantage of this system is the ease of transportation from the place of fabrication to the nearest port for onward shipment to Antarctica. The inner walls of the rooms will be lined with plasterboards to create a comfortable indoor environment. The inner layer will consist of mineral-wool for fire protection as well as thermal insulation and sound absorption. Floors of the rooms will be built up with a mineral-wool filling and floor panels. Between the outer shell and the walls of the containers, a cavity will be created to prevent condensation effects. The windows in the outer shell will also be included in the inner walls and will have provision for inner darkening by using roller blinds. For safety of the station, the outer windows will be fixed type.

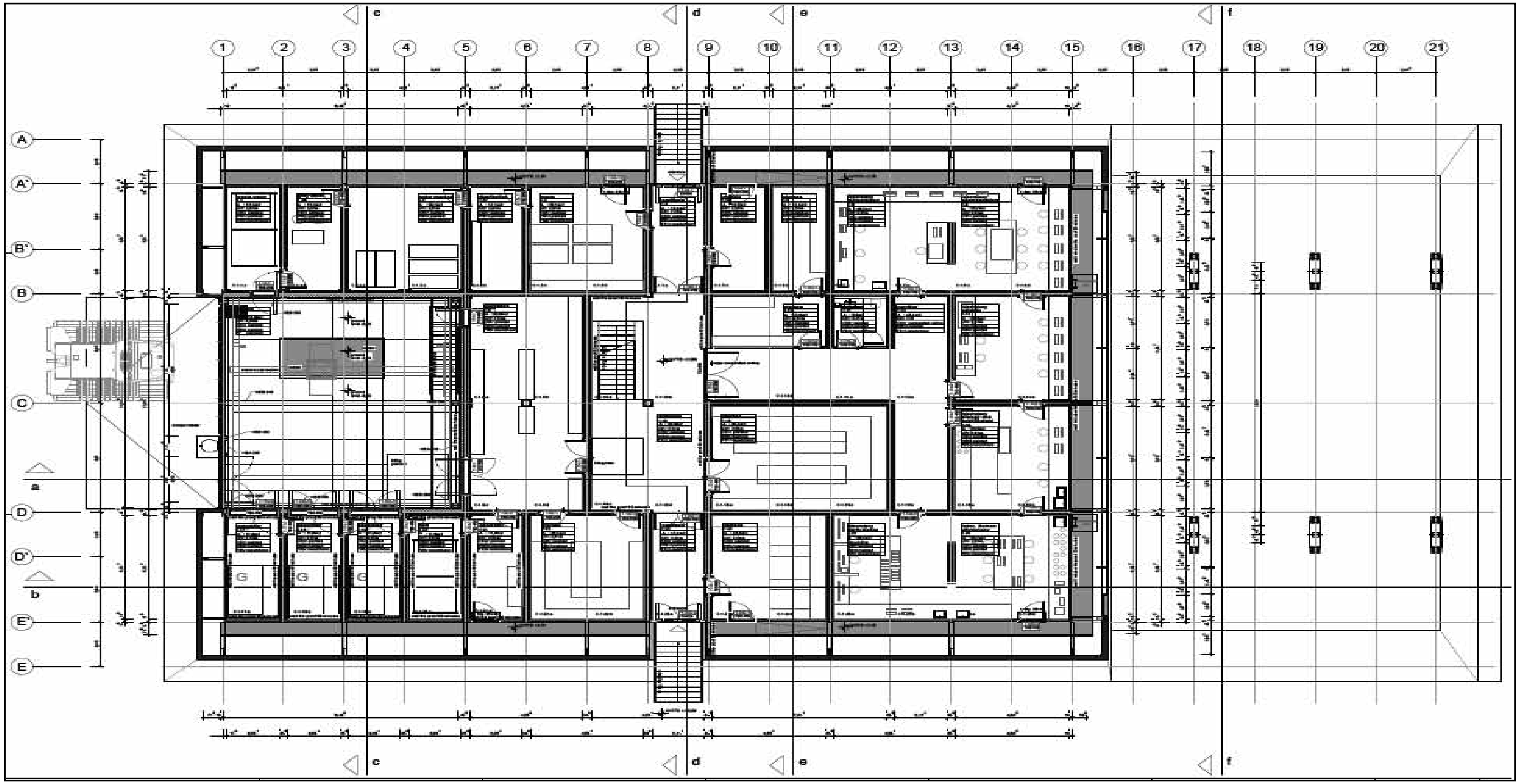


FIGURE 18 : FACILITY DISTRIBUTION IN THE GROUND FLOOR

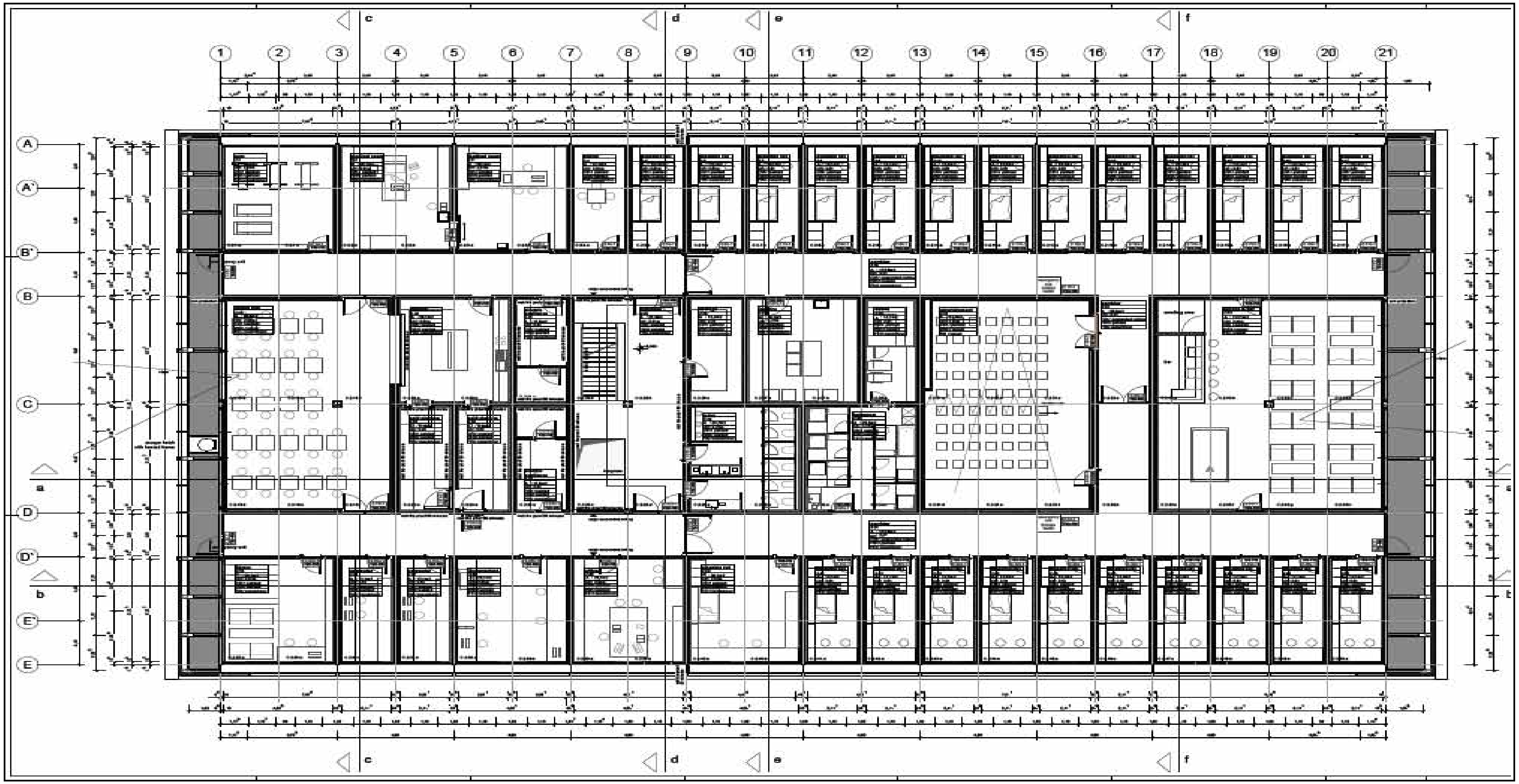


FIGURE 19 : FACILITY DISTRIBUTION IN THE SECOND FLOOR

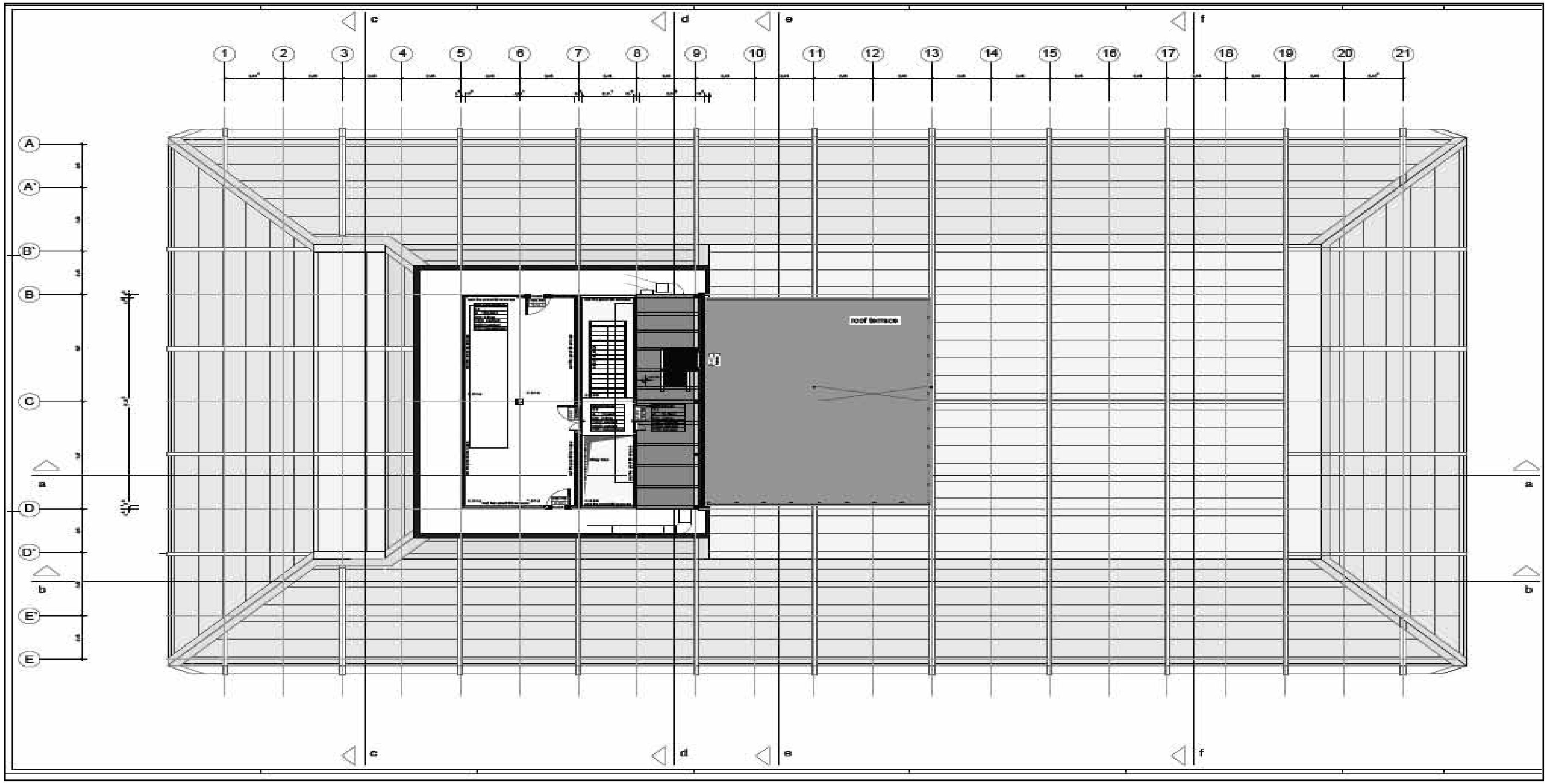


FIGURE 20 : FACILITY DISTRIBUTION IN THE THIRD FLOOR

3.3.1 FIRE PROTECTION

Besides the fire detection system like smoke detectors and alarm systems, the building design also considers protection against fire. Each room will be an isolated fire compartment and rated at F30 (Fire resistance for 30 minutes). Rooms with higher fire loads or fire risks will be rated F90. For the fire protection, groups of rooms will be separated by fire walls into fire areas. Emergency stairs will be provided into safe areas for emergency evacuation and the escape routes will be marked. Safety lights and a smoke extraction system will be provided. All materials used in the station will be fire proof or at least fire resistant. As far as possible, non-flammable material will be used to frame the structure. The façade adjacent to garage is designed according to fire resistance rating F-90. The ceiling of inside structure will be clad with vapor barrier, oriented strand board, mineral wool (200 mm), glulam scantlings and promaxon type A for 90 minutes fire protection (Figure 21) .

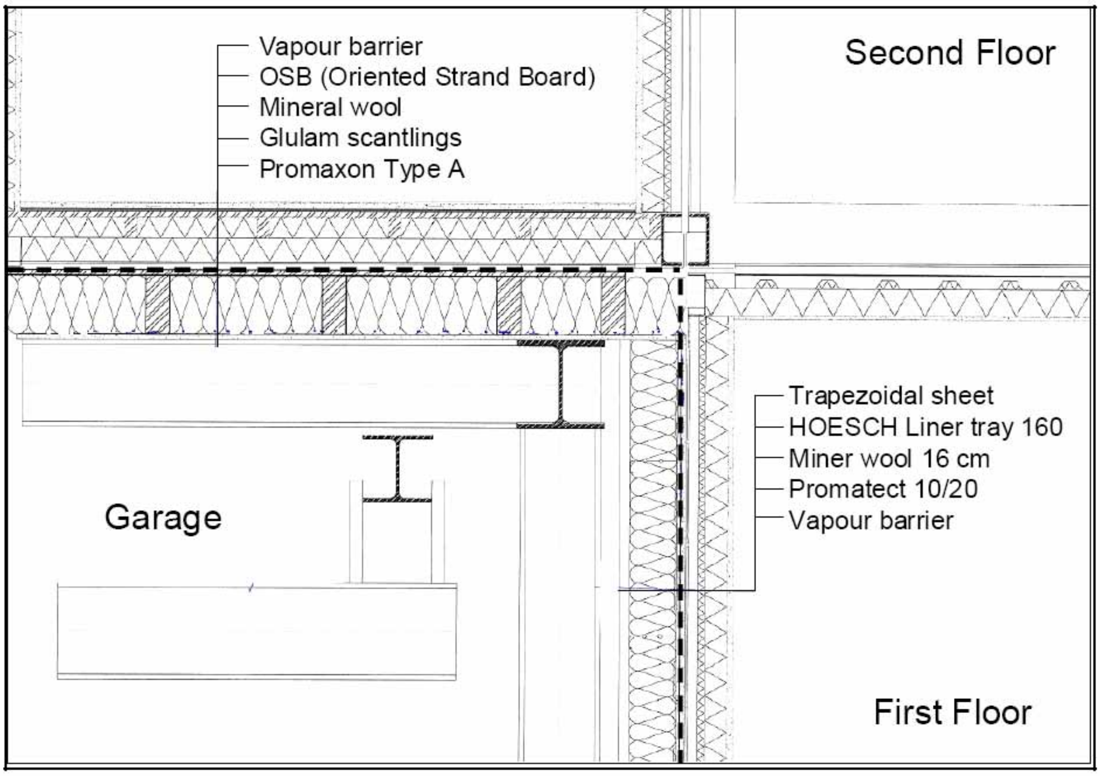


FIGURE 21 : GARAGE CEILING CLAD WITH VARIOUS MATERIALS

For better protection automated fire extinguishing system will be installed in the place where high risk of fire occurrence is envisaged. Smoke detection devices will be installed in the rooms. Smoke compartment doors with auto closing system will be installed at probable areas of fire occurrence. It is also proposed to provide portable fire extinguisher (N_2-type) in places like garage and server room. Kitchen and workshop will be protected with fire blankets as well as hand triggered fire extinguishing system. Water, water-mist and powder type fire extinguishing system will be used at appropriate places.

The station will also be equipped with Video Control System and smoke detection system in corridors, kitchen, workshop, terrace, medical room, and entrance and CHP compartments to monitor any eventuality that occurs due to fire or by any other means.

3.3.2 ENERGY SUPPLY

The station will be supplied with power (electrical energy) and heat (thermal energy) by CHP units (combined heat and power) only (Figure 22). CHP units will be designed to perform for the complete range from minimum to maximum energy demand, which will be operated with ATF. Maximum peak load is estimated to be around 153 kW, whereas minimum load is estimated to be around 96kW. To meet the power demand three generator units, each of 100 kW will be installed inside the station in the first floor.

Out of three generators, one will be operated to meet the basic load demand of 96 kW, the second one will be automatically switched on to meet additional peak load of 57 kW and the third generator will be operated and act as alternate for basic and peak generation. In addition to these three CHP, four 25 kVA generators will also be installed to take care of any eventuality. Wind energy generators and solar cells will be established as alternate source for electrical energy as supplement system to save fossil fuel and control associated emissions. Low noise diesel engines, low voltage switch gear, heat distribution panel, hot water generators, diesel tank (one day capacity) and automatic fire extinguishing system will be installed in the plant room.

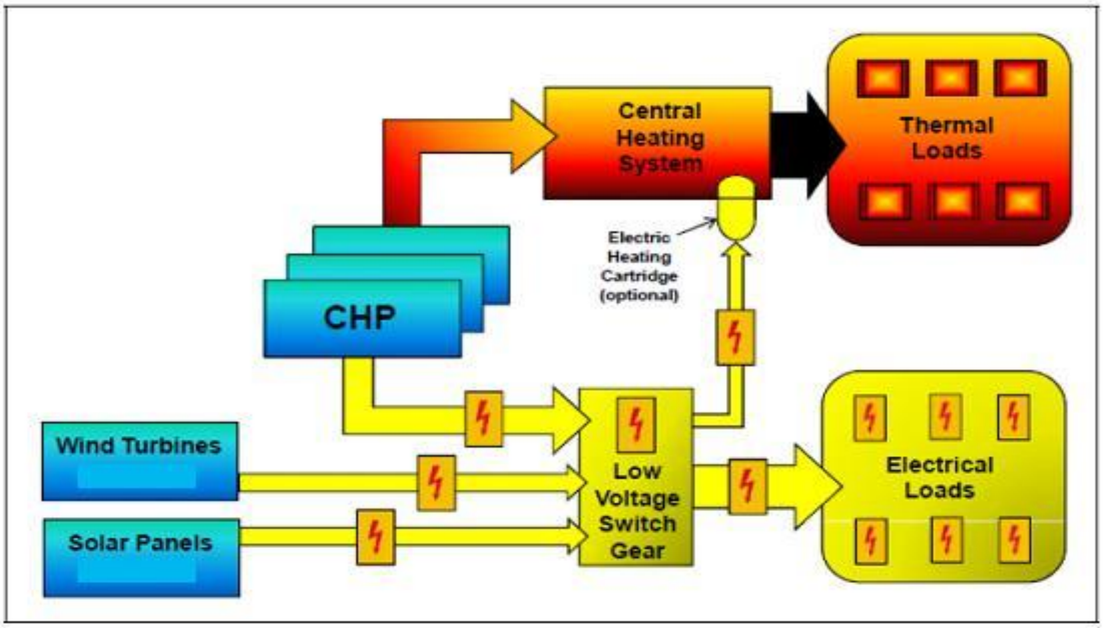


FIGURE 22 : ELECTRICAL ENERGY PROVISION IN GRID SYSTEM OF STATION

3.4 FUEL STORAGE AND SUPPLY

Fuel farm located outside the station, around 500 meters away, is designed to store 300 kL of ATF. From the main storage, fuel will be pumped to another fuel tank having a capacity 13.6 kL and placed outside the station. The fuel will be distributed from here to meet the station, vehicle and helicopter requirements. Fuel will be supplied daily to each CHP by 500 litre tank, placed inside the generator room. The storage tanks with the capacity of 22 kL will be double walled, augmented with leak warning system, level indicator and overflow protection, to ensure maximum safety. Storage tanks will be filled with ATF, by supply tanks of the ship.

Supply tank and storage tank will be connected with solenoid valves. Fuel will be pumped from ship to the fuel farm through coupling hose. Fuel supply system will comply with European standard EN 14420 to fill the thirteen numbers of tanks. Foundation of the fuel tank farm will be laid over pre-cast concrete elements. These storage tanks will rest over steel structures embedded in the pre-cast concrete, using twist and lock mechanism. Tanks will be placed in two rows with clear ground clearance of one meter as shown in Figure 23.

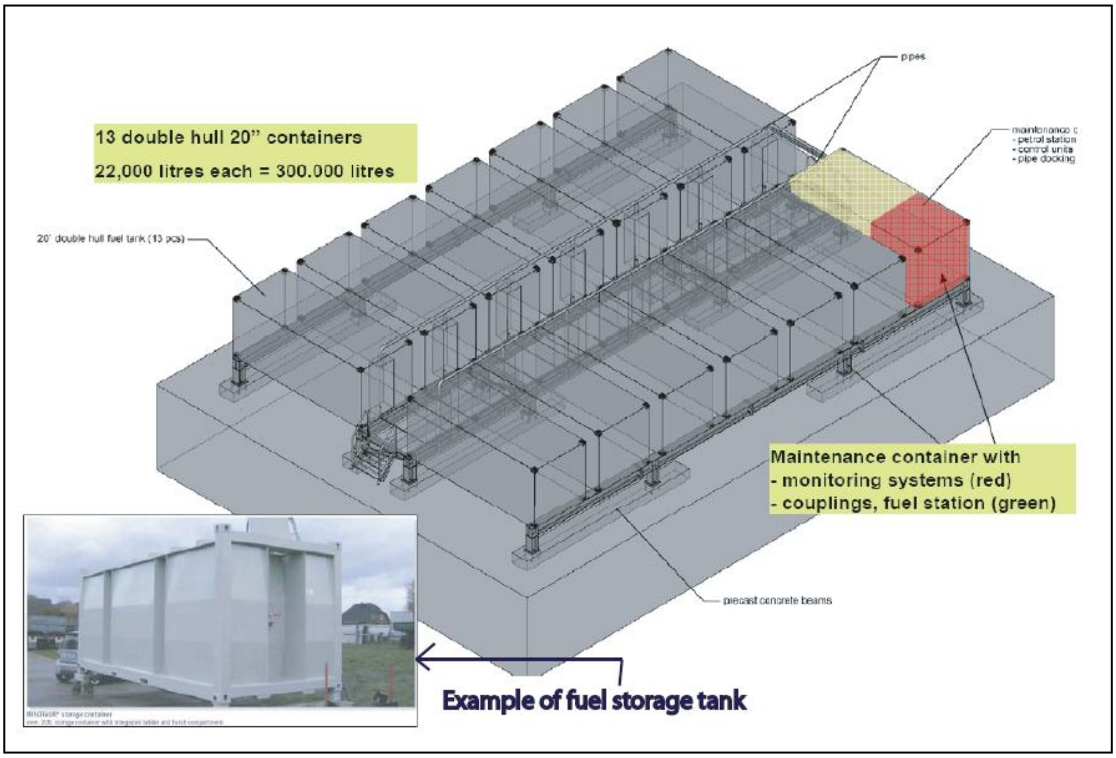


FIGURE 23: FUEL TANK FARM

3.5 PIPING SYSTEM

Piping to be used for heating purpose will be of stainless steel and/or of synthetic compound, insulated with aluminum-coated mineral wool. Pipes for intake water from sea and the wastewater discharge will be thermally insulated with trace heating elements. Pipes will be aligned in gradient for gravity drain-off of liquid so that warming of the pipe system can be avoided for longer duration. This will save energy, required for trace heating elements to keep pipe warm during idle period.

There will be three major pipeline systems to be laid out; waste water, fresh water and fuel pipeline. For good visibility, pipelines will be laid 1.5 meter above the ground in such a way that it will follow the path. Wastewater generated from the station will be treated and discharged into the sea through a pressure pipeline of about 640 meter length. Water will be collected from sea through intake pipe with total length of around 325 meters. The piping system would be equipped with self regulating electrical heating system with insulation. Fuel pipeline will connect fuel farm to the station and helipad. At helipad, fuel will be distributed to helicopter as well as vehicles. Around 230 meter length of fuel pipeline will be laid out to meet the designated purpose.

3.6 HEATING VENTILATION AND AIR CONDITIONING (HVAC)

A detailed study on the thermal envelope of the station façade and in between containers has been carried out to optimize the temperature, humidity and ventilation regulation. Heating and air conditioning of the station have been designed keeping in view the outside minimum temperature of -40^0C during winter and maximum $+10^0$C during summer periods. The HVAC system has been designed to maintain a temperature of 16^0C in the garage, 26^0C in sanitary room and 22^0C at all other areas of the station. Heating of the station will be provided by thermal radiators (the utilization of waste heat helps to reduce the number of CHP units to two).

Maximum thermal load of the station has been estimated to be around 155 kW. One 100 kW generator will produce approximately 120 kW of thermal energy. Therefore the thermal demand of the station will be supplemented with operation of basic and peak demand generators, together. In comparison with oil based radiator, this system will help in saving of diesel fuel and therefore the emissions to air will reduce the impact on environment. In order to minimize heat loss, the heat piping will be installed inside the container casing.

Conditioned air will be supplied to the station according to minimum rate of fresh air supply and heating of the station will be done by thermal radiators. The operational expenses will therefore be minimized. Airflow regulators will allow optimum adaptation of air flow to the areas of demand. The two-stage heat recovery system will enable the reutilization of humidity from the discharged air at stage two and hence operational expenses of the air conditioning system are very efficiently minimized. The “intelligent” integration of heat recovery system will allow reutilizing the heat of the discharged air optimally (Figure 24).

Sound attenuation will be applied so as to minimize the noise to avoid disturbance to the occupants and surroundings. Provision will be made to control ventilation from rooms and zones whenever required. Relative humidity of 30-35% at 22^0C shall be maintained inside the station rooms. HVAC will be designed in such a way that in case of fire it will be switched off automatically. It can be triggered manually to extract the smoke. Exhaust from the rooms, corridor and generator room will be discharged through exhaust aluminum pipes insulated with coated mineral wool. A separate exhaust system will be provided at sanitary rooms, kitchen, hospital, workshop, laboratories and in a part of the lounge.

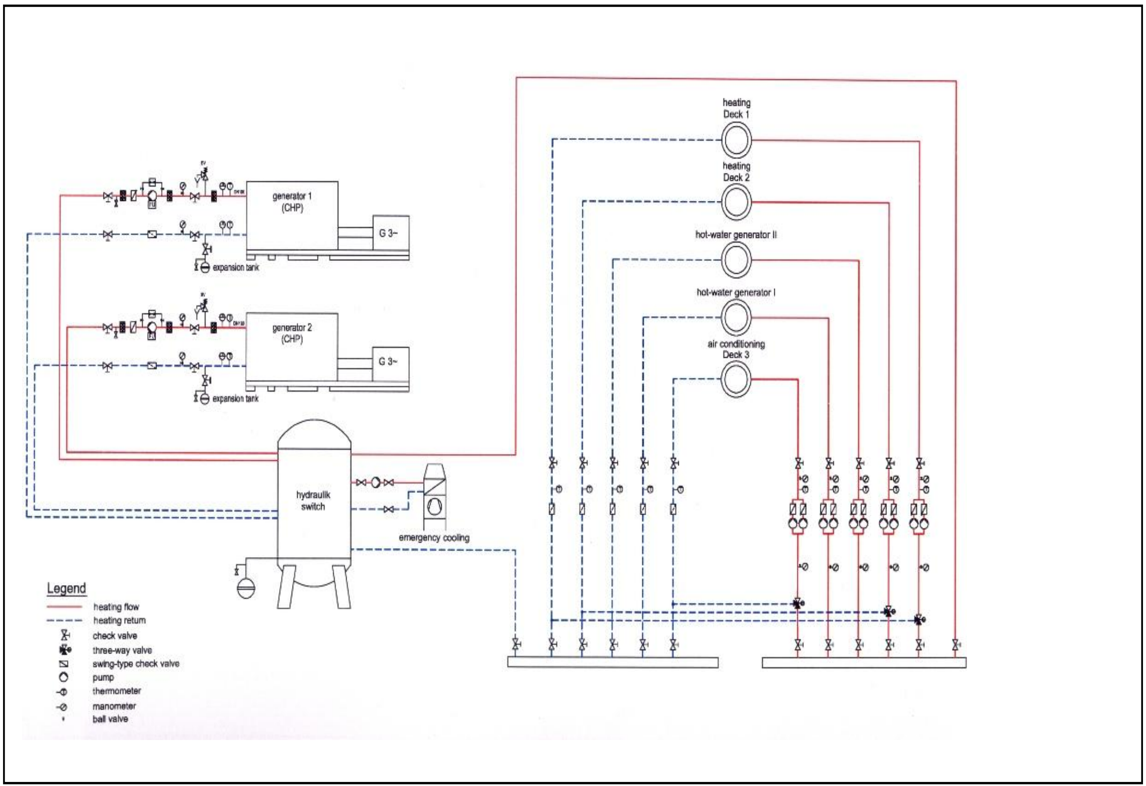
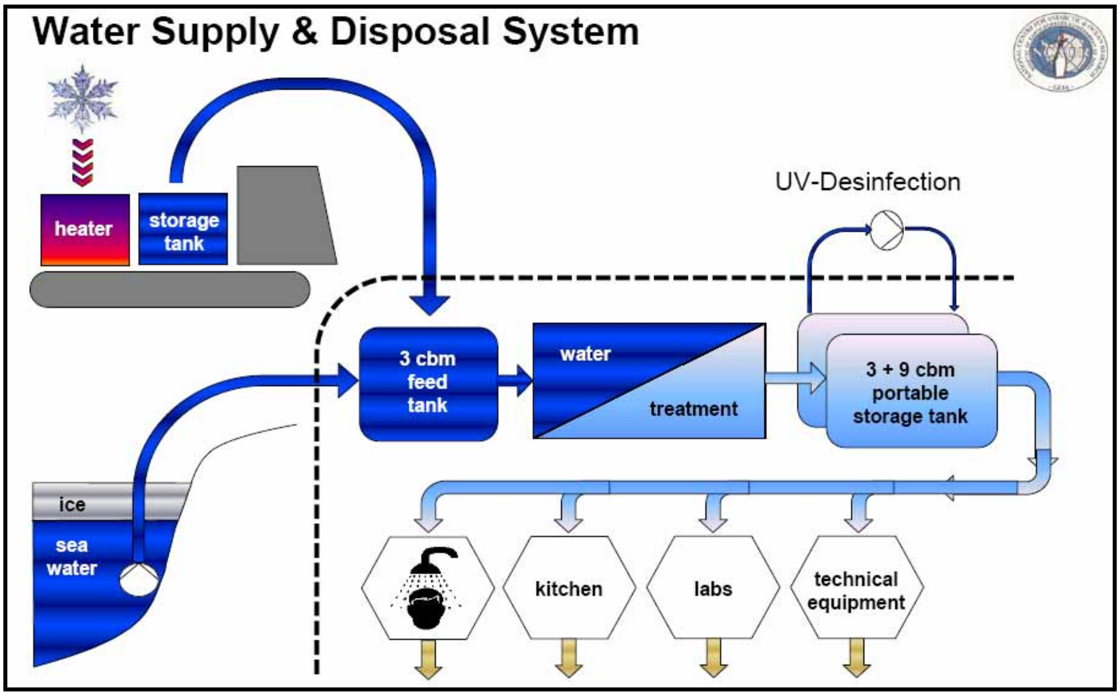


FIGURE 24 : PROPOSED HVAC SYSTEM

3.7 WATER SUPPLY AND WASTEWATER MANAGEMENT

It is intended to draw water from the sea to meet the potable water requirement. Seawater will be pumped to feed in reverse osmosis and after filtration it will be distributed for various uses. Water will be sourced from lake only in case of emergency or non-functioning of other sources and water will be subjected to two stage filtration for improving its quality. Fresh water demand will be reduced by reutilization of treated bathing effluent. Corrosion proof materials will be used for complete water supply system.

The design of the waste water system with biological clarification plant will be selected to maintain the desired effluent standards. Sewage treatment plant will be based on biologically activated sludge and membrane technology (Figure 25). Sludge generated during the process will be collected and dewatered in a filter bag to reduce the sludge volume and then it will be stored and transported back to mainland once a year. Wastewater generated from the kitchen as well as garage, shall pass through oil and grease trap before feeding to sewage treatment plant. Waste generated from the laboratories will be collected separately and will be transported back to India for proper disposal.



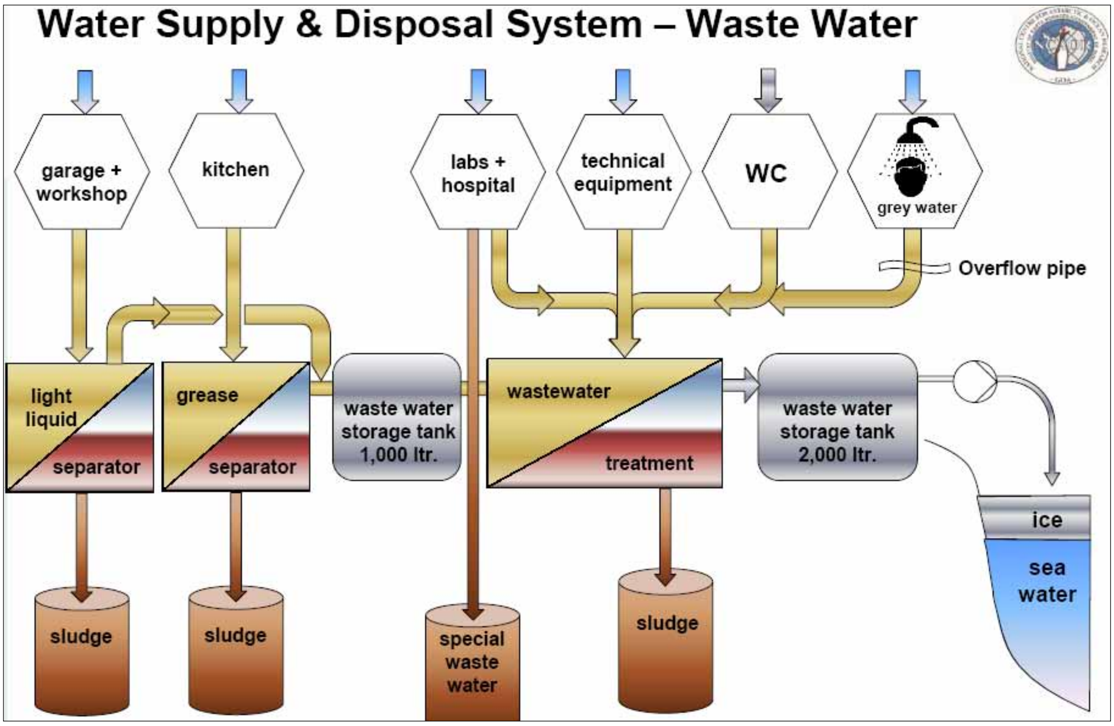


FIGURE 25: WATER SUPPLY AND WASTEWATER TREATMENT SYSTEM

Greywater generated from showers, washbasins and bathtub will be treated by bio-mechanical process and will be used for toilet flushing, thereby minimizing water demand by reutilization. By this means volume of seawater could be saved by 30%. Finally treated effluent from the seawater treatment plant will be passed through UV lamp to sterilize the effluent up to 99%. Effluent quality of the sewage treatment plant will meet the EU bathing water standards. Ultimately treated wastewater will be discharged into sea in NNW direction from the station using 640 meters insulated pipeline with trace heating element, in batch mode. Installation of wastewater piping inside the thermal insulation casing will be frost proof.

3.8 LIGHTING

Lighting fixtures will be equipped with energy saving technology. Incandescent lamps with "warm" light will be installed in comfort zones. At other places compact fluorescent lamps or fluorescent lamps with electronic ballast will be fixed (Figure 26). Electronic ballast will help to reduce the noise generated due to lamps, instant start of lamps without flickering, as well as saving electricity by 20%. The lighting system will conform to DIN EN 12464 standards. All lamps will be installed as per requirement of light and temperature in the rooms. Living and common rooms will be fitted with "warm white" light (3,000 K); offices, laboratories and technical rooms with "neutral white" light (4,000 K). Areas with a brightness of 2,000 Lux or more will be equipped with "bio lamps" (6,500 K); as these provide light which is largely same as natural sunlight.

A light calculation has been made for each area in order to provide optimum adequacy in illumination. Glare less and easy handling lamps will be considered for the selection of lighting fixtures. The lighting installation will provide possibility to adapt the illumination depending upon seasons. All the cables to be installed outside will be designed to work in -30^{O} C to -40^{O} C, whereas inside the station it will be adequate to withstand +5^{O} C. Emergency lighting system, with appropriate illumination, is envisaged to be installed along the evacuation path.

Laboratory

Living Room

FIGURE 26 : ARTIST'S IMPRESSION OF LIGHTING ARRANGEMENT IN ROOMS

3.9 SHIPPING AND TRANSPORTATION

To the maximum extent possible, material for construction purpose will be transported through barge after berthing of ship around 100 meters from the landing site. However, a part of the construction material may be transported by helicopters that have carrying capacity of 4500 kg. The container modules may or may not be fully equipped, depending upon the load carrying capacity of the helicopter. Equipping of modules will be effected in mainland, so that required changes, if any, can be made before loading these on the ship. Supply of material to station from a boat landing may also be considered. The vehicle access path from landing site to station will be used. The pontoon of the boat landing may be constructed, if required. For unloading from the barges, mobile cranes will be used.

3.9.1 APPROACH PATH AND LANDING SITE

The proposed landing site, according to previous survey was earmarked at NNE direction of station site at $69^0$24’12.9” S and $76^0$11’41.29” E. During subsequent surveys and work carried out at the site, better approach was located at NE direction from station site at $69^0$24’16.1” S and $76^0$11’57.35” E. This change has brought down the length of the approach path by 40% as compared to earlier design. An approach path of total length of 500 meters was constructed on existing rocky terrain (Figure 27).

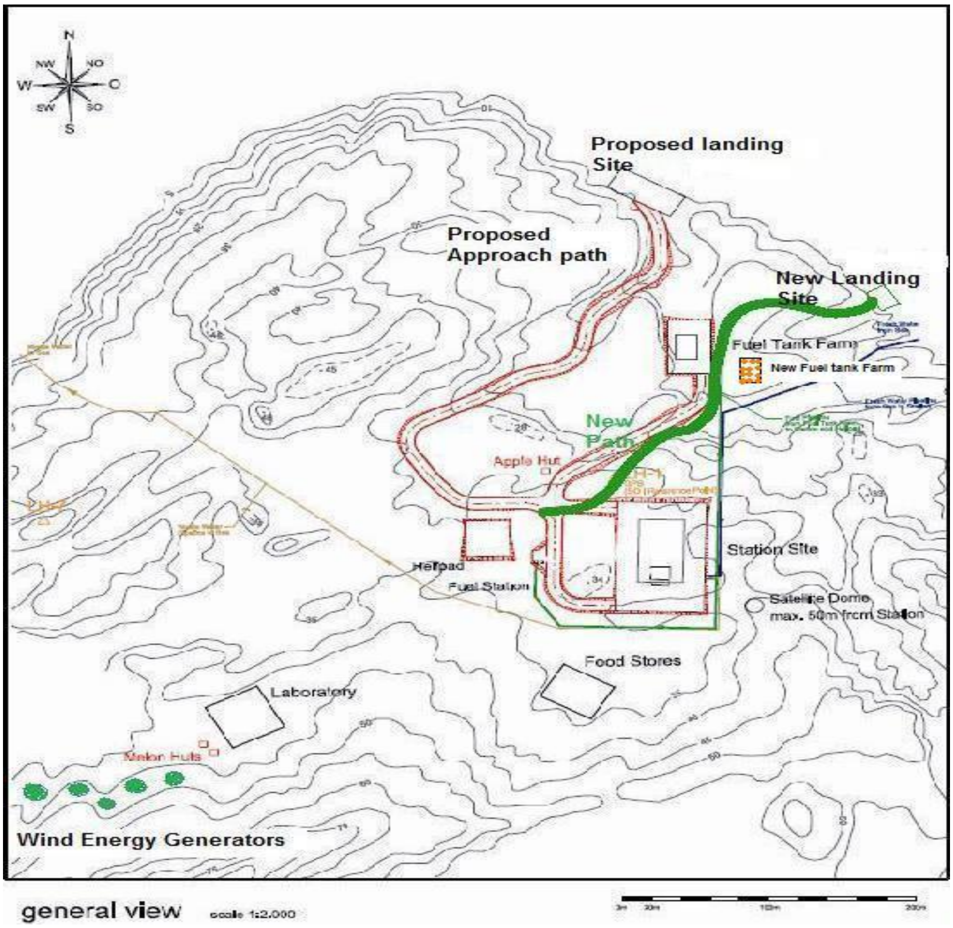


FIGURE 27 : PROPOSED AND REVISED APPROACH PATH

3.10 EMISSION ABATEMENT IN STATION DESIGN

Station design has been prepared in conformity with the provisions of Environmental Protocol. Prefabrication of the materials will reduce the activity at the construction site and will ultimately reduce the noise and air emissions. Optimization of the cable and piping length will reduce raw material utilization, maintenance requirement and manpower. Use of eco-friendly materials with high insulation will have control over heat loss from the building thereby saving extra energy requirement. Introduction of CHP will help in reducing the fossil fuel requirement for station heating.

Water conservation in terms of optimization and reutilization will reduce the water requirement and thus energy demand required to collect, transport and treat the water and wastewater. This will be achieved by using optimized spray shower, waterless urinals and recycling of gray water after treatment for flushing the toilet.

Energy system is being designed to implement electrical energy produced from solar and wind power, thus having less dependency upon fossil fuel based generators. CFL will replace incandescent lamps at all the places according to light calculation, thus minimizing electrical load and giving better illumination.

3.11 DECOMMISSIONING

Decommissioning of the building will be executed similar to the erection by unlocking the fixing elements and lifting off the containers. Provisions are made in design not to produce waste material at site. All the building modules can be removed completely and transported back to India after decommissioning.

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ALTERNATIVES TO PROPOSED ACTIVITY

A review of the Indian Antarctic Programme was undertaken by an Expert Committee constituted by Government of India, which recommended broadening of India's scientific data base in Antarctica for having a regional spread of the data rather than a localized one (Rao, 1996). As a follow-up action, a Task Force was constituted to go into the details and recommend a suitable site after considering all the pros and cons. This Task Force under the leadership of Dr. Rasik Ravindra, undertook reconnaissance traverses along the eastern coast of Antarctica from India Bay at 11° E longitude to 78°E longitude in Prydz Bay, to examine all possible alternatives suiting the scientific and logistic requirements set for the proposed station (Ravindra, 2004).

4.1 ALTERNATIVE LOCATIONS AT REGIONAL LEVEL

Based on the scrutiny of published literature and feedback from different Indian and international expeditions to Antarctica, three alternatives were suggested in the Review Report, mentioned above. These are:

a) *Antarctic Peninsula,*
b) *Filchner Ice shelf*
c) *Amery Ice shelf – Prydz Bay area*

4.1.1 ANTARCTIC PENINSULA

Antarctic Peninsula is the most crowded place in Antarctica, so far as the stations of different nations and the visits of tourists to the icy continent are concerned. The area is also very sensitive to global warming as has been demonstrated by the international studies, that have shown that the Peninsula has warmed by 2° C since 1950 (Cook et al., 2005; Mayewski et al., 2009).

4.1.2 FILCHNER ICE SHELF

The Filchner Ice Shelf poses serious logistic constraints in maintaining a research station as the sea ice conditions in this area are very tough. The Weddell Sea expedition by India in 1989-90 had brought to light the unpredictable ice conditions in this area.

4.1.3 AMERY ICE SHELF – PRYDZ BAY AREA

Against this backdrop, the Task Force comprising experts in domains of science and logistics (Appendix 4) explored the Amery Ice shelf -Prydz Bay region of East Antarctica during February 2004 and examined the area between 66^0 E and 78^0 E longitude in detail. After extensive traverses in the Vestfold Hills, Rauer Group of islands, Larsemann Hills and Bolingen islands, apart from the area along the Mawson Coast, the Task Force, after careful consideration of all aspects, recommended a rocky promontory between Quilty Bay and Thala Fjord in the central part of the Larsemann Hills, bound by latitudes $69^0 24'$S and $69^0 25'$ S and longitudes $76^0 10'$E and $76^0$14'E, as the most suitable location after Vestfold Hills.

4.2 ALTERNATE SITES EXAMINED WITHIN PRYDZ BAY

4.2.1 VESTFOLD HILLS

The task Force took extensive traverses in Vestfold Hills, Rauer Group of islands, Larsemann Hills and Bolingen islands. While the Vestfold Hills, supporting the Australian Station Davis, was found to be an ideal location, it was observed that the approach to this low lying rocky terrain supported a number of rookeries and colonies of giant Antarctic and snow petrels, molting sites of seals etc. The depth to the bedrock in the open waters was generally shallow, as indicated by the grounded icebergs, north of the Long Peninsula. The area has limited fresh water resources. The area of ASPA 143 on the Marine Plains and ASPA 167 on Hawker Island on one side and the existing station Davis in the central parts does not leave much space for developing any additional infrastructure.

4.2.2 RAUER GROUP OF ISLANDS

The Rauer Group of islands was found to comprise a number of closely spaced islands of limited aerial extent. The number of fresh water lakes as the source of potable water and flat land essential for construction purposes, were limited. The Task Force landed on five sites in the Rauer Group and measured depth, temperature and conductivity of lake water at two sites. The sites visited are:

- *Filla Island ($68^0$48'20" S Lat & $77^0$49'15" E Long)*
- *Hop Island ($68^0$49'20" S Lat & $77^0$41'30" E Long)*
- *Varyag Island ($68^0$51'00" S Lat & $77^0$47'30" E Long)*
- *Torckler Island ($68^0$53'30"S Lat & 77^0 50' 00 E Long) and*
- *Macey Peninsula ($68^0$55'12"S Lat & $77^0$55' 30" E long)*

The CTD measurements in one of the pro-glacial lakes in Macey Peninsula indicated depth of the melt water lake to be 12 m. The water being fed by a glacier was of good potable quality. The two other lakes examined in the Filla Island were of shallow depth and contained brackish water. The Varyag, Hyslop, Lokot and Torckler Islands, located in the central and southern parts, have a difficult approach from the sea due to presence of a number of isolated islands blocking the passage as well as the cluster of icebergs brought together by westerly currents (Figure 28).

Rauer Group is a rare area of wild life concentration. The islands support breeding grounds for Snow, Cape, Antarctic and Southern Giant petrels as well as Southern Fulmar. There are several rookeries of Adelie penguins and haul-out area of Weddell Seals spread over in the area. The northern islands (Lookout, Slon and Filla Islands) are known for concentration of Weddell Seals. The central parts of Filla island shelter snow petrels. The western ends of this island, as also the Buchan Island north of it, are the sites of Adelie penguins' rookeries. The Hop Island, in the western end, is another area of concentration of wildlife. One of the biggest penguin rookeries of this region is located here (Figure 29). Restrictions on flying operations are in vogue in most of the area in Rauer Group of islands.

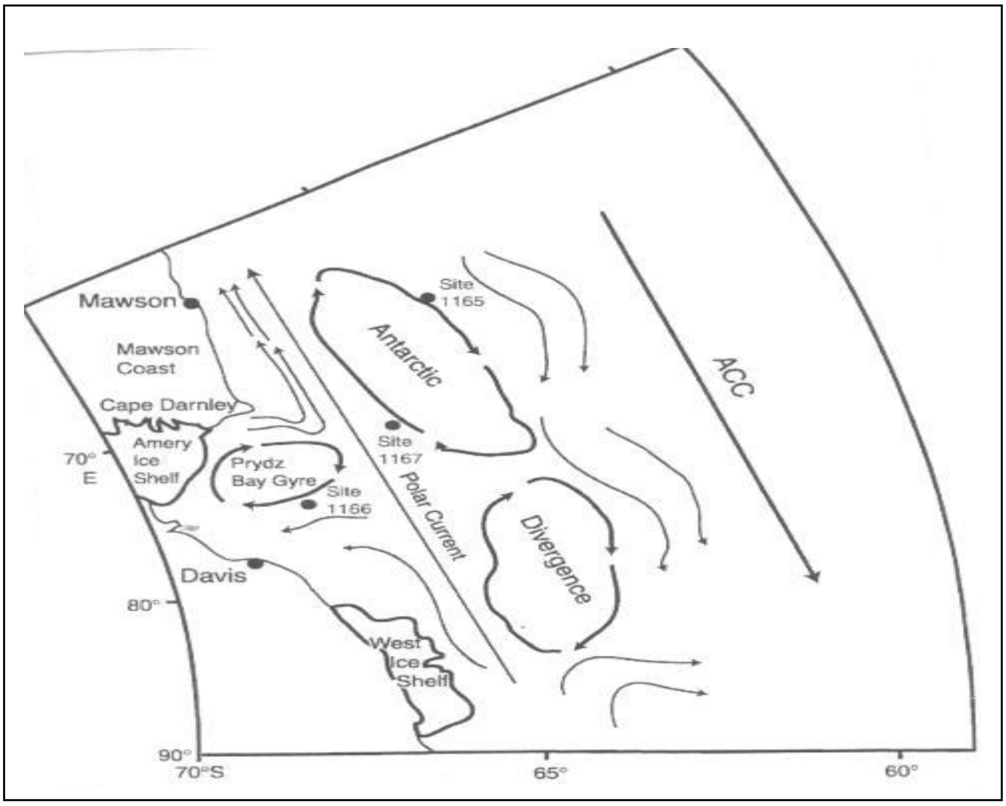

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FIGURE 28 : OCEAN CURRENTS IN THE PRYDZ BAY AREA

FIGURE 29 : PENGUIN ROOKERY AT RAUER GROUP ISLAND

There are no Antarctic stations located in this area. However, Australian Antarctic Division is managing two "Refuge Huts", (an Igloo and a Googol) at Hop Island for monitoring the breeding and behavioral pattern of penguins. The Task Force did not recommend this site keeping in view the intrinsic wild life values of the area (Ravindra et al., 2004).

4.2.3 AREA BETWEEN THE BOLINGEN AND SVENNER ISLANDS (LARSEMANN HILLS)

The area between Bolingen and the Svenner islands (Figure 30) bounded by the Polar Record Glacier, off the Publication Ice shelf on one side and the Brattstrand Bluffs on the other side, was found to encompass many ice free peninsulas and Islands. Within the limits of this region, the Task Force focused its attention on Larsemann Hills.

The Larsemann Hills (69^{o}20'S to 69^{o}30'S Lat ; 75^{o}55'E to76^{o}30'E Long) at Prydz Bay is an ice-free oasis on the Ingrid Christensen Coast, Princess Elizabeth Land, located approximately midway between the eastern extremity of the Amery Ice Shelf and the southern boundary of the Vestfold Hills. At 50 km^2, it is the second largest of four major ice-free oases found along East Antarctica's 5000 km coastline (Hodgson, et al. 2006; 2009). The region includes two main peninsulas, the western, named Stornes and the eastern named Broknes. In between these two peninsulas, there are a number of islands of varying dimensions. Four Antarctic stations viz. Progress I & Progress II (Russia), Law- Racovita (Romania) and Zhongshan (China) are located along the edge of the Broknes peninsula. A cluster of icebergs and some islands such as Striped, Lovering and Manning Islands mark the northern boundary of the Broknes Peninsula. The westerly currents break the fast ice during early summer facilitating the entry of the vessels quite close to the stations. Westwards, the Clemence Fjord separates Broknes Peninsula from Stinear Peninsula and Fisher Island. The area north and west is marked by a number of islands, namely Harley, Easther, Breadloaf, Butler, Betts, McLeod, Jeason, Solomon and Sandercock.

In the Larsemann Hills, a promontory located between Quilty Bay and Thala Fjord, was found to be the most suitable site for the Indian base. The promontory has a number of fresh water lakes. At least one with sufficient depth can serve as the emergency source for drinking water. The approach from the sea opens in February and ships can come quite close to the landing site, where the barges could be put into operation. The area is located in the central part of Larsemann Hills and is about 10-km crow flying distance from the existing Antarctic stations of Australia-Romania, China and Russia.

The pear shaped promontory (Grovnes) where the station is to be built has its wider end facing the sea, trending NE-SW. The northern and western slopes have a high gradient with the edge being exposed in the form of a steep cliff. The southern margin separates Polar ice margin and the hills thereupon by a narrow bay. This part has ice up to 50 m thick at places and hence is not suitable for approaching the land. The area is fairly undulating and encased within Thala Fjord and Quilty bay which remains ice-free during most of the summer months. Water is available in the form of one big and five small lakes. The big lake holds water with saline characteristics, but water in small lakes was found suitable for drinking purposes. It is possible to access the site through sea from NNE part of the Promontory.

The advantages of the proposed site have been mentioned in Chapter 2.

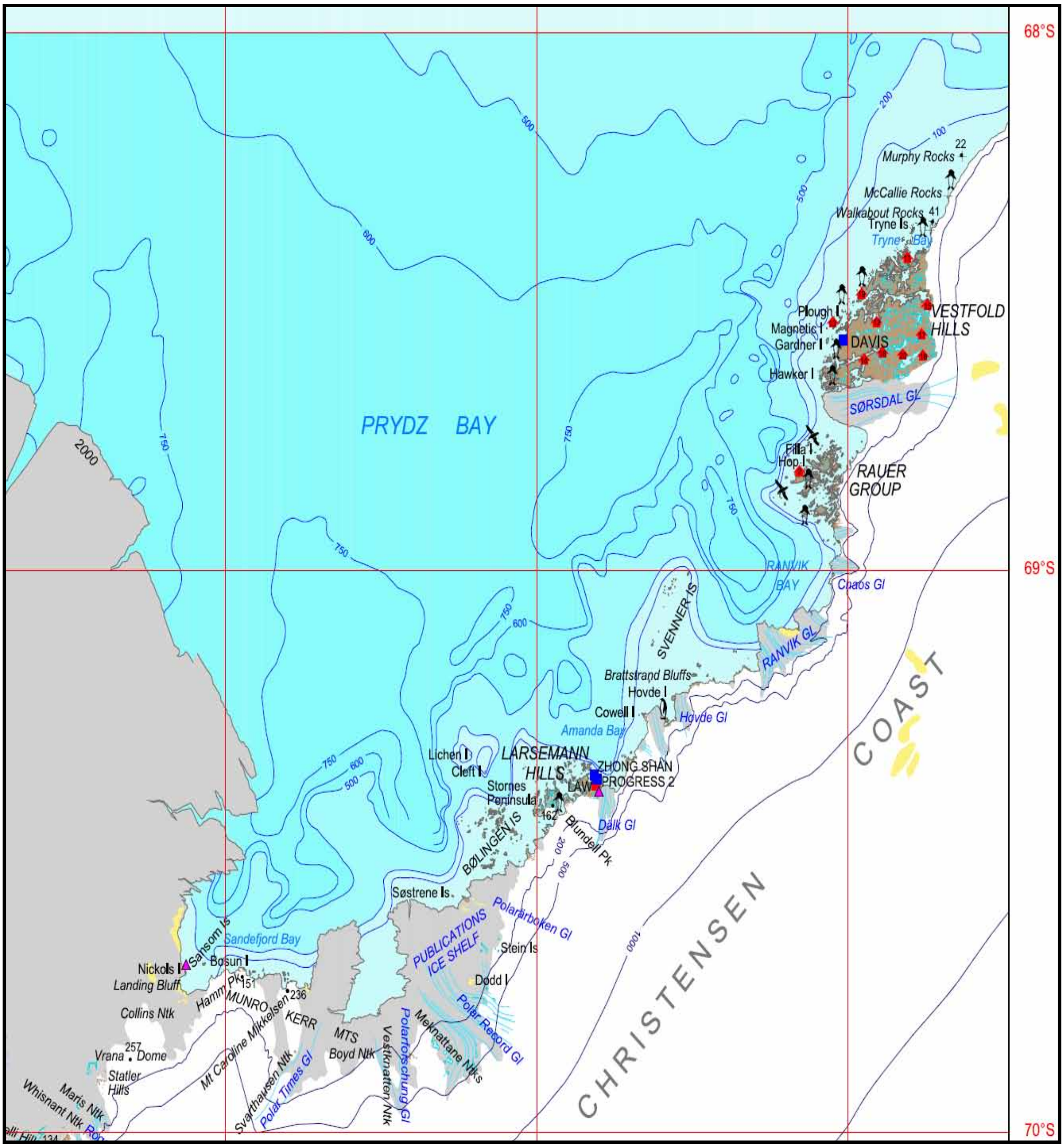

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FIGURE 30 : LOCATION OF BOLINGEN AND SVENNER ISLANDS, RAUER GROUP AND VESTFOLD HILLS

4.3 ALTERNATIVE LOCATIONS IN LARSEMANN HILLS

The alternate sites examined in the Larsemann Hills include:

- *Tonagh Promontory at the western edge of Larsemann Hills*
- *Area adjoining Lake Ferris and northern margins of Stornes Peninsula*
- *Area west of Johnston Fjord*
- *Donovan Promontory*
- *Fisher Island*
- *Area north of Murkwater Lake, on the Promontory between Quilty Bay and Thala Fjord*

TONAGH PROMONTORY: A promontory located on the western edge of Larsemann Hills exposes a flat terrain rising approximately 40 m above the sea. A landing was made at $69^0$26'00.6" S Latitude and $75^0$59'37.8" E Longitude. A chain of small islands northwards was found to block the entry to this promontory. A number of grounded icebergs were found within the fast ice, west of the hills, indicating shallow depth to bedrock. The area is devoid of a fresh water source and hence was not considered suitable for habitation.

LAKE FERRIS AND NORTHERN MARGIN OF STORNES PENINSULA: Lake Ferris and the area adjoining it are located at the northern most margin of Stornes Peninsula ($69^0$24'S Latitude and $76^0$08.5'E Longitude) and can be approached from the sea. Low lying, beach landing is available. There are two interconnected lakes fed by snowmelt but there is no permanent source of recharge like a feeder channel from a glacier. Most of the lakes are of shallow depths and were found in frozen condition. The area is extremely undulating but of great geological significance.

Profuse growth of algae and moss was observed on the exposed rock surface. Fast ice could still be seen in the adjoining area in sea at the time of visit i.e. middle of February. Lots of seals were found molting on this ice. The occurrence of fossiliferous marine Pliocene sediments about 4 Ma old in this peninsula makes this area of geological significance that requires preservation (Quilty, 1990;1993; Quilty et al., 1990). Rare aluminum borosilicate-boralsilite described in 1998 from this area is known from only one other locality worldwide (WP8, 2006). It was thought best to leave the area undisturbed for reasons mentioned above.

JOHNSTON FJORD**:** The location at $69^0$24'47.1" S. Latitude & $76^0$03'48.4" E Longitude at the hills east of Johnston Fjord is marked by the presence of a very prominent lineament running N-S. The lineament can be traced from west of Malachite Lake to west of Tumbledown Hill and further in the northerly direction up to Hill Island. There are two lakes in the immediate vicinity of the site but both are shallow with moderate to high salinity. The approach from the north and east is blocked by a number of islands. This area was not found suitable for the purpose of supporting a station.

DONOVAN PROMONTORY: This promontory at the eastern extremity of Stornes Peninsula also exhibits a prominent N-S trending lineament, parallel to the one described above (Johnston Fjord). The area exposes a number of glacial lakes, viz. Lake Gillieson, Lake Burgess and channels like Stuwe Gully etc. A landing was made at $69^0$24.7' S Latitude & $76^0$08.5'E Longitude. The area was found to be rugged and lacking suitable topographic flat for construction activity. Though there are a number of lakes in the area, they are very small and shallow in depth. The sheltered Bay (Blair) is too narrow with steep cliffs on the hill side. The topography and general lay out of the area do not justify locating a station on this site.

FISHER ISLAND: Separated from the Broknes and Stornes Peninsulas by Clemence and Thala Fjords, respectively, the Fisher Island is a bow shaped island situated very close to the continental ice. It is one of the biggest islands in terms of geographical area. Its approach from the north is blocked by a group of small islands, but the western margin can be approached from McLeod Island. Physiographically, the western part has high relief with the highest peak at 117 m. In comparison, the eastern part exhibits moderate relief and open stretches. The location at $69^0$23’32”S Latitude & $76^0$13’23.4” E Longitude offers a near flat ground very close to fast ice for landing purposes. Australia maintains an astronomical station at this site. There are six lakes in the eastern parts but none has sufficient depth or area. Fresh water bodies of limited depth and extent are present.

The Island is not connected to the continental ice of the Antarctica as a narrow stretch of open sea separates it from Stinear Peninsula, hence not found suitable for station building.

4.3.1 BROKNES PENINSULA

The Broknes Peninsula is ice free and undulating in general, except the north eastern part where three stations namely Law- Racovita, Progress II and Zhongshan already exist. A few lakes are available to cater to the routine water demands of the existing stations. There is a general scarcity of the potable water. Water in most of the lakes has high salinity. Ships providing supply to stations are usually anchored 5 nm away from the coast because access to the eastern shore of Broknes by small boat or barge is difficult (and sometimes impossible) due to ice debris that cover hundreds of metres offshore, blown by the prevailing north-easterly winds. Sea ice conditions are highly variable. Helicopters are therefore the only reliable means by which personnel and supplies can be transported ashore quickly.

The positioning of the new Indian station in this area was not found sustainable due to following considerations:

- *There are already three stations existing within close proximity,*
- *Resources in respect of drinking water are scarce,*
- *Regular scientific observations on meteorology, magnetism, atmospheric conditions are being carried out by the three stations. Setting up of any additional Observatory in the area would not serve the scientific purpose.*
- *The area south of Seal Cove in the Broknes Peninsula is rugged and does not provide an easy access to the ship for off loading the cargo.*
- *The area is already impacted from environmental point of view.*

4.3.2 ENVIRONMENTAL FACTORS FOR SELECTION OF SITE

Main environmental factors that limited for short listing of the present site are:

- *No penguin rookeries or nesting site of birds exist on the promontory*
- *No designated ASPA exists nearby*
- *Treated waste disposal to the sea rather on land or ice*
- *Relatively open sea access for about a month during austral summer*
- *Availability of flat terrain*
- *Proximity to sea water for station use (potable purpose by desalination, flushing purpose) rather than totally depending upon fresh water lake*

Recent experience of shifting material to the site over fast ice and berthing of ship, very close to landing site, has shown that the selected site is more accessible compared to the Broknes. This will avoid large distance flying of helicopters and barge movement thus curtailing the air, noise and water pollution. In pursuance to Article 3 (b) (vi) of the Environmental Protocol, the activities in the Antarctic Treaty area shall be planned and conducted so as to avoid degradation of, or substantial risk to, areas of biological, aesthetic or wilderness significance. The selected site falls under ASMA 6 and India being a member of the ASMA group, all the activities within ASMA periphery is being carried out adhering to the management plan and in consultation with other ASMA members. Scientific observations will be rationalized to complement those of other stations.

4.4 ALTERNATIVE TRANSPORT TO THE STATION

The essential men and materials, as far as possible, shall be transported by helicopters from the ship (Figure 31). This may produce some noise pollution due to flying of helicopters to the site, but as there are no penguin rockeries or Antarctic bird colonies along the proposed corridor of flight operation, the impact on the wild life is expected to be negligible. For the helicopter operation Guideline for the operation of aircraft near concentration of birds in Antarctica (ATCM resolution 2, 2004) and ASMA guideline shall be followed. The barges may be put into operation once a facility to offload the cargo on to a platform near the landing site is finalized. Recent experience during austral summer of 2009-10 to berth the ship around 100 meters away from landing site provided new insight on transportation. The fast ice in between edge of promontory and the berthing site of ship was found to be strong enough till mid December at least to take the loads of vehicular transportation. This has proved to be efficient in transporting piston-bully, bulldozer and heavy machinery i.e. crane of total weight around 50 ton, over fast ice from ship to the landing site.

A few other alternatives to access the station site were also assessed. These are:

- *Transporting of all the men and material from Hobart/ Cape Town to the air strip located near the site by using air operators network of either Australian or DROMLAN. However, the steep gradient and lack of well defined route makes the option unviable.*
- *Sharing the ship with other stations located in this region for logistic purposes, to encourage minimum environmental impact. This option will be explored once the major shipment of construction materials is over.*

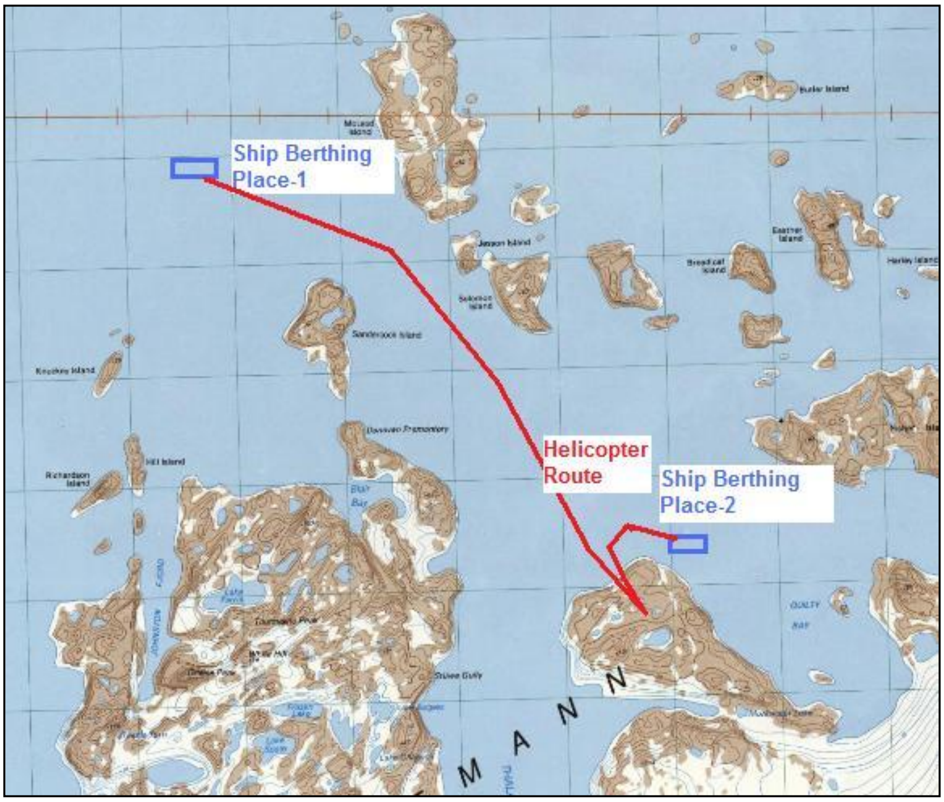

FIGURE 31 : HELICOPTER CORRIDOR FOR TRANSPORTATION OF MEN AND MATERIALS

4.5 ALTERNATIVES FOR THE APPROACH PATH

Four alternate routes marked as A, B, C and D in Figure 32 below, were considered for development of approach path. There are not many options for landing as the promontory exposes steep escarpment in the north, north-west and south- eastern parts. Route “A” which originates in the south-eastern part was not considered suitable because the landing site is generally covered by thick fast ice for most part of the year and the total length of the path would be around 2.5-3 km. Route “C” with approach from northern part was not considered practical because of the steep vertical escarpment that would be required to be negotiated to reach the land from the sea. The path along the route “B”, being along a natural depression has the least gradient and follows the contours, but is covered with a thick blanket of loose snow (2 to 3 m) till middle of January, which will make vehicular movement very difficult. This would have been a natural alignment for summer period, when the snow would be gone. The alignment along the route “D” was considered as the best option and selected for this purpose because (a) it is the shortest route to station and fuel dump, (b) requires minimum amount of cutting and filling, (c) would cause minimum disturbance to the environment and (d) approach from fast ice is gentle with least gradient.

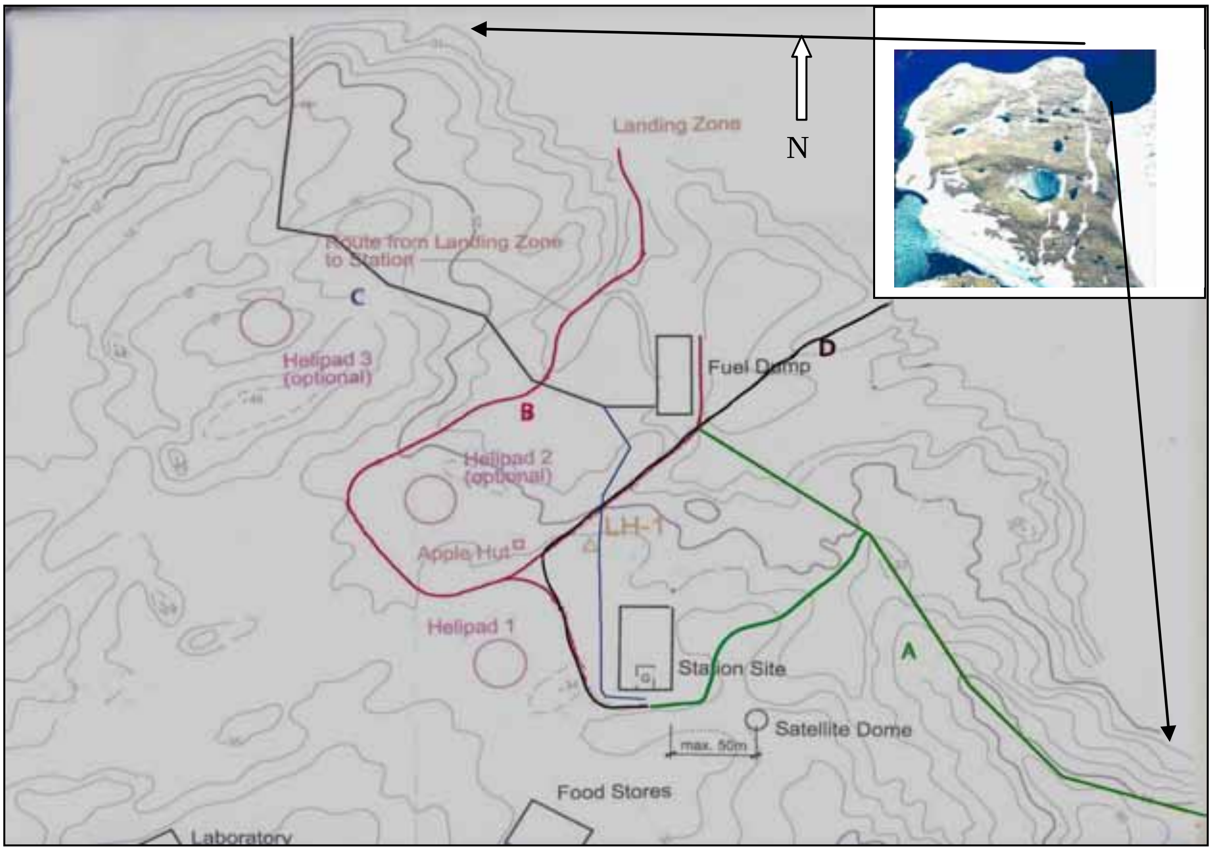

FIGURE 32 : ALTERNATE SITES FOR DEVELOPMENT OF APPROACH PATH TO THE STATION

4.6 ALTERNATIVE DESIGN

To develop the concept design three firms out of 33 proposals received were selected based on Antarctic experience, capability of firms, eco-friendly tasks undertaken earlier and annual turnover. The three firms that were asked to submit the concept design are;

- *M/s IMS Ingenieurgesellschhaft mbH, Germany*
- *M/s Ferrari Choi, Honululu*
- *Hugh Broughten, UK*

The concept designs submitted by M/s Ferrori Choi (Figure 33) and M/s Hugh Broughton (Figure 34) were not found suitable due to lack of compactness, greater foot print, problem of material transport to site due to limitation imposed by carrying capacity of helicopter, congenial connectivity of various sections to each other etc. The concept design of M/s IMS Ingenieurgesellschhaft mbH, Germany was found to be the most suitable considering all the above mentioned factors and therefore the firm was offered to develop the final design. Design of the station is described in Chapter 3.

FIGURE 33: ARTIST'S IMPRESSION OF STATION DESIGN (M/S FERRARI CHOI)

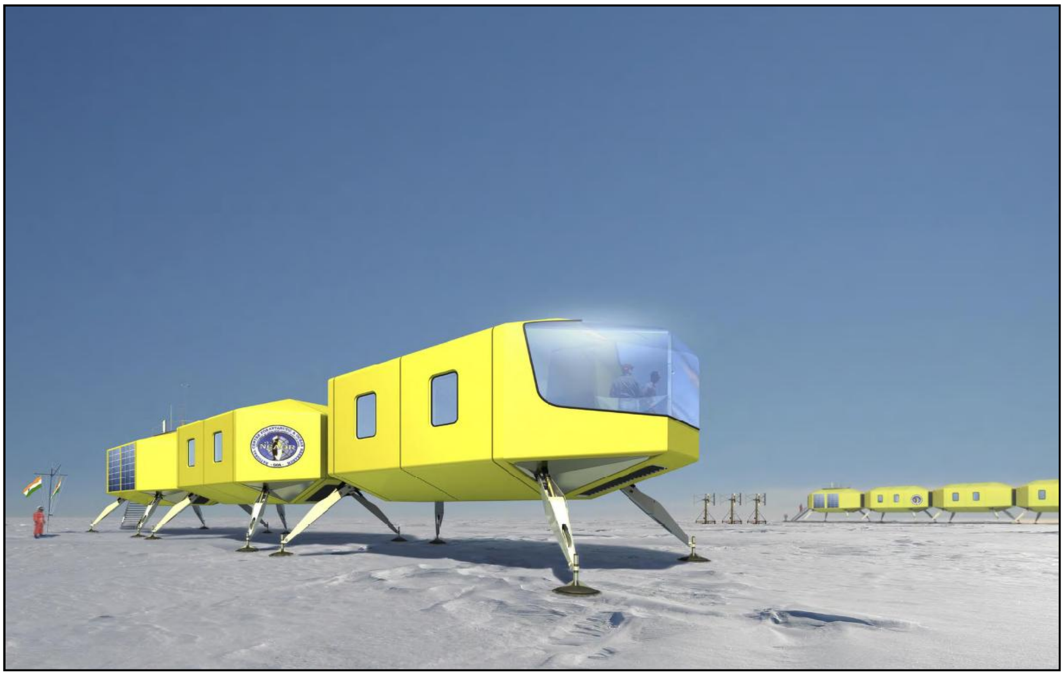

FIGURE 34 : ARTIST'S IMPRESSION OF STATION DESIGN (M/S HUGH BROUGHTON)

4.7 ALTERNATIVE TO NOT PROCEEDING WITH THE ACTIVITY

The alternative to not proceeding with the activity has been given due thought during the planning phase. It was considered whether the proposed research could be carried out from existing stations in the Larsemann Hills or any other station in the region. However, the option did not find favor because of not meeting the national aspirations of having a station located favorably to supplement the data collected from other parts of Antarctica.

The Prydz Bay region between Mawson and Davis was thoroughly reconnoitered and no site was found suitable for the purpose of a Research Station. Larsemann Hills are certainly not unique, but this is undoubtedly the best location after Vestfold Hills.

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INITIAL ENVIRONMENTAL REFERENCE

5.1 LOCATION

The Larsemann Hills (69°20'S to 69°30'S Lat: 75°55'E to76°30'E Long), an ice-free area of approximately 50 km^2, is located on the Ingrid Christensen Coast of Princess Elizabeth Land in East Antarctica. To the northeast of the hills are the Rauer Islands and the Vestfold Hills and to the west-southwest are the Bolingen Islands and the Amery ice shelf. The area was not discovered until 1935 when Captain Klarius Mikkelsen, led an expedition for the Norwegian whaling magnate, Lars Christensen. Subsequently, Australian National Antarctic Research Expedition (ANARE) led by Dr. Phillip G. Law landed in the area in March 1954 (Burgess et al., 1994; other similar studies).

Four research stations namely the Progress I & Progress II (Russia), Law- Racovita (Australia-Romania) and Zhongshan (China) are located on the Larsemann Hills. The westerly oceanic currents break the fast ice during late summer, facilitating the entry of the vessels quite close to these stations. The Indian Antarctic base is proposed to be located on an ice-free rocky area, situated between Quilty Bay on the east and Thala Fjord on the west (Figure 35).

(Source: AAD)

FIGURE 35 : LARSEMANN HILLS

5.2 GEOLOGY

5.2.1 GEOLOGY OF THE LARSEMANN HILLS

The local coastline has many indentations with fjords forming deep inlets. The highest point in the promontory, where the station is being proposed is around 105 meters above msl. Geology of the area has been established by the detailed work of Sheraton and Collerson (1983); Stuwe and Powell (1989); Carson et al. (1995); Zhao et al. (1995); Wang et al. (1997); Reading (2006) and others. The area is dominated by paragneisses which are more aluminous than similar rocks of the Rauer Group. Magnetotelluric deep sounding study in the region of Zhongshan station has established that the lithospheric thickness of Larsemann Hills is 140 km, and that the crustal high conductivity layer is situated at 22 km (Kong et al., 1994). The detailed bibliography concerning Larsemann Hills is available in the Working Paper No 8 submitted at XXIX ATCM, Edinburgh.

5.2.2 GEOLOGY AT THE PROPOSED STATION SITE

The proposed station site predominately exposes gneisses trending NE-SW and at low angles ranging 30^{o} to 45^{o} towards SE in the northern and northwestern part and near vertical in the southern and southeastern parts. On the basis of mineralogical assemblages and mode of occurrence of garnets, three distinct gneissic litho-units and a granitic body are identified (Beg et al., 2005).

Granitoids: Exposed south-east of the intersection of 69^{o} 25’ S & 76^{o} 12’ E and north-east of Lake L-9 (Figure 36), the granitoids are medium to coarse grained with alkali feldspar as porphyroclasts. These granitoids are traversed by thin aplitic veins.

Garnetiferous granitic gneisses: Exposed in the eastern part of the area, the gneisses are composed of quartz, pink-feldspars and very fine crystals of garnet, with biotites defining the foliation planes sympathetic to the general trend of NE-SW. The primary foliations are masked by horizontal to sub-horizontal tensional fractures almost conforming to the topography. Sheeting effects are commonly seen in granites due to the release of superincumbent load. In the extreme east of the exposure, close to polar ice cap, a few enclaves of pink granites are also seen.

Garnet-magnetite-biotite gneisses: Trending NE-SW, 30 to 45 degrees due SE, this unit is exposed around the central lake (L-7), and extends up to lake L2 in the northwest and up to about 250 m southeast from the edge of the Lake L-7 (Figure 36). A small patch of the same unit is exposed at the northwestern extremity of the peninsula. The quartz-magnetite-biotite gneiss occupying the higher grounds is marked by the presence of small magnetite crystals evenly distributed throughout. At places, small sized garnets are found in pockets. These gneisses are traversed by pegmatite, and aplitic veins have partly digested enclaves of older gneisses.

Garnet bearing quartz-feldspar-biotite gneisses: Most predominant litho-unit of the area, this unit is exposed in the northwestern part of the peninsula and north of lakes L-8 & L-12 (Figure 36). These gneisses consist of quartz and feldspar with biotite defining the foliation planes. Garnets occur as porphyroblasts within the gneisses. The size of the garnets varies from about 2 mm in the north-western side to less than 1 mm in the south eastern parts and is evenly distributed throughout. These are traversed by thin pegmatite and aplitic veins and have a few partially digested enclaves of older gneisses rich in melanocratic minerals.

5.2.3 GLACIOLOGY

The glaciological history of the Larsemann Hills is conspicuously different from most of the known ice-free areas of Antarctica in the sense that parts of the Larsemann Hills have been shown to be ice-free during the Wisconsin times. The dating of the moss deposits at 24,950 years BP (Burgess et al., 1994) has necessitated a reconsideration of the Pleistocene history of the region as the earlier workers (Gillieson et al., 1990) had postulated that the Larsemann Hills became ice-free by 10,000-20,000 years BP. More recently, the late Quaternary climate history of the region has been reconstructed by Verleyen et al. (2004).

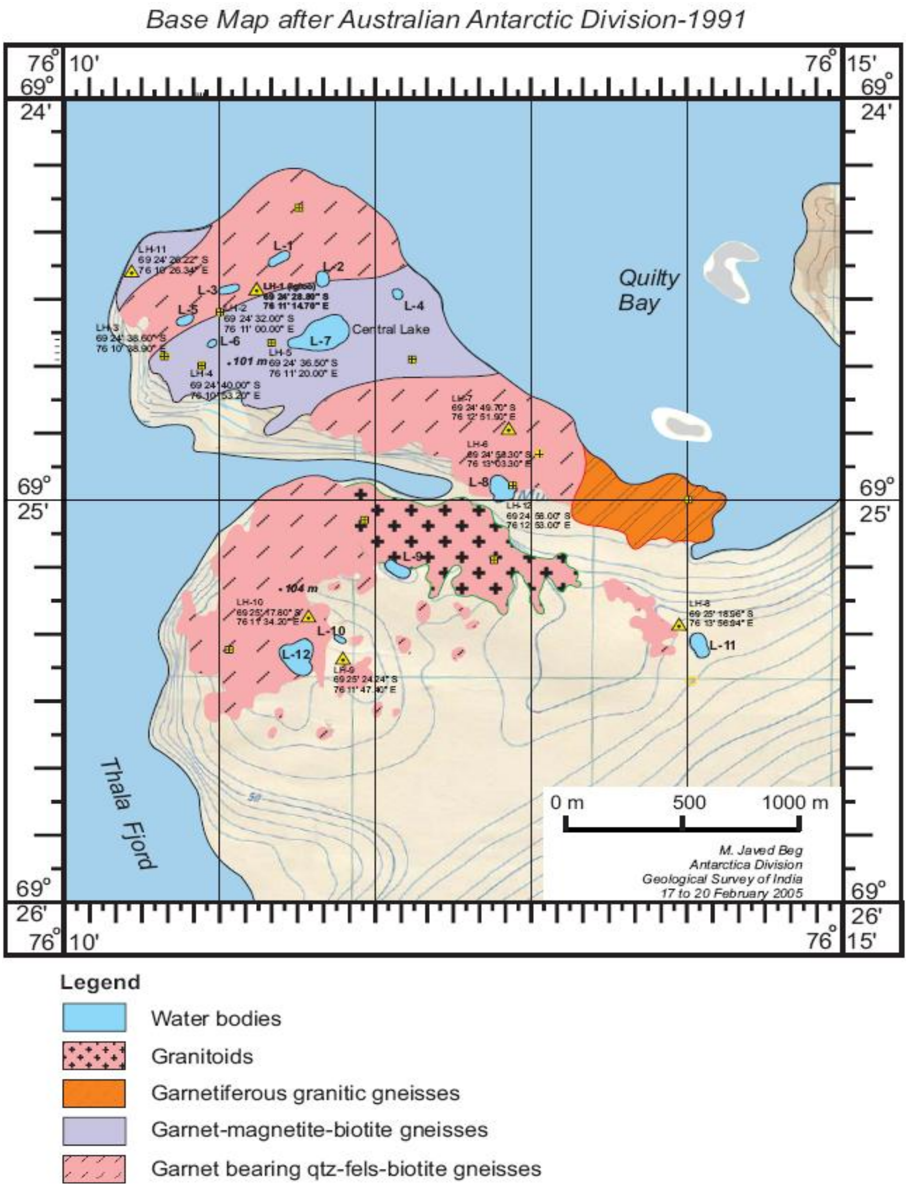


FIGURE 36 : GEOLOGICAL MAP OF GROVNES PENINSULA

5.2.4 GEOMORPHOLOGY

The area has a low, gentle and rolling topography merging with the polar ice cap in the south-southeast and surrounded by sea in other three directions. It is punctuated with small islands to the north & northeast. Starting from the mean sea level, it rises up to an elevation 150 m near the polar ice cap with the highest rocky outcrop exposed at 104 m above mean sea level.The area is generally devoid of glacial morains but at a few places glacial striations are noticed. The area is dotted with small, perennial lakes.

An enhanced digital elevation model of Larsemann region is depicted at Appendix 5 (Jawak et al., 2010).

5.3 SOIL

The remarkable characteristic of the Larsemann Hills is the absence of moraine deposits as in most coastal areas of east Antarctica (Gasparon et al., 2004). Due to low temperatures, weak chemical weathering processes take place, resulting in the enrichment and migration of chemical elements. The highest migration is noted in Ca, followed by Mg, Sr, Zn, K and Na. The average ratio of SiO_2/Al_2O_3 is 5.79, which shows a weak chemical weathering property of the soil. Compared with the parent rock, SiO_2 and Al_2O_3 have been eluviated. There is a trend of increasingly strong weathering from south to north (Wang, et al. 1997).

5.4 LAKE WATER CHARACTERISTICS

There are over 150 freshwater lakes in the Larsemann Hills, ranging from small ponds less than 1 m deep to glacial lakes up to 10 ha and 38 m deep. Some of these water bodies are ice free for brief periods or partially ice free in the summer months when their water temperatures increase rapidly, reaching $+8^0$C in some of the shallower ones. For the remainder of the year (8–10 months) they are covered with ca 2 m of ice (Hodgson et al., 2005; 2006; 2009). The lakes around the proposed site are in general young excepting the major lake (L-37, Gillieson et al., 1990). The waters have low conductivity and exceptionally low turbidity.

Data on hydro-chemical properties of 13 lakes in the proposed site indicates that Na^+ and Cl^- are predominant ions in the water, but no CO_3^{--} is present. Hence, all lakes belong to Na^+ group. The concentrations of nutrient substances (N, P, SiO_2) are rather low; inorganic nitrogen exists mainly in the form of NH_4^+-N, both in water and in the snow. The relatively high concentrations of Na^+, Cl^- and SO_4^{--} suggest that the precipitation in the Larsemann Hills is dominated by marine conditions.

5.5 FLORA AND FAUNA

Sampling of the coastal areas from the Vestfold Hills to the Larsemann Hills indicates that the flora of the Ingrid Christensen Coast is relatively uniform, and restricted to bryophytes, lichens and terrestrial algae. Although few collections have been made, it is believed that the nature of the basement rock, the relatively recent exposure from the ice cap and the prevailing wind direction in the greater Prydz Bay area contribute to the fact that less than 1% of the Larsemann Hills has vegetative cover. Five introduced vascular species have been observed in the vicinity of the existing station buildings of Broknes peninsula.

Most terrestrial life, including mosses, lichens and accompanying invertebrates are found inland from the coast. Nevertheless, large moss beds are known to occur in sheltered sites on the larger islands (particularly Kolløy and Sigdøy), associated with Adelie penguin moulting sites, and nunataks in the southwest. There are seven positively identified moss species in the region: *Bryum pseudotriquetum* which is most abundant, *Grimmia antarctici, Grimmia lawiana, Ceratodon pupureus, Sarconeurum glaciale, Bryum algens* and *Bryum argentum*.

The bryophyte flora also comprised one species of liverwort *Cephaloziella exiliflora,* which is found on an unnamed outcrop south of Stornes and known from only four other Antarctic localities. Lichen coverage is considerable on north-eastern Stornes and Law Ridge on Broknes and the lichen flora of the region comprises at least 25 positively identified species. Although no systematic studies have been undertaken in the area, similar work conducted in nearby locations on the Ingrid Christensen Coast suggests that it would not be unreasonable to expect the Larsemann Hills to exhibit close to 200 non-marine algal taxa, and 100–120 fungal taxa (WP8, 2006). Diatom flora study has been carried out in the fresh and saline water Lakes of Larsemann Hills and Rauer Island by Sabbe et al. (2003), including the LGR lake nearby site. In LGR the abundance of taxa reported are *A. verneta, Centric diatoms Sp.1, P. abundans, C.cf. molesta, P. microstauron, and S. inermis.*

Most of the phytoplankton comprises autotrophic nanoflagellates, though dinoflagellates occur in many lakes, and a desmid belonging to the genus *Cosmarium* is a major component of at least one lake. Heterotrophic nanoflagellates are more common than autotrophic nanoflagellates, though exhibiting low species diversity (only three or four species in most lakes), and particularly abundant in shallow lakes (*Parphysomonas* is very common). Ciliates are found in low numbers with *Strombidium* the most common species, and a species of *Holyophyra* also found in most lakes. Rotifers occur sporadically in a number of lakes and the cladoceran *Daphniopsis studeri* is widespread, but found in low numbers.

The most obvious biotic feature observed in almost all the lakes is an extensive blue-green cyanobacterial felt, which has accumulated since ice retreat and is consequently thickest on the islands and thinnest in young lakes adjacent to the polar plateau. These cyanobacterial mats are found to be of exceptional thickness of up to one meter (not normally observed in other Antarctic freshwater systems) and are also widely distributed in streams and wet seepage areas (WP 8, 2006).

Extensive surveys have been carried out in this area. Seventeen species of rotifers (10 Monogononta and six Bdelloidea), three tardigrades, two arthropods, as well as protozoans, platyhelminth and nematodes have been reported from 13 freshwater lakes (Dartnall, 1995). The benthic communities of the deepwater lakes are dominated by thick cyanobacterial mats (Ellis-Evan et al., 1998).

Near the new station location, no known breeding sites for any vertebrates exist. At Broknes, ecological and biological studies on the south polar skua *Catharacta maccormicki* have been carried out during January 1989-February 1990 by Wang. The study indicates that the Larsemann Hills also provide breeding sites for other seabirds, such as the snow petrel *Pagodroma nivea* and Wilson's storm petrel *Oceanies oceanicus*, which nest mainly in the eastern part of the Hills (Wang, 1991).

Three species of seabird, south polar skuas, Snow petrels and Wilson’s storm petrels, breed within the Larsemann Hills. Approximate numbers and locations of breeding pairs are documented for Broknes, and particularly eastern Broknes, but their distribution throughout the remaining area is uncertain.South polar skuas (*Catharacta maccormicki*) are present between mid-late October and early April, with approximately 17 breeding pairs nesting on Broknes and similar numbers of non-breeding birds. Snow petrel (*Pagodroma nivea*) and Wilson’s storm petrel (*Oceanites oceanicus*) nests are found in sheltered bedrock fragments, crevices, boulder slopes and rock falls, and are generally occupied from October until February. Approximately 850–900 pairs of Snow petrel and 40–50 pairs of Wilson’s storm petrel are found on Broknes, with concentrations of Snow Petrels at Base Ridge and on rocky outcrops adjacent to the Dålk Glacier in the east and the plateau in the south.

Despite the suitably exposed nesting habitat, no Adelie penguin (*Pygoscelis adeliae)* breeding colonies are found at the Larsemann Hills. However birds visit from colonies of nearby islands during summer to moult. Emperor penguins (*Aptenodytes forsteri*) also occasionally visit from the Amanda Bay rookery.

Weddell seals (*Leptonychotes weddelli*) are numerous on the Larsemann Hills coast. Aerial surveys during the moulting period have observed greater than 1000 seals, with multiple large groups (50–100 seals) hauled out in Thala Fjord and on rafted ice immediately to the west of Stornes, and numerous smaller groups amongst offshore islands and ice to the north-east of Broknes. Crabeater seals (*Lobodon carcinophagus*) and Leopard seals (*Hydrurga leptonyx*) are also occasional visitors (WP8, 2006).

Little research has been conducted with regard to terrestrial invertebrates in the Larsemann Hills. Five genera of terrestrial tardigrade (*Hypsibius*, *Minibiotus*, *Diphascon*, *Milnesium* and *Pseudechiniscus*), which include six species, are known to be present in localities associated with vegetation. The lakes and streams provide a series of habitats that contain a rich and varied fauna very typical of the Antarctic region. Seventeen species of rotifer, three tardigrades, two arthropods, protozoans, a platyhelminth and nematodes have been reported. The cladoceran *Daphniopsis studeri*, one of few species of freshwater crustacea known to occur in the lakes of continental Antarctica, has been identified in most Larsemann Hills lakes and represents the largest animal in these systems (WP8, 2006).

5.6 CLIMATE

5.6.1 OVERVIEW

The area is marked by persistent strong katabatic winds that blow from the north-east on most summer days. Daytime air temperatures from December to February frequently exceed 4˚C, with the mean monthly temperature a little above 0˚C. Pack ice is extensive inshore during early summer period, and the fjords and embayment are rarely ice-free. Snow cover is generally thicker and more persistent on Stornes Peninsula than Broknes Peninsula. Severe weather is experienced in the region with the occurrence of storms and the intensity of some low exceeds that of a tropical cyclone/hurricane with central pressures as low as 930 hPa and maximum winds of 50 meter/second (~100 kt). Extreme minimum temperature recorded so for is -40^0 C (Turner and Pendlebury, 2004).

5.6.2 SNOWFALL

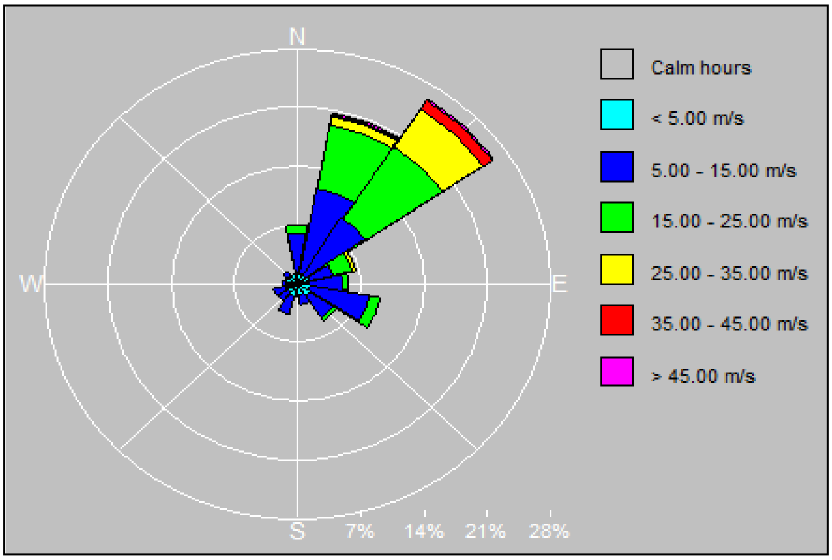
Frequency of snowfall days is higher in winter than in summer; the percentage of sunshine days is 50% in summer while overcast and cloudy days are dominant in winter. Precipitation occurs as snow and is unlikely to exceed 250 mm water equivalent annually (Hogdson et al., 2001).

5.6.3 KATABATIC WIND

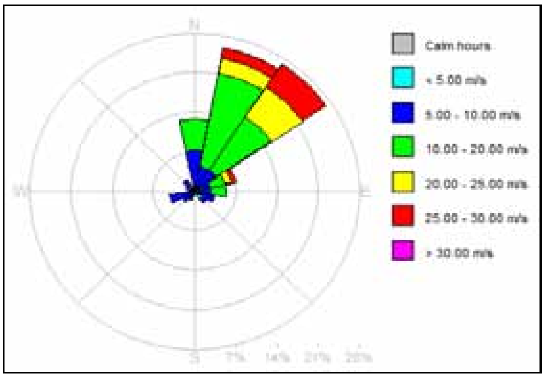
Data indicates that calm conditions often occur between 1800 to 2400 hr (local time) and gales between 0700 and 1200 hr in summer and autumn. Observations made at Zhongshan station situated close to the proposed site, depicts that katabatic winds are dominant in January and October (Turner and Pendlebury, 2004).

Gale frequency is considerably higher in winter than in other seasons with no diurnal variation. Annual mean wind speed recorded at Zhongshan station is 7 m/s. Maximum wind speed recorded is 50 m/s. Number of gale days prevailing are 47% (171 days) on an annual mean basis.

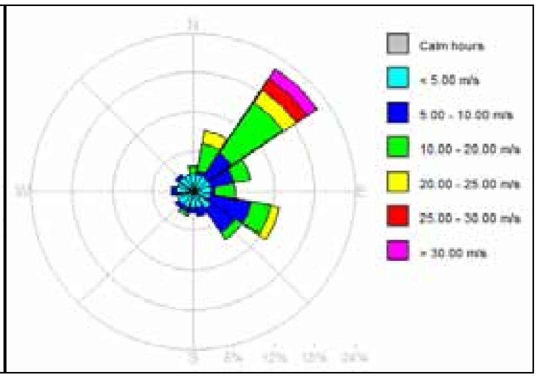
Wind rose of the area is prepared based on met data of daily average, obtained from Davis station and depicted in Figure 37. As seen from the monthly average wind direction record on an annual basis, east-south-east to north-north-east wind directions (45-22.5) have a frequency of 53%, of which 25% is due to the north-east wind, 20% due to north-north-east wind and 8% is due to east-south-east winds.



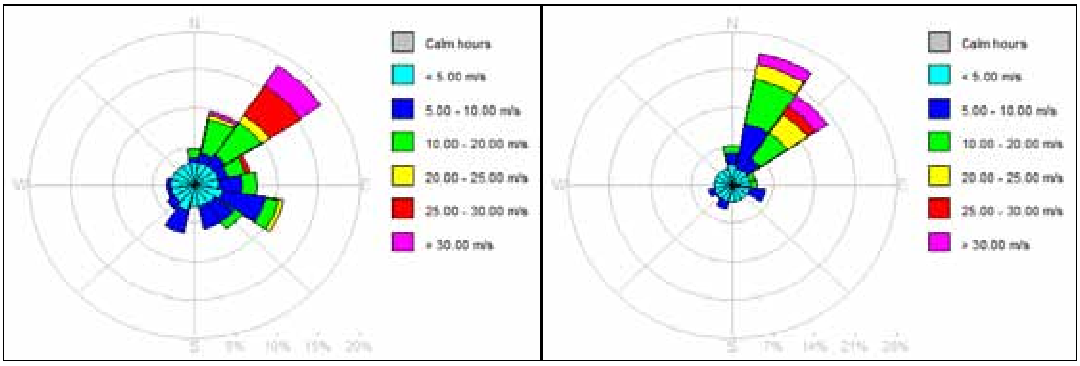
(a) Yearly wind rose (January to December 2008)



(b) January to March wind rose



(c) April to June wind rose



(d)July to September wind rose (e) October to December wind rose

FIGURE 37 : WINDROSE AT DAVIS STATION

5.6.4 HUMIDITY

The relative humidity is 57% on a yearly average. It is higher in the Larsemann Hills only when the temperature is above 0^{o}C, leading to a higher content of water in air in mid-summer. Additionally, during a snowstorm or blowing snow episode, the relative humidity is higher, sometimes in excess of 90% but absolute humidity remains low (Turner and Pendlebury, 2004).

5.6.5 SEA ICE

The sea ice conditions in the Prydz Bay are controlled by the presence of Dalk Glacier. This glacier produces large icebergs. The sea ice situation is improved with westerly winds, but the frequency of westerly wind events is very insignificant in this area. During the summer period, the Bay is clear of ice except in the fjords where ice breakout does not occur in some seasons.

The sea ice grows steadily during March – September, with maximum growth in April – June; it experiences steady melting in November – December, and to a minimum extent in February. Based on 1973-92 observations, the ice extends as far north as 57^{o}S as its northernmost limit (Turner and Pendelbury, 2004).

It has been observed that ice-free sectors often emerge on the west side of the Prydz Bay and an ice dam occurs on the east side in December – January, and the ice is nearly disintegrated in February. In contrast, ice along the Larsemann Hills shore is always present in some of the years and moves away only when westerly winds are persistent. However, the westerlies have low frequency of occurrence, which is indicative that the ice distribution bears a close relation to wind direction and orography on a local basis.

5.7 ANTHROPOGENIC IMPACT - BACKGROUND INFORMATION

Human occupation commenced in this area in 1986, with the establishment of four scientific bases by Australia (Law Base), Russia (Progress I and II) and China (Zhongshan) situated around 10 km away in NE direction from the proposed site. All these stations are situated within a radius of 2 km from each other. Ninety-three organic compounds including n-alkanes, lipidal isopentadienes, aromatic hydrocarbons, polycyclic aromatics, alcohols, aldehydes, ketones, esters, monocarboxylic acids and phthalic esters in the range of 0.027-

4.79 mg/L have been recorded in the Mochou and Heart lakes of the of Broknes area. Organic compounds like BHC, DDT and PCBs have also been detected in the water at concentrations of 0.012-0.356 mg/L (Li et al., 1997a, b). Occasional ship-based tourist visits have also been made to the area since 1992. Trace metal study has been carried out by Gasparon and Burgess (2000), Gasparon and Matschullat (2006 a, b, and other similar studies) in Broknes peninsula to establish baseline levels and to quantify the extent of pollution. It was concluded in the study that main elements contributed in the region by various source including long range transport of metals was in the order Pb>Zn>Cr$\geq$Cu$\geq$Cd.

5.8 BASELINE MONITORING INFORMATION – AIR ENVIRONMENT

5.8.1 AIR QUALITY

Ambient air quality of the Larsemann Hills where the Indian station is going to be established was analysed for the following parameters, viz. Suspended particulate matter (SPM), Respirable particulate matter (RSPM), Sulfur dioxide (SO_2), Nitrogen dioxide (NO_2) and Carbon monoxide (CO). The data were collected for four successive years for a few days during stay in summer (December - March) of 2006-07, 2007-08, 2008-09 and 2009-10.

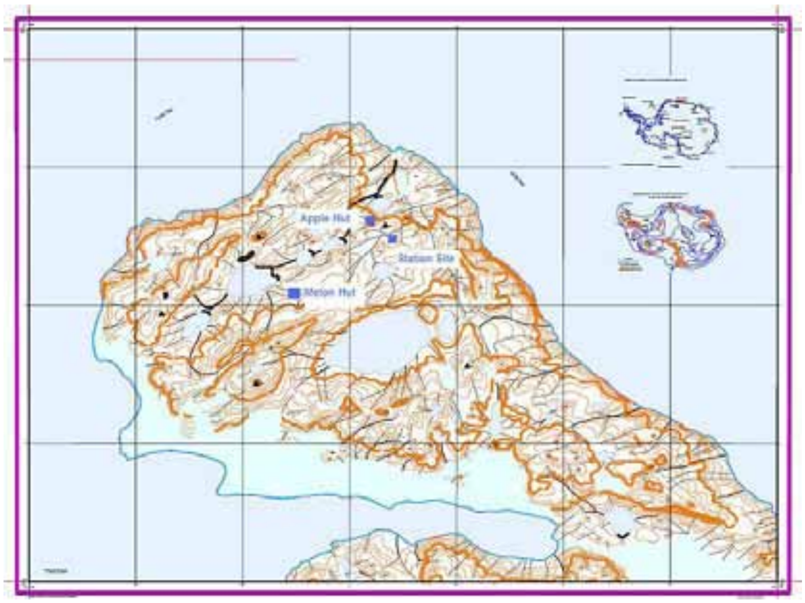


FIGURE 38 : AMBIENT AIR QUALITY MONITORING STATIONS

Sampling was made from three locations, viz. near Apple Hut, near Living Module (Melon Hut) and proposed site shown in Figure 38. Analytical data during the monitoring period, level of SPM, RSM, SO_2, NOx and CO in ambient air at all the three locations at Grovnes Promontory is given in Table 2

TABLE 2 : AMBIENT AIR QUALITY AT PROPOSED SITE

DURING 26TH ISEA (IP-139, 2007)

SPM (µg/m3)			SO2 (µg/m3)		NOx (µg/m3)	
Date of Sampling	Melon Hut	Apple Hut	Melon Hut	Apple Hut	Melon Hut	Apple Hut
9 March 07	-	-	1.4	-	4.4	8.1
10 March 07	1.6	3.2	-	4.6	-	11.2
11 March 07	-	5.2	1.6	3.4	6.2	10.4
12 March 07	-	4.7	0.8	1.8	4.7	10.2
13 March 07	5.6	5.8	0.13	0.3	5.2	8.1
14 March 07	5.0	-	1.8	-	5.7	7.9
15 March 07	-	-	3.9	0.8	-	10.6

DURING 27TH, 28TH, 29TH ISEA

SPM

Sampling Location	Sampling ID	Concentration in µg/m^3		
		27th ISEA	28th ISEA	29th ISEA
Near Apple Hut (69°24’18.00”S) (76°11’42.00”E)	1	5.3	15.3	21
	2	2.7	12.8	20
	3	7.2	16.2	23
	4	7.0	14.7	16
	5	4.7	16.5	12
	6	10.5	15.1	8
Near Melon Hut (69°24’25.20”S) (76°11’46.55”E)	7	-	-	18
	8	-	-	11
	9	-	-	14
Proposed Station Site (69°24’22.10”S) (76°11’44.90”E)	10	-	-	16
	11			20
	12			21

RSPM

Sampling Location	Sampling ID	Concentration in µg/m^3		
		27th ISEA	28th ISEA	29th ISEA
Near Apple Hut (69°24’18.00”S) (76°11’42.00”E)	1	1.2	2.1	7
	2	0.5	1.0	5
	3	0.8	1.9	8
	4	1.0	1.2	6
	5	1.4	2.0	4
	6	1.7	1.8	3
Near Melon Hut (69°24’25.20”S) (76°11’46.55”E)	7	-	-	5
	8	-	-	3
	9	-	-	4
Proposed Station Site (69°24’22.10”S) (76°11’44.90”E)	10	-	-	6
	11	-	-	8
	12	-	-	9

(SIIR, 2010)

SO_2

Sampling Location	Sampling ID	Concentration in μg/m³		
		27th ISEA	28th ISEA	29th ISEA
Near Apple Hut (69°24'18.00"S) (76°11'42.00"E)	1	*	2.7	<1
	2	*	<1	2.9
	3	*	3.9	<1
	4	*	2.9	<1
	5	*	3.4	2.1
	6	*	3.2	<1
Near Melon Hut (69°24'25.20"S) (76°11'46.55"E)	7	-	-	1.2
	8	-	-	0.8
	9	-	-	1.1
Proposed Station Site (69°24'22.10"S) (76°11'44.90"E)	10	-	-	1.4
	11			1.2
	12			1.6

NOx

Sampling Location	Sampling ID	Concentration in μg/m³		
		27th ISEA	28th ISEA	29th ISEA
Near Apple Hut (69°24'18.00"S) (76°11'42.00"E)	1	-	4.1	3.1
	2	-	5.0	8.0
	3	-	4.9	6.9
	4	-	5.1	5.1
	5	-	6.7	8.7
	6	-	7.4	5.4
Near Melon Hut (69°24'25.20"S) (76°11'46.55"E)	7	-	-	5.2
	8	-	-	3.8
	9	-	-	6.1
Proposed Station Site (69°24'22.10"S) (76°11'44.90"E)	10	-	-	4.4
	11			3.2
	12			6.6

(SIIR, 2010)

CO

Sampling Location	Sampling ID	Concentration in mg/m3		
		27th ISEA	28th ISEA	29th ISEA
Near Apple Hut (69°24'18.00"S) (76°11'42.00"E)	1	<0.1	0.7	0.8
	2	<0.1	0.6	1.0
	3	<0.1	0.4	0.8
	4	<0.1	0.3	0.7
	5	<0.1	0.4	1.0
	6	<0.1	0.5	0.8
Near Melon Hut (69°24'25.20"S) (76°11'46.55"E)	7	-	-	0.6
	8	-	-	0.8
	9	-	-	1.0
Proposed Station Site (69°24'22.10"S) (76°11'44.90"E)	10	-	-	0.5
	11			0.6
	12			0.8

(SIIR, 2010)

The ratio of RSPM vs SPM indicates that the RSPM (<10 µm) was 11 to 37% of the SPM (<100 µm) concentration near Apple Hut. At living module area the ratio of RPM vs SPM was in the range of 27-28%. At Proposed Station area the ratio of RPM vs SPM was in the range of 27-28%. During 29th ISEA, increase in concentrations of SPM and RSPM were noticed due to site preparation activities. SO_2 concentration varied from <1 to 3.9 µg/m^3 during 2008-09 and <1 to 2.9 µg/m^3 during 2009-10, where as NOx varied form 4.1-7.4 µg/m^3 during 2008-09 and 3.1 to 8.7 µg/m^3 during 2009-10. Most of the time CO was recorded below 1 mg/m^3, while it was monitored for back ground concentration.

5.8.2 BLACK CARBON AEROSOL

Aethelometer was operated for 24 hours at the site for two different days in March 2007 (with a gap of 4 days) to obtain black carbon concentration at site. Results showed the range of carbon concentration as 26.5±16.2 ng/m^3. During 28th ISEA the same instrument was operated for 17 days at site and average concentration recorded was 13±5 ng/m^3 (Chaubey et al., 2010).

5.9 BASELINE MONITORING INFORMATION - WATER ENVIRONMENT

Water samples collected from various lakes in the vicinity of the proposed site during the summer of 2004 were analyzed for dissolved salts. Excepting L-7 (Figure 36) which was saline in nature, the water quality from other lakes was in general potable. Some of the important physico-chemical parameters of water of these lakes are provided in Table 3. The water bodies L1, L2, L3, & L5 (Figure 36) being shallow revealed low hydraulic detention period/ high flushing rate.

TABLE 3 : PHYSICO CHEMICAL PROPERTIES OF WATER BODIES AT LARSEMANN HILLS

Parameters	Lake-L1	Lake-L3	Lake-L7	Lake-L8	Lake-L9
Temperature (oC)	-0.1	-0.1	-0.1	0.1	0.1
pH	6.1	6.1	6.1	6.4	6.0
Conductivity (ms/cm)	80	80	930	120	20
PO_4 (mg/l)	0.73	0.71	0.72	0.72	-
NO_3 (mg/l)	0.3	0.4	0.2	0.2	0.2
Fe (mg/l)	0.12	0.03	0.08	0.15	0.13
Alkalinity (mg/l)	4.0	4.0	16	6.0	4
Chloride (mg/l)	5.95	5.26	70.73	8.0	2.04

The lake water samples were collected from two lakes in the McLeod Island located close to the proposed site for multi-parameter probe analysis. The results of the physico-chemical analysis of same lakes numbered as 33 and 34 by Gillieson et al., (1990 and other similar studies) are shown below in Table 4.

TABLE 4 : PHYSICO CHEMICAL ANALYSIS OF LAKES OF MCLEOD ISLAND

Parameters	Lake-33	Lake-34
Water temperature (0C)	3.7	2.6
pH	6.57	6.74
Conductivity (μS/cm)	197	261
Chloride (mg/l)	59.3	75.7
Sodium (mg/l)	14.7	13.1
Potassium (mg/l)	0.5	0.5
Calcium (mg/l)	0.5	0.5
Magnesium (mg/l)	3.0	3.0

ND – Not Detected

Samples were collected during 26th ISEA (Figure 36) from various Lakes situated at Grovnes Peninsula and results of some trace metals and anion and cations are presented in Table 5 and 6. It can be seen that though most of the parameters were within range of potable water quality, chloride, sulfate, sodium, calcium, magnesium, TDS and conductivity were relatively at higher levels in Lakes 6 and 7, indicating that the water quality is not generally acceptable for drinking purpose.

During subsequent summer expeditions i.e. 2007-08, 2008-09 and 2009-10, water samples were collected from more lakes in the Grovnes Peninsula, McLeod Island and Stornes Peninsula and from sea for estimating the physico-chemical parameters and pesticides. During these expeditions, water samples were analysed for more parameters and those for the Larsemann Hills are listed below (Tables 7 - 9).

TABLE 5 : ION AND PHYSICO-CHEMICAL ANALYSIS OF LAKE AND SEA WATER

Sample Identification	Anions (mg/l)				Cations (mg/l)				pH	Conductivity	TDS
	Fluoride	Chloride	Nitrate	Sulfate	Sodium	Potassium	Calcium	Magnesium		(µs/cm)	mg/l)
L1	0.03	80.23	ND	11.03	40.79	1.80	2.77	5.01	7.59	368	184
L1 (A)	0.02	146.93	0.22	21.75	76.02	2.46	6.47	11.85	6.93	514	251
L1 (B)	0.02	141.30	0.34	20.85	70.57	1.89	6.54	11.20	6.0	516	258
L1 (C)	0.03	173.30	ND	27.94	90.96	2.88	5.84	12.12	6.93	591	297
L2 (A)	0.11	307.48	ND	46.72	163.47	6.02	15.86	23.94	7.47	557	271
L3	0.02	57.71	ND	13.25	37.05	1.09	2.33	4.26	6.69	122.9	62.2
L4	0.08	363.50	ND	22.70	194.15	7.79	8.04	17.44	7.8	1102	551
L5	0.03	104.05	0.04	16.21	56.68	1.77	4.97	7.81	6.91	394	197
L6	0.13	1123.20	ND	76.98	571.42	19.33	27.91	70.99	8.26	3210	1600
L7	0.12	691.75	ND	118.05	394.36	15.06	43.77	53.66	7.2	2420	1210
L8	0.05	126.37	0.04	23.04	75.64	3.49	17.35	8.65	6.96	546	273
L8A	0.76	2558.47	ND	219.07	1196.77	39.40	123.61	113.38	7.05	5700	2840
Sea Water (East)	ND	19931.59	ND	2455.31	11222.31	286.72	369.03	1268.19	7.8	15150	7560
Sea Water (South)	ND	20163.34	ND	2511.29	11230.43	315.04	372.49	1298.67	7.63	15290	7660

(IP-139, 2007)

TABLE 6 : TRACE METAL ANALYSIS OF VARIOUS LAKES AROUND PROPOSED SITE

Lake ID/Element	Li (ppb)	Na (ppm)	Mg (ppm)	Al (ppb)	K (ppb)	Cr (ppb)	Mn (ppb)	Fe (ppb)	Co (ppb)	Cu (ppb)	Zn (ppb)	Se (ppb)	Cd (ppb)	Ba (ppb)	Pb (ppb)
L1	0.9	42.2	5.4	4.7	2155.0	1.2	4.6	60.0	0.0	1.0	11.1	0.2	0.0	0.8	0.9
L1 (A)	1.3	52.1	11.1	0.6	2412.0	0.2	22.7	6.1	0.0	0.6	9.2	0.3	0.0	1.0	0.0
L1 (B)	1.2	52.1	9.9	1.7	1864.0	0.1	203.1	15.2	0.1	0.3	20.0	0.3	0.0	1.0	0.3
L1 (C)	1.4	52.1	9.9	1.1	2391.0	0.1	1.2	4.7	0.0	0.4	7.4	0.4	0.0	0.7	0.0
L2	3.4	52.1	19.6	1.5	4642.0	0.2	0.2	11.6	0.0	0.5	3.8	0.3	0.0	2.1	0.1
L3	0.7	28.0	3.3	0.9	1062.0	0.1	1518.0	2.9	0.2	0.5	19.2	0.1	0.1	1.0	0.1
L4	2.9	52.1	12.8	1.2	5413.0	0.1	0.2	5.4	0.0	0.4	0.4	0.1	0.0	0.6	0.0
L5	1.0	42.2	6.0	1.3	1495.0	0.6	64.2	4.2	0.0	0.5	13.6	0.2	0.1	1.0	0.1
L6	5.8	446.4	55.5	3.7	13050.0	0.4	49.5	19.7	0.1	1.7	8.1	0.3	0.3	2.1	0.2
L7	8.4	208.5	41.0	2.7	10720.0	0.2	165.8	27.2	0.1	0.5	2.4	0.4	0.1	6.9	0.1
L8	2.2	51.7	6.7	1.5	2550.0	0.1	13.6	10.8	0.0	1.2	7.2	0.2	0.0	3.0	0.1
L8A	20.4	521.2	131.3	3.9	28630.0	0.4	76.5	98.5	0.7	2.0	9.4	1.6	0.2	17.0	0.2

(IP-139, 2007)

TABLE 7 : PHYSICOCHEMICAL CHARACTERISTICS OF LAKE WATER (L1, L2, L3, L5, L6) AT GROVNES PENINSULA (SIIR, 2010)

S. No.	Parameter	Lake: L-1 Latitude (S) - Longitude (E) 69°24′18.70′′ -76°11′38.11′′			Lake: L-2 Latitude (S) – Longitude (E) 69°24′26.03′′ -76°11′38.29′′			Lake: L-3 Latitude (S) – Longitude (E) 69°24′26.9′′ - 76°11′02.3′′			Lake: L-5 Latitude (S) – Longitude (E) 69°24′31′′ - 76°10′50.3′′			Lake: L-6 Latitude (S) – Longitude (E) 69°24′36.9′′ -76°11′02..7′′		
		27th ISEA	28th ISEA	29th ISEA	27th ISEA	28th ISEA	29th ISEA	27th ISEA	28th ISEA	29th ISEA	27th ISEA	28th ISEA	29th ISEA	27th ISEA	28th I SEA	29th ISEA
1.	Colour, Hazen unit	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
2.	Odour	UO	UO	UO	UO	UO	UO	UO	UO	UO	UO	UO	UO	UO	UO	UO
3.	Turbidity, NTU	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
4.	pH	7.9	6.5	7.2	7.9	7.0	7.7	6.5	6.6	7.4	7.5	6.8	7.5	7.5	7.3	7.4
5.	Total hardness (as $CaCO_3$), mg/l	32	26	12	35	28	Nil	18	9	Nil	84	13	13	420	64	25
6.	Iron (as Fe), mg/l	0.2	<0.01	<0.01	0.05	0.01	0.01	0.01	0.2	0.01	0.05	0.09	<0.01	0.06	0.1	<0.01
7.	Chloride (as Cl), mg/l	61	42	54	170	42	19	4	20	6	172	27	92	836	175	58
8.	Fluoride (as F), mg/l	<0.1	<0.1	<0.1	0.14	0.20	<0.1	<0.1	<0.1	0.1	0.1	0.06	<0.1	0.4	0.1	<0.1
9.	Dissolved Solids, mg/l	136	106	115	393	109	45	36	80	*	387	60	176	2354	404	132
10.	Magnesium (as Mg), mg/l	5	3.4	1.4	6.0	3.6	Nil	2	1.7	Nil	12	2.6	1.2	28	12	1.4
11.	Calcium (as Ca), mg/l	5	4.8	2.4	5.0	5.2	Nil	4	6	Nil	13	02	3.2	4	4.8	7.6
12.	Copper (as Cu), mg/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.012	0.015	0.006	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
13.	Manganese (as Mn), mg/l	0.01	<0.01	<0.01	0.02	0.01	0.001	0.003	0.006	0.001	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
14.	Sulfate (as SO_4), mg/l	5	1	7	24	<1	<1	5	6	<1	24	4	<1	49	6	7
15.	Nitrates (as NO_3), mg/l	<1	<1	2.2	<1	<1	<1	1	2	*	<1	<1	6..9	<1	<1	1.2
16.	Phenolic Compounds (as C_6H_5OH), mg/l	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
17.	Mercury (as Hg), mg/l	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
18.	Cadmium (as Cd), mg/l	<0.01	<0.01	<0.001	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
19.	Selenium (as Se), mg/l	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
20.	Arsenic as As,mg/l	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
21.	Cyanide (as CN), mg/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
22.	Lead (as Pb), mg/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	0.02	0.027	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
23.	Zinc (as Zn), mg/l	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	0.04	0.01	0.02	0.01	<0.01	0.02	<0.01	<0.01
24.	Anionic Detergents (MBAS) mg/l	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
25.	Chromium (as Cr^{+6}), mg/l	<0.01	<0.01	<0.01	<0.01	<0.01	0.004	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
26.	Mineral Oil, mg/l	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
27.	Alkalinity (as $CaCO_3$), mg/l	21	28	6	41	30	5	8	6	4	18	6	9	86	19	15
28.	Aluminum (as Al), mg/l	<0.02	<0.02	<0.02	<0.01	<0.01	<0.01	<0.02	<0.02	<0.02	<0.002	<0.002	<0.002	<0.02	<0.02	<0.02
28.	Phosphate (as PO_4), mg/l	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05

S. No.	Parameter	Lake: L-1 Latitude (S) - Longitude (E) 69°24′18.70′′ -76°11′38.11′′			Lake: L-2 Latitude (S) – Longitude (E) 69°24′26.03′′ -76°11′38.29′′			Lake: L-3 Latitude (S) – Longitude (E) 69°24′26.9′′ - 76°11′02.3′′			Lake: L-5 Latitude (S) – Longitude (E) 69°24′31′′ - 76°10′50.3′′			Lake: L-6 Latitude (S) – Longitude (E) 69°24′36.9′′ -76°11′02..7′′		
		27th ISEA	28th ISEA	29th ISEA	27th ISEA	28th ISEA	29th ISEA	27th ISEA	28th ISEA	29th ISEA	27th ISEA	28th ISEA	29th ISEA	27th ISEA	28th I SEA	29th ISEA
29.	Boron (as B), mg/l	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
30..	Total Organic Carbon (TOC), mg/l	-	-	0.935	-	-	0.783	-	-	1.361	-	-	1.573	-	-	1.778
31.	Dissolved Oxygen (DO), mg/l	-	-	12.8	-	-	10.8	-	-	12.2	-	-	13.2	-	-	10.4
32.	MPN Coliform /100 ml	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil

TABLE 8 : PHYSICOCHEMICAL CHARACTERISTICS OF LAKE WATER (L7‹LGR›, L8, L9, L12) AT GROVNES PENINSULA (SIIR, 2010)

S. No.	Parameter	Lake: L-7 (LGR) Latitude (S) – Longitude (E) 69°24′33.45″ - 76°11′36.02″			Lake: L-8 Latitude (S) – Longitude (E) 69°24′52.26″ - 76°12′42.19″			Lake: L-9 (Southern Part) Latitude (S) – Longitude (E) 69°25′04″ - 76°12′19.16″			Lake: L-12 (Southern Part) Latitude (S) – Longitude (E) 69°25′08.14″ - 76°11′52.32″		
		27th ISEA	28th ISEA	29th ISEA	27th ISEA	28th ISEA	29th ISEA	27th ISEA	28th ISEA	29th ISEA	27th ISEA	28th ISEA	29th ISEA
1.	Colour, Hazen unit	<5	<5	-	<5	<5	<5	<5	<5	-	<5	<5	<5
2.	Odour	UO	UO	-	UO	UO	UO	UO	UO	-	UO	UO	UO
3.	Turbidity, NTU	<1	<1	-	<1	<1	<1	<1	2	-	<1	<1	<1
4.	pH	7.8	7.7	-	7.1	7.1	7.2	6.8	6.9	-	6.9	7.8	7.1
5.	Total hardness (as $CaCO_3$), mg/l	176	174	-	48	36	32	106	12	-	19	17	Nil
6.	Iron (as Fe), mg/l	0.03	0.03	-	0.03	0.03	<0.01	0.03	0.3	-	0.03	0.8	0.01
7.	Chloride (as Cl), mg/l	353	351	-	123	112	128	55	36	-	31	37	31
8.	Fluoride (as F), mg/l	<0.1	<0.1	-	0.2	0.2	0.1	0.4	0.2	-	0.4	0.1	<0.1
9.	Dissolved Solids, mg/l	853	845	-	270	210	280	193	81	-	78	79	65
10.	Magnesium (as Mg), mg/l	29	24	-	5	4	5.0	5	1.4	-	2	2.4	Nil
11.	Calcium (as Ca), mg/l	22	19	-	13	09	4.0	25	2.4	-	5	2.8	Nil
12.	Copper (as Cu), mg/l	<0.01	<0.01	-	<0.01	<0.01	<0.01	<0.01	0.01	-	<0.01	<0.01	<0.01
13.	Manganese (as Mn), mg/l	<0.01	<0.01	-	0.01	0.01	0.01	<0.01	<0.01	-	<0.01	<0.01	<0.01
14.	Sulfate (as SO_4), mg/l	92	89	-	9	6	24	1	1	-	2	1	1
15.	Nitrates (as NO_3), mg/l	<1	<1	-	<1	<1	<1	<1	4	-	1.0	1.0	1.8
16.	Phenolic Compounds (as C_6H_5OH), mg/l	ND	<0.01	-	ND	ND	ND	ND	ND	-	ND	ND	ND
17.	Mercury (as Hg), mg/l	<0.001	<0.001	-	<0.001	<0.001	<0.001	<0.001	<0.001	-	<0.001	<0.001	ND
18.	Cadmium (as Cd), mg/l	<0.01	<0.01	-	<0.01	<0.01	<0.01	<0.01	<0.01	-	<0.01	<0.01	<0.01
19.	Selenium (as Se), mg/l	<0.005	<0.005	-	<0.005	<0.005	<0.005	<0.005	<0.005	-	<0.005	<0.005	ND
20.	Arsenic (as As) mg/l	<0.005	<0.005	-	<0.005	<0.005	<0.005	<0.005	<0.005	-	<0.005	<0.005	<0.005
21.	Cyanide (as CN), mg/l	<0.01	<0.01	-	<0.01	<0.01	<0.01	<0.01	<0.01	-	<0.01	<0.01	<0.01
22.	Lead (as BP), mg/l	<0.01	<0.01	-	<0.01	<0.01	<0.01	<0.01	<0.01	-	<0.01	<0.01	<0.01
23.	Zinc (as Zn), mg/l	0.02	0.04	-	0.02	0.02	0.02	0.01	0.02	-	0.01	0.02	0.01
24.	Anionic Detergents (MBAS) mg/l	ND	ND	-	ND	ND	ND	ND	ND	-	ND	ND	ND
25.	Chromium (as Cr^{+6}), mg/l	<0.01	<0.01	-	<0.01	<0.01	<0.01	<0.01	<0.01	-	<0.01	<0.01	<0.01
26.	Mineral Oil, mg/l	ND	ND	-	ND	ND	ND	ND	ND	-	ND	ND	ND

S. No.	Parameter	Lake: L-7 (LGR) Latitude (S) – Longitude (E) 69°24′33.45′′ - 76°11′36.02′′			Lake: L-8 Latitude (S) – Longitude (E) 69°24′52.26′′ - 76°12′42.19′′			Lake: L-9 (Southern Part) Latitude (S) – Longitude (E) 69°25′04′′ - 76°12′19.16′′			Lake: L-12 (Southern Part) Latitude (S) – Longitude (E) 69°25′08.14′′ - 76°11′52.32′′		
		27th ISEA	28th ISEA	29th ISEA	27th ISEA	28th ISEA	29th ISEA	27th ISEA	28th ISEA	29th ISEA	27th ISEA	28th ISEA	29th ISEA
27.	Alkalinity (as $CaCO_3$), mg/l	38	35	-	35	28	12	15	8	-	8	12	3
28.	Aluminum (as Al), mg/l	<0.02	<0.02	-	<0.02	<0.02	<0.02	<0.02	<0.02	-	<0.02	<0.02	<0.02
28.	Phosphate (as PO_4), mg/l	<0.05	<0.05	-	<0.05	<0.05	<0.05	<0.05	<0.05	-	<0.05	<0.05	0.1
29.	Boron (as B), mg/l	-	-	-	<1	<1	<1	<1	<1	-	<1	<1	<1
30..	Total Organic Carbon (TOC), mg/l	-	-	-	-	-	1.822	-	-	-	-	-	0.439
31.	Dissolved Oxygen (DO), mg/l	<1	<1	-	-	-	10.8	-	-	-	-	-	11.5
32.	MPN Coliform /100 ml	Nil	Nil	-	Nil	Nil	Nil	Nil	Nil	-	Nil	Nil	Nil

TABLE 9 : PHYSICOCHEMICAL CHARACTERISTICS OF LAKE WATER AT STORNES PENINSULA, MCLEOD ISLAND AND SEA WATER (SIIR, 2010)

S. No.	Parameter	Lake: 1- McLeod Island Latitude (S) – Longitude (E) 69°22′15″ - 76°08′34.50″			Lake: 1- Stornes Peninsula Latitude (S) – Longitude (E) 69°24′45.95″ - 76°07′42.56″			Sea Water Latitude (S) – Longitude (E) 69°24′26.3″ - 76°12′43.9″		
		27th ISEA	28th ISEA	29th ISEA	27th ISEA	28th ISEA	29th ISEA	27th ISEA	28th ISEA	29th ISEA
1.	Colour, Hazen unit	<5	<5	<5	<5	<5	<5	<5	<5	<5
2.	Odour	UO	UO	UO	UO	UO	UO	UO	UO	UO
3.	Turbidity, NTU	1	<1	<1	1	<1	<1	<1	1	<1
4.	pH	6.8	6.6	7.0	6.8	7.0	7.1	7.7	8.0	8.0
5.	Total hardness (as $CaCO_3$), mg/l	10	10	78	16	21	19	6466	5480	6718
6.	Iron (as Fe), mg/l	0.01	0.2	0.01	0.01	0.04	0.02	0.4	0.2	0.02
7.	Chloride (as Cl), mg/l	12	56	221	45	55	58	20370	11211	16005
8.	Fluoride (as F), mg/l	<0.1	<0.1	0.2	0.2	0.2	<0.1	1.1	0.4	0.8
9.	Dissolved Solids, mg/l	22	113	462	134	135	118	36850	30044	31430
10.	Magnesium (as Mg), mg/l	2	4.1	13.4	2	2.9	2.6	1379	1104	1432
11.	Calcium (as Ca), mg/l	1	1.6	8.8	3	3.6	3.2	305	352	408
12.	Copper (as Cu), mg/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.2	0.05	<0.01
13.	Manganese (as Mn), mg/l	<0.01	<0.01	0.001	<0.01	<0.01	<0.01	0.06	0.03	<0.01
14.	Sulfate (as SO_4), mg/l	1	1	32	1	1	2	330	5411	1159
15.	Nitrates (as NO_3), mg/l	0.026	4	5.4	0.026	<.1	2	<1	68	175
16.	Phenolic Compounds (as C_6H_5OH), mg/l	ND	ND	ND	ND	ND	ND	ND	ND	ND
17.	Mercury (as Hg), mg/l	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
18.	Cadmium (as Cd), mg/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
19.	Selenium (as Se), mg/l	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
20.	Arsenic (as As) mg/l	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
21.	Cyanide (as CN), mg/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
22.	Lead (as Pb), mg/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.7	<0.01
23.	Zinc (as Zn), mg/l	0.02	0.02	0.02	0.01	0.03	0.01	0.01	0.03	0.01
24.	Anionic Detergents (MBAS) mg/l	ND	ND	ND	ND	ND	ND	ND	ND	ND
25.	Chromium (as Cr^{+6}), mg/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
26.	Mineral Oil, mg/l	ND	ND	ND	ND	ND	ND	ND	ND	ND
27.	Alkalinity (as $CaCO_3$), mg/l	4	6	18	46	34	5	114	137	121
28.	Aluminum (as Al), mg/l	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
28.	Phosphate (as PO_4), mg/l	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
29.	Boron (as B), mg/l	<1	<1	<1	<1	<1	<1	<1	<1	<1
30.	Total Organic Carbon (TOC), mg/l	-	-	2.086	-	-	1.336	-	-	0.468
31.	Dissolved Oxygen (DO), mg/l	-	-	12.2	-	-	10.2	-	-	8.7
32.	MPN Coliform /100 ml	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil

Generally, water quality parameters did not show significant variations. However, some parameters showed marginal inter-annual variations between lakes. For instance, chloride values in all lakes were within the range of freshwater, but in Lakes – 6 (58-836 mg/l) and 7 (351-353 mg/l) the values varied widely and also indicated saline water influence. Dissolved solids content in Lake-7 was high (range, 845-853 mg/l) while in some other lakes, the dissolved solids content though relatively high, was within the permissible limit for drinking water. Most of the metals analysed were showing values either below detectable to very low values. Nutrient parameters such as PO_4 and NO_3, though varied marginally between lakes, showed lower values, suggesting that the lake in Larsemann Hills are not subjected to organic or inorganic pollution.

In the McLeod Island, most water quality parameters showed relatively lower values compared to those of the Larsemann lakes (Table 9). Dissolved solids during the three years showed wide variations (22 – 462 mg/l), but were lower than those recorded for some of the lakes in Larsemann Hills. All inorganic non-metal and metal concentrations were either very low or non-detectable, showing that the lakes in McLeod Island are not polluted or contaminated in any manner.

In Stornes Peninsula also, the lake water quality was found to be of drinking water standard (Table 9). The dissolved solids content was slightly higher (118 - 135 mg/l), but compared to some lakes in Larsemann Hills, these values were much lower. The inorganic metal and non-metal concentrations were either non-detectable or very low, indicating that the lake water in this Island is not contaminated.

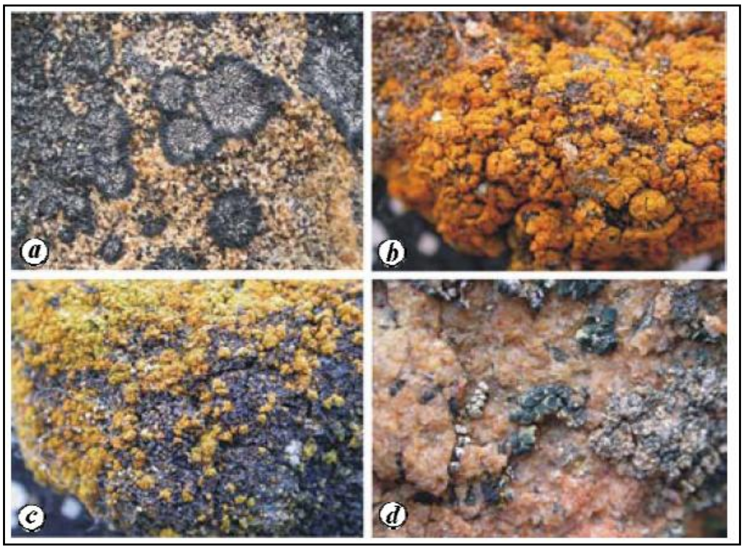
Dissolved solids (30044 - 36850 mg/l), Chloride as Cl (11211 – 20370 mg/l), Total hardness as $CaCO_3$ (5480-6718 mg/l), pH (7.7 - 8.0) and Alkalinity as $CaCO_3$ (114-137 mg/l) of seawater samples around the Larsemann Hills area were typical of marine environment (Table 9). When chlorinity was converted to salinity, the highest value of 36.8 ppt was observed during the 27^{th} ISEA (2007-08 summer) while the lowest (20.3 ppt) was observed during the 28^{th} ISEA (2008-09 summer). This clearly shows that the seawater quality can drastically change depending on local events, particularly melt water. Inorganic non-metal and metal concentrations were within the acceptable ranges for seawater. The overall picture indicates that the seawater is uncontaminated.

Several pesticides were tested for their presence in the lake waters of Larsemann Hills, Fisher and McLeod Islands during the 28^{th} and 29^{th} expeditions. All the tests were negative, indicating the waters are devoid of any pesticide contamination.

5.10 BASELINE MONITORING INFORMATION - FLORA AND FAUNA

5.10.1 FLORA

During the 26^{th} Scientific Expedition to Antarctica (2006-07 summer), lichen distribution on the McLeod Island was studied (Singh et al., 2007). In all 25 species were identified from 196 colonies and of these 12 were new records to this area. Table 10 shows all the species of lichens recorded from this area and also includes those recorded by the Australians. The lichen flora was dominated by crustose lichens consisting of 19 species. Foliose lichens collected comprised *Physcia caesia*, *P. dubia*, *Xanthoria elegns* and *X. mawsonii.* The only species of fruticose lichen found was *Pseudephebe minuscule. Buellia* frigida with 53 colonies was the most abundant species distributed in the island. It was followed by *Candelariella flava* with 29 colonies, *Rhizoplaca melanophthalma* with 23 colonies and *Caloplaca citrina* with 18 colonies (Figure 39).



a. *Buellia frigid* b. *Calo-placa citrine* c. *Candeleriella flava* d. *Rhizoplaca melanophthalma*

FIGURE 39 : MOST COMMON LICHENS IN MCLEOD ISLAND, LARSEMANN HILS

TABLE 10 : LICHEN DISTRIBUTION IN MCLEOD ISLAND

Lichen taxa	Substratum	Growth form
Acarospora gwynnii C. W. Dodge & E. D. Rudolph	Rock	Crustose
Arthonia lapidicola (Taylor) Branth & Rostr.*	Rock	Crustose
Buellia frigida Darb.	Rock	Crustose
Buellia grimmiae Filson#	Moss, soil	Crustose
Caloplaca athallina Darb. #	Moss	Crustose
Caloplaca sp. A	Moss	Crustose
Caloplaca citrina (Hoffm.) Th. Fr.	Rock	Crustose
C. lewis-smithii Søchting & Øvstedal*	Moss	Crustose
C. saxicola (Hoffm.) Nordin*	Rock, soil	Crustose
Candelariella flava (C. W. Dodge & Baker) Castello & Nimis	Rock, soil, moss	Crustose
Carbonea vorticosa (Flörke) Hertel*	Rock	Crustose
Huea coralligera (Hue) C. W. Dodge & G. E. Baker*	Moss	Crustose
Lecanora expectans Darb.	Soil, moss	Crustose
L. geophila (Th. Fr.) Poelt*	Moss	Crustose
Lecidea cancriformis C. W. Dodge & G. E. Baker	Rock, soil	Crustose
Lecidella patavina (A. Massal.) Knoph & Leuckert*	Rock, soil	Crustose
L. siplei (C. W. Dodge & G. E. Baker) May. Inoue*	Rock	Crustose
Lepraria sp.#	Rock, soil, moss	Crustose
Physcia sp.*	Rock, soil	Foliose
P. caesia (Hoffm.) Furnr.	Rock, moss	Foliose
P. dubia (Hoffm.) Lettau*	Rock	Foliose
Pseudophebe minuscula (Nyl. ex Arnold) Brodo & D. Hawksw.	Rock, soil	Fruticose
Pseudephebe minuscule (Nyl. ex Arnold)#	Rock	Fruticose
Rhizoplaca melanophthalma (Ram.) Leuckert & Poelt	Rock, soil, moss	Crustose
Rinodina olivaceobrunea C. W. Dodge & G. E. Baker	Soil, moss	Crustose
R. peloleuca (Nyl.) Mull. Arg.*	Rock	Crustose
Sarcogyne privigna (Ach.) A. Massal.*	Rock, soil	Crustose
Umbilicaria decussata (Vill.) Zahlbr.#	Rock	Foliose
Usnea antarctica Du Rietz#	Rock	Foliose
Xanthoria elegans (Link) Th. Fr.	Rock	Foliose
Xanthoria mawsonii C. W. Dodge	Rock	Foliose

5.10.2 MICROBIAL FLORA

During the 26th Indian Scientific Expedition (2006-07 summer), the bacterial population in some brackish water lakes of Larsemann Hills was enumerated (Krishnan et al., 2009). Both freshwater and saline bacteria were encountered in the lakes. The manganese oxidizing bacterial population was also estimated. The culturable heterotrophic population (freshwater and marine) in the lakes ranged from non-detectable to 10^6 CFU/l (Figure 40) while the direct bacterial counts (DC) ranged from 10^7 to 10^8, suggesting that majority of the culturable counts were less by two order of magnitude than DC. These lakes were also found to harbor a large number of manganese oxidizing bacteria (10^5 – 10^6 CFU/l), predominantly belonging to the genera *Shewanella*, *Pseudomonas* and an unclassified genus in the family Oxalobacteriaceae. Their occurrence in marine agar medium indicates the past marine history.

During the 28th and 29th Indian Expeditions (2008-09 and 2009-10 summer), also bacterial population in some lakes of Larsemann Hills was enumerated. No pathogenic population such as Coliform, Salmonella, Staphylococcus and Psedomonas was encountered.

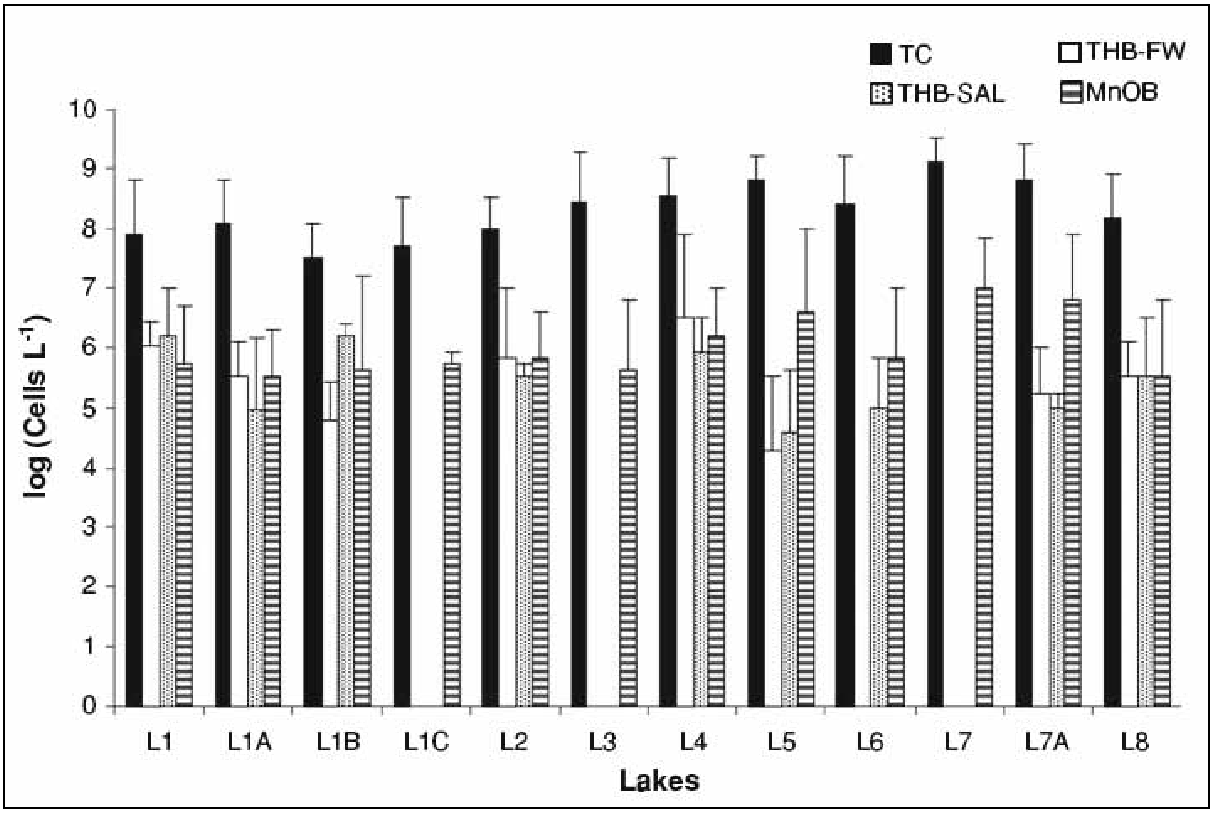


FIGURE 40 : ABUNDANCE (MEDIAN VALUE) OF CULTURABLE FRACTIONS OF HETROTROPIC BACTERIA (FRESHWATER AND SALINE) AND MANGANESE-OXIDIZING BACTERIA AND TOTAL MICROBIAL COUNTS FROM VARIOUS LAKES

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5.10.3 LAKE AND STREAM BIOTA

During the 26th Indian Expedition, surface water samples were filtered for studying the community structure of phytoplankton and zooplankton in the lakes of Larsemann Hills. The six genera of phytoplankton identified in the lakes, *Coscinodiscus* was most abundant and widely distributed. Next in abundance was *Nitzchia*. The data showed that phytoplankton community in the lakes of Larsemann Hills are restricted in distribution and is low in abundance (Table 11).

TABLE 11 : GENERIC COMPOSITION (%) OF PHYTOPLANKTON IN THE LAKES (IP-139, 2006)

Genera/Lake	L1	L1a	L1b	L1c	L2	L3	L5	L6	L7	L7a	L8
Coscinodiscus	80	50	50	-	-	10	-	100	20	10	50
Epithemia	-	-	-	-	-	10	10	-	20	-	10
Nitzchia	20	30	40	10	70	60	90	-	20	10	30
Thalassiosira	-	10	10	90	-	-	-	-	-	30	10
Oscillatoria	-	-	-	-	-	-	-	-	30	30	-
Chaetoceros	-	-	-	-	-	-	-	-	10	-	-
Unidentified genera	-	10	-	-	30	20	-	-	-	20	-

Surface zooplankton composition and abundance was assessed during the 26th expedition and the results showed (Table 12) that they were poorly represented. Only a few species were encountered in the lakes and at Lake-5 more than one group was present. *Cladocera* and Copepoda were more common and abundant.

TABLE 12 : ZOOPLANKTON COMPOSITION AND ABUNDANCE IN THE LAKES (NO./M^3)

Sample No.	Plankton Type	Abundance	Remark
L1(N)	Copepod nauplius	50	Debris present
L1 a	Copepod	100	Debris present
L1 b	none	0	Decaying algal debris
L1 p	Cladocera	500	Decaying algal debris + rock fragments
L2 A	none	0	Debris + rock fragments
L3	Cladocera	50	Debris present
L5	Pteropod	50	Debris present
	Oikopleura	50	
	Unidentified sp.	50	
L6	none	0	Decaying algal mats + debris
L7	none	0	Debris + rock fragments
L8	none	0	
S1 p	Cladocera	100	
S2 p	none	0	Debris + rock fragments

5.10.4 VERTEBRATE FAUNA

During a study conducted in austral summer of 2009-10, penguin rookery sites, one of Emperor Penguin (numbering 5000+birds) and another Adelie penguin (numbering 3000 + birds) found in eastern part of the Larsemann Hills.

5.10.4.1 SEALS

During 2009-10 austral summer, five aerial surveys were conducted for about 200 km coastline of the Larsemann hills region starting from close to the Vestfold hills in the south to the start of the Amery Ice Shelf in the north The Weddel seal was the most commonly recorded species and a total of 1350 seals were counted during December, while along the same survey routes in January, 1900 seals were counted.

5.11 BASELINE MONITORING INFORMATION - SOIL QUALITY

Soil characteristics from some selected areas of the Larsemann Hills were analysed during the 27th, 28th and 29th Indian expeditions. The results are presented in (Table 13). The parameters that were considered are pH, electrical conductivity, phosphorous, calcium, magnesium, chloride, sulfate, cadmium, iron, aluminium, copper, chromium, zinc, manganese, sodium and potassium.

The soil pH was generally in the alkaline range, indicating the fertile nature of the soil in this area. Most metels were in lower range except Mn (80.39-533.4 mg/kg). Marginal inter-annual variations were observed in most of the parameters. The overall soil conditions indicate no anthropogenic interference.

TABLE 13 : SOIL CHARACTERISTICS NEAR STATION SITE (SIIR, 2010)

S. No.	Parameter	Soil-1- (Near Melon Hut Latitude (S) – Longitude (E) 69° 24′ 31.0″- 76° 11′ 50.0″			Soil-2- (Near Apple Hut Latitude (S) – Longitude (E) 69° 24′ 18.3″-- 76° 11′ 42.1″		
		27th ISEA	28th ISEA	29th ISEA	27th ISEA	28th ISEA	29th ISEA
1	pH	9.5	7.7	9.1	10.1	8.2	9.2
2	Conductivity µs/cm	171.4	54	161	215	78	296
3	Sodium (as Na_2O) % by mass	3.2	1.5	3.75	2.8	0.1	8.78
4	Potassium(as K_2O) % by mass	4.3	3.8	2.77	5.2	0.3	4.78
5	Calcium (as CaO) % by mass	1.7	1.2	5.6	1.7	0.3	10.79
6	Magnesium (as MgO) % By mass	2.2	1.4	45.9	1.7	0.6	19.77
7	Iron (as Fe_2O_3) % by mass	7.9	3.9	5.5	5.4	1.4	12.20
8	Aluminum (as Al_2O_3) % by mass	11.5	10.8	25.9	11.2	1.05	14.87
9	Phosphorus (as P_2O_5) mg/kg	0.14	0.14	40.5	0.16	0.07	51.53
10	Cadmium (as Cd) mg/kg	7.1	6.6	0.87	5.8		2.58
11	Chromium (as Cr) mg/kg	39.7	39.7	7.6	49.8	49.8	9.8
12	Zinc (as Zn) mg/kg	50.2	56.7	23.39	41.9	38.9	46.56
13	Manganese (as Mn) mg/kg	533.4	312	80.39	597.4	84.4	161.32
14	Copper (as Cu) mg/kg	19.7	14.8	6.93	12.8	14.4	10.97
15	Chloride (as Cl) % by mass	0.06	0.04	0.08	1.39	0.1	1
16	Sulfate(as SO_4) % by mass	0.04	0.04	0.06	0.02	0.06	0.02
17	Radiation Contamination * (as Cs-137) Bq/kg	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL

Soil Characteristics Near Station Site (SIIR, 2010)							
S. No.	Parameter	Soil-3- (Near Lake No.3, Latitude (S) – Longitude (E) 69° 24′ 18.3″-- 76° 11′ 42.1″			Soil-4- (Near Lake No.5 Latitude (S) – Longitude (E) 69° 24′ 19.1″-- 76° 11′ 13.1″		
		27th ISEA	28th ISEA	29th ISEA	27th ISEA	28th ISEA	29th ISEA
1	pH	7.7	7.7	7.7	204	197	162
2	Conductivity µs/cm	311	263	134	2.4	2.3	2.8
3	Sodium (as Na_2O) % by mass	1.2	2.5	3.98	3.7	4.1	2.3
4	Potassium(as K_2O) % by mass	3.2	4.4	14.7	1.6	1.7	6.25
5	Calcium (as CaO) % by mass	0.9	2.9	17.26	1.3	2.0	19.77
6	Magnesium (as MgO) % By mass	0.7	2.4	12.1	3.0	5.9	9.89
7	Iron (as Fe_2O_3) % by mass	2.3	3.2	10.2	15.6	14.4	24.01
8	Aluminum (as Al_2O_3) % by mass	9.3	9.2	10.9	0.11	0.07	100.78
9	Phosphorus (as P_2O_5) mg/kg	0.09	0.11	45.62	2.8	BDL	0.688
10	Cadmium (as Cd) mg/kg	2.3	BDL	2.78	25.0	43.2	6.29
11	Chromium (as Cr) mg/kg	32.6	43.2	24.33	30.3	94.3	20.75
12	Zinc (as Zn) mg/kg	31.3	41.9	20.75	285.1	409.3	39.40
13	Manganese (as Mn) mg/kg	209.2	110.5	90.62	49.8	24.4	5.12
14	Copper (as Cu) mg/kg	19.7	14.8	6.93	12.8	14.4	10.97
15	Chloride (as Cl) % by mass	0.06	0.04	0.08	1.39	0.1	1
16	Sulfate(as SO_4) % by mass	0.04	0.04	0.06	0.02	0.06	0.02
17	Radiation Contamination * (as Cs-137) Bq/kg	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL

5.12 BASELINE MONITORING INFORMATION - RADIATION CONTAMINATION IN LAKE WATER

The lake water in the Larsemann Hills area was tested for radioactive contamination as there is possibility of such contamination from naturally occurring minerals due to manmade activities. Lake samples (L-3 to L-5) were analysed. No radiation contamination was detected in any sample, indicating that lake water samples are fit for drinking.

5.13 PROTECTED AREAS AND HISTORIC SITES AND MONUMENTS

The Larsemann Hills area is proposed to be designated as Antarctica Specially Managed Area (ASMA) with the joint efforts of Australia, China, Russia, Romania and India. Other than proposed ASMA no other ASPA or HSM exist in the area. Two protected areas in the Prydz Bay region are ASPA 143: Marine Plain (68°3'36"S 78°6'57"E), located on Mule Peninsula and ASPA 167: on Hawker Island (68°35' S 77°50'E). Historic Site and Monument (HSM) 6: Walkabout Rocks (68°21'57"S 78°31'58"E) and HSM 72: Cairn on Tryne Islands (68°21'57"S 78°24'E) is also located within the Vestfold Hills.

5.14 PREDICTION OF FUTURE ENVIRONMENTAL REFERENCE IN THE ABSENCE OF PROPOSED ACTIVITY

In the Larsemann Hills, human presence has continued since 1986. Sporadic tourist activity has also been reported. In the absence of the proposed activity, the aesthetic and natural values of the area adjacent to the proposed base are likely to remain unchanged. However, with proposed operation in Larsemann Hills some minor impacts may occur.

IDENTIFICATION, PREDICTION OF IMPACTS AND MITIGATING MEASURES

6.1 METHODS AND DATA USED FOR PREDICTION OF IMPACTS

For evaluation of environmental impact assessment, a number of environmental indicators have been selected. These are subjected to value judgment, relevance to the area and construction activity involved. Baseline information has been obtained from primary and secondary data available from various scientific publications. Site-specific baseline information for environmental monitoring has also been collected to establish the environmental conditions prevailing prior to commencement of project activity. Specific project activities including energy, water supply, waste management, scientific activities and associated logistics etc. have been clearly defined to demarcate station footprints.

Necessary references have been adopted from USEPA, the Greenhouse Gas Inventory and the Emission Source Classification, Central Pollution Control Board, New Delhi, National Atmospheric Emission Inventory etc. U.K. EIA guidelines have been considered while identification and prediction, and mitigation measures have been defined by putting the benchmark of Madrid Environmental Protocol.

Further, direct, indirect, cumulative and unavoidable impacts have been examined and matrix has been drawn to assess the predictive impact. Accordingly, the following areas have been identified for studying the possible impacts:

- *Physical disturbance*
- *Air*
- *Water*
- *Noise*
- *Oil spill and other waste*
- *Flora and Fauna*

From construction to decommissioning, strict environmental conservation measures will be adopted under the supervision of NCAOR. In view of the prevailing environmental conditions and specific working window available, it has been decided to execute the complete project activity in the following phases:

Site preparation

Before commencement of construction activity, it was necessary to transport heavy machineries to the site i.e. Crane, Bulldozer, Excavator and Piston Bully. Since the terrain is undulating in nature, it was necessary to carve out an approach path over rocks. Activities pertaining to scheduled tasks were performed during the austral summer of 2009-10.

Construction of the Station

To withstand high wind velocity and to avoid snow accumulation, appropriate foundation is required before building the superstructure. Foundation reinforcement, laying pipe system and preparation of fuel farm will be undertaken during the austral summer of 2010-11 (Phase I), while superstructure over base foundation will be built during austral summer of 2011-12 (Phase II).

Mitigating Measures

Prediction of environmental impact due to construction activity of the new Indian research station is made, observing the potential impacts. Distinct mitigation measures to be adopted and implemented during activities to be carried out (or already carried out) are prepared based on long experience on environmental monitoring carried out for scientific and logistics activities in Antarctica. Measures stated below are based on the expertise of the contributors/scientists, through knowledge acquired while working in Antarctic environment as well as investigation on very specific environmental projects completed at mainland.

Mitigation measures likely to be adopted at site during site preparation and construction activity (Phase I and II) are adequately addressed below. Standard procedure and most practically achievable methods in Antarctic environment have been described to mitigate the potential impact defining them as direct, indirect, cumulative and unavoidable impacts.

6.2 IMPACT DUE TO SITE PREPARATION AND CONSTRUCTION ACTIVITIES

6.2.1 PHYSICAL DISTURBANCE

The proposed site for development of the station is located approximately 240 meters from the edge of the promontory. The path from the landing site was constructed during the austral summer of 2009-10. The path is six meters wide and approximately 500 meters long. To maintain a gentle gradient of path for easy movement of vehicles, cutting and filling was required along the route. The path was designed in such a way that the gradient is gentle and quantity of rock/soil excavated has been balanced by the quantity required for filling. It was estimated that approximately three to four thousand cubic meter of the rock was to be cut, and more or less the same quantity was utilized for filling. Around 3000 m^2 area was affected from natural condition due to path development and this contributed to physical disturbance.

The site construction activity will take place in the form of construction of the building for living and laboratory complex, utility services, fuel storage, associated pipelines, helipad and landing point. Wind turbine is proposed to be installed in order to supplement the energy demand. This turbine will occupy some space in the vicinity of the station. Construction of two helipads, covering an area of 60 m^2 in front of the main building will also contribute to the physical disturbance to the area. Equipment needed for construction of the building, living modules for shelter, laying pipeline and cables will occupy about 150 m^2, whereas fuel farm will occupy around 290 m^2 footprint.

There will be some disturbance to the rocks used as foundation for the stilts anchored to these rocks. Wind Energy Generators (WEG) will be installed in phases near the station. One WEG will require approximately 2.5 m^2 of area, while the sweep area may vary from 30 to 50 m^2, depending on the capacity of WEG. For installation of 6 WEG approximately 15 m^2 area will be required, which will add to physical disturbance. Three Radom foundations will be constructed for satellite communication and they will occupy around 250 m^2 each of ground coverage and this will also add to physical disturbance.

To erect the foundation on GEWI piles, 31 pile holes of 30 cm diameter and approximately 4.3 meter long, have to be drilled in the rock. This will disturb around 40 m^3 of soil and add to physical disturbances. Footprint for the three storey station building is estimated to be 1630 m^2. External laboratories will contribute to around 75 m^2 footprint, and these laboratories will be established in the container and similar footprint will be added by outside food storage, which will also be made by containerized module.

MITIGATING MEASURES

Site preparation activities involved development of path by breaking rocks. To achieve the disintegration of rocks, special Non-X cartridges have been used. They have minimal flying rock attribution, minimal vibration, lower noise, low overpressure levels, and negligible noxious gases. Previously total path length was approximately 800 meters with 6-8 meter width. To minimize the physical disturbance, path alignment was changed and the length reduced to 500 meters and width to 5-6 meters, thus reducing the footprint by 53%.

After completion of the building the equipment used during the construction phase would be removed from the site. The discharge pipelines will be laid avoiding the catchment area of the lakes.

6.2.2 IMPACT ON AIR QUALITY

There is likely to be some transient effect on the air quality because of ship and air operations, use of generators and deployment of various equipments for site preparation and construction activities. Construction activity will be carried out in two phases, during two consecutive austral summers. Fossil fuel consumption will result in emissions of SO_2, NOx, CO, CO_2 and suspended particulate matter into the atmosphere.

6.2.2.1 IMPACT DUE TO SSUPPLY SHIP

It is estimated that two austral summers will be required to complete construction of the station. Site preparation and path development were already completed during the austral summer of 2009-10. The ship was anchored near the shore for 50 days to facilitate the site preparation activity. It is estimated that during (first and second phase) construction activity (in each austral summer), the ship will remain anchored for nearly 112 days including 15 days of ice navigation from few tens of kilometers to anchoring point near the site . Supply ship use Intermediate Fuel Oil (IFO) and Marine Diesel Oil (MDO). For the calculation of fuel consumption and emission, the data of Ice class ship Emerald Sea has been used. However, cumulative and daily fuel consumption may change depending upon the weather, sea ice condition and speed of the ship during operation. Fuel consumption during drifting in the ice may vary from 35 MT/day to 42 MT/day of IFO and 3.5 MT/day of MDO. However at idling stage, the consumption may drop to 4 to 4.5 MT/day of IFO and 3.5 MT/day of MDO. In open seas area, fuel consumption pattern may be 26.5 to 45 MT/day of IFO and 3.5 MT/day of MDO considering that the ship may run on single or twin engines. The details of emission during the voyage in open sea, ice navigation and idling period are given in Table 14.

TABLE 14 : PREDICTED AIR EMISSION FROM SHIP DURING SITE PREPARATION AND CONSTRUCTION ACTIVITY

Emission Factor

Emission Factor Kg/m3 of fuel Burnt*	PM	SO_2	NOx	CO	TOC	Methane	NMTOC
IFO	0.84	27	5.64	0.6	0.1248	0.0336	0.0912
MDO	0.24	28.26	2.88	0.6	-	-	-

**Emission factor calculation has been taken from USEPA air chief, AP-42 Ver 8.0. IFO is considered as No 4 fuel oil and MDO is considered as No 2 fuel oil with uncontrolled burning. Sulfur content in the fuel oil is considered as 15000 ppm*

Total Emission during Site Preparation

Type of Fuel	Fuel Consumption in 50 Days (m^3)		Total Emission of Pollutant considering 50 days including 35 days idling and 15 days ice navigation in kg						
	Ice Navigation	Idling Condition	PM	SO_2	NOx	CO	TOC	Methane	NMTOC
IFO	555.5	148	591	19000	3969	422	88	24	64
MDO	62	145	50	5846	596	124	-	-	-
Total	617.5	293	641	24846	4565	546	88	24	64

Total Emission during Construction Activity (Same for Phase I and Phase II)

Type of Fuel	Fuel Consumption in 112 Days (m^3)		Total Emission of Pollutant considering 112 days including 97 days idling and 15 days ice navigation in kg						
	Ice Navigation	Idling Condition	PM	SO_2	NOx	CO	TOC	Methane	NMTOC
IFO	555.5	410.5	812	26086	5449	580	121	32	88
MDO	62	401.5	111	13094	1339	278	-	-	-
Total	617.5	812	923	39180	6783	858	121	32	88

MITIGATING MEASURES

During site preparation the ship was berthed far away from the promontory in the initial days. By negotiating sea ice and fast ice condition and available bathymetry data of the area, the ship could reach within 100 meters from the edge of the Grovnes promontory and was berthed there for nearly 15 days. The Ship was kept under idle condition to avoid high fuel consumption and associated air emission. As the ship was berthed near to promontory the travel time of helicopter could be reduced there by directly reducing the overall emission in the area and indirectly reducing secondary gases.

Since the supply ship will be berthed during construction phase far from the site (in initial few days) till it reaches near promontory, the emissions from the ship at the idling stage are likely to be minimum, there by producing insignificant impact on the station site. To the best possible, the ship will run on single engine with low sulfur fuel. The expedition ship will comply with the provisions of MARPOL Annex VI on air emissions. The possibilities of sharing the ship logistics with other stations after the construction stage will also be explored.

6.2.2.2 IMPACT DUE TO HELICOPTER OPERATION

Site preparation was carried out during austral summer of 2009-10, by deploying a Kamov helicopter to transfer equipment and machinery from ship to the site. A small helicopter for very short duration was also used to facilitate shifting of the technical persons from the ship to the site. During 50 days of stay at Larsemann Hills area, on an average, four sorties were made by Kamov helicopter for nearly 25 days and four sortie per day were made by six seated helicopter for survey and transportation of men and materials. Total fuel consumed during the site preparation was estimated to be approximately 15 ton of ATF, with each sortie operated for 10 minutes. The fuel consumption and emissions are shown in Table 15.

TABLE 15 : PREDICTED EMISSION FROM HELICOPTERS (SITE PREPARATION)

Parameters	Pollutant (kg) for helicopter operation (2 helicopters)						
	PM*	SO_2	NOx	CO	CO_2	Methane	NMVOC
Emission Factor (kg/t) of fuel consumption	0.2	0.72	0.19	12	859	1.43	2.84
Emission Load (kg)	3.03	10.9	2.9	182	13034	21.7	43.1

Source: UK National Atmospheric Emission Inventory (2002)

** Particulate Matter refers to particles produced by fuel consumption with a diameter less than or equal to 10 µm*

Shifting of men and materials during construction phase I will be mostly done by two helicopters, one capable of carrying at least 4-5 tons under slung and another 6 seated helicopter. It is estimated that approximately 29 ton ATF (Jet A-1), will be required to operate both the helicopters (All calculations are based on fuel consumption of MI8/Kamov and Squirrel helicopter). During phase II of construction activity, around 51 ton of ATF will be consumed by deployment of two Kamov 32A/MI8 or similar helicopters. This fuel consumption will emit pollutant as as shown in Table 16:

TABLE 16 : PREDICTED EMISSION FROM HELICOPTERS (CONSTRUCTION)

Total Emission (Construction Activity – Phase I)

Parameters	Pollutant (kg) from helicopter operation (2 helicopters)						
	PM*	SO_2	NOx	CO	CO_2	Methane	NMVOC
Emission Factor (kg/t) of fuel consumption	0.2	0.72	0.19	12	859	1.43	2.84
Emission Load (kg)	5.8	20.9	5.5	348.2	24928	41.5	82.4

Source: UK National Atmospheric Emission Inventory (2002)

** Particulate Matter refers to particle produced by fuel consumption with a diameter less than or equal to 10 µm*

Total Emission (Construction Activity – Phase II)

Parameters	Pollutant (kg) from helicopter operation (2 helicopters)						
	PM*	SO_2	NOx	CO	CO_2	Methane	NMVOC
Emission Factor (kg/t) of fuel consumption	0.2	0.72	0.19	12	859	1.43	2.84
Emission Load (kg)	10.2	36.9	9.7	614.0	43974	73.2	145.2

The potential impacts associated with helicopter traffic include chemical emissions from flights; chemicals or wastes from heli-lift of cargo (e.g., sling loads); and exhaust, hydraulic fluid leakage, effect on lakes, and soil disturbance upon takeoff and landing. There is also the probability of bird hit during helicopter flight.

MITIGATING MEASURES

During the site preparation, phase helicopter was used to transfer men and machinery in approximately 75 sorties. Travel time for each sortie was 15 minutes only. Care was taken to switch off the engine following standard protocol, while it landed either on ship or on land so as to reduce the fuel consumption and consequent air emission. During construction phase also, the helicopter will remain in the air only for 10 to 15 minutes for each sortie and will fly 600 to 1000 feet above the msl so that all the emissions will have very high probability of dilution and dispersion (due to higher ventilation coefficient). As it will be a line source and not a point source emission, it will have larger dispersal area. It will not affect directly or indirectly, the flora or fauna or lake system of the area. The landing site shall be kept far away from the lakes

6.2.2.3 IMPACT DUE TO GENERATORS

During site preparation activity, two generators of 2 kVA capacity and two generators of 1 kVA capacity were used to operate small machinery and instruments. These generators were used for approximately 25 days intermittently and total fuel (ATF) consumed by these generators was estimated to be approximately 1.1 ton. Considering 25 days of operation, the emissions from the generators are provided in Table-17.

TABLE 17 : EMISSION FROM THE GENERATORS

Site Preparation

Generator	Fuel Consumption	Total Emission of Pollutants (kg)				
		PM 10#	SO_2	NOx	CO	TOC
*Emission Factor (kg/m3) of fuel burnt		1.0248	0.744	11.724	0.8064	0.2856
2 kVAx2 and 1kVAx2 Genset (12 hours run for 25 days)	1.3 Ton	1.3	0.9	14.9	1	0.4

**USEPA, AP-42 of electric generation from internal combustion engine, uncontrolled operation*
#PM-10= particulate matter assumed to be less than or equal to 10 µm aerodynamic diameter and greater than and equal to 1 µm diameter

Construction (Phase I)

One generator each of 70 kVA, 7 kVA and 2 kVA capacity will be used during the Phase I and Phase II construction activities in order to provide required electricity to the equipments needed for building erection, carpentry and for electric radiator in shelter hut. These generators will run on ATF and it is estimated that approximately 31.5 tons of ATF will be consumed by these generators. Emissions from generators may affect Lake Ecosystem. The generators may be operated round the clock. Considering 60 days operation, the estimated emissions from the generators are provided in Table-18.

TABLE 18 : EMISSION FROM THE GENERATORS

Generator	Fuel Consumption	Total Emission of Pollutant (kg)				
		PM 10#	SO_2	NOx	CO	TOC
*Emission Factor (kg/m^3) of fuel burnt		1.0248	0.744	11.724	0.8064	0.2856
70 kVAx1, 7kVAx1 and 2kVAx1 Genset (24 hours run for 60 days)	31.5 Ton	32.2	23.4	368.9	25.4	9

**USEPA, AP-42 of electric generation from internal combustion engine, uncontrolled operation*
#PM-10= particulate matter assumed to be less than or equal to 10 µm aerodynamic diameter and greater than and equal to 1 µm diameter

MITIGATING MEASURE

During the site preparation, two generators of 2 kVA and two generators of 1 kVA have been used for nearly 25 days. These generators were operated only when required and not 24 hourly. This drastically reduced fuel consumption. Since ATF was used as fuel the emission was very low. Emissions from the generators are not very significant, as the ventilation coefficient is very high. Generators will be operated on ATF and not on diesel so that emission as compared to diesel is low. These generators will meet the environmental norms of EU/USEPA and CPCB. To avoid contamination of the lakes, the generators will be placed suitably, taking into consideration the prevailing wind direction. The upkeep and maintenance of the generators will be given high priority to keep the emissions at minimum.

6.2.2.4 IMPACT DUE TO USE OF FORKLIFT

Use of forklift will be unavoidable during the construction phase. However, the operation will be limited to move material from the landing point to the construction site. This machine with 2 t capacity will be operated on gasoline for 6-8 hours a day. Air emission from the forklift is estimated to be insignificant (Table 19).

TABLE 19 : EMISSION STANDARDS FOR FORK LIFTER (EMISSION STANDARDS FOR NEW NONROAD VEHICLES, 2002-USEPA)

Year of implementing	NO_X+HC	CO
2007	2.7 g/kW-hr	4.4 g/ kW-hr

6.2.2.5 IMPACT DUE TO AIR COMPRESSOR AND EXCAVATOR

A compressor of 75 HP was used during site preparation. An excavator of 47 kW was also deployed for path development during austral summer of 2009-10. The emission estimated from the total operation is shown in Table 20.

TABLE 20 : EMISSION DUE TO OPERATION OF AIR COMPRESSOR AND EXCAVATOR

Parameter	PM-10	SOx	NOx	CO	CO2	TOC
Emission Factor (kg/kw-hr)	0.001337	0.001246	0.0188	0.00406	0.699	0.00150
51kW Air compressor (8 hours a day for 25 days) kg	13.6	12.6	191.4	41.3	7118.6	15.2
47 kW Excavator (8 hours a day for 25 days) kg	12.3	11.5	174.0	37.6	6473	13.9

6.2.2.6 IMPACT DUE TO MACHINERIES (PHASE I AND II)

One crane of 50 ton capacity, Drilling Rig, Excavator, Stone crusher, Concrete Mixer, Piston Bully and Bull Dozer will be operated at the construction site during Phase I. The air emission from these machineries is shown in Table 21. Table 22 shows air emission due to various machineries during construction Phase II, due to operation of Crane, Piston Bully and Bull dozer. Vehicle movement and associated emission may affect Lake Ecosystem.

TABLE 21 : EMISSION DUE TO OPERATION OF VARIOUS MACHINERIES (PHASE I)

Parameter	PM-10#	SOx	NOx	CO	CO_2	TOC
Emission Factor* (kg/kw-hr)	0.001337	0.001246	0.0188	0.00406	0.699	0.00150
158 kW Crane (12 hours a day for 60 days) kg	152.1	141.7	2138.7	461.8	79518.2	170.6
47 kW Excavator (8 hours a day for 25 days) kg	12.3	11.5	174.0	37.6	6473	13.9
90 kW Drilling rig (12 hours a day for 25 days) kg	36.0	33.6	507.6	109.6	18873	40.5
30 kW Stone Crusher (8 hours a day for 25 days) kg	8.0	7.4	112.8	24.4	4194	9
7.5 kW Concrete Mixer (4 hours a day for 25 days) kg	1.0	0.93	14.1	3.0	524.2	1.1
240 kW Piston Bully (8 hours a day for 25 days) kg	64.1	59.8	902.4	194.9	335552	72
60 kW Bull Dozer (8 hours a day for 25 days) kg	16.0	14.9	225.6	48.7	8388	18

**USEPA, AP-42 of diesel industrial engine, uncontrolled operation*
#PM-10= particulate matter assumed to be less than or equal to 10 µm aerodynamic diameter and greater than and equal to 1 µm diameter

TABLE 22 : EMISSION DUE TO OPERATION OF VARIOUS MACHINERIES (PHASE II)

Parameter	PM-10#	SOx	NOx	CO	CO_2	TOC
Emission Factor* (kg/kw-hr)	0.001337	0.001246	0.0188	0.00406	0.699	0.00150
158 kW Crane (12 hours a day for 60 days) kg	152.1	141.7	2138.7	461.8	79518.2	170.6
240 kW Piston Bully (8 hours a day for 25 days) kg	64.1	59.8	902.4	194.9	335552	72
60 kW Bull Dozer (8 hours a day for 25 days) kg	16.0	14.9	225.6	48.7	8388	18

**USEPA, AP-42 of diesel industrial engine, uncontrolled operation*
#PM-10= particulate matter assumed to be less than or equal to 10 µm aerodynamic diameter and greater than and equal to 1 µm diameter

MITIGATING MEASURES

During site preparation and construction activities, vehicles and machineries are essential for development of approach path, drilling operation, excavation for leveling of site and transportation of construction material, which are unavoidable and will have direct and indirect impacts on air quality. Care will be taken to maintain the vehicles to a high standard to reduce fuel consumption. Proper planning and logistics will reduce the use of vehicles and machinery. To the maximum extent possible, machineries will be operated on ATF rather than on diesel to reduce emissions. Engines of the vehicles will remain switched off, while not in operation to reduce fuel consumption.

6.2.3 CUMULATIVE IMPACT ON AIR ENVIRONMENT

Cumulative impact means growing by successive addition over time by addition of pollutants or by source of pollutants or additional routes of impact. This term may also be used to describe an individual’s integrated exposure to pollutants while engaged in daily activities and moving through successive environment (Pratt, 2000). The cumulative impact for this project is categorized as in air, water and noise environments. These emissions will have direct impact on air quality and indirect impact on water and snow if settled at particular place and under long run accumulation occurs. Further, it is estimated based on various years of activities such as site preparation, construction and operation taking place in successive austral summer, after a gap in which most of the sources are not common during each year of activity. The pollutants that were considered to assess the maximum concentration at a particular point are Suspended Particulate Matter (SPM), Sulfur dioxide (SO_2) and Oxides of Nitrogen (NOx).

6.2.3.1 SITE PREPARATION

Prediction for cumulative impact on air environment was made considering operation of ship, air compressor, excavator, generators and disintegration of rocks, by employing ISCST 3 air quality prediction model. Inputs for meteorological data were obtained from Davis station and predictions were made for 24 hourly averages for the month of January and February. Isopleths showing contours of particular pollutant around site are depicted in Figures 41-43.

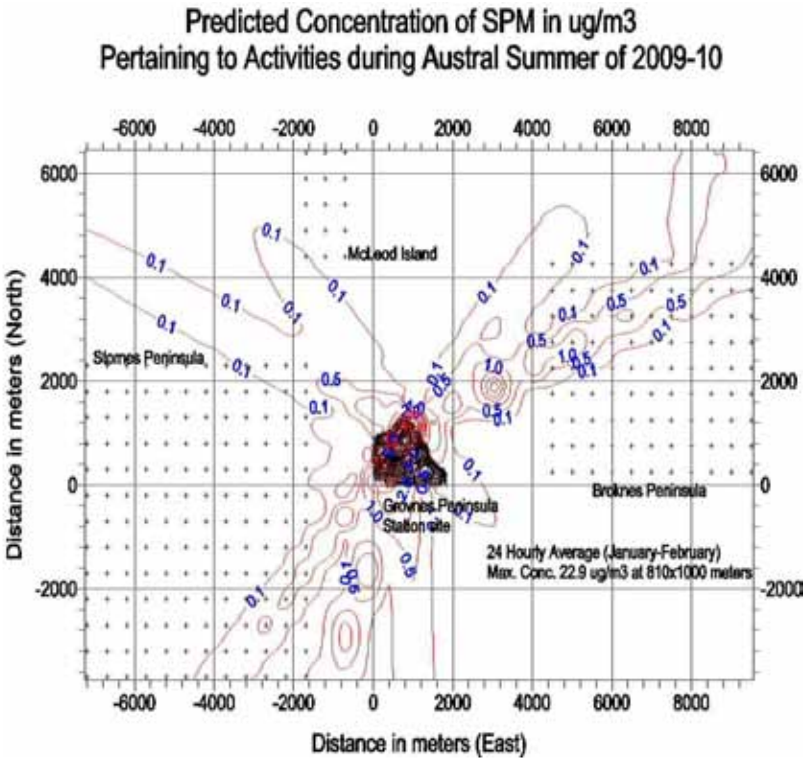


FIGURE 41 : PREDICTED CUMULATIVE IMPACT OF SPM (SITE PREPARATION)

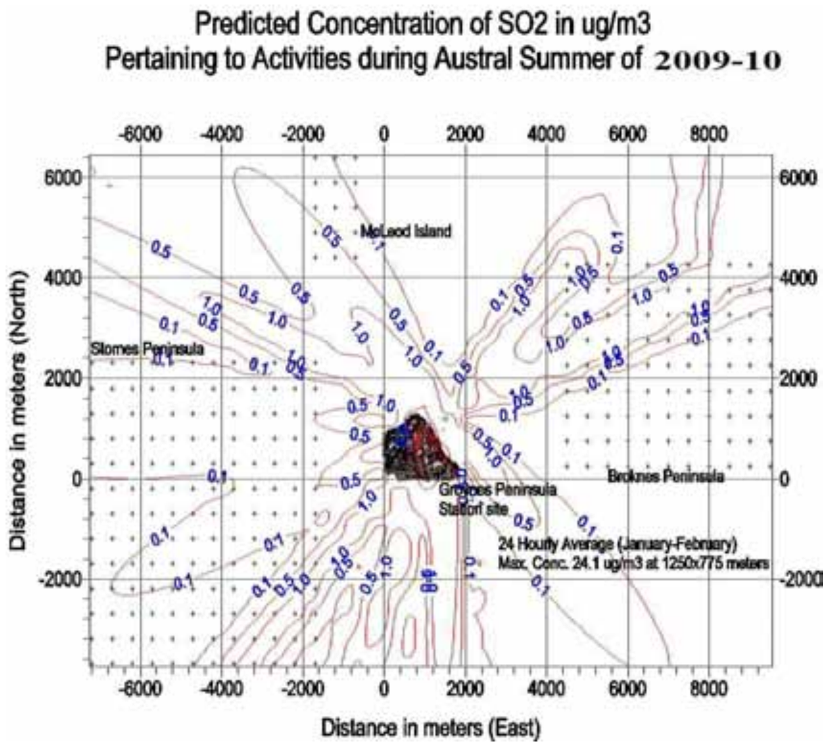


FIGURE 42 : PREDICTED CUMULATIVE IMPACT OF SO_2 (SITE PREPARATION)

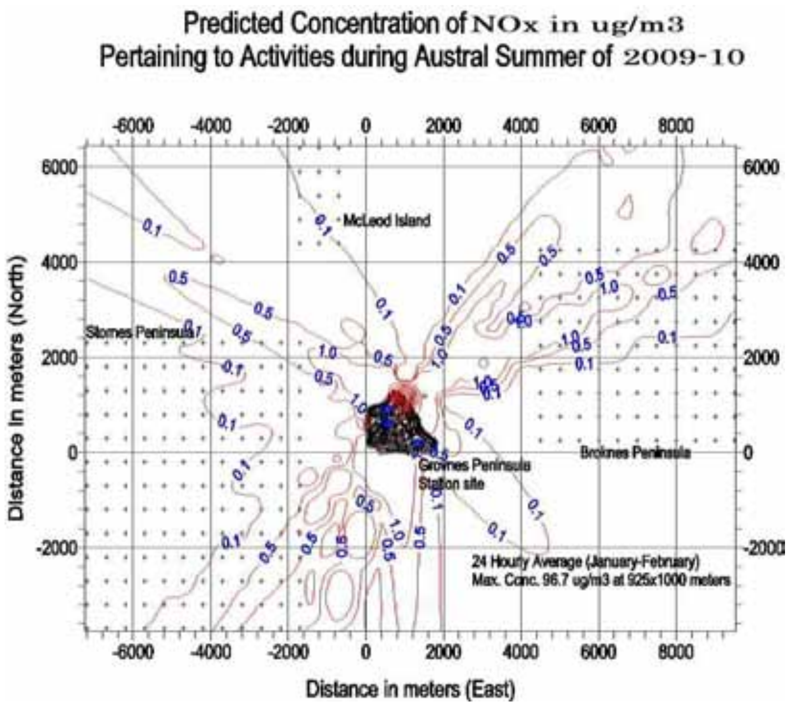


FIGURE 43 : PREDICTED CUMULATIVE IMPACT OF NOX (SITE PREPARATION)

Twenty four hourly average concentrations showed maximum cumulative concentration of SPM as 22.9 µg/m^3 at 810x1000 meters, 24.1 µg/m^3 of SO_2 at 1250x775 meters and 96.7 µg/m^3 of NOx at 925x1000 meters.

6.2.3.2 CONSTRUCTION PHASE I

Prediction for cumulative impact on air environment was made considering operation of ship, drilling rig, crane, concrete mixer, stone crusher, excavator, generators, piston bully and bull dozer, by employing ISCST 3 air quality prediction model. Inputs for meteorological data were obtained from Davis station and predictions were made for 24 hourly average for the month of January and February. Isopleths showing contours of particular pollutant around site are depicted in Figures 44-46.

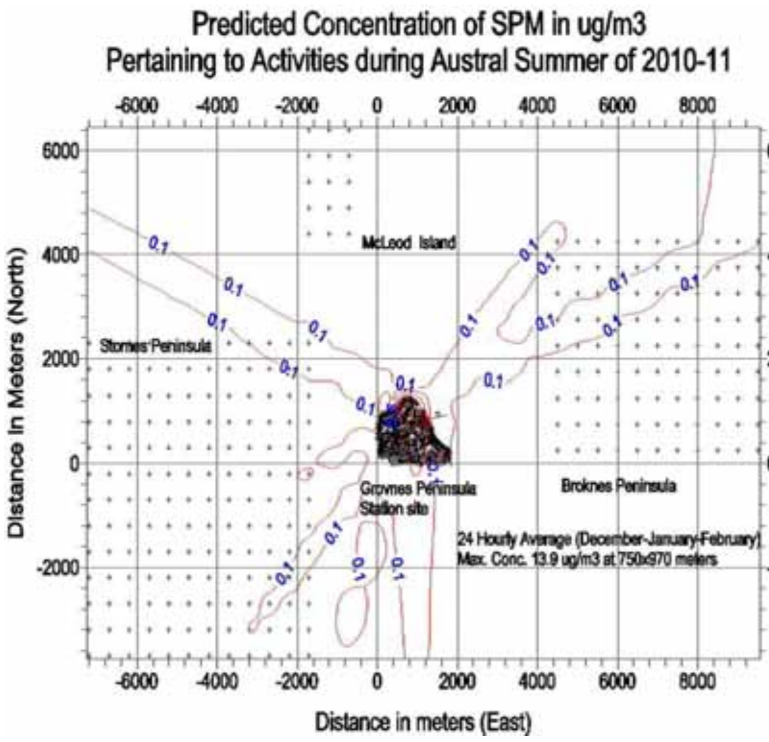


FIGURE 44 : PREDICTED CUMULATIVE IMPACT OF SPM (CONSTRUCTION- PHASE I)

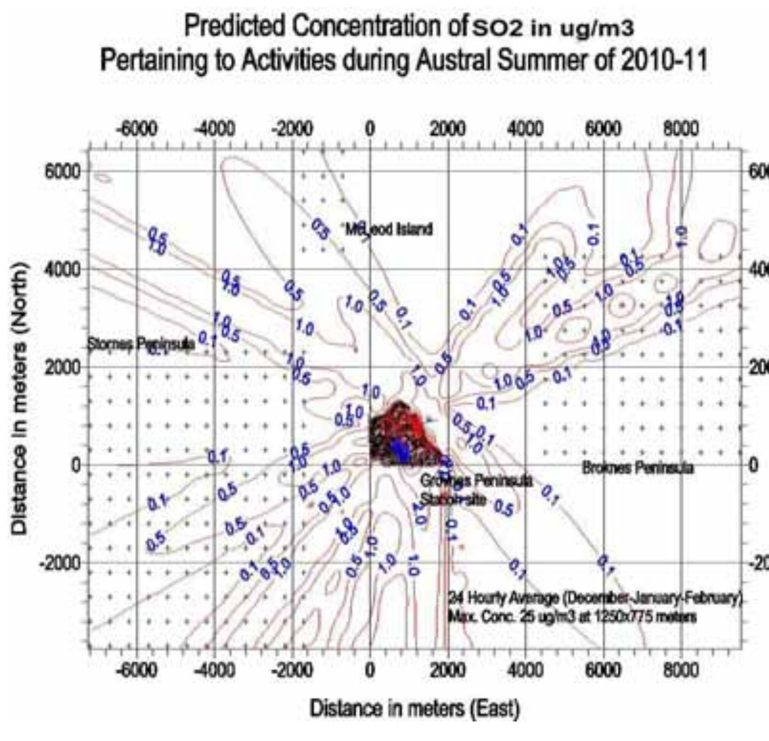


FIGURE 45 : PREDICTED CUMULATIVE IMPACT OF SO_2 (CONSTRUCTION- PHASE I)

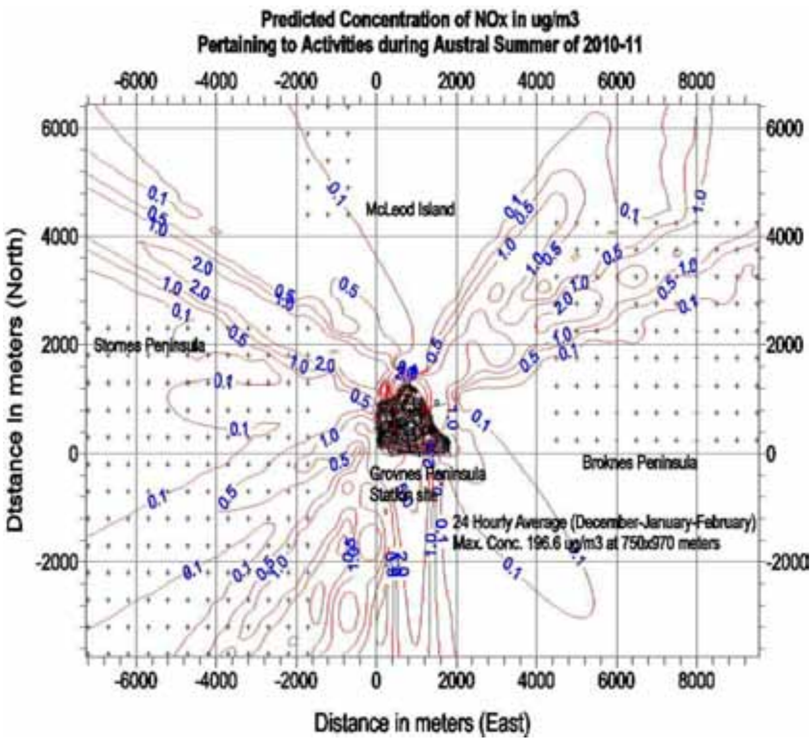


FIGURE 46 : PREDICTED CUMULATIVE IMPACT OF NOX (CONSTRUCTION- PHASE I)

Twenty four hourly average concentrations showed that the maximum cumulative concentration of SPM as 13.9 µg/m^3 at 750x970 meters, 25 µg/m^3 of SO_2, at 1250x775 meters and 196.6 µg/m^3 of NOx at 750x970 meters.

6.2.3.3 CONSTRUCTION PHASE II

Prediction for cumulative impact on air environment was made considering operation of ship, crane, generators, and piston bully and bull dozer, by employing ISCST 3 air quality prediction model. Inputs for meteorological data were obtained from Davis station and predictions were made for 24 hourly average for the month of January and February. Isopleths showing contours of particular pollutant around site are depicted in Figures 47-49.

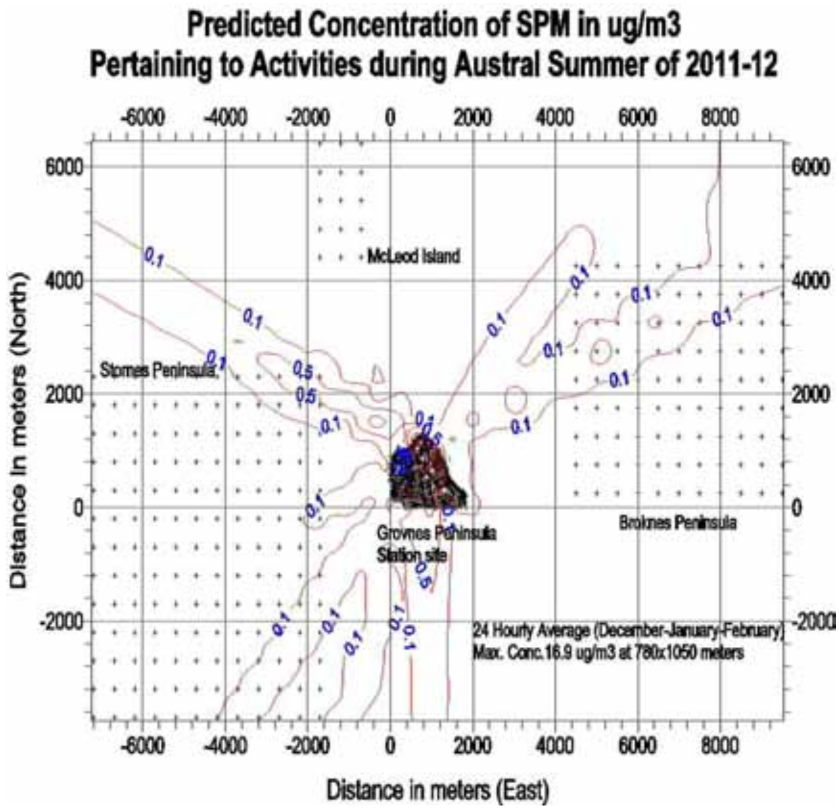
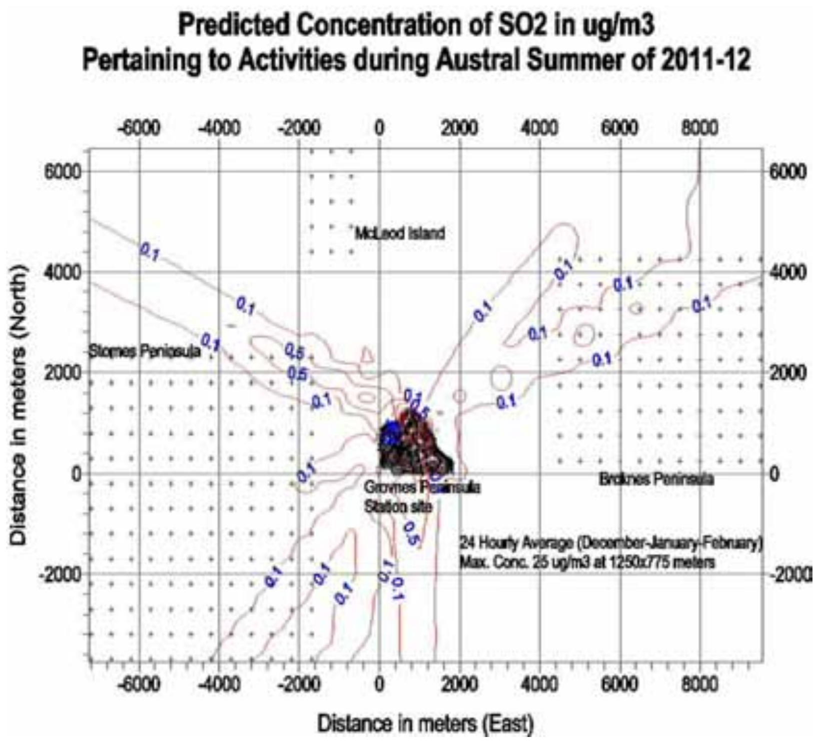


FIGURE 47 : PREDICTED CUMULATIVE IMPACT OF SPM (CONSTRUCTION- PHASE II)



GURE 48 : PREDICTED CUMULATIVE IMPACT OF SO_2 (CONSTRUCTION- PHASE II)

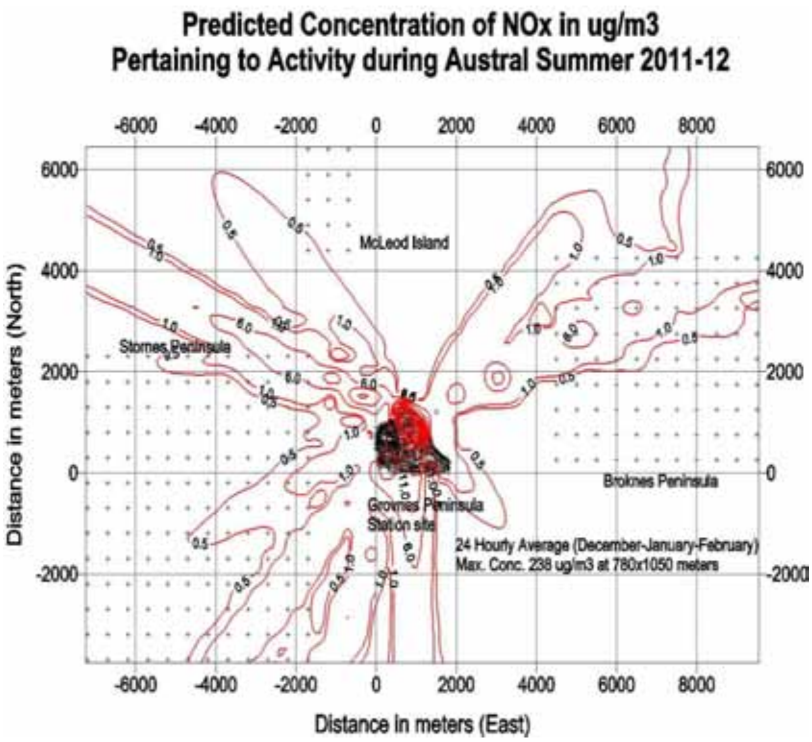


FIGURE 49 : PREDICTED CUMULATIVE IMPACT OF NOX (CONSTRUCTION- PHASE II)

Twenty four hourly average concentrations showed that the maximum cumulative concentration of SPM as 16.9 µg/m^3 at 780x1050 meters, 25 µg/m^3 of SO_2 at 1250x775 meters and 238 µg/m^3 of NOx at 780x1050 meters.

MITIGATING MEASURES

A cumulative impact on the environment has been predicted from the emission generated from the machinery and equipments and will be controlled by optimization of the same. All the vehicles used for construction and operational purposes will be maintained efficiently to ensure low air emission.

Change in the approach path location has also reduced disturbance due to vehicle movement and thus reduced emission generated from the vehicles. Water obtained from desalination plant of ship was sprinkled, from time to time, to suppress the dust emission during rock/soil transportation and compaction.

Predicted cumulative impact on air quality has been defined in terms of SPM, SO_2, NOx, CO, CO_2, CH_4 and TOC. The prediction modeling has been carried out, considering pollutants like SPM, SO2 and NOx. Prediction has been made considering the worst case scenario, for example, vehicles were considered as point source rather than moving source and also that all the sources perpetuate emissions concurrently. Comparing all seasons' activity SPM concentration on 24 hourly average has shown higher during site preparation, whereas NOx concentration has been predicted high during construction phase II. Higher concentration of SPM is seen very near the path, due to path development activity, when no suppression water is used. However in actual practices water was sprinkled to suppress the dust generation. High NOx concentration is very close to the source at a single point. However after 300 meters the concentration reduces to 1 µg/m^3. It is depicted that concentration level of pollutants further reduce to 0.1 µg/m^3 of SPM, 0.5 µg/m^3 of SO_2 and 0.5 µg/m^3 of NOx, at Stornes peninsula. Predictions have been made considering all the machineries, generators and vehicle operating at the same time. However in actual practices all machineries and vehicles will not be operated at the same time. Hence cumulative impact on air quality will be much less than that predicted.

6.2.4 IMPACT ON WATER QUALITY

6.2.4.1 WASTE FROM SHIP

All the workers engaged in construction work will be staying on board the ship. Including the crew members, around 95 people will be on board. They will produce approximately 10 m^3 of waste per day. If liquid and semisolid organic wastes are discharged into the sea, it may have the potential to affect the sea environment.

MITIGATING MEASURE

The expedition ship will abide by MARPOL, Antarctic shipping guidelines and provisions of the environmental protocol. No waste produced in the ship will be discharged in the Treaty area. Treated wastewater will be discharged as per the prevailing provisions.

6.2.4.2 OIL SPILL AND OTHER WASTE

Fuel is required at the construction site for ship, barge, helicopters, generators and other vehicles. Mainly IFO/MDO, ATF, gasoline and lubricants will be used for various operations. For helicopter operations, refueling will be done on the ship and ATF will be stored in 10 kl double-skinned tanks or drums. At the site, fuel will be stored in 5 kl tanks and 20 barrels containing ATF for emergency purposes. Fuel spill may also take place while refueling. The spilled fuel may contaminate the top soil and may become toxic in nature. Small cans of 10 and 20 liters will be used during construction phase for storage and transportation. Fuel and oil spill may occur during maintenance and fuelling of helicopter, vehicles, generators and damaged drums may be the probable sources of fuel spill.

Construction activity may also generate non-hazardous wastes comprising mainly packing materials, plastics, wood, small tins etc. and hazardous waste comprising batteries, waste fuel, lubricants, paints, sealant etc. There may be indirect impact of oil spill from vehicle, ship and helicopter operation on water and snow. If this become cumulative in nature, may affect the biota in the region and reduce the scientific value of the area.

MITIGATING MEASURES

Site preparation activity needed operation of small generators and a few types of machinery. Refueling of machineries and vehicles was done with utmost care to avoid even very small quantity of oil spill. For this purpose a few barrels of ATF were kept near the site but far away from any lake catchment area. During the construction phase, few barrels of Jet A-1 will be stored at the site (over a platform) to avoid any direct contact with the ground and to facilitate recovery of oil leakage, if any. Care will be taken to avoid any oil spill during refueling or decanting from the barrels. They will be checked frequently for any leakage. Sorbent material will be kept at fuel-handling sites. An oil spill contingency plan will be in force at the station, during operational phase, to take care of any unforeseen eventuality.

6.2.4.3 IMPACT ON FLORA AND FAUNA

Even though there are no rookeries at the site, stray penguins visit has been noticed occasionally. Seals have also been observed near the site. The noise produced during construction activity may result in some disturbance to these animals. There is also a possibility of introducing alien species to the environment.

MITIGATING MEASURES

While None-X cartridges were used during site preparation, care has been taken to cover the area with sheets to prevent dust diffusion and to prevent contamination of adjacent lakes.

During the construction phase, water will not be drawn from the lakes, except in emergency. Since very little quantity of water may be withdrawn from the lakes and also considering that these lakes will get additional water by snow accumulation, significant impact on flora and fauna is not visualized. The ship will be used as a platform for most of the activities during construction phase, thereby reducing the water requirement for human consumption at site.

6.2.5 CUMULATIVE IMPACT ON WATER ENVIRONMENT

Around the station site many small lakes are present. Site preparation and construction activity will entail vehicular movement, generators and helicopter operation. Dust disturbance, engine emissions, fuel spills and introduction of non-native species, associated with personnel, fresh food and building material, may cause environmental risk to these lakes and the environmental quality may be threatened by biomagnifications on flora and fauna.

MITIGATING MEASURES

Since prefabricated material will be used for the erection of the building, the generation of the solid waste will be at minimum. All the packing materials will be stored in boxes and back-loaded to ship. Maintenance-free battery will be used to minimize chances of acid leak. ASMA guidelines and protective measures as mentioned in IP17 of XXXI-ATCM, to prevent introduction of invasive alien species shall be followed.

6.2.6 IMPACT ON AESTHETIC AND WILDERNESS VALUES

Machineries associated with construction activity will have minor visual impact and loss of the wilderness value.

MITIGATING MEASURES

All the vehicles and machineries used for construction purpose will be removed from the site after completion of construction phases.

6.2.7 IMPACT OF NOISE

Noise pollution has been recognized as an emerging threat in Antarctica. Anthropogenic noise may have detrimental impact on human being as well as marine life. Helicopter is one of the sources of noise pollution which generates more than 120 dBA noise. Other vehicles and generators that will remain in operation at the site for longer duration may have adverse impact on the workers. Table 23 shows the noise levels considered to be generated from various machineries and vehicles used at two meter distance from source that are used for the prediction purpose.

TABLE 23 : NOISE LEVELS FROM VARIOUS SOURCES

Description	Noise Levels (dBA)
Genset 2 kVA, 1 kVA	65
Genset 7 kVA, 70 kVA and 100 kVA	75
Excavator	98
Bulldozer	85
Ship	80
Helicopter (600 kg under sling)	120
Helicopter (4500 kg under sling)	150
Piston Bully	102
Drilling rig	110
Stone Crusher	90
Crane (50 ton)	97
Concrete Mixer	85
Air compressor	75
Jack hammer	88

6.2.8 CUMULATIVE IMPACT OF NOISE ON ENVIRONMENT

6.2.8.1 SITE PREPARATION

During site preparation activity, noise generation from various sources i.e., helicopter, ship, bulldozer, excavator and generator have been taken into account. Noise level prediction was made employing Predictor 7810 model of Bruel and Kjaer while cumulative impact of day noise level, night noise level and total noise level (Ldn) is depicted in Figures 50-52, with the help of isoline.

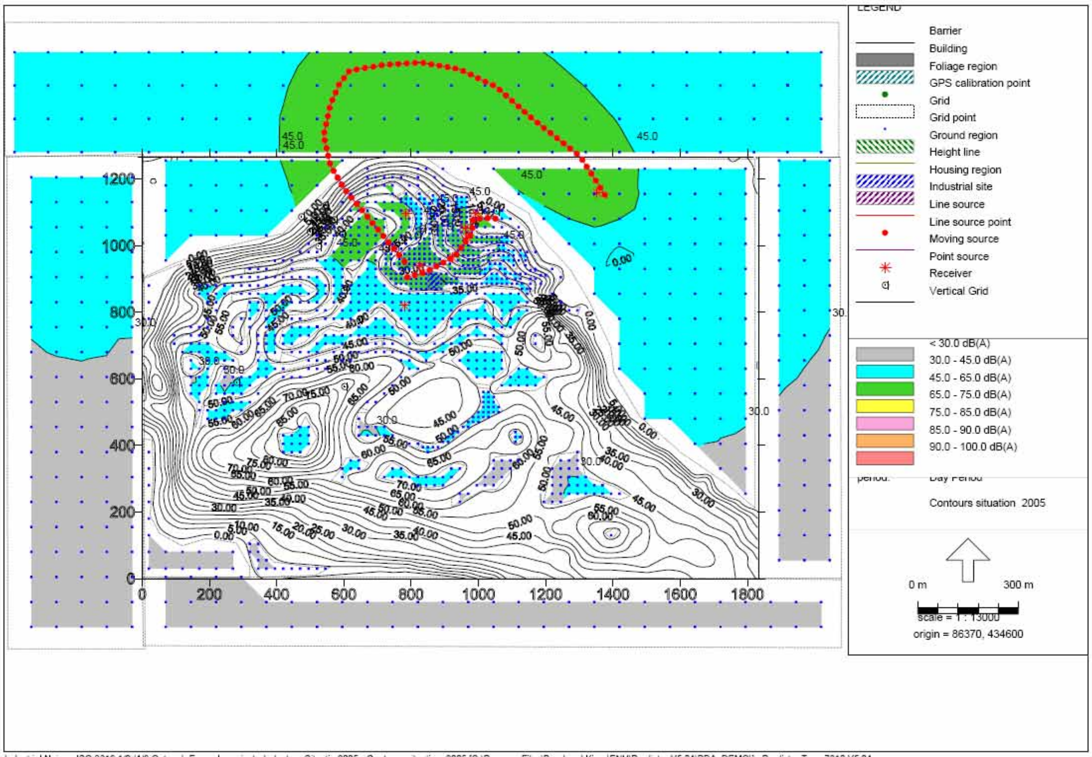


FIGURE 50 : DAY NOISE LEVELS DURING SITE PREPARATION

(X and Y coordinates in figure are represented in meters)

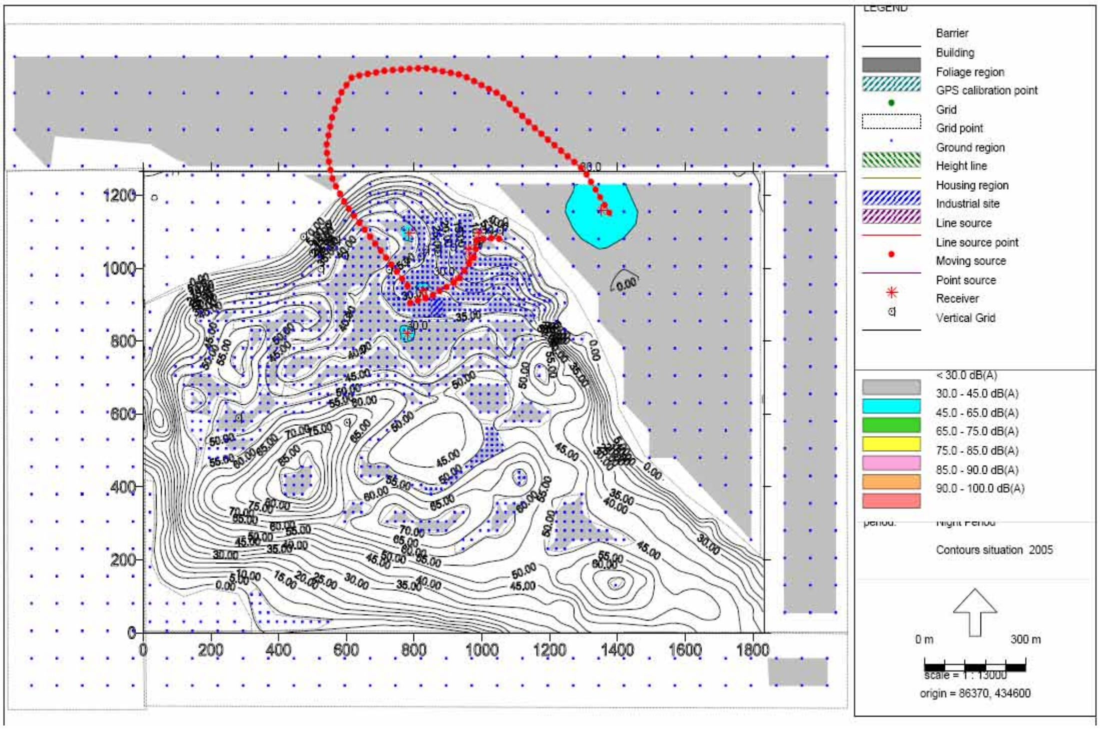


FIGURE 51; NIGHT NOISE LEVELS (SITE PREPARATION)

(X and Y coordinates in figure are represented in meters)

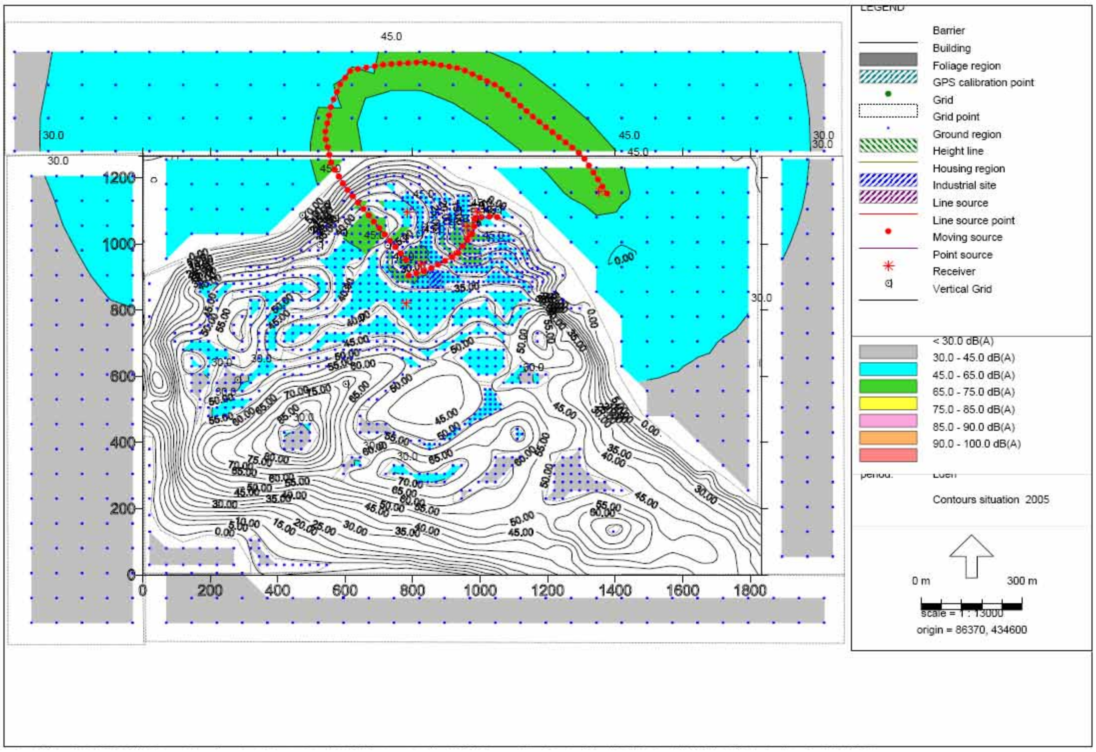


FIGURE 52 : DAY-NIGHT NOISE LEVELS (LDN) DURING SITE PREPARATION

(X and Y coordinates in figure are represented in meters)

It is seen from above figures that mostly, noise of 65-45 dBA will be contributed by helicopter operation, whereas noise levels due to vehicle and stationary sources will be within acceptable limits and may result only in local impact.

6.2.8.2 CONSTRUCTION PHASE I

During construction phase activity (Phase I), noise generation from various sources i.e., helicopter, ship, crane, bulldozer, excavator, stone crusher, concrete mixer, piston bully and generators have been taken into account. Cumulative impacts of various machineries and vehicles day noise level, night noise level and total noise level (Ldn) are depicted in Figures 53-55, with the help of isoline.

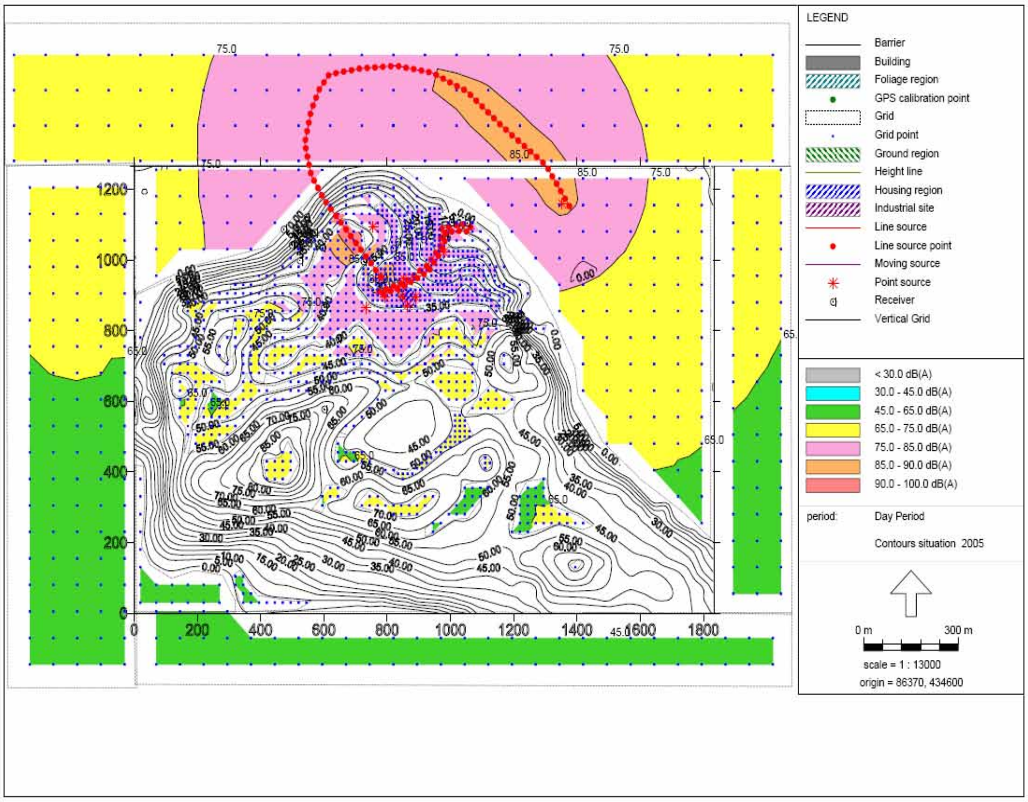


FIGURE 53 : DAY NOISE LEVELS DURING CONSTRUCTION PHASE I

(X and Y coordinates in figure are represented in meters)

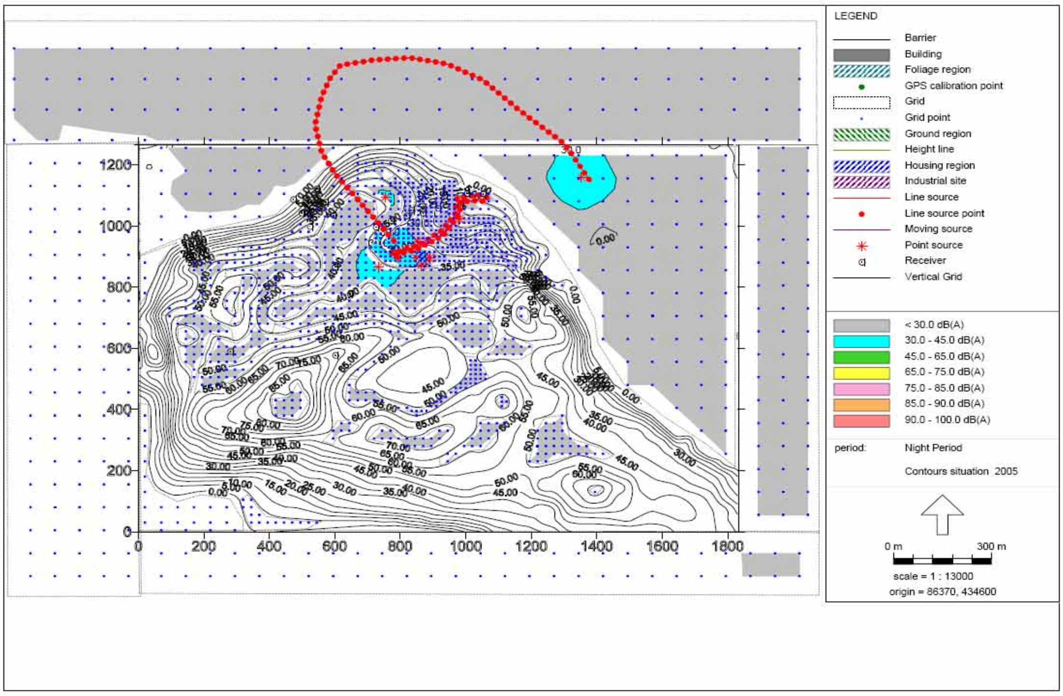


FIGURE 54 : NIGHT NOISE LEVELS DURING CONSTRUCTION PHASE I

(X and Y coordinates in figure are represented in meters)

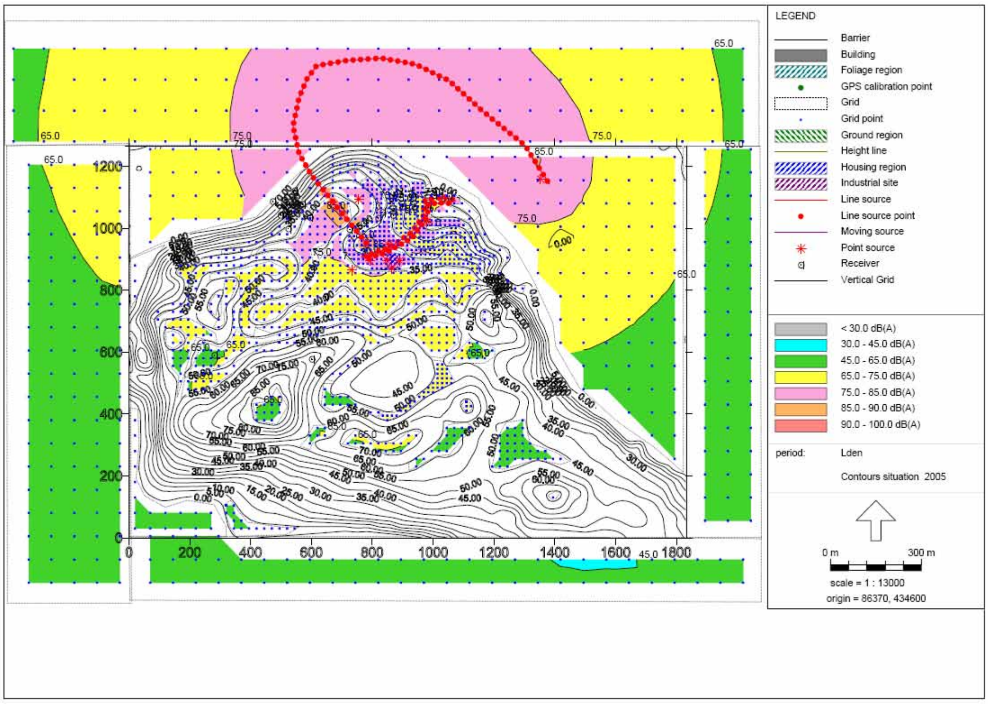


FIGURE 55 : DAY-NIGHT NOISE LEVELS (LDN) DURING CONSTRUCTION PHASE I

(X and Y coordinates in figure are represented in meters)

It is clear from above figures that mostly noise of 90-85-75-65 dBA will be contributed by helicopter operation, whereas due to vehicle and stationary sources noise levels in the range of 75-65 dBA will be added to local operational area. Southern part of the promontory will not be affected by the construction activity. Since most of the machineries are under non working stage during night time, Ldn value shows less area affected by higher noise levels.

6.2.8.3 CONSTRUCTION PHASE II

During construction phase activity (Phase II), noise generation from various sources i.e., helicopter, ship, crane, bulldozer, excavator, stone crusher, concrete mixer, piston bully and generators have been taken into account. Cumulative impacts due to various machineries and vehicles (day noise level, night noise level and total noise level <Ldn>) are depicted in Figures 56-58, with the help of isoline.

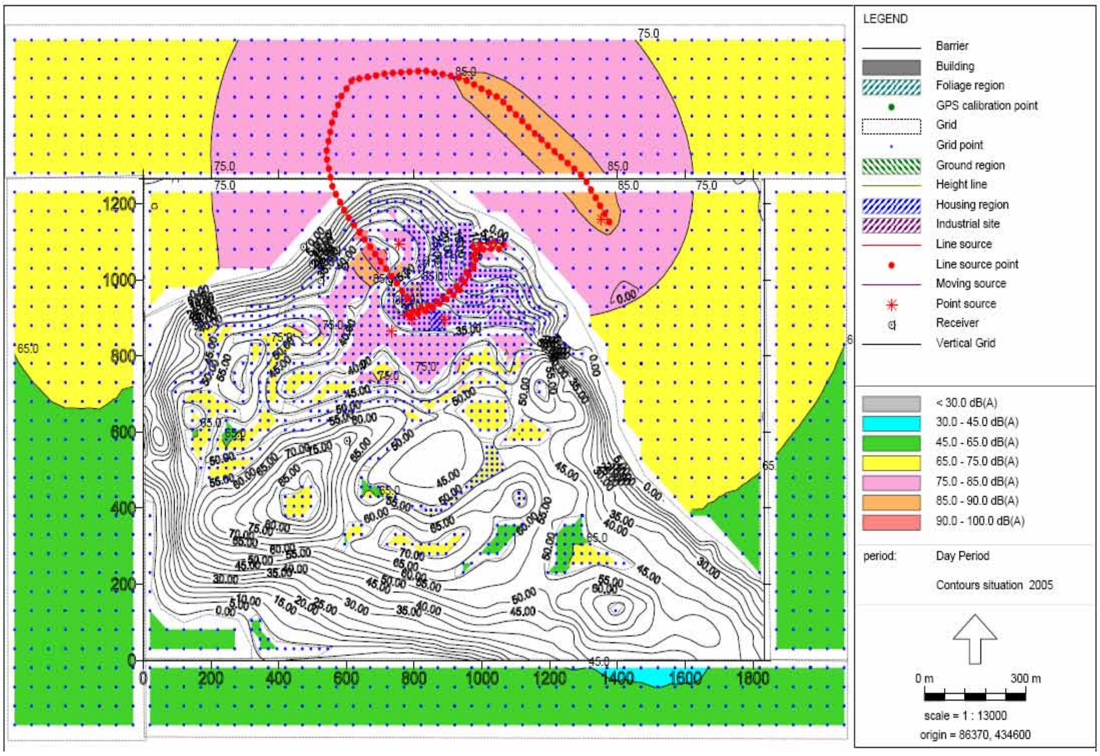


FIGURE 56 : DAY NOISE LEVELS DURING CONSTRUCTION PHASE II

(X and Y coordinates in figure are represented in meters)

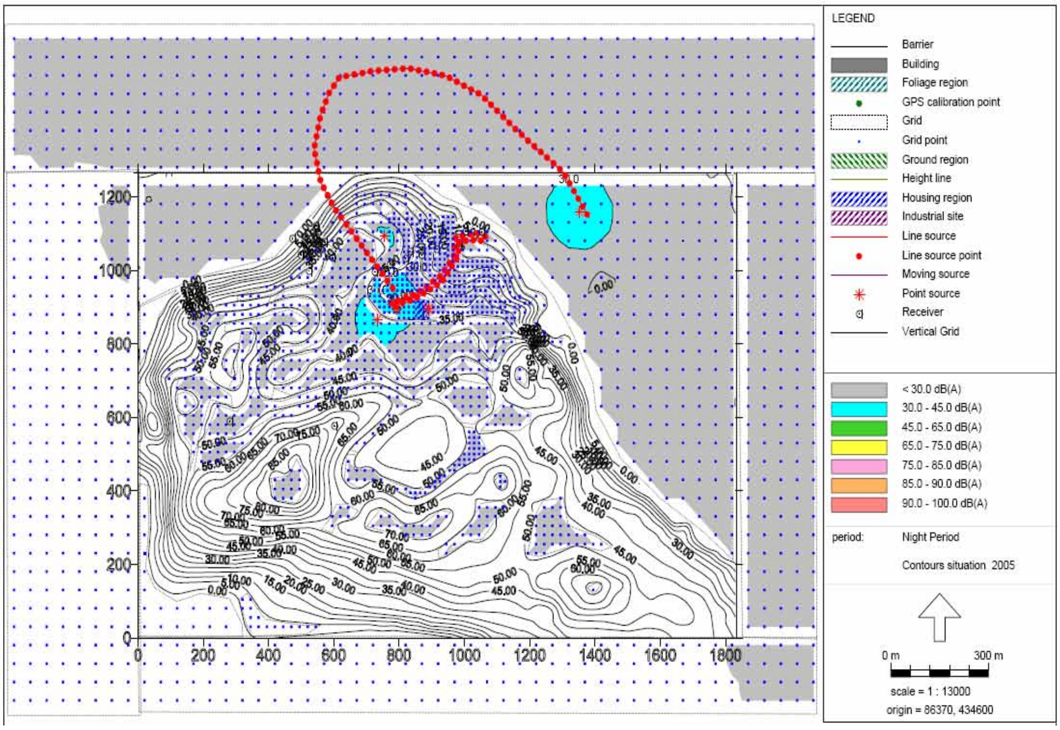


FIGURE 57 : NIGHT NOISE LEVELS DURING CONSTRUCTION PHASE II

(X and Y coordinates in figure are represented in meters)

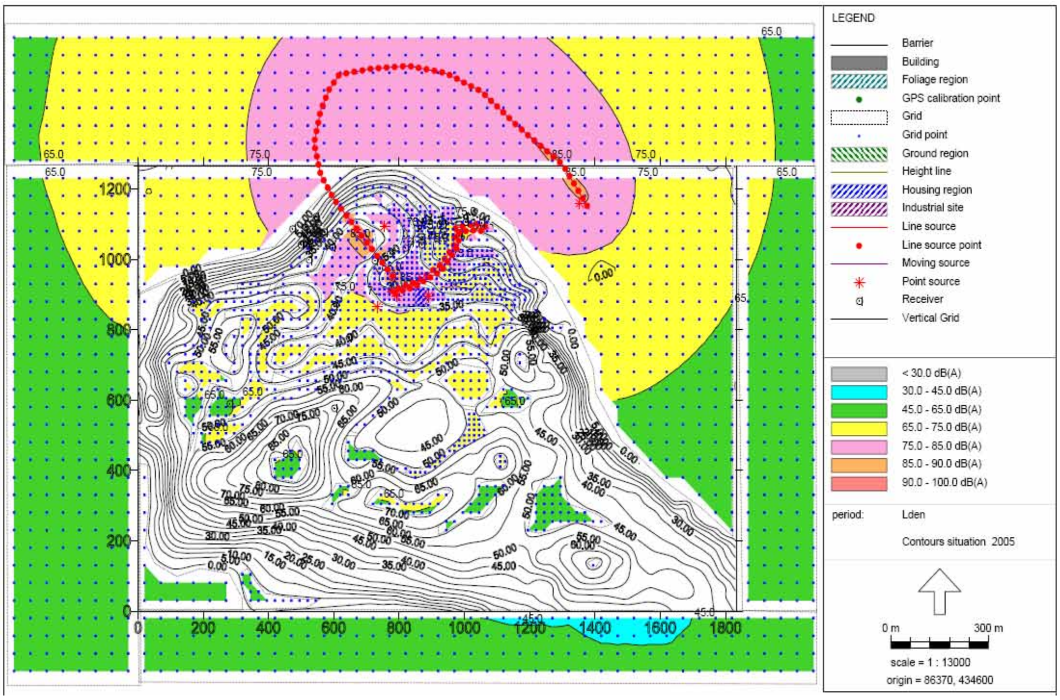


FIGURE 58 : DAY-NIGHT NOISE LEVELS (LDN) DURING CONSTRUCTION PHASE II

(X and Y coordinates in figure are represented in meters)

It can be seen from above figures that mostly noise of 90-85-75-65 dBA will be contributed by helicopter operation, whereas due to vehicle and stationary sources noise levels in the range of 75-65 dBA will be added to local operational area. Southern part of the promontory will not be affected by the construction activity. Since most of the machineries are under non working stage during night hours, Ldn value shows that less area will be affected by higher noise levels.

MITIGATING MEASURES

Prediction of noise levels during site preparation, construction and operational phase has been made considering all the probable sources. Further, the Day, Night and Day-Night (Ldn) noise level contour, anticipated at and around the activity area has been generated. During site preparation maximum noise level of 65-45 dBA would occur at receptor level within 300 meters wide stretch below the helicopter route and during construction phase maximum noise level of 85-90 dBA would be generated within 150 meters wide stretch which then will reduce to 75 dBA. However, at the site it would further reduce to 45-65 dBA. Around the site since ground level is higher than the msl of transportation path and station structure, propagation of noise would reduce much below.

Substantial care will be taken to optimize the flight path and timing of helicopter landing so that cumulative impact of noise levels due to operation of various noise generating sources could become inconspicuous. Further, the workers will be provided with head gear and ear muffs to protect themselves against high noise levels. Since this high noise level will occur only around a limited area covering a small portion of sea and part of land at promontory, adverse effect on fauna, if present any, will be very low.

The ship will be berthed away from the peninsula to minimize the disturbance due to the noise. The engines of helicopters will be shut off at the site to minimize noise disturbance. Silent generators adhering to the USEPA and CPCB standards will be used to keep the noise levels at minimum

6.3 IMPACT DUE TO OPERATION ACTIVITY OF THE STATION

6.3.1 PHYSICAL DISTURBANCE

Equipment installation for scientific experiments for long term or short term requirement will contribute to physical disturbance. Electrical cables will be required to transmit electricity from the generator room to the building, laboratory and other modules. This encased cabling may result in physical disturbance. Piping for wastewater discharge from the treatment plant to the discharge site at sea will occupy some area. It is estimated that approximately 3240 m^2 (1630 m^2 for station, 570 m^2 for fuel farm, 75 m^2 for food storage, 75 m^2 for laboratories, 120 m^2 for two helipad and 770 m^2 for three radoms) of land area will be required to build the structure inclusive of the main building, fuel and food depot, platform at landing site etc.

Around 325 meter piping will be required for water intake from sea and around 640 meter piping has to be laid for wastewater discharge into the sea. In addition, a 250 meters long fuel distribution line is proposed from the fuel depot to the station building. All these structures and piping may cause physical disturbance to the area. The likely footprints of the activity are shown in Figure 7.

MITIGATING MEASURES

Establishment of station structure, fuel farm, outside laboratories, food storage, satellite communication radome and WEG cannot be avoided. Hence associated footprints also are unavoidable. However, designing the station building in three storey configuration has reduced the foot prints to approximately 30% of a normal single storey structure. Disturbance would be controlled by restricting most of the activities to a limited area. Human impact will be confined to predefined areas whereas access path was leveled without causing much disturbance. All elements of the structure have been designed in such a way that, during maintenance or repairs, various elements/parts or after expiry of life, it can be easily replaced. This will cause no additional adverse impact.

6.3.2 AIR EMISSION

During the operation of the station, air emission will be resulting from supply vessel, helicopters, generators, and vehicles. Fugitive emissions are also expected from stored fuel tanks. These emissions will contain carbon dioxide, carbon monoxide, oxides of sulfur, nitrogen and other gases along with heavy metals if they cross the permissible limits.

6.3.2.1 SUPPLY SHIP

Ice-class ship will be used for supplying materials, fuel, bringing back the harmful non-degradable waste from the station and transportation of scientists and logistics personnel to and from the station. The emissions from the ship will be as given in Table 14, depending upon the period of stay of ship at the outer anchorage near the station.

MITIGATING MEASURES

Since the supply ship will be berthed during operational phase far from the site (initial few days) till it reaches near promontory, the emissions from the ship at the idling stage are likely to be minimum, there by producing insignificant impact on the station site. As far as possible, the ship will be run on single engine with low sulfur fuel. The ship will comply with the provisions of MARPOL Annex VI on air emissions. The possibilities of sharing the ship logistics with other countries having bases nearby will also be explored after the construction stage.

6.3.2.2 HELICOPTER

When station is fully operational, higher capacity helicopters will be replaced by smaller ones such as AS-350, Bell 407 etc., which will be used for traversing to inner mountain ranges. Fuel consumption of these engines may be in the order of 170 liter/hr of ATF (Jet-A1). Around 20 sorties are anticipated for transferring to and fro, ship to station and another 25-30 for scientific traverses beyond the limits of the station. It is estimated that total fuel consumption for the operation confined to station site, will be in order of 950 kg. The predicted emission from the helicopters is shown in Table 24:

TABLE 24 : PREDICTED EMISSION FROM HELICOPTERS AROUND THE SITE

Parameters	Pollutant (kg)						
	PM	SO_x	NOx	CO	CO_2	Methane	NMVOC
Emission Factor (kg/t) of fuel consumption	0.2	0.72	18	12	859	1.43	2.84
Emission Load (kg)	0.2	0.7	0.2	11.5	820	1.5	2.5

MITIGATING MEASURES

During operational phase also, the helicopters will remain in the air only for 10 to 15 minutes for each sortie and will fly 600 to 1000 feet above the msl so that all the emissions will have very high probability of dilution and dispersion (due to higher ventilation coefficient). It will not affect directly or indirectly, the flora or fauna or lake system of the area. The landing site shall be kept far away from the lakes. Flying the helicopters during the operational stage to the mountains will not have any direct impact on the site, because of the distance involved.

6.3.2.3 GENERATORS

Maximum peak load is estimated to be around 153 kW during summer, whereas minimum load is estimated around 96 kW during winter period. To meet the power demand, three generator units each of 100 kW will be installed inside the station in the first floor. Two generators will be operated according to demand and one generator will act as standby. Fuel operated generators will be used as main power source. The heating system inside the station will work on Combined Heat and Power (CHP) mechanism. Following emissions are expected to impact the air quality (Table 25):

TABLE 25 : EMISSION FROM DIESEL GENERATORS DURING STATION OPERATION IN A YEAR

Generator	Fuel consumption (m^3/year)	Total Emission of Pollutant (kg)				
		PM 10#	SO_2	NOx	CO	TOC
*Emission Factor (kg/m^3) of fuel burn		1.0248	0.744	11.724	0.8064	0.2856
100 kVA Gensets and second 100 kVA on 50% load	258	264.4	192.0	3025	208	74

**USEPA, AP-42 of electric generation from internal combustion engine, uncontrolled operation*
#PM-10= particulate matter assumed to be less than or equal to 10 µm aerodynamic diameter and greater than and equal to 1 µm diameter

MITIGATING MEASURES

During operational phase, 100 kVA generators will be operated on ATF to provide electricity and to keep station premises warm. Since these generators have been designed as CHP the extra burden on fuel consumption due to boilers is avoided. The stack height of generators will be sufficiently high for proper dispersion of pollutants. Energy system like WEG and solar panel to supplement the energy demand would be alternate sources of energy. This effort will further reduce the fossil fuel consumption and associated emissions in the air.

Building will be designed as energy efficient and sandwitched glass panels will be provided to make best possible use of day light and to avoid heat loss. Occupants will be given proper training to use energy efficiently. The water intake and discharge pipes will be heated only during the operations to save energy. Wherever possible the flow of recycled water, fuel and collection of waste water will be gravity based.

6.3.2.4 VEHICLES

During operational activities of the station, two ATVs will be plying between station, food depot and laboratories, to ferry material and scientific equipments. Considering 15 mile run of two ATVs and maximum number of 100 days of plying in a year, total emission into the air will be of the order of 0.3 kg of particulate matter, 0.9 kg of oxides of nitrogen, 130 kg of carbon monoxide and 2.4 kg of hydrocarbon.

Cranes and forklift will have limited use once the station is fully operational. Crane will be used only for replacement of the panel, vehicle maintenance and transfer of material from barge to the platform. Forklift will also be used occasionally to shift the materials. Use of these vehicles will be limited to the confined area and for a few hours in a year. Operation of these vehicles will release insignificant quantities of pollutant into the air. It is estimated that fuel required for the crane is about 500 liters of ATF and 200 litres of gasoline for forklift every year.

MITIGATING MEASURES

Care will be taken to maintain the vehicles to a high standard to reduce fuel consumption. Proper planning of logistics will reduce the use of vehicles and machinery. To the maximum extent possible, machineries will be operated on ATF and not on diesel to reduce emissions. Engines of the vehicles will be switched off, while not in operation to reduce fuel consumption.

6.3.3 CUMULATIVE IMPACT ON AIR ENVIRONMENT

Emissions from various sources will have direct impact on air quality and indirect impact on water and snow if settles at particular place for a long time. Prediction of cumulative impact on air environment has been made considering operation of ship, helicopters, and generators. Predictions have been made employing ISCST 3 air quality prediction model. Inputs for meteorological data were obtained from Davis station and predictions have been made for 24 hourly average for the entire year of operation. Isopleths showing contours of particular pollutant around the site are depicted in Figures 59-61.

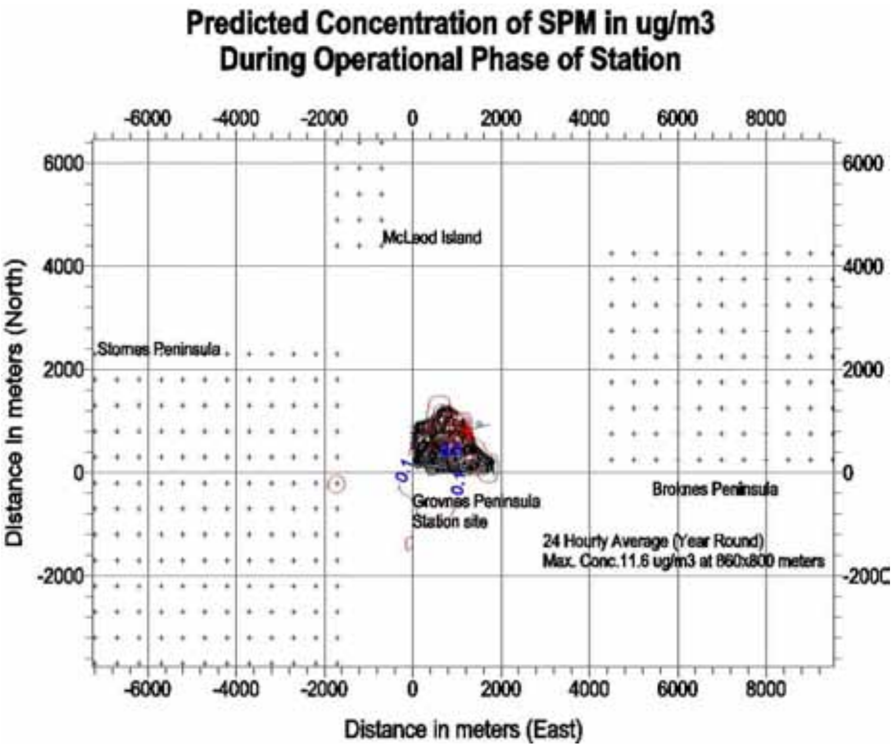


FIGURE 59 : PREDICTED CUMULATIVE IMPACT OF SPM (STATION OPERATION)

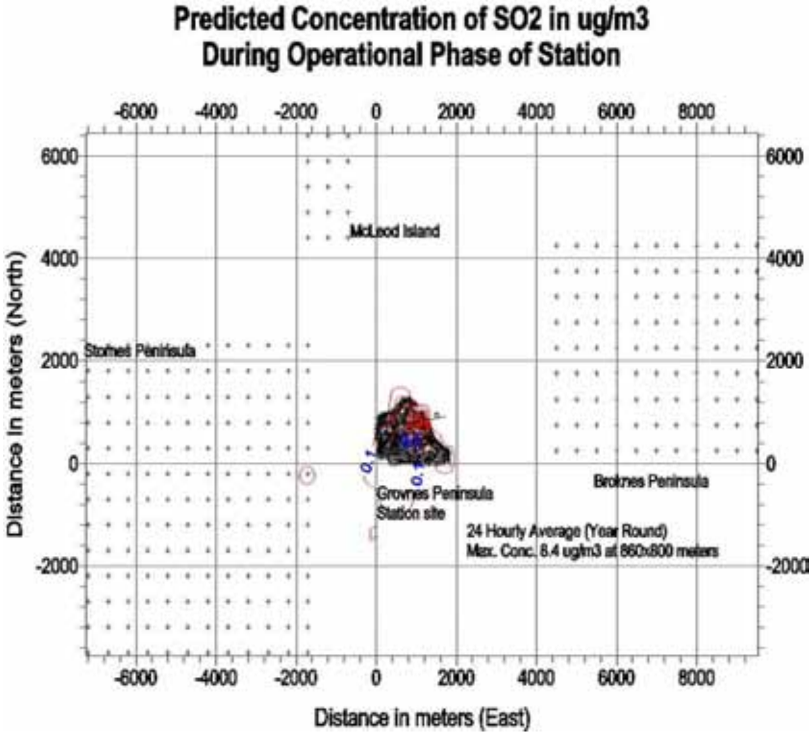


FIGURE 60 : PREDICTED CUMULATIVE IMPACT OF SO_2 (STATION OPERATION)

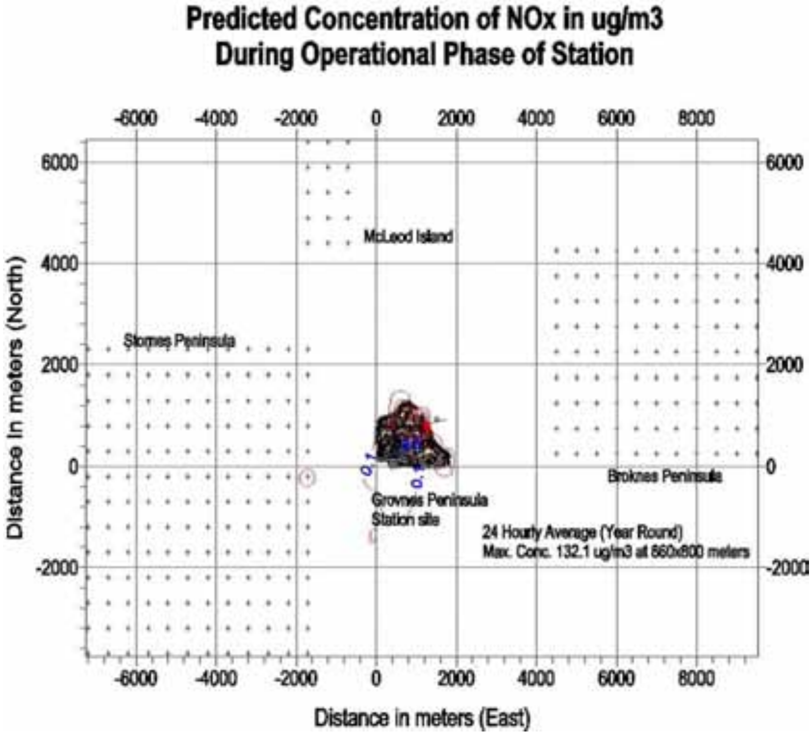


FIGURE 61 : PREDICTED CUMULATIVE IMPACT OF SO2 (STATION OPERATION)

Twenty four hourly average concentrations showed that the maximum cumulative concentration during operational phase of station is estimated to be 11.6 µg/m^3 of SPM at 860x800 meters, 8.4 µg/m^{3}of SO_2 at 860x800 meters and 132.1 µg/m^3 of NOx at 860x800 meters.

MITIGATING MEASURES

A cumulative impact on the environment has been predicted from the emission generated from the machinery and equipments and will be controlled by optimization of the same. All the vehicles used for construction and operational purposes will be maintained efficiently to ensure low air emission.

Comparing all seasons' activity, 24 hourly average concentrations has shown negligible concentration of SPM and SO_2 during operational phases, whereas NOx concentration was predicted higher during construction phase II. High NOx concentration was very close to the source at a single point. However, after 50 meters the concentration reduces to less than 1 µg/m^3. Predictions were made considering generators and vehicle operating at the same time. However, in actual practice all machineries and vehicles will not be operated at the same time. Hence cumulative impact on air quality will be much less than that predicted.

6.3.4 IMPACT ON WATER QUALITY

6.3.4.1 CUMULATIVE IMPACT OF WASTEWATER DISCHARGE

Total water requirement during summer will be around 2400 liters per day for 40 persons, out of which 20% (500 liters) will be recycled to use for toilet flushing. During winter around 900 liters will be required per day for 15 persons and around 200 litres will be recycled for toilet flushing. The quality of water in the lakes is likely to be affected if the water is drawn from the lakes as these are shallow ones. The station structure will be so located to keep the lake ecosystem free of any effect of the emissions from generators and the vehicular movements.

About 2.3 m^3 of wastewater will be generated per day from the toilets, laundry, and kitchen during summer and 0.8 m^3 per day during winter. After treatment, the wastewater will be discharged into the sea through pipes. There are chances of leakage through the pipes. Reject from RO system may affect the biota of the seawater. Wastewater discharge into the sea may also temporarily affect the quality of seawater. If the waste water is not treated properly or in case of a failure of the treatment plant, it could adversely affect the water quality and the flora and fauna inhabiting the coastal region and if continued for long time cumulative impact on seawater biota may occur. The particulate matter, both organic and inorganic, if contained in excessive amount will have direct and indirect impact on biota, and will increase the turbidity of the shallow coastal water around the discharge point and may affect the sunlight penetration which is very important for photosynthesis, thereby affecting the food web dynamics. Besides the organic matter contained in the waste water will get deposited to the bottom of the shallow coastal region. Microbial degradation of the organic matter will release excessive nutrients in the water column, causing eutrophication and algal blooming, which will result in oxygen depletion and adverse impact to the biota. Inefficient treatment of the waste from toilet, laundry and kitchen will bring in toxic materials into the coastal waters which will affect the biota and can increase the alkalinity and temporarily alter the chemical composition of the coastal water.

Dilution and dispersion of the wastewater discharge is shown in Figures 62 and 63. For this study Cormix 6 model was applied, while effluent BOD concentration was considered as 20 mg/l (against 5 mg/l designed effluent quality), under two scenarios of effluent discharge into nearby sea during summer and winter period.

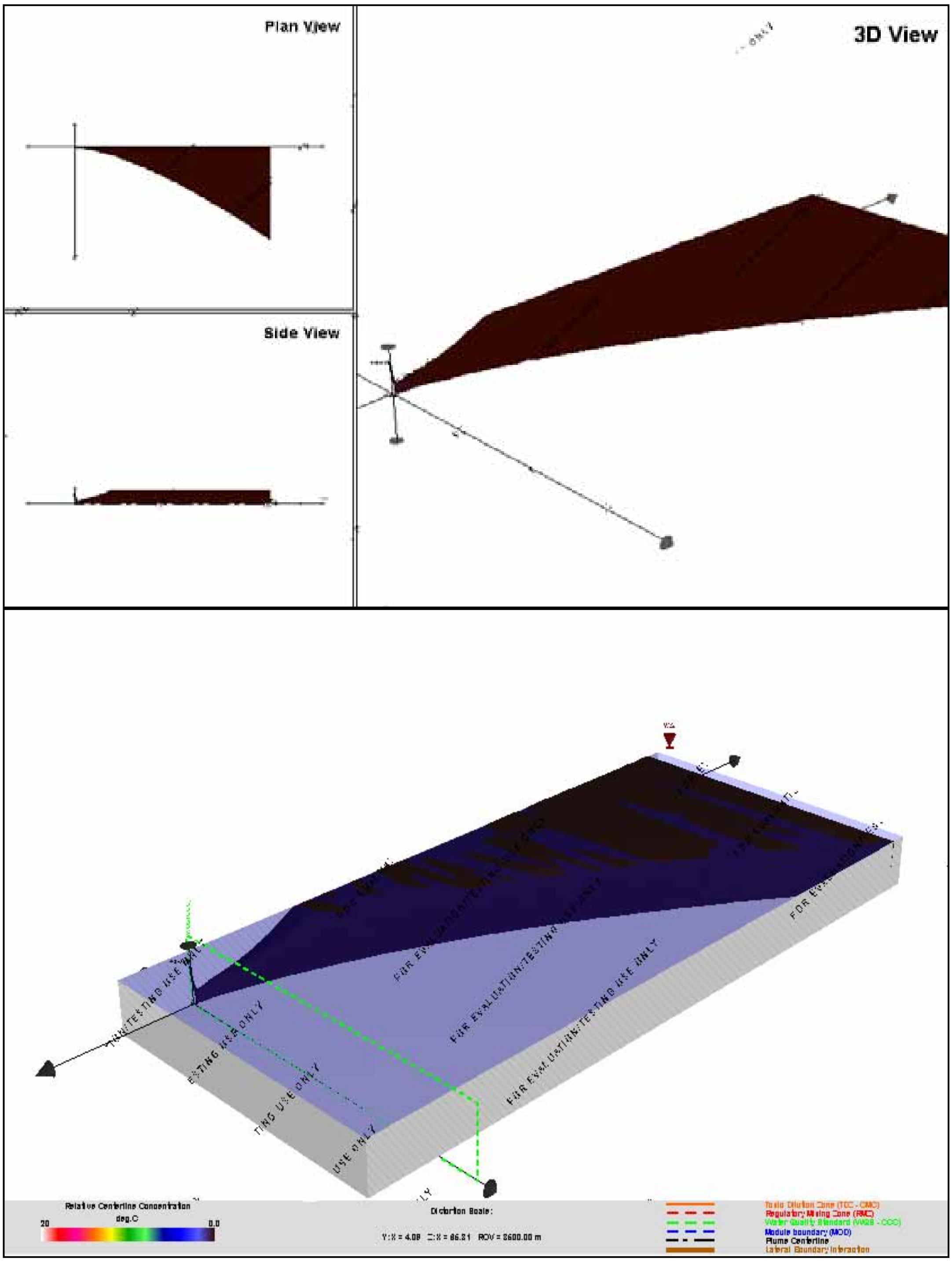


FIGURE 62 : DILUTION AND DISPERSION OF TREATED WASTEWATER EFFLUENT (SUMMER PERIOD)

It was considered that total effluent will be discharged three meter deep into the sea in two hours. Ambient velocity of seawater was considered as 0.1 m/s and wind velocity as 2 m/s. Effective dilution is predicted as 989 times at 23.1 meters from discharge point, while the travel time will be around four minutes to reach to maximum dilution level.

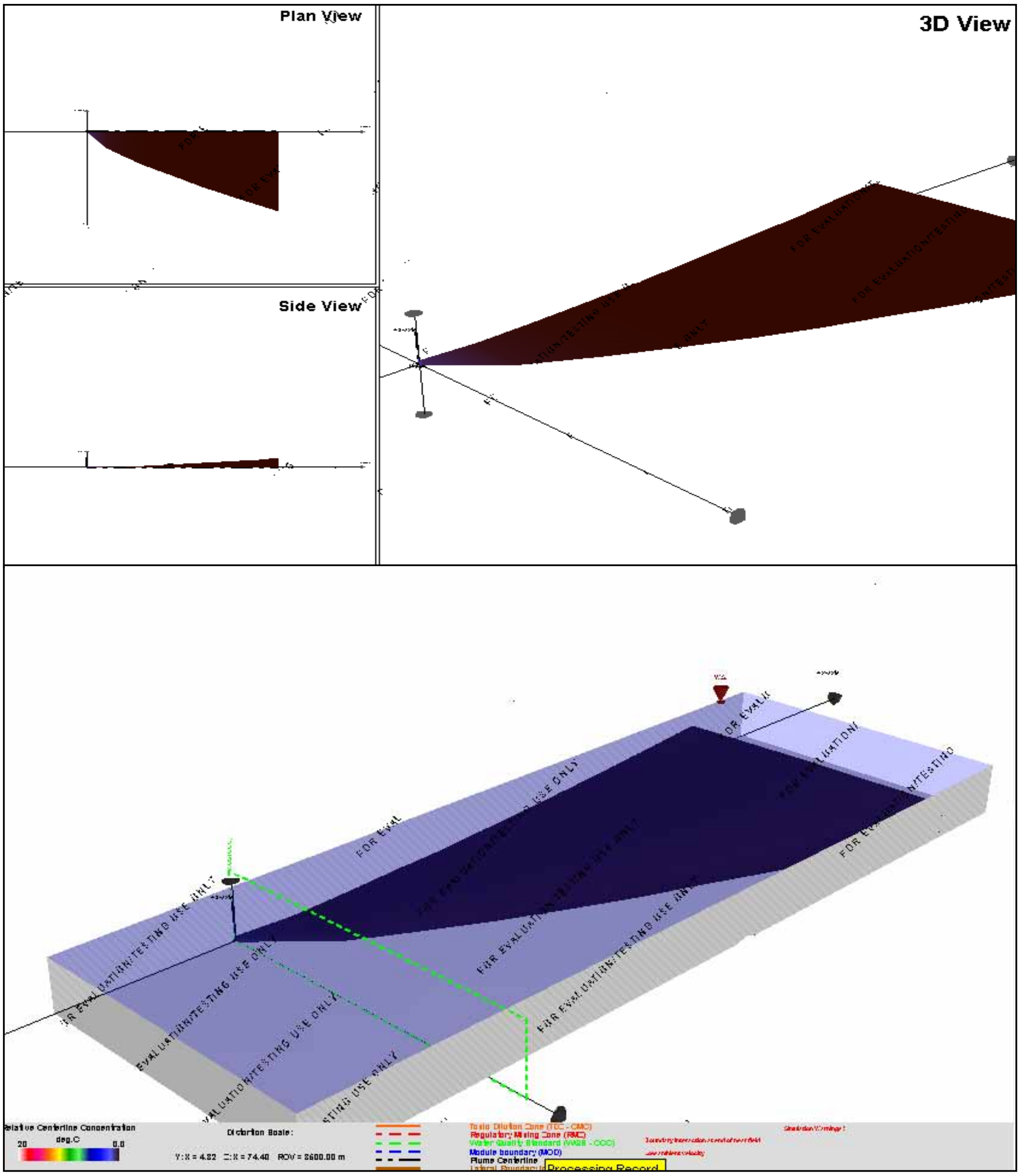


FIGURE 63 : DILUTION AND DISPERSION OF TREATED WASTEWATER EFFLUENT (WINTER PERIOD)

It was considered that during winter period there will not be any wind mixing taking place as top three meter will be covered with ice and that total effluent will be discharged three meters deep into the sea, within two hours. Effective dilution is predicted 173 times at 3.7 meters from discharge point, while travel time will be around five minutes to reach maximum dilution.

MITIGATING MEASURES

Potable water requirement will be supplemented by drawing and treating seawater with reverse osmosis (RO) filtration system during operational phase. Seawater will be pumped from sea to the station building where it will be made available for further use after desalination. Since lakes are supposed to be used during emergency only and there is annual recharge of lakes due to snow melt, the impact on the water quality and flora and fauna is visualized to be very low.

Method of wastewater treatment and disposal will be in compliance with the basic requirements of the Protocol on Environmental Protection to the Antarctic Treaty. Wastewater from the laboratories shall be produced in least quantity. This will not be mixed with sewage, rather it will be collected in tanks and once in year will be sent back to mainland for proper disposal. Biological wastewater treatment system with membrane filter will be installed to achieve an effluent quality of 5 mg/L BOD_5, 80 mg/l COD and <500cfu/100ml E. coli. The system will be able to disinfect the pathogenic bacteria before its final discharge into the sea. Basic specified criteria includes high effluent quality, compactness, low power use, low sludge generation, reliability, simplicity of operation and the ability to treat variable wastewater loads. Extra care would be taken to check and eliminate the leakages.

For the operational phase, the assessment of the impact of treated wastewater discharged into the sea has been carried out through dilution dispersion study of waste water. Two scenarios have been considered viz. winter and summer period. The BOD level was kept four times above the designed discharge effluent quality. Results showed high dilution and dispersion of effluent during summer and sufficient dilution and dispersion during winter, when the top layer is covered with sea ice. The quantity of effluent discharge is low. However, care will be taken to discharge effluent intermittently and at low flow level.

Structures like fuel farm, intake and discharge pipes and approach path have been designed so as to avoid contamination of catchment area of lakes, in case of oil spill or physical disturbance. Saline water generated from the Reverse Osmosis (RO) process, will be 10-40% of total water demand. This concentrate will be mixed with treated wastewater and will be discharged into the sea, far away from the location of intake water.

6.3.4.2 WASTE FROM SHIP

Ship will produce approximately 4 m^3 of waste per day, generated by crew members. If liquid and semisolid organic wastes are discharged into the sea, it may have the potential to affect the sea environment.

MITIGATING MEASURES

The expedition ship will abide by MARPOL, Antarctic shipping guidelines and provisions of the environmental protocol. No waste produced in the ship will be discharged in the Treaty area. Treated wastewater will be discharged as per the prevailing provisions.

During operations, stress will be on summer scientific activities of three months at the Larsemann Hills site. The ship will move away from the area as soon as material transfer is over. At the end of summer it will come again to collect the waste material from the site. Hence in all, the ship will remain at the site for only 10-15 days.

6.3.4.3 WASTE (SOLID AND SEMI SOLID)

Approximately 15 kg of solid waste is expected to be generated per day in the form of organic waste from the kitchen during winter and about 20 kg during summer. Other solid waste will include packing materials, unserviceable items such as steel, tin, wood, glass etc., sludge generated from wastewater treatment system and dewatering unit. Some waste will also be generated from the workshop. Organic wastes will not be incinerated at the site. After segregation and compacting the organic waste material, it will be stored and transported back to mainland once a year.

Waste generated inside the station will be of different categories. If left unattended, it may be hazardous to the environment and may have both short and long term effects. Waste will also be generated from launching of the meteorological balloons as well as from laboratories. Prevailing wind may sweep the litter, if left unattended to rest on sea or nearby peninsula and may affect the lake quality.

While ship will be berthed near the site, crew members will stay onboard the ship till all the summer activities such as transportation, offloading, fuel pumping etc. gets over. Around 40 people will be living onboard, which will produce approximately 4.5 m^3/day of waste. If liquid and semisolid organic waste discharged into the sea, it will have the potential to affect the sea environment.

MITIGATING MEASURES

Solid waste will be generated from the sources i.e.; household from station, kitchen, medical, and workshop. Liquid and semisolid wastes will be collected as sludge from wastewater treatment plant, medical, laboratory, and used oil from workshop etc. A comprehensive waste management plan will be enforced. A proper collection, segregation and disposal technique will be adopted. Waste will be removed from the Treaty area and brought back to India for disposal. A compactor will be used for reducing the volume of the solid non-combustible waste. The ash will be collected and sealed in drums for disposal. Medical wastes will be disposed as per the USEPA/CPCB Guidelines. Sludge obtained from the treatment system and other allied units will be dewatered through filter bags and collected, stored and transported back to mainland. Solid sludge will be collected in drums, sealed and removed from the Treaty area. Wastewater collected from kitchen as well as garage shall be passed through oil and grease separator, prior to feeding in treatment plant.

6.3.4.4 OIL SPILL AND OTHER WASTE

Fuel is required for generators, barge, helicopters and other vehicles. Mainly IFO/MDO, ATF, gasoline and lubricants will be used for various operations. Around 400 kL of ATF will be stored in the fuel farm apart from few hundred liters of lubricants. Fuel spill may occur during filling the tanks from the barge, leakage from the vehicle engines and from the barrels filled with ATF and lubricants. Fuel spill may also take place while refueling, decanting and due to accidents. The spilled fuel may contaminate the top soil as well as sea water.

It is envisaged that most spills are likely to be less than 10 liters and maximum risk is from loss of fuel from tanks and connecting supply pipe which will join from ship to storage tanks. Fuel is volatile and rapidly evaporates in warm condition but leaves some residue. A fugitive emission occurs during fuel spill subject to quantity of fuel spilled over ground. There are chances that during refilling of tanks from ship fuel and oil spill may migrate downwards from fast ice and mix with seawater thus affect the flora and fauna. Spills during the construction phases may have an indirect effect on the scientific value of the area during operation phase. Over a time, fuel spills will contribute to the cumulative impact.

Oil spills can cause permanent damage to the biota depending on the size and depth of the surrounding lakes. Although some fractions of the oil are volatile, the remaining oil will form a film on the surface of the lakes, preventing mixing of atmospheric oxygen thus causing oxygen depletion in the water body. It will also prevent sunlight penetration which is essential for photosynthesis, thereby interfering with the food web dynamics and population of the inhabiting flora and fauna. The oil can also cause mortality of micro and macro organisms, due to depletion of dissolved oxygen and/or interfering with the respiration of the organisms. Although the gravity of the situation may be less in the coastal region due to enormous volume of water and circulation, some minor impacts of temporary nature can be expected to the flora and fauna.

Operational activity will generate non-hazardous waste comprising mainly of packing materials, plastics, wood, tins etc. and hazardous waste comprising of batteries, waste fuel, lubricants, paints sealant etc.

MITIGATING MEASURES

When station is in operational phase, fuel will be stored in fuel farm, designed to store 300 kL of ATF in 13 numbers of tanks. The storage tanks will be double walled, augmented with leak warning system, level indicator and overflow protection, to ensure maximum safety. Storage tanks will be filled once in a year by supply tanks of the ship. Supply tanks and storage tanks will be connected with solenoid valves. Fuel will be pumped from ship to the fuel farm through coupling hose. Fuel supply system will comply with European standard EN 14420. Foundation of the fuel tank will be laid over pre-cast concrete elements so that, in case of leakage, fuel will not be in direct contact with ground and can be recovered by proper means.

Gasoline will be stored in 10 numbers of 205 liter drums. Other lubricants will also be stored in drums. As a safety measure, part of the fuel will be stored in an alternate fuel dump at a safe distance from the previous one. To avoid any spillage from the fuel pipeline it will be covered with jacket tube. The fuel stored in the jacket can be recovered later. Due care will be taken to ensure that these dumps do not fall on the catchment area of the lake system. Oil spill contingency plan for the operational phase of the station will be available once station is operational.

6.3.5 ALIEN SPECIES AND WILDLIFE

During operational phase of the station, possibility of introduction of alien species through various vectors may arise. Local wildlife may also get affected due to movement of persons around station area.

MITIGATING MEASURES

Utmost care will be taken to avoid any interference with the local wildlife. Precautions will also be taken to avoid introduction of any alien species of microorganisms to the environment. Before taking to site, care shall be taken to irradiate the food items and other material, associated with personnel, vehicles and building materials, with UV light (wherever practically possible) to kill microorganism present, if any. ASMA guidelines and protective measures as mentioned in IP17 of XXXI-ATCM, to prevent introduction of invasive alien species shall be followed.

6.3.6 NOISE QUALITY

During the operation of the station, noise will be generated from the helicopter operation, generator operation and vehicular movement. Helicopter will produce around 120 dBA at 10 meter distance. Keeping engine on for longer duration may cause temporary hearing impairment, if persons remain present close to the helicopter.

Although the generators will be fitted with acoustic enclosures for noise barrier and will maintain the USEPA and CPCB standards for the noise emission, some noise would, however, be generated.

6.3.6.1 CUMULATIVE IMPACT

During operational phase, noise will be generated from various sources i.e., helicopter, ship, piston bully and generators. These sources have been taken into account for prediction of cumulative impact from day noise level, night noise level and total noise level (Ldn) which are depicted in Figures 64-67, using isoline.

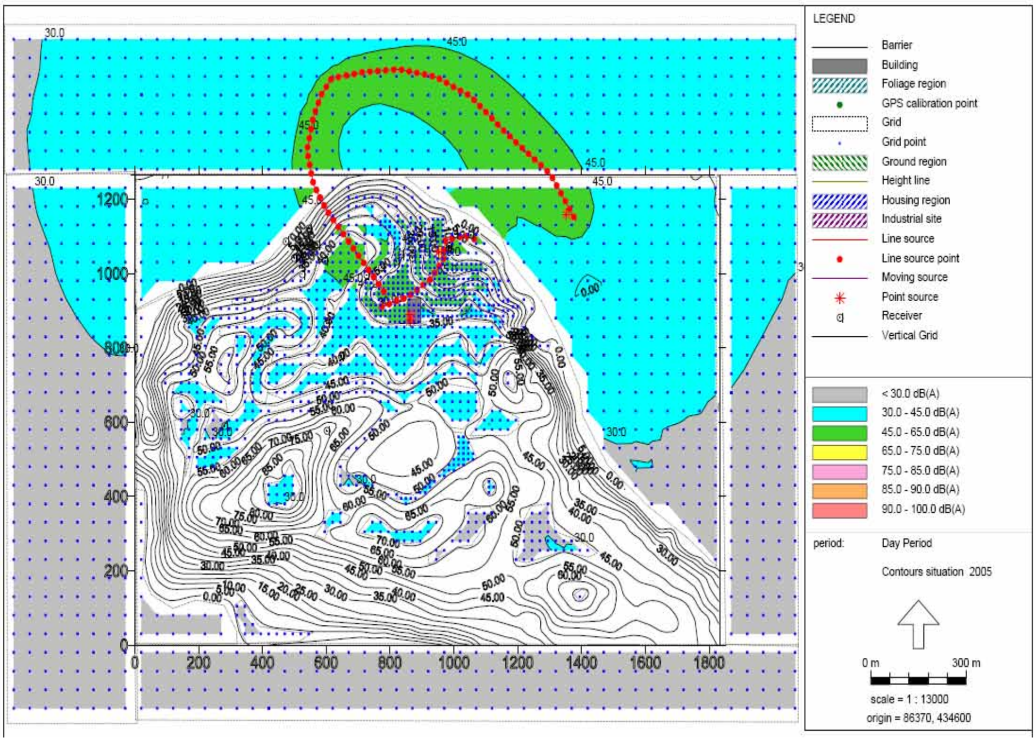


FIGURE 64 : DAY NOISE LEVELS DURING OPERATIONAL PHASE

(X and Y coordinate in figure represented in meters)

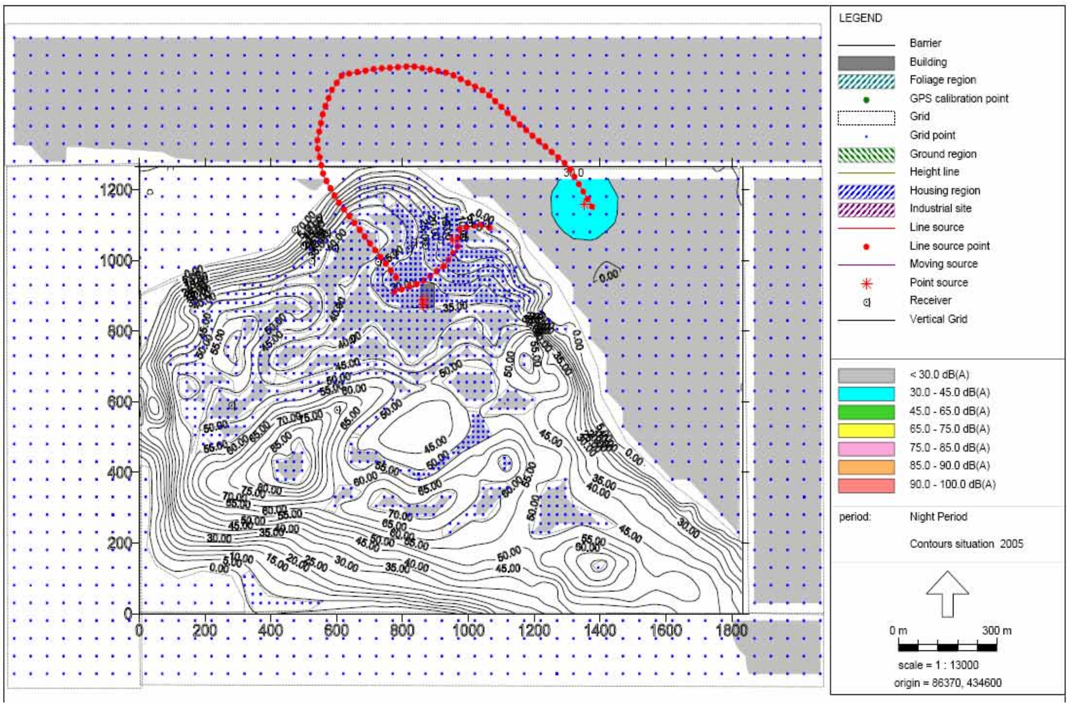


FIGURE 65 : NIGHT NOISE LEVELS DURING OPERATIONAL PHASE

(X and Y coordinate in figure represented in meters)

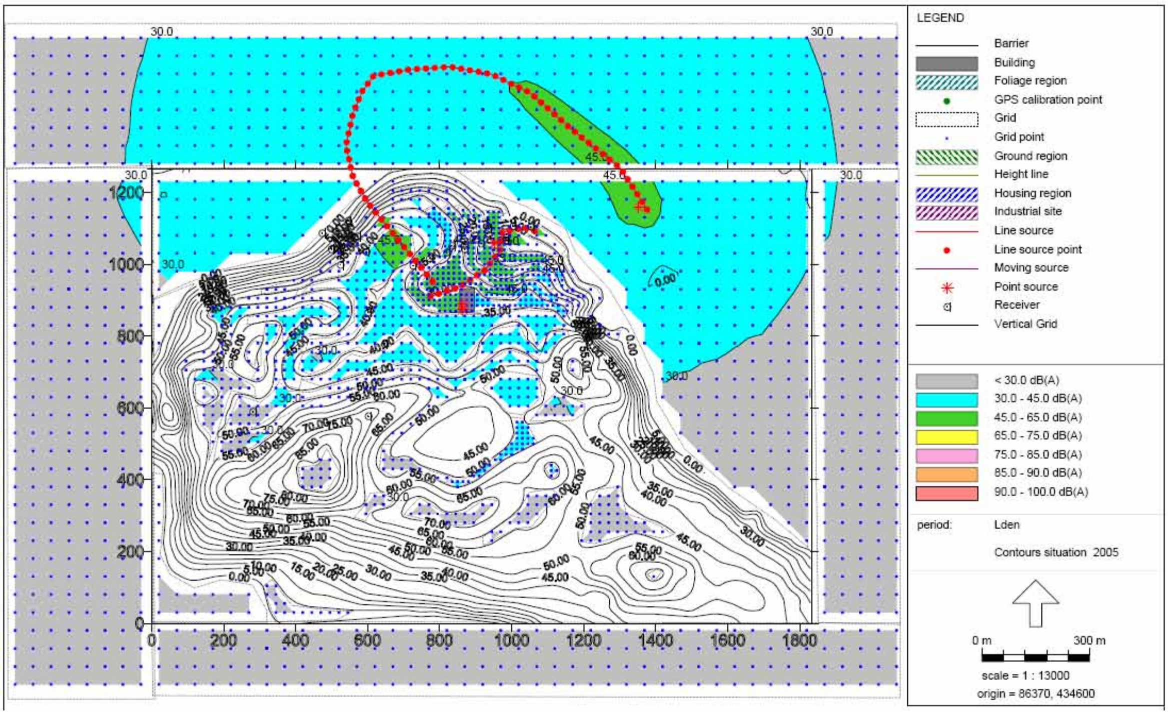


FIGURE 66 : DAY-NIGHT NOISE LEVELS (LDN) DURING OPERATIONAL PHASE

(X and Y coordinate in figure represented in meters)

It is seen from the above figures that mostly noise of 65-45 dBA near helicopter route and 45-30 dBA surrounding the station within 1200 meters of radius may prevail. However, considering Ldn value this will further be reduced to within acceptable limits.

6.3.7 DISTURBANCE DUE TO SCIENTIFIC ACTIVITY

Instruments to be used during scientific experiments and observations could be vulnerable to strong radio signals and may have adverse impact on personnel.

MITIGATING MEASURES FOR SCIENTIFIC ACTIVITY

All the experiments related to astronomy, geomagnetism and atmospheric sciences will be conducted in separate laboratories, away from the station. All the electrical equipments installed at the station will meet the Electromagnetic Compatibility standards.

6.3.8 AESTHETIC AND WILDERNESS VALUE

The station is designed as three-storey building covering around 1800 m^2 of area including laboratories, food and storage facilities etc. Operation of the station and movement of the rotor of the wind turbine at the site may slightly affect the aesthetic look of the area to the visitors and also to some extent affect the wilderness value. However, the station will be visible from the sea only if the line of the sight is clear.

MITIGATING MEASURES

The station design and location will have minimum impact on the aesthetic value as the structure is in a low-lying area and will not have a strong visual impact. Wind turbine of smaller capacity will be preferred over larger capacity turbine to reduce visual impact.

6.3.9 UNAVOIDABLE IMPACT

Site preparation and construction activities include development of path from landing site to station site, for transporting the material by vehicles so as to reduce over flight impact. This developmental activity entails breaking of rocks and deployment of necessary machineries i.e. bulldozer, excavator, air compressor, generators, drilling rig etc. Disturbance by ship and cargo activity is unavoidable. Air and noise emission due to operation of the life supporting system and scientific equipments is also unavoidable.

The operation of these machineries during different segments of time could not be avoided as no alternate solution is available in the project site for taking up construction activities. Similarly, during operational phase, bulldozer and piston bully will be used to transport materials, and the impact generated from vehicular movement cannot be avoided. For energy management, fossil fuel generators will be used inside the station, as these generators will be life supporting system and impact from these generators cannot be avoided as alternate source of energy will not be available throughout the year. However, installation of WEG and solar panels will reduce the load on generators and these arrangements will be made in a phased manner. Sea water quality composition for short span due to discharge of treated and disinfected waste is unavoidable.

6.4 IMPACT MATRIX

Impacts associated with station's operation and construction activities are identified and defined in matrices (Table 26 and 27). Impacts, mitigation measures related to the impact and ranking of the activities are defined according to their extent, duration, intensity and significance.

Extent	*Site Specific*	*Area adjoining to operational or construction site*
	local	*Within Larsemann Hills, approach way from ship to site and other modules*
	regional	*Prydz Bay Area*
	continental	*Antarctica and southern ocean*
	global	*All continents and sea*
Probability	*unlikely*	*Should not occur under normal operation and condition*
	Low	*Possible but unlikely*
	Medium	*Sometimes may occur*
	High	*Likely to occur during span of project*
	Certain	*Certain to occur*
Duration	*very short*	*Few minutes to Few hours*
	short	*Few hours to Few weeks*
	medium	*Few weeks to Few months*
	long	*Few months to Few years*
	very Long	*Decade to Century*
Significance	*A*	*Very low - Ecosystems or natural processes or scientific research not affected*
	B	*Low – Changes to ecosystems or natural processes or scientific research are less than minor or transitory*
	C	*Medium – Changes to ecosystems or natural processes or scientific research are minor or transitory*
	D	*High change to ecosystems or natural processes or scientific activities are greater than minor or transitory*
	E	*Very high – Major changes to ecosystem or natural processes or scientific research are significant and irreversible*

TABLE 26 : IMPACT MATRIX AND MITIGATION MEASURES DURING SITE PREPARATION

Environmental Parameters / Indicator	Potential Impact from activities	Extent	Duration	Probability	Significance	Mitigation Measures
Physical Disturbance	An area of around 3000 square meter shall be developed for path	Site specific	Short	Certain	B	The path was developed only for approach road from landing site to fuel storage and station sites to facilitate the transportation of construction material and fuel to the designated area while station construction will be carried out later. Once construction of station is over the vehicular movement will be very minimal except those used for transportation of supply materials. Approach path was relocated to save physical disturbance by 53%.
Air	Impact from ship, helicopter, bulldozer, excavator, crane and generator's operation and movement Airborne dust emission due to drilling operation and excavation and filling Rock splitting and surrounding rock damage	Local	Medium	Certain	B	As the ship was berthed away from the site for initial few days there would not have been any direct or indirect impact on the air quality at the site. However later, after negotiating through the sea ice it reached near promontory and berthed for around 15 days. Helicopters did a total of about 50 sorties during the entire period of operation. The engines were shut while at the site. The impact on the air was, therefore, expected to be minimal. Machineries viz. dozer and excavator were operated with ATF which emits much lower particulate matter and exhaust gases as compared to the diesel fuel. However, care was taken to operate the machineries to minimum required time and engine was switched off when not in use. The portable generators used at the site conformed to that of Central Pollution Control Board, India and USEPA emission standards and therefore the emission levels were expected to be minimal. Moreover, the generators were operated only for six to eight hours a day for about 25 days. Drilling for holes was carried out by enclosing the area to arrest the dust. Water was sprinkled to reduce the possibility of generating air borne dust. Rock splitting was carried out at minimum possible locations and only when found essential. NoneX cartridges were placed in the drill holes manually. The spoils were removed and used for filling the depressions

Environmental Parameters / Indicator	Potential Impact from activities	Extent	Duration	Probability	Significance	Mitigation Measures
						along the path. The detonation frequency was 3-4 per day, or once every two days, depending on the necessity and removal of the spoils. All major activities associated with rock splitting were carried out taking due precaution of forming barriers to stop rock flying, if any. Rocks splitting produced by these cartridges were of low vibration resulting in significantly reducing damage to surrounding rock.
Water Quality	Airborne particulate matter due to drilling, excavation, filling and vehicular movement operation may have impact on surrounding small water bodies	Site specific	Short	Low	B	Care was taken to put up barriers in the form of sheets in the leeward wind side to arrest the airborne particles. However, as the prevailing wind direction was mostly from east to north-east direction, the effect on the water bodies was minimal. Vehicles/machineries were operated on ATF which emits minimal particulate matter and gases. Care was taken to operate the vehicles during appropriate wind condition to avoid dispersion of the particulate matters in the ecologically sensitive area. Speed of the vehicles were maintained 2-5 kmph to avoid higher consumption of fuel.
Noise Quality	Helicopter, generator and machineries and rock splitting operations may affect the fauna of the area	Local	short	Certain	A	Helicopters were prevented from remaining in air for long. At the landing site engine was switched off. Helicopter did not fly over any breeding site of terrestrial fauna i.e. penguins, seals etc. Small silent generators of 2kVA and 1 kVA do not have potential to emit much noise. Low noise drilling machines were used. Rock splitting did not produce more than 85dBA noise.
Solid-waste	Waste generated will be of different categories. If left unattended, it may be hazardous to the environment and have both short and long term effects.	Local	Short	Low	A	All the persons stayed in the ship after completion of day to day work. Any solid or liquid waste produced in the ship was stored for proper disposal outside of Treaty area. All the packing materials were stored in boxes and back loaded to ship.
Flora and Fauna	Bird hit by helicopter flying Alien species may be introduced from human	Local	Very short	Unlikely	A	The site does not fall under any observed migratory route of birds and the probability of bird hit is negligible. It was ensured that adequate cleaning and inspection of materials were

Environmental Parameters / Indicator	Potential Impact from activities	Extent	Duration	Probability	Significance	Mitigation Measures
	clothing etc					done before sending these to Antarctica.
HSM,ASPA, ASMA	Present site falls under ASMA 6	Local	Long	Certain	A	No direct impact on the area, but the ASMA guidelines were strictly followed.

TABLE 27 : IMPACT MATRIX AND MITIGATION MEASURES DURING CONSTRUCTION AND OPERATION

Environmental Parameters / Indicator	Potential Impact from activities	Extent	Duration	Probability	Significance	Mitigation Measures
Physical Disturbance Construction	Erection of the structure, pipe laying, access pathway, wind turbine	Local	Long	Certain	B	Physical disturbance would be controlled by restricting most of the activities in limited area.
Operation	Occupied area of building, fuel and food depots, piping and off-loading platform, cable laying, laboratories etc.	Local	Long	Certain	B	All activities will be carried out in defined area. Laying of pipes will avoid use of frequent transportation for fuel and related activities. Structure shall be removed after useful life is over.
Air Quality Construction	Supply Ship, Helicopter, Generator and Vehicles, Use of fossil fuel	Local to global	Medium	Certain	C	Abiding by MARPOL 73/78. Annex IV will ensure use of quality fuel and thereby controlled emissions.
Operation	Generator, incinerators for organic waste burning, supply ship, helicopter	Local to global	Medium	Certain	B	Abiding by MARPOL 73/78. Annex IV will ensure use of quality fuel and thereby controlled emissions. Ship and helicopter will be operated for very short duration. Organic waste will be stored and removed for proper disposal at mainland. Alternate energy source will reduce the fossil fuel consumption
Water Quality Construction	Solid-waste and wastewater release from the ship, which will introduce nutrients, heavy metals, faecal coliforms to the marine ecosystem	Regional	Short	Low	B	All kind of solid waste will be stored for proper disposal out of Treaty area. Treated and disinfected sewage will be stored in the tanks for disposal in mainland.
	Lakes at the site may be affected due to dispersal of solid waste and mixing of the carbon soot from the emission of vehicles, generator	Local	Medium	Medium	B	Generator will be kept away from lake during construction phase. All the persons will use ship for accommodation purpose. All the packing material will be stored carefully and brought back to ship for proper disposal out of treaty area.
	Consumption of drinking water	Local	Long	Low	C	Potable water requirements will be mostly met by desalinated water from

Environmental Parameters / Indicator	Potential Impact from activities	Extent	Duration	Probability	Significance	Mitigation Measures
Operation	from the lake will reduce water level in the lake, wastewater pipe may leak from discharge pipe and mix with lake and contaminate water Solid-waste and wastewater release from the ship, which will introduce nutrients, heavy metals, faecal coliforms to the marine ecosystems Wastewater discharge into sea will introduce heavy metal, bacteria, nutrient and deplete dissolved oxygen which may be detrimental to phyto and zoo plankton of marine ecosystem	Local Local	Short Medium	Low Medium	A C	sea. Lake water will be used only in emergency. During operation generators will be inside room fitted with stack for higher dilution ration in the air. All kind of solid wastes will be stored for proper disposal out of Treaty area Treated and disinfected sewage will be stored in the tanks for disposal in mainland. Dilution and dispersion prediction study shows good dilution and dispersion of effluent during winter and summer periods.
Noise Quality Construction	Noise will be produced during helicopter flying, generators and vehicle movement. High noise will disturb the fauna of the area like breeding activity, migration and other biological activity	Local	Medium	Certain	B	During construction phase noise intensity will be of short duration. However, limited flying hours, silent generators and adequate construction method will mitigate noise levels and its duration.
Operation	Noise will be produced during ice breaking, helicopter flying, generators and vehicles. High noise will disturb the fauna of the area like breeding activity, migration and other biological activity	Local	Long	Certain	B	The ship will be berthed away for few days till it reaches near site to minimize the disturbance due to the noise. However since ship will be under idle stage while berthed near site nearly for 15 days to offload the material, noise produced will be low. The engines of helicopters will shut off at the site to minimize noise disturbance. The silent generators adhering to the USEPA and CPCB standards will be used to keep the noise levels at minimum.

Environmental Parameters / Indicator	Potential Impact from activities	Extent	Duration	Probability	Significance	Mitigation Measures
Oil Spill Construction	Decanting of fuel and refueling.	Local	Long	Low	B	Sorbent material will be available at site. Proper attention will be taken and high standards of valves, tanks and drums shall be used for storage of the fuel. Suitable platform to keep drums will be made and due care will be taken to follow gradient of land towards sea rather than lakes. .
Operation	Decanting of fuel and refueling.	Local	Long	Low	C	Sorbent material will be available at site. Proper attention will be taken and high standards of valves, tanks and drums shall be used for storage of fuel. Suitable platform to keep drums will be made and due care will be taken to follow gradient of land towards sea rather than lakes Oil spill contingency plan will help to combat any accidental spills.
Solid-waste Construction	Waste generated will be of different categories. If left unattended, it may be hazardous to the environment and have both short and long term effects.	Local	Medium	Low	B	All the packing material will be stored in boxes and back loaded to ship. Maintenance free batteries will be used
Operation	Waste generated inside the station will be of different categories. If left unattended, it may be hazardous to the environment and have both short and long term effects.	Local	Medium	Low	C	All the packing material will be stored in boxes and back loaded to ship. Maintenance free batteries will be used Comprehensive waste management plan will be enforced. A compactor will be used for reducing the volume of the solid non-combustible waste. Medical waste will be disposed as per the USEPA/CPCB Guidelines. Sludge obtained from the Biological wastewater treatment and other allied units will be dewatered through centrifuge. Solid sludge will be collected in drums, sealed and removed from the Treaty area.
Flora and Fauna	Bird hit by helicopter flying	Local	Very short	Low	A	The site does not fall under any observed migratory route of birds and the probability of bird hit is negligible.

Environmental Parameters / Indicator	Potential Impact from activities	Extent	Duration	Probability	Significance	Mitigation Measures
Construction	Alien species may be introduced from human clothing etc					It will be ensured that adequate cleaning and inspection of materials are done before sending these to Antarctica. ASMA guidelines and protective measures as mentioned in IP17 of XXXI-ATCM to prevent introduction of invasive alien species shall be followed.
Operation	Bird hit by helicopter flying Alien species may be introduced from human clothing etc	Local	Long	Medium	B	The site does not fall under any observed migratory route of birds and the probability of bird hit is negligible. It will be ensured that adequate cleaning and inspection of materials are done before sending these to Antarctica. ASMA guidelines and protective measures as mentiones in IP17 of XXXI-ATCM to prevent introduction of invasive alien species shall be followed.
Aesthetic and wilderness values Construction	Vehicle movement, and other construction activities will lead to loss of wilderness and aesthetic value	Local	Long	Certain	A	All the activities will be confined to defined areas. Removing the equipment and machinery after use will reduce the impact on wilderness value.
Operation	Emerged building, modules, platform, wind energy generators etc. will lead to loss of wilderness and aesthetic value	Local	Long	Certain	B	All the activities will be restricted to designated areas. Removing the equipment and machinery after use will reduce the impact on wilderness value. Building and modules will be removed when the useful life span is over. Wind turbine of smaller capacity will be preferred over larger capacity to reduce the impact value.
HSM,ASPA, ASMA (construction and Operation)	Present site falls under ASMA 6	Local	Long	Certain	A	No direct impact on the area, but the ASMA guidelines will be strictly followed.

ENVIRONMENTAL MONITORING

Published baseline data on Larsemann Hills as well as that generated during the course of the work at the site during the summer seasons of 2003-04 to 2009-10 have been used to establish the "footprint" of the station. A regular systematic monitoring program will be developed to integrate the work undertaken by other national agencies operating in the area. An environmental monitoring laboratory will be equipped with instruments like aethalometer, aerosol spectrometer, multistage impactor etc. for long term monitoring including physico chemical parameters of lake, marine and air environments. The environmental monitoring programme will establish close linkage between predicted and actual values during construction and operation of the station and facilitate devising mitigation measures that are needed to reduce the adverse impacts if any. All the workers and the occupants of the station will be given environmental training on the established guidelines. Following parameters (Table 28) are needed to be monitored with regard to environmental indicators:

TABLE 28: ENVIRONMENTAL MONITORING PARAMETERS

Environmental Indicators	Parameters	Duration
Air	Ambient Air Quality Monitoring for SO2, NOx, CO, ,PM10, carbon soot,	8 hourly, 24 hourly during Summer period (three points)
	Wind velocity, wind direction temperature, snow, humidity, cloud cover, rainfall, solar radiation, wind rose	Hourly average on yearly basis
Radiation	Radon level and Gamma counts in atmosphere, soil and rock	Monthly (4-5 points within 1 km radius)
Noise Quality	Ambient noise levels, day and night noise levels (L10, L50, L90),	During Summer (1 m from machines, 4 points on periphery of station 0.5 km radius)
Water Quality (Sea and Lake)	Physico-chemical analysis (conductivity, pH, color, TSS,TDS,TOC,DO,BOD,COD, Total hardness, Ca, Mg, Cu, Fe, Mn, Nitrate, Phenolics, Hg, Cd, Se, As, Cn, Pb, Zn, , Cr, Anionic Detergents, Polynuclear Aromatic Hydrocarbons, Mineral Oil, Alkalinity, Acidity, Organic Nitrogen, Phosphate, Sulfate, Chloride, Fluoride, Total coliform, Fecal coli form, phytoplankton and Zooplankton. Sediments (Grain Size, TOC, TIC, Cu, Pb, Zn, Cd, Hg, petroleum hydrocarbons, and PAH (benzo a-pyrine, benzo e-pyrine)	Once a month (from all the available sources minimum six places) during summer period

Environmental Indicators	Parameters	Duration
Land	Soil analysis (TOC, TIC, Cu, Pb, Zn, Cd, Hg, total petroleum hydrocarbon and PAH), grain size, type,erosion potential pre and post construction, permafrost layer depth	Once a year
Ecology of Marine and Lake system	Population size, breeding success, spatial extent, metals, alien species and distribution	Once a year
Station Monitoring	Stack emissions of station, frequency analysis of station generators and other machineries, fuel spill monitoring, actual station footprint, water balance, solid waste assessment, effluent discharge impact study, introduction of alien species	Once a year

Apart from the above-mentioned monitoring parameters, fuel spill monitoring from the fuel storage tank, supply vessel, and refueling into machinery and vehicle shall be carried out. Strict adherence to environmental protocol will be one of the prime responsibility during construction and operation of the station. Any fuel spill substantive in nature will be reported. Introduction of alien species will be avoided by taking necessary precautions. Routine visual inspection will be carried out as a part of the environmental monitoring.

GAPS IN KNOWLEDGE AND UNCERTAINTIES

The following gaps and uncertainties exist in the assessment of the environmental impacts of the construction and operation of the new Indian base in the Larsemann Hills:

- *Uncertainty of sea ice extent during the period January-March. However, recent experience has shown that ship can be berthed as close as 25 m to promontory.*
- *The exact berthing spot of the ship close to the landing site is not known.*
- *The CEE is based on the final design of the station, but there may be some last minute modifications based on the site requirements, practical difficulties etc.*
- *Impact matrix and evaluation have been done according to expert judgment, which are based on the predicted values, and are subjected to change depending on the environmental conditions.*
- *During the long life span of the station, the need-based scientific activities and the energy scenario may change with developments in technologies.*

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CONCLUSION

India is proposing to establish a scientific base at Grovnes promontory in the Larsemann Hills in order to expand the present research activities on a regional scale. A path has been laid from the landing area to the site to transport men and materials for preparing the site during the summer of 2009-10. The station design has been finalized and the actual construction is proposed in two phases, viz. Phase I during summer of 2010-11 and Phase II during summer of 2011-12. The final Comprehensive Environmental Evaluation (CEE) has been prepared so as to address all the relevant environmental issues related to the establishment of the station and suitable monitoring and mitigation measures to be adapted.

The construction and operation of the station at Grovnes promontory in the Larsemann Hills will have more than minor and transitory impacts on the Antarctic environment. Major impacts are expected on air, water, noise emissions and human footprints. Proper mitigation measures as described in the final CEE and their effective implementation will reduce environmental impacts (like use of CHP concept for heating the station and the renewable energy sources, low sulfur fossil fuel, optimization of vehicle movement, use of lake water for drinking in emergency situation, efficient treatment of effluents, bringing back hazardous and sanitary wastes to mainland for disposal etc.).

Establishment of the research base at this site will enhance the scientific efforts and scope for co-operation with neighboring stations.

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During the process of preparing the CEE guidance has been received from several quarters including following experts*

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ABBREVIATIONS and ACRONYMS

AAD	-	Australian Antarctic Division
AFPOS	-	Asian Forum of Polar Sciences
ALCI	-	Antarctic Logistics Centre International
ASMA	-	Antarctic Specially Managed Area
ASPA	-	Antarctica Specially Protected Area
ATCM	-	Antarctica Treaty Consultative Meeting
ATF	-	Aviation Turbine Fuel
ATS	-	Antarctic Treaty System
ATV	-	All Terrain Vehicle
BHC	-	Benzene Hexachloride
BOD	-	Biochemical Oxygen Demand
CEE	-	Comprehensive Environmental Evaluation
CEP	-	Committee for Environmental Protection
CFD	-	Computational Fluid Dynamics
cfu	-	Colony Forming Unit
CHP	-	Combined Head and Power
CO	-	Carbon Monoxide
COD	-	Chemical Oxygen Demand
COMNAP	-	Council of Managers of National Antarctic Programme
CPCB	–	Central Pollution Control Board
CTD	-	Conductivity, Temperature, Depth
DDT	-	Dichloro-Diphenyl Trichloroethane
DFM	-	Digital Fluxgate Magnetometer
DIM	-	Declination Inclination Magnetometer (DIM)
EIA	-	Environmental Impact Assessment

EMC	-	Electro Magnetic Compatibility
EU	-	European Union
GPS	-	Global Positioning System
GSI	-	Geological Survey of India
HSM	-	Historic Site and Monument
HVAC	-	Heat Ventilation and Air Conditioning
IEE	-	Initial Environmental Evaluation
IERS	-	International earth Rotation Service
IFO	-	Intermediate Fuel Oil
IP	-	Information Paper
ISC	-	International Seismological Centre, U.K.
ISCST	-	Industrial Source Complex Short Term
ISEA	-	Indian Scientific Expedition to Antarctica
ITRF	-	International Terrestrial Reference Frame
MARPOL 73/78	-	International Convention for the Prevention of Pollution from Ships 1973, as modified by the Protocol of 1978
MDO	-	Marine Diesel Oil
MEPC	-	Marine Environment Protection Committee
NCAOR	-	National Centre for Antarctic and Ocean Research
NMTOC	-	Non Methane Total Organic Compounds
NMVOC	-	Non methane volatile organic carbon
NOx	-	Nitrogen Oxides
OCM	-	Ocean Color Monitor
PCB	-	Polychlorinated Biphenyl
PM	-	Particulate Matter
PPM	-	Proton Precession Magnetometer
RO	-	Reverse Osmosis

ROSA	-	Radio Occultation Sounder for Atmosphere
RSPM	-	Respirable Suspended Particulate Matter
SCAR	-	Scientific Committee on Antarctica Research
SO_2	-	Sulfur dioxides
SPM	-	Suspended Particulate Matter
TEC	-	Total Electron Current
TOC	-	Total Organic Compounds
USEPA	-	United States Environmental Protection Agency
USGS	-	U.S. Geological Survey
UV	-	Ultraviolet
WEG	-	Wind Energy Generator
WMO	-	World Meteorological Organization
WP	-	Working Paper

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APPENDICES

Appendix I

Schedule of Area

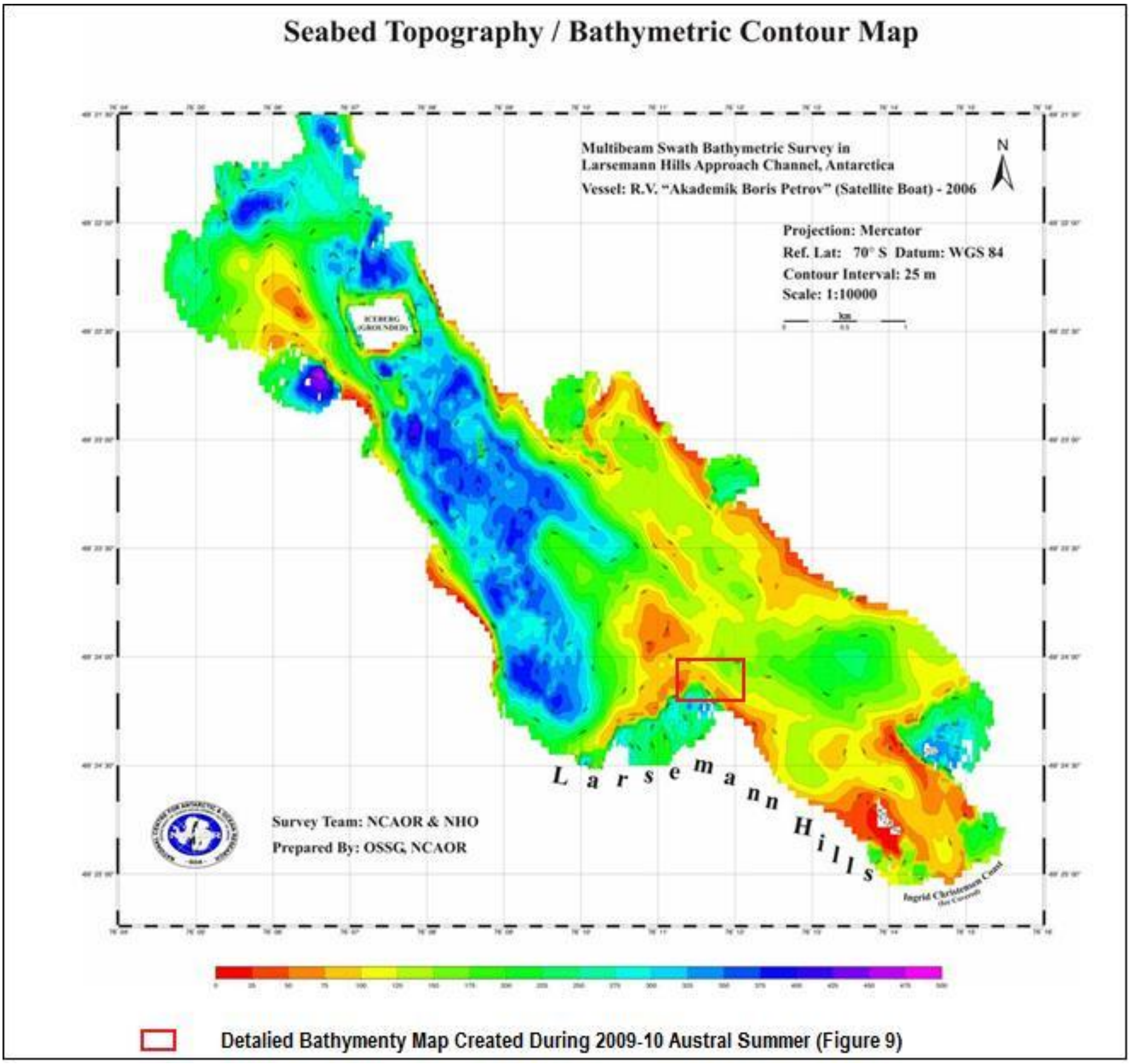
Number	Room	m2	sq.ft
1.1	Waste Water	41,7	503
1.2	Water Storage	27,4	331
1.3	Garage	80,5	972
1.4	Workshop	55,7	672
1.5	Generator Rooms	52,4	633
1.5e	fuel	13,1	158
1.6	Waste collection Room	27,4	331
1.7	Store Room	20,3	245
1.8	Store Room	12,8	155
1.9	Store Room	41,7	503
1.10	Store Room	27,4	331
1.11	Laboratory Meteorology	27,4	331
1.12	Laboratory Geomagnetism	27,4	331
1.13	Laboratory Seismic	27,4	331
1.14	Laboratory Biology	27,4	331
1.15	Laboratory Human Physiology	27,4	331
1.16	Laboratory Earth Science	27,4	331
1.17	Corridor	62,0	748
1.18	Vestibule	13,1	158
1.19	Vestibule	13,1	158
1.20	Change Room	6,1	74
1.21	Toilet	6,1	74
1.22	Staircase	42,0	507
Ground Floor and Level +1	**Total Area**	**707,20**	**8.537**
	Gross Floor Area	**860,00**	**10.381**

Number	Room	m2	sq.ft
2.1	Gymnasium	27,4	331
2.2	Medical Room	27,4	331
2.3	Medical Room	27,4	331
2.4	Computer Room	13,1	158
2.5	Computer Room	13,1	158
2.6	Dining Hall	84,8	1.024
2.7	Kitchen	27,4	331
2.8	Cold Store Room	26,2	316
2.9	Toilet	27,4	331
2.10	Sauna	13,1	158
2.11	Bathroom	27,4	331
2.12	Laundry	27,4	331
2.13	Store Room	13,1	158
2.14	Electric Appliance	26,2	316
2.15	Entertainment Room	84,8	1.024
2.16	Lounge & Bar	114,0	1.376
2.17	Library	27,4	331
2.18	Office	27,4	331
2.19	Communication	27,4	331
2.20	Prayer Room	13,1	158
2.21	Sleeping Room	13,1	158
2.22	Sleeping Room	13,1	158
2.23	Sleeping Room	13,1	158
2.24	Sleeping Room	13,1	158
2.25	Sleeping Room	13,1	158
2.26	Sleeping Room	13,1	158
2.27	Sleeping Room	13,1	158
2.28	Sleeping Room	13,1	158
2.29	Sleeping Room	13,1	158
2.30	Sleeping Room	13,1	158
2.31	Sleeping Room	13,1	158
2.32	Sleeping Room	13,1	158
2.33	Sleeping Room	13,1	158
2.34	Sleeping Room	27,4	331
2.35	Sleeping Room	13,1	158
2.36	Sleeping Room	13,1	158
2.37	Sleeping Room	13,1	158
2.38	Sleeping Room	13,1	158
2.39	Sleeping Room	13,1	158
2.40	Sleeping Room	13,1	158
2.41	Sleeping Room	13,1	158
2.42	Sleeping Room	13,1	158
2.43	Sleeping Room	13,1	158
2.44	Sleeping Room	13,1	158
2.45	Corridor	109,5	1.322
2.46	Staicase	37,5	453
2.47	Corridor	27,5	332
2.48	Corridor	109,5	1.322
Level + 2	**Total Area**	**1.288,20**	**15.550**
	Gross Floor Area	**1.555,00**	**18.771**

Number	Room	m2	sq.ft
3.1	Air condition	27,4	331
3.2	Air condition	27,4	331
3.3	Staircase	14,5	175
3.4	Vestibule	27,8	336
Roof level	**Total Area**	**97,10**	**1.172**
Roof level	**Gross Floor Area**	**150,00**	**1.811**

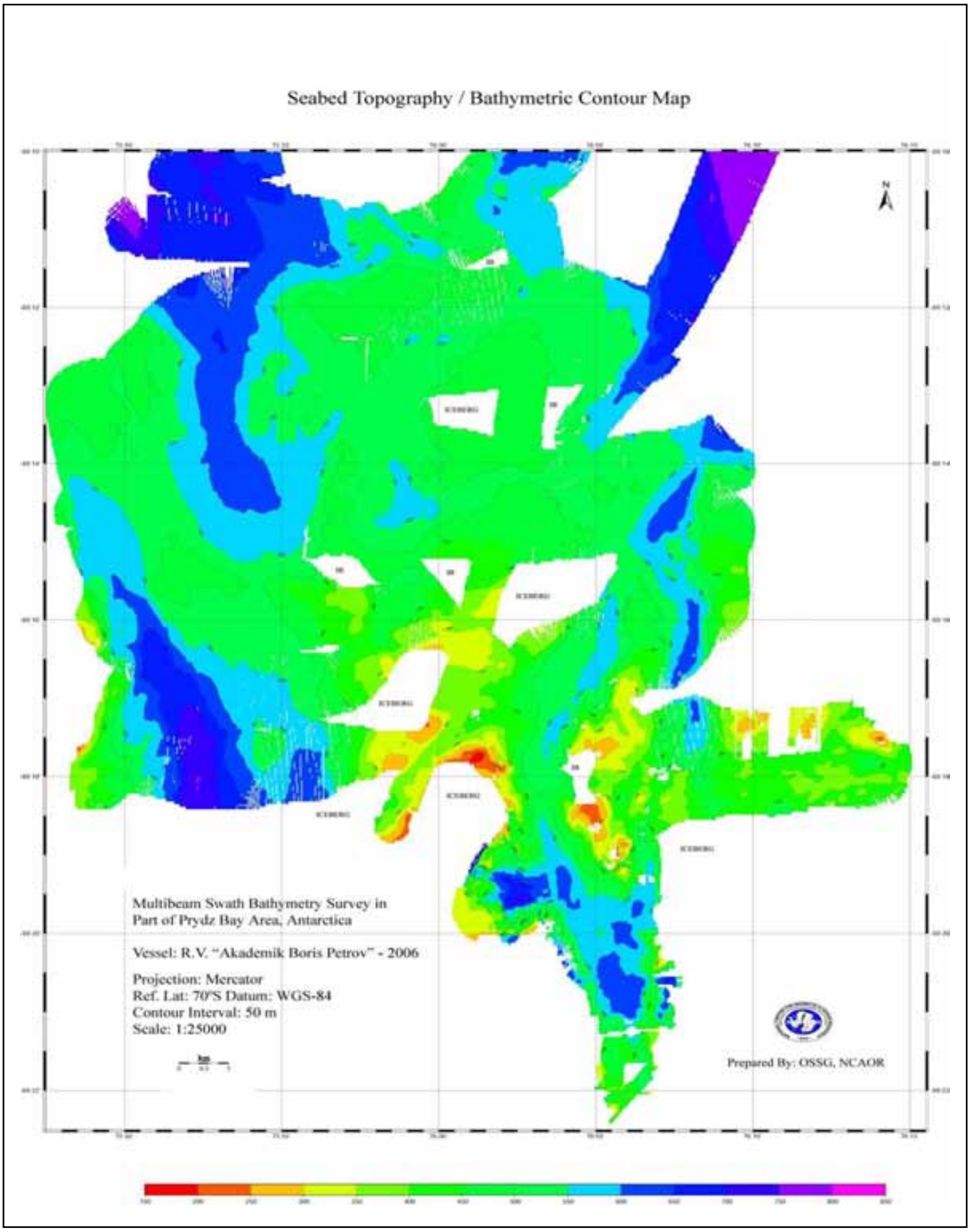
Total Area	**2.092,50**	**25.259**
Gross Floor Area	**2.565,00**	**30.963**

Appendix2



Multibeam Swath Bathymetry in Approach Channel

Appendix 3



Multibeam Swath Bathymetry in Other part of Prydz Bay

Appendix 4

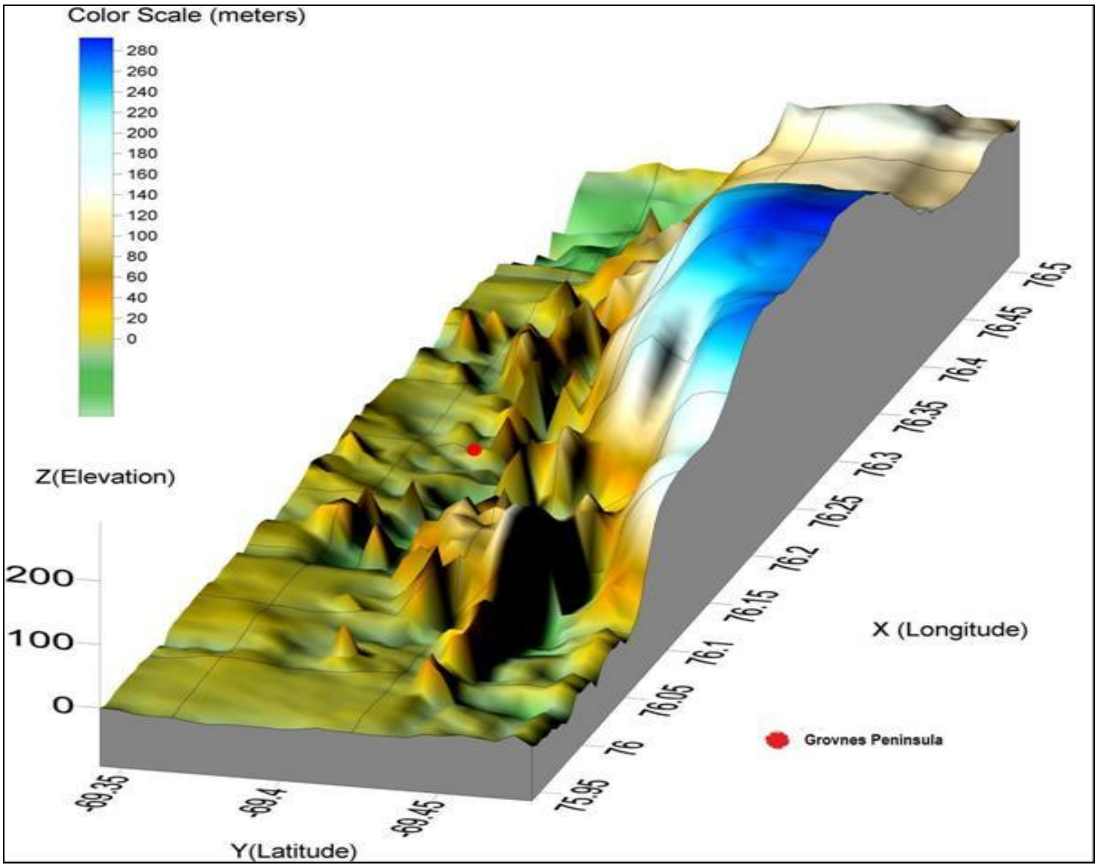
Task Force Composition

- *Rasik Ravindra :* *Task Force Leader, The Then, Director, Antarctica Division, Geological Survey of India, Faridabad, India*
- *Dr. S Rajan :* *Senior Scientist , National Centre of Antarctic & Ocean Research, Goa, India*
- *Ajay Dhar : Technical Officer, Indian Institute of Geomagnetism, Mumbai, India*
- *Dr. P. Malhotra :* *Chief Medical Officer, Central Government Health Services, Kolkata, India*

Appendix 5

A new DEM of Larsemann Hills area using synergistic use of satellite-derived laser altimetry (GLAS/ICESat) and Radarsat Antarctic Mapping Project (RAMP)

An enhanced digital elevation model (DEM) of the Larsemann Hills region, east Antarctica is generated synergistically by using highly accurate ground-based GPS measurements, satellite-derived laser altimetry (GLAS/ICESat) and Radarsat Antarctic Mapping Project (RAMP) DEM-based point elevation data. This is India's first attempt to generate a DEM of any part of Antarctica, which is essential to model the ice elevation change and address the ice mass balance. The DEM presented in this work a vertical accuracy approximately 1.5 times better than RAMP DEM and several times better than GLAS/ICESAT based DEM. Available DEMs of Antarctic region generated using radar altimetry and the Antarctic Digital database indicate elevation variations of up to hundreds of meters in the study area, which necessitated the generation of local DEM model and validation by using ground truth checking. The RAMP DEM heights were corrected using ICESAT/GLAS heights as ground-truth data, and the accuracy obtained after using ground survey is found to be better than that of existing DEM based on GLAS or RAMP alone. After using accurate GPS data as true Ground Control Points reference elevations, the approximation to the actual surface of the DEM extracted here is much more accurate (with least avg. RMSE of 34.49 m) than that of the DEM yielded by using ICESAT/GLAS and RAMP combined as true reference.



Combined use of ramp, glas/icesat and ground survey (gps) data to construct an accurate dem of the larsemann hills region

Appendix 6

Comments received on Draft CEE and responses to comments

Draft CEE was circulated to all Consultative Parties on 28th December 2006 through Diplomatic channel and it was informed that it is available for public review, at NCAOR website by accessing web link. Comments were received on Draft CEE from;

- *Australian Antarctic division, Department of Environment and Water Resources, Australia government*
- *Federal Environment Agency, German Antarctic Competent Authority*
- *Foreign and Common Wealth Office, UK*
- *Ministry of Foreign Affairs and Trade, New Zealand*

Responses to comments were submitted to XXX-ATCM at New Delhi (IP-139). Subsequently comments were incorporated in Final CEE. Responses to comments have been appended along with CEP advice to ATCM XXX on Draft CEE.

Australian Government

Department of the Environment and Water Resources
Australian Antarctic Division

Rasik Ravindra
Director, National Centre for Antarctic and Ocean Research
Head Land Sada
Vasco da Gama 403 804
India

Dear Rasik,

Thank you for the opportunity to comment on the draft Comprehensive Environmental Evaluation (CEE) "New Indian Research Base in Larsemann Hills, Antarctica".

As the lead agency for Australia's Antarctic program, the Australian Antarctic Division (AAD) of the Department of the Environment and Water Resources coordinated a review of the draft CEE within Australia. The document was made available to the public, to relevant government agencies, and to operational, scientific and environmental experts within the AAD.

We welcome India's proposal to undertake scientific activities in the East Antarctic region and provide the accompanying comments for consideration when preparing the final CEE.

In summary:

- Australia supports the plans to use low-impact approaches to the construction and operation of the proposed station, including complete removal of facilities on decommissioning, very low-emission treatment of organic waste, and the use of renewable energy sources. We note that detailed information on some aspects of station operations is currently unavailable, and encourage the inclusion of further details in the final CEE.

- The description of the initial environmental reference state provides limited information specific to the immediate surrounds of the proposed station site. Such baseline information is critical for accurate identification and verification of predicted impacts, and we suggest that additional information be included in the final CEE.

- We have highlighted issues that could be considered in the discussion of impact prediction and mitigation, and have suggested restructuring those sections to more directly illustrate the relationship between proposed mitigation measures and predicted impacts.

- As raised during discussions in the margins of the Antarctic Treaty Consultative Meetings (ATCMs) in Stockholm and Edinburgh, and the Council of Managers of National Antarctic Programs (COMNAP) meeting in Hobart, Australia has some concerns about the ability of resupply vessels to readily access the proposed station site. We note this matter is identified in the draft CEE as a gap in knowledge, and we have identified sources of archived satellite imagery that may provide a greater understanding of past sea ice conditions. I have requested Australian sea ice experts to provide advice on ice conditions in the region. I will contact you again if I receive information that may be useful for your deliberations.

- We note that the document does not appear to cover a number of matters that, under Article 3 of Annex I, must be addressed in a CEE, including: consideration of possible indirect impacts or second order impacts; consideration of cumulative impacts; identification of unavoidable impacts; and consideration of effects scientific research.

My staff would be pleased to provide further clarification if required – please direct any queries to Mr Ewan McIvor, Senior Environmental Policy Officer (ewan.mcivor@aad.gov.au, +61 3 6232 3413).

I look forward to seeing you in New Delhi next month for the Antarctic Treaty Consultative Meeting, and trust that your preparations are proceeding smoothly.

Yours sincerely,

AJ Press
Director, Australian Antarctic Division

19 March 2007

Comments Received from Australia to Include Information in Final CEE

Section	Comment	Response addressed in Final CEE
Non-technical summary		
Introduction	1. The Introduction states that the CEE is for the "establishment" of a base, but should also indicate that it covers the proposed operations at the base for a period of approximately 25 years. We suggest including the statement of scope given in paragraph 1 of Section 2.3.	Included. Sea Para after section 1.1.7
	2. If construction of the station is to commence in the summer following "approval" by the ATCM, it is not clear when the additional information on "the gap areas" will be collected. It would be important to address some of the uncertainties identified in Section 9 before station construction commences.	Included. Sea section 2.6, 3.1, 3.2, 3.3.2, 3.7, 3.9.1, 4.5, 5.8-5.12. Detailed topographical survey (1:5000) of Grovnes promontory prepared by Survey of India is also appended.
Site selection and alternatives	3. As the Non-technical summary may be the only part of the document available in all official languages, and because a CEE is primarily an evaluation of the environmental aspects of the proposed activity, it would be appropriate to specify here the "various environmental factors" considered when selecting the proposed location in addition to the logistical factors (flat terrain etc).	Include, main environmental factors considered for selection of proposed location, in Non Technical Summary, under heading Site Selection and Alternatives
	4. The statements about "ease of cargo operations" and "open sea approach to the site" conflict with statements elsewhere in the document about the sea ice conditions (Sections 5.6.1, 5.6.5) and gaps in knowledge regarding sea ice extent (Section 9).	Recent experience during austral summer 2009-10 has proven that berthing of ship possible close to promontory. See section 2.6 and 5.5.1
Description of the area and environment	5. This description includes only two sentences to describe the promontory on which it is proposed to locate the station. We feel this is not adequate, because this is the only description of the initial environmental reference state available to some readers and does not give sufficient detail to support an informed judgment about the likely environmental impacts of the proposed activity.	Included additional baseline summary in this section
	6. The statement "Lakes present in the Larsemann Hills are mostly saline in nature" is incorrect. Gillieson et al. 1990 states the lakes are mostly fresh water, with a few brackish lakes near the coast. It also conflicts with statements elsewhere in the CEE (e.g. Section 5 "There are over 150 freshwater lakes in the Larsemann Hills…")	Correction is incorporated in this section
Impact assessment and mitigation measures	7. The list of "main environmental disturbances" should also include contamination of lakes.	Suggestion incorporated in this section as well as in section 6.2.4
1. Introduction		
1.2 Planned Scientific activities at the new base	8. We welcome NCAOR's scientific interest in the Larsemann Hills, Prydz Bay and East Antarctica. The AAD conducts and supports a range of research in these areas and invites India to discuss opportunities to maximise cooperation and minimise duplication of effort and infrastructure, particularly in relation to atmospheric studies.	Collaborative projects are always welcome. India is also keen to have bilateral/multinational

Section	Comment	Response addressed in Final CEE
		collaboration on the scientific projects to be undertaken in Prydz area with other neighboring nations
2. Description and Need of the Proposed Activity	9. Sections 2 and 3 of the draft CEE provide an adequate general summary of the proposed activity, although we note that detailed information is lacking for some aspects of the station's construction and operation, which are in the preliminary design stage – specific examples are given below. To the extent that it is known, such further information should be provided at the earliest opportunity, and included in the final CEE, as that will greatly assist with the identification and mitigation of potential environmental impacts.	Section 2 and 3 have been updated based on final design of station
2.1 Need for the station	10. It is unclear why research cruises in the Antarctic-Southern Ocean sector of the Indian Ocean require the establishment of a land-based station. If there is no connection, this paragraph should be removed from the section "Need for the station".	As suggested this particular paragraph is separated. See section 2.2
	11. The dot points listed in this section (auroral zone, magnetic field lines, earth station, Lambert Graben) outline broader regional – not site-specific – scientific and logistical drivers for the proposed site; it would be more accurate to introduce them as such.	Suggestion incorporated. See section 2.1
2.4.1 Living accommodation	12. The ratio of support staff to scientific staff is an important aspect of the operational efficiency of an Antarctic station and can be used as a measure of the environmental efficiency of a station. In the final CEE it would be helpful to provide a break-down of the functions of station personnel during the summer and winter seasons.	See section 2.5.1
2.4.2 Laboratories	13. The early establishment of a laboratory to monitor environmental change during station construction is a good idea.	Noted
	14. It is not clear whether meteorology, astronomy, geomagnetism and seismology laboratories would be co-located in a single building or in separate buildings.	See section 2.5.2
2.4.6 Waste Management; 2.4.7 Water Management; 2.4.8 Energy Management; 2.7 Installation of Wind Turbines and Solar Panels	15. Australia supports the plans to minimise environmental impact due to waste generation, to utilise grey water for supplementing water requirements for toilets, and to supplement the station power supply with renewable energy sources.	Noted
2.5.2 Transportation and movement	16. It is not clear how personnel and cargo would be transported from the Russian airstrip to the promontory (if that option was used). Ground access between the promontory and the ice plateau would be extremely difficult. Similarly, it is not clear how large equipment would be brought ashore if the wharf area is not ice-free.	See section 2.6.2
2.6 Construction of station	17. This section states that station construction is proposed to commence in the "austral summer of 2008" but it is not clear whether this means the southern hemisphere summer of 2007/08 or 2008/09.	See section 2.7
3. Station Design		

Section	Comment	Response addressed in Final CEE
3.1 Station Design	18. We note that the station design and layout incorporates measures to minimise footprint. In the final CEE it would be useful to provide a single diagram that combines the information separately illustrated in parts (a) and (b) of Figure 6, and that clearly indicates the location of all facilities referenced in the text. Also, parts (c) (e) of Figure 6 require captions.	See section 3.9.1 and figure 27
3.3.2 Energy supply	19. Specific details on the number and type of wind turbines and solar panels are not given. We recognise these details would likely be determined at a future date once the actual load profile for the station is known. However, to support the statement in the Non-technical summary that “Emphasis will be on use of alternative energy to reduce the fossil fuel consumption” India may wish to consider specifying a target for the amount of renewable energy in the station’s energy mix.	See section 2.8 and 3.10
3.3.4 Water and wastewater management	20. Several information gaps relating to water management prevent the reader from gaining a full understanding of likely environmental impacts and should be addressed when producing the final CEE: − which particular lake or lakes will be used as the potable water source? − will annual snow melt be sufficient to recharge this lake (or lakes)? − what is the expected volume and proportion of water to be sourced from the lake(s) / treated seawater?.	See section 2.5.7 and 3.7
	21. This section refers to “desired effluent standards”. As no standards are prescribed under the Protocol, other than maceration, it would be appropriate to indicate what standards would be applied	See section 2.5.6 and Table 1
3.5 Emission abatement in station design; 3.6 Decommissioning	22. We support the plans to minimise construction waste by installing prefabricated modules that can completely removed on decommissioning, and to use practical water and energy saving devices and systems. It would also be interesting to learn more about the “eco-friendly material” to be used for insulating the buildings.	See section 3.2.1, 3.2.2, 3.3, 3.3.1, 3.3.2, 3.4, 3.5 and 3.8
4. Alternatives to Proposed Activity	23. The discussion of alternatives provides considerable information about several unsuitable locations in the Prydz Bay region. However, the discussion of alternatives should also address other aspects of the proposed activity. Examples include: − the use of existing / temporary / smaller facilities; − alternative methods for sourcing potable water (see comments above); and − alternative designs for the station itself.	See section 2.5.7, 3.7, 4.5 and 4.6
	24. Regarding the last point above, the document indicates (on page 2) that the chosen conceptual design was selected from 32 design proposals. In the final CEE it would be very informative to summarise the environmental and other criteria used for the selection process and the reasons why the particular design was chosen.	See section 4.6
4.3.1 Broknes Peninsula	25. The discussion of alternative locations, particularly on Broknes, does not refer to the draft Antarctic Specially Managed Area (ASMA) management plan for the Larsemann Hills, which defines a Facilities Zone on Broknes where new infrastructure is to be preferentially located, and which includes management objectives for minimising disturbance. On the points raised against locating the proposed station at Broknes, we note: − Point 2: Drinking water is also scarce on the promontory in question, and the proposed method of supplementing potable water supply by treating seawater could also be used at a station established on Broknes. − Point 3. The presence of scientific observatories on Broknes could possibly diminish the case for doing similar research at a separate location nearby. − Point 4. Ease of access by ship to the promontory in question has also been identified as a gap in knowledge (Section 9) and the document states that some effort will be required to carve out a flat area for off-loading cargo (Section 2.2).	See section 4.3.1

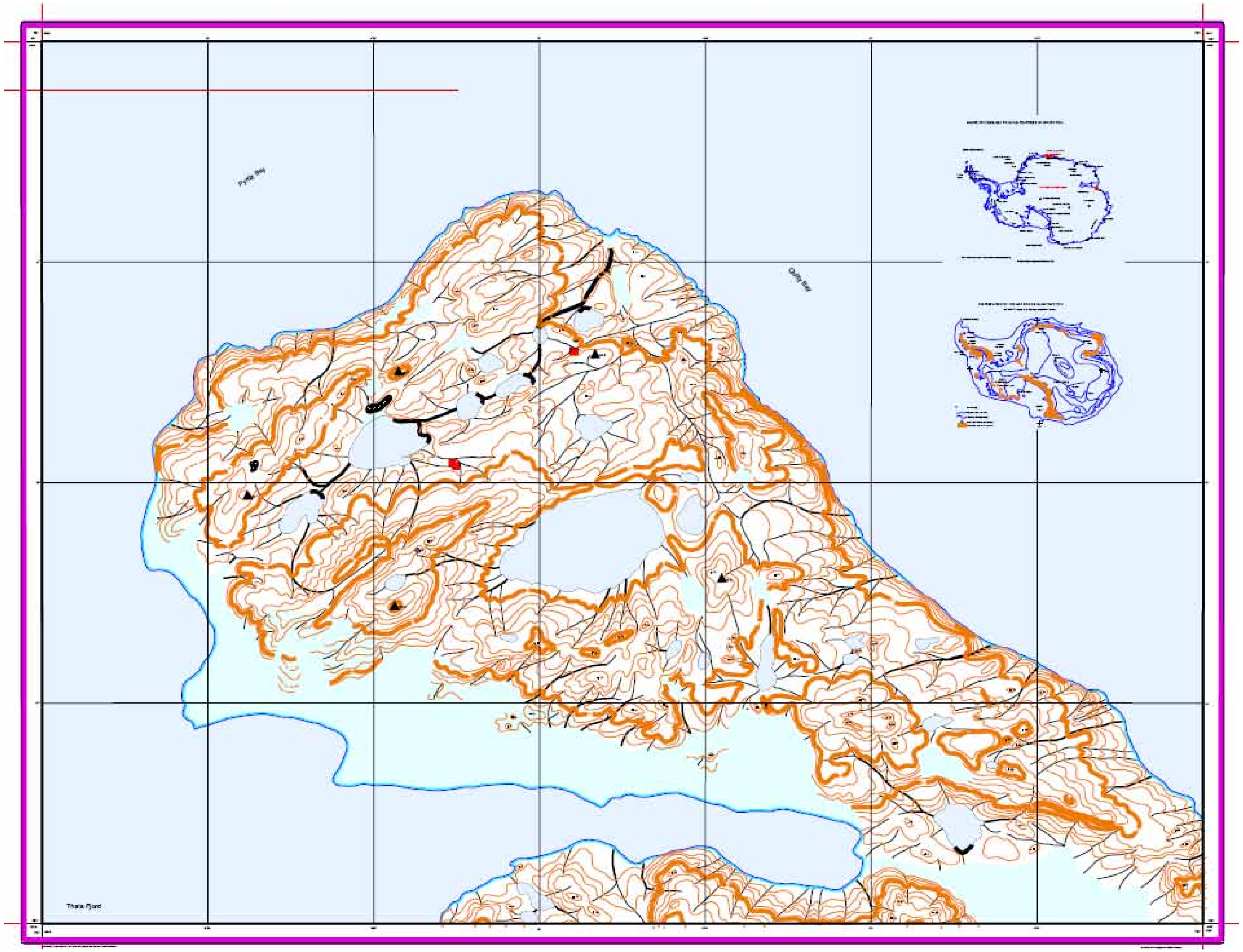
Section	Comment	Response addressed in Final CEE
4.4 Alternative transport to the station	26. This section states that there are no penguin or bird colonies in the proposed flight corridor, but it does not indicate the location of the flight corridor (a map would be helpful) and does not refer to studies that confirm the absence of flying birds or other animals within the recommended approach distances (see Guidelines for the Operation of Aircraft Near Concentrations of Birds in Antarctica).	See section 4.4 and figure 31
	27. This section also notes that opportunities for shared shipping would be explored after station construction is complete. We note that consultation with Parties active in the area during the planning and construction phases would also be worthwhile. The AAD would be interested to discuss collaborative logistics with NCAOR.	See section 4.4. India will look forward to share the ship during construction phase also.
4.5 Alternative of not proceeding	28. This section states that consideration was given to the possibility of carrying out the proposed research from existing stations in the Larsemann Hills or that region. It would be valuable for the final CEE to include a summary of the main points addressed in the deliberations on which the conclusion was drawn.	See section 4.7
	29. This section mentions the establishment of an earth station for the OCEANSAT II satellite, but the location of the structure is not referred to elsewhere in the document.	See figure 27
5. Initial Environmental Reference	30. Other than the description of the geology given in Section 5.2.2 and Figure 19, and the information on lake water characteristics given in Section 5.7.1.1, detailed information about the environmental condition of the promontory is limited. If such baseline information is not available, further field studies may be useful to obtain reliable data about the state of the environment before beginning the activity.	See section 5.8, 5.9, 5.10, 5.11 and 5.12
	31. Section 5 does not describe the marine environment potentially impacted by the activity, including the near shore marine and coastal environment that may be affected by disposal of treated station waste. Because treated waste water will be discharged to the sea, it would be important to state whether the receiving marine environment is likely to provide "initial dilution and rapid dispersal" as required by Article 5 of Annex III.	See Table 9 and section 6.3.4
5.1 Location	32. The statement that "currents break the fast ice during early summer" conflicts with statements elsewhere in the document (e.g. 5.6.1, 5.6.5) and with our understanding of past ice conditions, outlined in Section 4.5 of the draft ASMA management plan.	Correction incorporated
	33. Figure 18 should be amended to accurately show the proposed station site (it currently points to a location in Thala Fjord).	Corrected. See figure 35
5.2.2 Geology at the proposed station site	34. Including information in the final CEE about the location and characteristics of soils on the promontory, would be helpful as this would inform the siting of structures, particularly fuel tanks and fuel lines (preferably on hard rock).	See section 5.10 and Table 13
5.5 Lake water characteristics	35. Because the lakes of the Larsemann Hills are a major value of the area (as identified in the draft Larsemann Hills ASMA management plan), we feel that additional information on the lakes of the promontory would assist with clearly establishing the initial environmental reference state. Noting India's intentions to draw potable water from one or more lakes, additional information might include lake volume, catchment size, and information about freshwater flora and fauna.	See section 5.8 and Table 7, 8 and 9
5.7 Anthropogenic impact – background information	36. The information given for lakes on Broknes is not relevant to the initial environmental reference state at the proposed station location.	The information was provided to give a holistic picture of the Larsemann Hills area.

Section	Comment	Response addressed in Final CEE
	37. This section should describe any anthropogenic modification to date at the promontory and other areas potentially impacted by the proposed activity to date.	There has been negligible anthropogenic activity in the promontory so far. See section 5.8.1 and 5.8.2
5.7.1 Baseline monitoring information	38. The whole statement of Initial Environmental Reference comprises the pre-activity baseline, so we suggest removing Section 5.7.1 and incorporating the information in Section 5.7.1.1 Water Quality into Section 5.5 Lake Water Characteristics.	See section 5.8. The baseline information collected during the austral summer of 2006 to 2010 included, so, consequently shifting of section may not be required.
5.8 Flora and fauna	39. This section indicates that extensive surveys of flora and fauna have been carried out in the "area", but the information given is largely drawn directly from the draft Larsemann Hills ASMA management plan and describes generally the flora and fauna of the Larsemann Hills region. No specific information is given on the terrestrial, freshwater or marine flora and fauna at or near the promontory.	See section 5.9
6. Identification and Prediction of Impacts	40. Indirect impacts are not explicitly covered in the document. Also, the document refers to several potential impacts on "the site", but the evaluation should also address potential impacts beyond the promontory. If no indirect or second-order impacts are expected, this should be stated in the document	See section 6.2.3, 6.2.4.2 and 6.3.4.1
	41. The only mention of cumulative impacts is in Section 7.2, which indicates that cumulative impacts from air emissions will be controlled through management of machinery and equipment. In the 25 year lifetime of the proposed station, some cumulativT¬impacts of ongoing activities would reasonably be expected, although the significance of these impacts may vary. For example, cumulative impacts may include: contamination of soil and water from fuel spills; air emissions from vehicles, generators and waste incineration; physical disturbance from vehicle use; modification of the near shore marine ecosystem from wastewater discharge. Further, the document should describe the potential for impacts due to overlapping research and operations in areas of the Larsemann Hills also accessed – or likely to be accessed – by other operators. Addressing cumulative impacts is important for all CEEs and, particularly for major activities proposed in the Larsemann Hills, given that minimising cumulative impacts is a main objective of the proposed ASMA.	See section 6.2, 6.2.2, 6.2.2.5, 6.2.3, 6.2.4.2, 6.2.5, 6.2.8, 6.3.1, 6.3.3, 6.3.4, 6.3.4.4 and 6.3.6.1 The impact due to other operator and collaborative research in future can not be defined and addressed at this stage.
	42. The document does not explicitly refer to unavoidable impacts.	See section and 6.3.9
6.1 Methods and data used for prediction of impacts	43. As indicated above, the description of initial environmental reference state lacks detailed information on some aspects, including: soil characteristics, terrestrial flora, freshwater flora and fauna, and the near shore marine environment. See also comments below on the Impact Matrix	See section 5.9and Table 7, 8 and 9, 5.10 and Table 13
6.2.1 Physical disturbance	44. This section should expand on plans to "carve out" an area near the shore for off-loading cargo (Section 2.2) and discuss the resulting physical impacts. The impacts to lakes and lake catchments from the 800 m access pathway should also be discussed.	See section 6.2.1. Jetty will not constructed however only small berthing place is defined
6.3.3 Impact on	45. The impact matrix identifies additional potential impacts on water quality that should also be discussed in detail	See section 6.2.4 and 6.3.4

Section	Comment	Response addressed in Final CEE
water quality	here: contamination of the marine environment from ship discharges; contamination of lakes from solid waste and particulates/emissions; reduction of lake levels; contamination from leakage of discharge pipes; waste water discharge into the sea	
	46. This section should explain how much of the 2.6m3 of water per day will be drawn from the lake(s), how much drawn from the sea, and what effects on water quality and freshwater flora and fauna are expected.	See section 2.5.7 and 6.3.4
6.3.6 Fuel spill	47. This section should describe the predicted environmental impacts if fuel spills were to occur, including during ship to shore transfer (e.g. to lake water quality, marine flora and fauna, freshwater flora and fauna, soil quality).	See section 6.3.4.4
Impact Matrix	48. Suggest removing the term “land” from the description of significance categories (e.g. “not injurious to land”) – the assessment should consider all predicted “environmental” impacts.	Suggestion incorporated, see section 6.4
	49. There is no clear progression in the significance ratings, which state: A – insignificant low impact, B – measurable impact, C – high impact, D – impact, but considered good (?), E – detrimental impact. Suggest referring to the significance ratings used by the United Kingdom in the CEE for Halley VI, or a suitable environmental risk assessment standard.	Suggestion incorporated, see section 6.4
7. Mitigation Measures	50. It would assist the reader to understand the connection between the proposed mitigation measures and the predicted environmental impacts if the document was restructured to combine the detailed discussion separately contained in Section 6 Identification and Prediction of Impacts and Section 7 Mitigation Measures. Good examples of this approach are available in Section 5 of the Belgian Station CEE or Sections 6.2 and 6.3 of the Halley VI CEE.	Both the sections combined in section 6
7.1 Physical disturbance	51. Australia supports the intentions to minimise physical disturbance by predefining access areas and by installing structures in a way that will allow for their complete removal. Will that approach be possible for all facilities, such as helipads and foundations for wind turbines?	Final design has the provisions to remove at the time of dismantling. Self anchoring plates (Steel) that can be easily removed will be used for helipads. WEG will be anchored on rocks not on concrete foundation. However complete removal for example GEWI piles is not visualized
	52. It is not clear how the waste water discharge pipeline will avoid lake catchments when the proposed station site is surrounded by lakes. A diagram indicating the proposed orientation of the wastewater pipeline and pipelines for fuel would assist.	See figure 7 and section 3.5
7.2.1 Supply ship	53. This section states that the supply ship will be berthed far from the site, which conflicts with 6.2.2.1 which says that it will be near the site, and with Section 9 which lists the berthing location an uncertainty.	See section 6.2.2.1.As would be appreciated ships exact berthing in an open sea is never at an exact spot.
7.2.2 Helicopter	54. This section states that the helicopter landing site will be far away from the lakes but Figure 6 suggests that the helipad will only be around 100m, and generally upwind, from the small lakes.	In final design concern is given due consideration and location is

Section	Comment	Response addressed in Final CEE
		changed see figure 7
7.2.4 Generators	55. Australia notes that generators will be fitted with a particulate arrester and that station personnel will be trained in energy saving practices. This section could also highlight the proponent's intentions to use renewable energy sources (wind turbines and solar panels) to reduce fuel use and emissions.	See section 6.3.2.3
	56. Heating the water pipes only during intake and discharge operations will require the pipes to be purged after each use, otherwise the pipes are likely to split when they freeze.	See section 3.5
7.3.2 Water quality at site	57. This section should describe the controls that would be put in place to avoid disturbance to, and contamination of, lakes and lake catchments (e.g. arising from physical disturbance and sediment run-off, oil spills etc).	See section 6.2.4 and 6.3.4
	58. Drawing all water from the ocean would avoid direct impacting the lakes, and may be necessary for much of the year when the lakes are frozen (Section 5.5). As a potential lower-impact approach, the final CEE could usefully discuss this option.	See section 2.5.7 and 3.7
	59. This section states that the potable water supply will be supplemented by treating seawater with ultra filtration. Research by the AAD into water supply options for Davis station indicated that ultrafiltration would not treat seawater to a potable standard – the AAD would be happy to share this information. Instead, a reverse osmosis plant will be installed at Davis. The final CEE should detail proposed arrangements for disposal of the highly saline by-product of seawater treatment and for bulk storage of potable water.	Correction incorporated. See section 6.3.4.1
7.5 Impact of oil spill	60. Australia supports the intentions to provide spill recovery materials, to implement an oil spill contingency plan at the station, and to store fuel outside lake catchments. As fuel / oil spills have the potential to result in major impacts on the terrestrial, freshwater and marine environment at the proposed site, it would be appropriate to summarise the provisions of the oil spill contingency plan in the final CEE or to make that document available for reference.	See section 6.3.4.4
	61. We note that ATF will be stored in double-skinned tanks, in accordance with Resolution 3(2005), but the document does not describe measures to manage the risk of fuel spills when transferring bulk fuel from ship to shore.	See section 6.3.4.4
7.6 Impact of other waste	62. Australia supports the proposed general waste measures, although we note that little specific details are given. As with the oil spill contingency plan, it would be appropriate to include a summary of the "comprehensive waste management plan" or to make the plan available for reference	Summary of comprehensive waste management plan shall be articulated as suggested, during operational stage of station
	63. We particularly support India's plans to use a very low-emission method (plasma pyrolysis) to treat organic wastes. AAD previously investigated this technology and found it to be very expensive and energy intensive, so we would be interested to learn more about the approach India has identified as feasible for an Antarctic station. Such information would be very useful information for other Treaty Parties and may warrant presentation in an Information Paper.	See section 6.3.4.3
7.7 Impact on flora and fauna	64. This section provides little information on measures to prevent or minimise impacts on terrestrial, freshwater and marine flora and fauna. For example, there is no discussion of: impacts on lake flora and fauna from water use, emissions, or sedimentation; mitigating bird strike on wind turbines, guy wires.	See section 6.2.4, 6.2.5, 6.3.4 and 6.3.5, Table 26 and 27

Section	Comment	Response addressed in Final CEE
	65. We strongly support the plans to prevent introduction of alien species, including through treatment of food and packaging. Introduced plant species have been shown to survive in the Larsemann Hills (Section 5.8.1) and could have a regional impact, so we would encourage the cleaning and inspection of all cargo to be brought ashore.	Noted
7.8 Impacts on scientific activities	66. Other than local electromagnetic effects on the proposed station laboratories, there is no discussion of the effects of the proposed activity on the conduct of scientific research. In particular, there is no discussion of effects on potential future research on the lakes or geological features of the un-named promontory. The final CEE should identify such impacts or state that none are expected.	See section 6.3.7
8. Environmental Monitoring	67. In addition to the environmental monitoring parameters identified in this section, data relating to the operation of the station should also be monitored to verify predicted impacts. As well as fuel spill monitoring (page 70), environmental monitoring could include other parameters such as: actual station footprint (area modified through installation of structures, access ways); fuel use in generators, station vehicles and aircraft; total water use and amount of water drawn from lakes; person days on station; amount of treated liquid waste discharged into the marine environment; monitoring for introduced species; amount and types of solid waste treated on station and removed from the Antarctic Treaty area.	See Table 28
9. Gaps in Knowledge and Uncertainties	68. As indicated above, the initial environmental reference statement lacks detailed information on some aspects of the proposed station site and other areas accessed during the proposed operations. It would be preferable for the final CEE to provide such details, but if no further information is available this should be clearly identified as a gap in knowledge.	See section 5.8-5.12
	69. Regarding the uncertainty of sea ice extent, several AAD staff and other Australian Antarctic program researchers with past experience in the Larsemann Hills were very surprised that ice conditions allowed the Indian research vessel to approach close to the promontory in question. As indicated in the sea ice atlas provided to Indian representatives at the ATCM in Stockholm, and as described in scientific literature about the Larsemann Hills, it is usual for sea ice to remain in the fjords year round. There are a number of sources of archived satellite imagery that may provide a greater understanding of past sea ice conditions in the region, including DigitalGlobe (www.digitalglobe.com), Landsat (http://edcsns17.cr.usgs.gov/EarthExplorer/), SPOT (http://www.spotimage.fr), GeoEye (http://www.geoeye.com/), NOAA (http://www.natice.noaa.gov/) and National Snow and Ice Data Center (http://www.nsidc.org). Also, the AAD website provides links to low resolution imagery from the Sea Ice Atlas at http://aadc-maps.aad.gov.au/aadc/satellite/.	Information provided by AAD was quite useful, however for latest update see section 2.6
Appendix 1	70. This table indicates that external laboratories would only be heated for 6-8 hours per day, which may not be sufficient if these laboratories contain sensitive equipment.	In final design suggestions were incorporated



Detailed topographical survey (1:5000) of Grovnes promontory prepared by Survey of India

Comments by the Federal Environment Agency, German Antarctic competent authority

Preliminary Remarks

The National Centre for Antarctic and Ocean Research (NCAOR), an institution under the authority of the Ministry of Earth Science, Government of India, is planning to establish and operate a new research station in Larsemann Hills in East Antarctica. For this purpose India is carrying out an Environmental Impact Assessment (EIA) pursuant to Art. 8 and Annex 1 Art. 3 (3) of the Protocol of Environmental Protection (EP) to the Antarctic Treaty.

The first draft of an associated Comprehensive Environmental Evaluation (Draft CEE) was made available to all Parties to the Antarctic Treaty to give them the opportunity to comment on it.

The Federal Environment Agency has submitted the Draft CEE for public examination in accordance with Art. 16 paras. 1 and 2 of the German Act Implementing the Protocol of Environmental Protection to the Antarctic Treaty of 4 October 1991 (AIEP). It has also passed the document on to the authorities whose areas of responsibility are affected, and to the Alfred Wegener Institute for Polar and Marine Research. The Commission of independent scientific experts pursuant to Art. 6 AIEP has also provided comments.

The opinion which the Federal Environment Agency presents below takes into account all relevant comments and objections made by the above mentionend parties.

Evaluation

The Draft CEE deals with the construction, operation and dismantling of the planned “new Indian base at Larsemann Hills, Antarctica”. Having examined the document, we find that its configuration is formally in accordance with Annex I to the Protocol of Environmental Protection to the Antarctic Treaty (Cohen, 2002) and the Guidelines for Environmental Impact Assessment in Antarctica (Annex 7 to Resolution 4, XXVIII ATCM, 2005). However, there are some substantive points that would require further clarification. It should be taken into account here that the Draft CEE presented has been prepared at the beginning of the EIA and that therefore its contents generally require revision or extension. The following sections in particular should be supplemented or further specified: 2.4 – 2.8, 3.3 – 3.5, 4.3, 5.7 – 5.9, 6.3, 7, 8. and 10.

Comments Received from Germany to Include Information in Final CEE

Section	Comment	Response addressed in Final CEE
Need for the Station	NCAOR has been operating the "Maitri" station on the Schirmacher oasis since 1988. The Draft CEE contains no information on the lifetime of this station. Clarification is required with respect to the parallel operation of this station and the new station at Larsemann Hills. For environmental protection reasons, such a transitional situation cannot be maintained indefinitely.	See section 1.1.2, 2.1 and 2.9
Building materials used in station construction	The description of what construction materials would be used should be somewhat more specific so as to ensure that no material banned under the EP will be used.	See section 3.2, 3.3, 3.4, 3.5 and 3.8
Waste management	The management of solid, liquid and gaseous waste materials would follow the extended Antarctic Treaty guidelines and meet international standards. To avoid different and uncontrolled waste management strategies resulting from the operation of a total of four stations, one should consider to develop a management plan for treatment of waste, particularly greywater and solid waste, for the entire region.	See section 4.3.1 and 6.2.5 The proposed base is far from the other stations to have a practical common waste treatment facility.
Oil pollution	More information is required on how oil leakage is to be avoided. How and where would double-walled tanks and collecting basins be installed and how would oil depots be secured?	See section 3.4, 6.2.4.2 and 6.3.4.4
Site selection	The basis for site selection (data used, decision-making criteria, studies yet to be performed) should be described in greater detail, particularly the pros and cons of alternatives in Larsemann Hills described in section 4.3. For example, geographic proximity to the Law-Racovita, Progress II and Zhongshan research stations is an aspect that would be very much welcomed. Apart from logistic and safety-relevant advantages, a clustering of the stations would limit the influence on so far undisturbed wilderness areas considerably. According to Article 3 (b) (vi) of the Environmental Protocol, activities in the Antarctic Treaty area shall be planned and conducted as to avoid degradation of, or substantial risk to, areas of biological, aesthetic or wilderness significance. A clustering of the stations would thus have the advantage that the other parts of the ice-free Larsemann Hills area would remain free of long-term human influences. Furthermore, site selection and planning of logistics and other activities should be in accordance with the initiative for an ASMA (ref. WP 008 CEP IX).	See section 4.3, 4.3.1, 4.3.2 and 4.7
Flora and fauna	Systematic studies near the site were apparently not performed for preparation of the Draft CEE. The document merely cites findings and studies realised further away (e.g. Broknes Peninsula, 8 km away), some dating back 15 years, and applies them in part to the proposed site. In order to assess the potential impact which the construction of the station would have on the local flora and fauna, the current situation must be analysed. This is all the more important as the proposed Indian research programme also includes biological investigations.	See section 5.8, 5.9, 5.10 ,5.11 and 5.12
Summary	Having examined the Draft CEE, we find that its structure is formally in accordance with Annex I to the Protocol of Environmental Protection to the Antarctic Treaty (Cohen, 2002) and the Guidelines for Environmental Impact Assessment in Antarctica (Annex 7 to Resolution 4, XXVIII ATCM, 2005). In terms of contents, the Draft CEE still needs further completions or revisions. This concerns, in particular, sections 2.4 - 2.8., 3.3 - 3.5, 4.3, 5.7 - 5.9, 6.3, 7., 8. and 10. It is, in particular, desirable that site selection be reviewed in detail, especially the decision on a suitable site in Larsemann Hills. In addition, systematic flora and fauna studies should be carried out.	See section 2.5, figure 7, 2.5.7, 2.5.8, 3.3-3.8, 4.3, 5.8-5.12, section 6, 7 and 9

MINISTRY OF
FOREIGN AFFAIRS AND TRADE
MANATU AORERE

30 March 2007

Mr Rasik Ravindra
Director
National Centre for Antarctic and Ocean Research
Headland Sada
Vasco da Gama
Goa 403 804
INDIA

Dear Mr Ravindra

Thank you for the opportunity to comment on the draft Comprehensive Environmental Evaluation (CEE) for the proposed New Indian Research Base at Larsemann Hills, Antarctica, which was circulated to the Committee on Environmental Protection (CEP) on 29 December 2006 and to the Antarctic Treaty Parties on 9 February 2007.

We have referred the draft CEE to our environmental experts. They have commented that the CEE is a well laid-out and informative document prepared to a high standard with excellent attention to detail. In particular, the management of site specific impacts are well described.

Our experts have however also identified a number of points that we would like to bring to your attention in advance of the tenth meeting of the Committee for Environmental Protection (CEP X) where the draft CEE is to be considered. These comments are attached. Overall, we consider that the CEE is consistent with the provisions of Annex I to the Environmental Protocol.

Yours sincerely

Trevor Hughes
New Zealand Representative to the Antarctic Treaty Consultative Meeting

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Comments Received from New Zealand to Include Information in Final CEE

Section	Comment	Response addressed in Final CEE
Description of the proposed activity	The planned science programme to be carried out (section 2.1) includes: producing complementary data sets to extend studies to a comprehensive regional basis rather than being site specific; and using an earth station to extend coverage of the planned polar synchronous satellite “OCEANSAT 2” to the Indian Ocean sector of the Southern Ocean. These activities are in line with the principles and purposes of the Antarctic Treaty and its Environmental Protocol.	Noted. See section 2.1 and 2.2
Decommissioning	The construction model of the proposed station (sections 2.8 and 3.5) allows for all building modules to be completely removed and transported back to India after decommissioning. This is an excellent feature of the proposed design, allowing environmental impacts to be minimized after the station has been decommissioned	Noted. See section 3.11
Energy Management	Careful attention to energy management is evident in the proposed station design (section 3), including the use of solar panels, wind turbines, thermal insulation in the station’s structure, a two-stage heat recovery system for heating the station, and the use of energy saving technology in lighting fixtures. These measures, particularly the use of renewable energy sources, are likely to limit the impact of fossil fuels on air emissions.	Noted. See section 3.3- 3.8
Description of the proposed location	The proposed location of the station (including the geology of the coastline and site, glaciology, geomorphology, soil, lake water characteristics, climate, and anthropogenic impacts on lake and stream biota, vertebrate fauna including seals, and invertebrate fauna) have been described with careful attention to detail (section 5).	Noted. See section 5.2- 5.12
Identification and prediction of impacts	The range of mitigation levels for impacts considered in sections 5 and 6 are comprehensive, covering both the construction activities and the ongoing operational activities of the station (section 7 and table 11).	Noted. See section 6
Consultation with other Parties	In the view of our experts it would have been preferable for the environmental impact assessment process, including consultation with other Parties, to have begun earlier in the station planning process. As you may appreciate, the value of consultation on alternative sites when activity has already begun at one site is diminished.	Yes we agree. See section 4
Alternative sites	The selected site was preferred in the CEE over a number of alternative sites (section 4). Our experts have commented that the scientific activities studies outlined may not be dependent on or tied to the site chosen, as: rocks on the east coast of India have correlatives throughout Prydz Bay; the Larsemann Hills are not unique in regard to Gondwana; other sites may have good access to the key geological targets surrounding Lambert Glacier; and auroral, geomagnetic satellite base station studies could be carried out near the existing bases at Larsemann Hills or elsewhere in Prydz Bay. Our experts noted that placing the station at the Broknes Peninsula could reduce cumulative impacts by avoiding the spread of impacts into a relatively undisturbed area. Scientific observations could be rationalized to complement those of the other stations, and other arrangements might be made for offloading ship cargo and transport of personnel, as a trade off to minimizing cumulative impacts in the form of impacting an undisturbed area. Our experts additionally indicated that greater minimization of impact might be achieved if the exploration of	See section 4.2 and 4.3 See section 4.4

Comments Received from New Zealand to Include Information in Final CEE

Section	Comment	Response addressed in Final CEE
	vessel sharing with other stations located in the region for logistics purposes (section 4.4) were to begin prior to base construction.	
Impacts on freshwater lakes	The planned use of the freshwater lakes for potable water is of concern to our experts. The CEE notes that the quality of lake water is likely to be affected if the water is overdrawn as the lakes are shallow in depth (section 6.3.3), the lakes at the site may be affected due to dispersal of solid waste and mixing of the carbon soot from the emission of vehicles and generator (table 11) and that snow traps will be laid at appropriate location to increase the melt water content of the lakes (section 7.3.2). Our experts suggested that these environmental impacts on this geographic feature might be mitigated though using the planned desalination system (section 7.3.2) to provide 100% of the station's freshwater needs.	See section 2.5.7, and 3.7
Cumulative impacts	Our experts noted that cumulative impacts arising from extending the impact of intense human use into otherwise little disturbed areas were not raised in the CEE, and that the Antarctic Specially Managed Area tool for managing these impacts is referenced rather than utilized.	See section 6.2.3, 6.2.5, 6.2.8, 6.3.3 and 6.3.4.1

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11 April 2007

Rasik Ravindra
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India

By E-mail: director@ncaor.org

Dear Rasik,

DRAFT COMPREHENSIVE ENVIRONMENTAL EVALUATION (CEE): NEW INDIAN RESEARCH BASE IN LARSEMANN HILLS, ANTARCTICA

Thank you for the opportunity to comment on the draft Comprehensive Environmental Evaluation (CEE) "New Indian Research Base in Larsemann Hills, Antarctica".

We are pleased to note that the draft CEE addresses the major elements required by the Protocol on Environmental Protection to the Antarctic Treaty. We support the proposals to use renewable energy sources and low-impact approaches to station construction and operations, to minimise emissions and waste discharges, and to contribute to scientific knowledge in this region.

The Larsemann Hills have long been recognized of being of outstanding scientific interest, being one of the few examples of an area of Antarctic coastline that partially escaped the last glaciation, and being home to some rare and possibly endemic microbial organisms and a breeding site for birds and seals. It is also one of Antarctica's most diverse lake districts with more than 150 freshwater lakes and ponds, which are dominated by cyanobacteria. Sediments laid down in these lakes archive a history of biological, geological and environmental change stretching back over 120,000 years.

The need for a heightened degree of protection for many areas of the Larsemann Hills is reflected in the fact that human base infrastructure has been restricted to the easternmost peninsula, Broknes, where scientists and logistics personnel from a number of countries co-operate within a proposed 'facilities zone'.

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With these points in mind, we would suggest the following issues be clarified or expanded on for the final CEE:

- review of options to prevent expansion of the footprint of human activity in the region (including options for working with existing infrastructure in the region);
- inclusion of additional baseline information;
- consideration of potential for cumulative impacts and also indirect and second order impacts (including on lake ecosystems);
- environmental monitoring relating specifically to the predicted impacts;
- measures to prevent the introduction of non-native species.

Our detailed comments on specific sections of the CEE are included in the attached table, which we hope you will find helpful.

We would be pleased to provide further clarification if required – please direct any queries to Rob Bowman (rob.bowman@fco.gov.uk, +44 207 008 2616).

I look forward to seeing you in New Delhi in a few weeks time for the Antarctic Treaty Consultative Meeting.

Yours sincerely,

Jane

Jane Rumble
Head of Polar Regions Unit

Comments Received from United Kingdom to Include Information in Final CEE

Section	Comments	Response addressed in Final CEE
Site selection and alternatives	It would be helpful if the final CEE were to define 'Various environmental factors', and avoiding 'areas of wildlife concentration and critical natural values'.	See section in Non Technical Summary and 4.3.2
Description of the area and environment	The majority of the lakes in the region are fresh water i.e. oligo-saline with only two, Lake Reid and Sarah Tarn being hypo-saline (4.1 and 14 ‰ respectively (Verleyen et al., 2003)). Microbial diversity is high – for example, detailed morphological and molecular biological studies have described the biodiversity, biological composition and biotechnological potential of microbial communities in the Larsemann Hills, and a number of endemic taxa have been found (CORDIS, 2003; Hodgson et al., 2004; Sabbe et al., 2004; Sabbe et al., 2003; Taton et al., 2006a; Taton et al., 2006c). Whilst breeding penguins are absent, other birds such as the Snow Petrel and Wilson's Storm Petrel have established breeding colonies in the region.	While these details are true for Larsemann Hills in General, these are not specific to selected promontory. See section 5.8-5.12 See section 5.9.4
Impact assessment and mitigation measures	It would be useful to expand upon the description of 'proper treatment' when referring to the handling of solid waste and wastewater.	Suggestion incorporated. See section 3.7 and 6.3.4.4
1.2.2 Earth Science studies	As the Lambert glacier is already the focus of intensive glaciological study it would be useful to set out how existing and planned research might be integrated.	Noted.
1.2.4 Environmental studies	The CEE could usefully refer to previous environmental studies on the effect of the existing bases on the environment. Impacts identified have included, for example, nutrient pollution of lakes, introduction of alien organisms, dispersal of wind-blown debris and aerosols, and erosion from road construction (Burgess et al., 1992; Ellis-Evans et al., 1997).	See section 1.3.3
2.2 Location of site	The 'big lake' on Grovnes (shown in Figure 6) should be coded LGR and is oligo-saline with a salinity of 1.4 ‰ (Verleyen et al., 2003). LH37 and LH36 are located to the south of Grovnes (Gillieson et al., 1990). Other lakes have been proposed for 'drinking purpose' and the CEE should consider the specific impacts of this activity on the microbial communities living there especially as the lakes proposed for drinking water and station facilities receive their water from the melting of seasonal snow cover which may be quickly drawn down by the demands of a summer station. The alternative is to draw seawater and process this through reverse osmosis (distillation tends	See section 2.3 See section 2.5.7 and 3.7

Section	Comments	Response addressed in Final CEE
	to have temperature problems) to meet the station's needs. Whilst this has some energy consequences it would be more reliable long term (using the small lakes only for emergencies) and have less impact on the lake environments.	
2.6 Construction of station	Please clarify whether the 'austral summer of 2008' refers to the austral summer seasons of 2007/08 or 2008/09.	See section 2.7
2.7 Installation of Wind Turbines and Solar Panels	The proposal to include renewable energy sources is welcomed. However, more detail on the location and operation of the proposed wind turbines would be useful. Potential impacts regarding bird-strikes on wind turbines should also be considered.	See section 2.5.8, 2.8 and figure 7
3.3.4 Water Supply and Wastewater Management	It would be useful to provide further information on which lakes will be used to draw water for the station, the volume of water to be taken from the lakes, and the 'desired effluent standards' that will be maintained. (see also comments on the use of lakes for station/drinking purposes in section 2.2 above). Disposing of waste water in the sea is potentially feasible, but clarification would be helpful on how this will happen in winter. Investigation should be undertaken into currents in the Bay, and where waste water is likely to be carried once it is in the sea, and the impacts it may have. Clarification would also be helpful on how the seawater intake and waste outlet pipe are to be established in relation to each other; and how the pipes will be installed to resist effects of ice and be accessible for maintenance.	Clarification is cited above against section 2.2 See section 3.5 and 3.7
4.2.3 Alternate Sites within Prydz Bay – Area between Bolingen & Svenner Islands	There are several references (Page 36, para 1; also sections 5.1 and 5.7) to four stations on east Broknes. There are, however, only three as Progress I has been dismantled and removed for some time. Only two are capable of winter occupation and the Australian/Romanian summer-only station is small compared to Zhongshan and Progress II.	Progress I has not been dismantled and in view of use of airstrip it is likely to get a new lease of life
4.3.1 Alternative locations in Larsemann Hills – Broknes Peninsula	The CEE could usefully expand on the obstacles to locating the new base within the proposed joint 'Facilities Zone' especially as this would help reduce the footprint of human activity.	See section 4.3
5 Initial Environmental Reference	We would suggest that further detail be obtained on the coastal/nearshore marine environment at the proposed site, including marine flora and fauna.	See section 5.8-5.12
5.8 Flora and Fauna	This section could usefully comment on some of the more interesting aspects of the flora and fauna and of the unusual Quaternary history of the Larsemann Hills.	See section 5.10
6.2.1 Physical	Further detail on the total surface area of station buildings (including additional structures such	See section 6.2.1 and 6.3.1

Section	Comments	Response addressed in Final CEE
disturbance	as wind turbines) would be useful in this section.	
6.2.2.2 Impact due to air operations and 6.3.2.2 Impact due to operation activity – helicopters	When considering the impact of helicopters, it would be useful to make reference to the impact studies undertaken in the Dry Valleys where the carbon footprint of helicopter routes (due to exhaust fumes and aerosols) has been clearly demonstrated. The potential impact of helicopter overflight on birds should also be considered.	See section 5.7, figure 31, 6.2.2.3 and Table 26 and 27
6.2.5 Impact on flora and fauna	Consideration should be given to the potential routes for introduction of non-native species, e.g. associated with personnel, fresh foods, vehicles and building materials.	See section 6.2.4.3 and 6.3.5
6.3.2 Air emission	In relation to pollution, studies on Broknes eastern peninsula have shown that the prevailing winds sweep litter and aerosols westwards and evidence was found on western Grovnes, several kilometres from the source. Any litter and all aerosol/microparticulate emissions from Grovnes is likely to be carried towards Stornes which is only 2 km away from Grovnes. As there will be enhanced helicopter activity on and around Stornes in supporting the proposed science programme consideration should be given to the potential impact on Stornes as well as the impact on Grovnes.	See section 6.2.3, 6.2.8, 6.3.3 and 6.3.6.1
6.3.3 Impact on water quality	Further details would be helpful on measures to ensure that lake ecosystems are kept free of effects of emissions from generator and vehicle movements.	See section 6.2.2,6.2.3, 6.2.4 6.2.5 and 6.3.4
6.3.6 Fuel Spill	What are the potential effects of fuel spills on the nearshore/coastal marine environment, lake ecosystems, soils etc?	See section 6.2.4 and 6.3.4
7.1 Physical Disturbance	Further details are needed on the location of the 'predefined areas' to which human impact will be confined.	See figure 7. Predefined areas during construction will be the locations of the installed Igloo huts (temporary living shelters) During the operation of the station, the station itself will constitute such an area
7.2.4 Generators	As mentioned above, further information would be helpful on the location of generators with regard to the prevailing wind direction, in order to avoid contamination of the lakes.	In NNW direction away from station site
7.3.2 Water quality at site	With regard to using the lakes as a water supply (see also comments on p.16), we would suggest that all lakes greater that 2m deep should be avoided for any water extraction as it would be highly detrimental to the environment (see (Ellis-Evans et al., 1997).	Lakes will be used only in emergency.
7.6 Impact of other waste	Further detail would be helpful on the plasma pyrolysis system and Rotating Biological Contactor.	See section 3.7 and 6.3.4.3.
7.7 Impact on Flora and Fauna	The CEE should include more detailed descriptions of measures to prevent introductions of non-native species, specific precautions to be taken, and consideration of measures in addition to UV radiation (which may not affect all microbes, or other organisms). In particular, consideration should be given to the potential routes for the introduction of non-native species, e.g. associated	See section 6.2.4.3, 6.3.5

Section	Comments	Response addressed in Final CEE
	with personnel, fresh foods, vehicles and building materials, and measures to mitigate introductions through these specific routes.	
Table 11 Impact matrix and mitigation measures	Oil spill – what is the potential for damage to the fuel pipeline caused by ice? Aesthetic and wilderness values – where are the defined areas to which activities will be confined? The potential for introduction of non-native species should also be considered in Table 11.	See section 3.4, 6.2.4.2, Figure 7, Table 26 and Table 27

Appendix 3

CEP Advice to ATCM XXX on the draft CEE for the "New Indian Research Base at Larsemann Hills, Antarctica"

The Committee had extensive discussions on the draft CEE presented by India for the "New Indian Research Base at Larsemann Hills, Antarctica" contained in WP 4 and IP 7, and on additional information provided by India during the meeting in IP 139. This additional information took into account comments received from Members during the intersessional period.

Members rasied several questions, reflecting concerns related to the following issues:

1. Justification for the location of the new station;

2. Use of water from pristine lakes of high scientific value and the need for consideration of alternative methods to produce fresh water;

3. The need for consideration of possible cumulative impacts of human activities in the area;

4. The need for a description of procedures to minimise the risk of introduction of non-native species.

India responded to these questions and advised that all of them, as well as other questions received directly from some Membrs, will be addressed in the final CEE.

The CEP advises that, on the basis of the information provided by India:

- The document is well structured and meets the requirements of Annex I, Article 3, of the Protocol; and
- The proposed location of India's new facility is not inconsistent with the provisions of the draft "Larsemann Hills, East Antarctica, Antarctic Specially Managed Area, Management Plan" (WP 8).

The CEP recommends that the ATCM endorse this view.

IP 80

Agenda Item:	ATCM 15
Presented by:	India
Original Language:	English

India's endeavour for a new research Station in Antarctica- a report

India’s endeavour for a new research Station in Antarctica- a report

Introduction

This briefly introduces field activities that India conducted during the XXIII Indian Antarctic Scientific Expedition (IASE) and XXIV-IASE in the month of February 2004 and February 2005, towards selection of a suitable location for a new station, considering the requirement of research and to expand the scientific studies in other areas apart from Schirmacher Oasis. As a part of the XXIII Indian Scientific Antarctic Expedition to Antarctica (ISEA), a Task Force undertook reconnaissance surveys in the Amery Ice Shelf – Prydz Bay area between 66° E and 78° E longitude to identify a suitable site, preparation of IEE and if required CEE report. After extensive traverses in the Vestfold Hills Rauer group of islands, Larsemann Hills and Bolingen islands of the Prydz Bay area, the team finally identified the following two sites as probable locations for the station:

1. An unnamed promontory in the Larsemann Hills situated between Quilty Bay and Thala Fjord, bounded by latitudes 69°24'-69°25'S and longitudes 76°01' -76°14'E.
2. McLeod Island forming a part of the Larsemann Hills

Criterion for selection

These areas are found suitable because the open sea off the Antarctic coast, offers new opportunities for studies in biological, atmospheric and environmental sciences. Absence of ice shelf will also make logistic operations much easier and time saving. With the existing moderate weather conditions and sheltered location of hills and islands, working conditions will be comparatively less arduous at the new site.

Correlation study may open new scientific avenues as the bay area forms a key link in the India-Antarctica linkage during Gondwanaland; considering the fact that the present Prydz Bay in the Antarctica and the Indian Eastern Ghat Mobile belt once formed a contiguous landmass. Geologically, the area would offer possibilities of detailed correlation between the rocks exposed all along the eastern coast of India (high grade granulite, charnockites, khondalites) with rocks of Napier and Rayner complexes of Prince Charles mountains as well as the rocks of Prydz Bay area. It will also help to carry out detailed studies and verification the postulated correlation between the Kerala Khondalite belt of India and rocks of Lutzow-Holm Bay area as also the correlation between the Eastern Ghat of India and Mobile Belt Rocks with those of Prydz Bay region.

It is observed that Archaean to Tertiary Sequence are exposed on either side of the Lambert Glacier in Antarctica and Mahanadi Valley in India, offering a lateral continuity of the sequence. Study of Lambert Glacier, the fastest moving glacier in Antarctica, opens new fields in glaciological studies The selected sites are also found as an ideal location for another geomagnetic observatory; linking it with Maitri and India. Studies on the measurement of current drift of Indian sub continent with respect to Antarctica in this region will supplement similar studies being undertaken at Maitri and have far reaching scientific significance. Close proximity to Australian, Chinese and Russian stations will encourage collaboration and co-operation in science.

Site A: Larsemann Hills Promontory

In this area a fast reconnaissance was made and it revealed that promontory has a number of fresh water lakes with sufficient depths that can serve as source of drinking water. The approach from the sea in February was open and ships could come as closer as 3 to 4 km to the landing site where after, the barges could be put into operation. The area is located in the central part of Larsemann Hills and is about 10-km as a crow fly distance from Zhong Shan and Progress Stations of China and Russia, respectively. India could cooperate with these stations in scientific and logistic fields. The site is found to be almost flat which may be proved good for erection of living and laboratory complexes.

Site 2 : McLeod Island

This area has also few advantages to carryout scientific and logistic activity uninterrupted as;

- It supports three melt water lakes with good quality potable water.
- Easy access to the Island and ease of cargo landing.
- Flatter terrain for erection of living and laboratory complexes.

Scientific Study at Larsemann Hills, Ingrid Chirstensen Coast

During the XXVI-IASE in the month of February 2005 a Melon hut (Igloo Satellite Cabin) was erected at a suitable location to facilitate the scientists to carry out earmarked studies. This hut was erected at 69^{O} 24’ 28.8” S latitude and 76^{O} 11’ 14.7” E longitude at Larsemann hills. An area of around 12 square km bounded between 69^{O} 24’ 00” S to 69^{O} 26’ 00” S latitude and 76^{O} 10’ 00” E to 76^{O} 15’ 00” E longitude was traversed for geological studies. Two sediment cores were also collected from glacio-marine Lake about 4 miles short of Davis station and water samples were collected from other lakes situated in this area. Lichen, moss and aquatic algae samples were collected from the area to study the pigment concentration. More surveys of the selected sites in this area are required to be conducted to develop an IEE

ANTARCTIC TREATY
CONSULTATIVE MEETING 2006

Agenda Item:	CEP 15
Presented by:	India
Original:	English

Establishment of a New Indian Research Base in the Larsemann Hills, East Antarctica

Introduction

Antarctica is a vital element of the Earth's climate system. Regional processes on the icy continent and its surrounding oceans have important global consequences, from atmospheric composition to ocean circulation. The region is also vulnerable to change in our global environment, potentially giving rise to strong feedbacks, which could accelerate climate change. Of late, Antarctic science has also been increasingly contributing to our understanding of the origin and evolution of the continents, changes in the world climate pattern, global oceanic circulation, the plasma processes occurring in the earth's upper atmosphere, and global phenomena such as ozone hole, sea level rise etc.

India joined the global polar science community, recognizing the importance of Antarctica as a pedestal for front-ranking scientific research in 1981, when the first Indian Antarctic Expedition was launched. Since then, India has made constant strides both in Polar Sciences and related logistics, through a judicious and harmonious blend of multi-institutional expertise. This has paved the way for the country to sustain its scientific endeavor in the icy continent on a year-round basis since 1983, when the first permanent Indian Antarctic Base "Dakshin Gangotri" was commissioned on the ice shelf, off the Princess Astrid coast in Central Dronning Maud Land. This station built in the record time of a single polar summer, continued to host the members of Indian expeditions to Antarctica till 1989, when it had to be decommissioned due to excessive snow accumulation.

The scene of activity thereafter shifted to Schirmacher Oasis, where an ice free, rocky area was selected to build the second Research Station "Maitri (70^{o}45'52"S: 11^{o}44'03"E). The indigenously designed building erected upon this site it in 1988-89, has stood the test of time since then. The infrastructure available at this station has enabled the scientists to conduct front-ranking research in various disciplines such as Atmospheric Sciences & Meteorology, Earth Sciences & Glaciology, Human Biology & Medicines, Biology & Environmental Sciences, and Engineering & Communication. Furthermore, the station being the gateway to one of the largest mountain chains in central Dronning Maud land located south of Schirmacher, has helped Indian Geologists in surveying and preparing geological map of a large part of area in Wohlthat, Orvin, and Muhlig Hoffmann Ranges. Several of the research programs initiated by India in the Oasis area and its environs have also contributed directly to global experiments mounted under the aegis of the Scientific Committee on Antarctic Research (SCAR), and have had as active partners such as Germany, Italy, France, Peru, Russia, United States of America etc. India has also provided logistic support to scientists from Russia, Germany, Poland, Malaysia etc. keeping the Treaty mandate of international cooperation.

Even while using Antarctica as a platform for conducting scientific research, India has always recognized the importance of conserving the pristine nature of the continent, which modulates the intricate global processes. To uphold these commitments, India ratified the Protocol on Environmental Protection to the Antarctic Treaty in April 1998.

A new Indian Research Base in Antarctica- Basis of the proposal and its significance

Ever since 1981, the Indian endeavors on the icy continent have continued uninterrupted and annual scientific expeditions to Antarctica have remained one of the primary focus-areas of Indian national science programme. Till date, twenty five expeditions have been successfully launched. In addition, an expedition to the Weddell Sea and one for assessment of krill in the Antarctic waters has been undertaken. These expeditions have provided over 1500 scientists and logistics personnel from more than 60 national laboratories, universities, defense services and research institutes opportunity to conduct front-ranking experiments/studies in some of the frontier areas of polar sciences. These studies have contributed significantly to a better understanding of Antarctic continent in general and of the Central Dronning Maud Land in particular.

The availability of a pool of scientists with a sustained interest in the polar realm, and the ability to conduct front-ranking scientific research on a year-round basis prompted India to provide an opportunity to the Indian scientific community to look beyond the Dronning Maud Land. Following aspects has been given due weightage while deciding on the need for another research base in Antarctica:

- The Indian contributions till date to Antarctic science vis-à-vis the international scenario.
- The need to extend the ongoing and planned scientific experiments at Maitri with those that could be mounted at the new site, ensuring thereby that the studies are not merely site-specific endeavors.
- The relevance of the new Antarctic locale due to its past connectivity with the Indian landmass during Gondwana time, in the context of the planned growth of Indian science programme.
- The need for sustaining the spirit of co-operation in Antarctic science and increase Indian contribution in terms of science and logistic support for advance scientific endeavours.

Deliberations at different levels and debate between different experts on the best options for a new Indian research base in Antarctica finally narrowed down to Amery Ice shelf – Prydz Bay area, since it offers a unique opportunity to work on the India-Gondwana fit. The rocks in Prydz Bay area of Antarctica and the Eastern Ghat Mobile Belt of India have proven similarities.

Against the above backdrop, a Task Force constituted by the Government of India and comprising experts from geology and glaciology, oceanography, upper atmosphere and geomagnetism, biology and logistics; undertook a reconnitary visit to the Amery Ice shelf -Prydz Bay region of East Antarctica during February 2004 and examined the area between 66^0 E and 78^0 E Longitude. After extensive traverses in the Vestfold Hills, Rauer Group of islands, Larsemann Hills and Bolingen islands, the Task Force recommended a rocky promontory between Quilty Bay and Thala Fjord in the central part of the Larsemann Hills, bound by latitudes $69^0$24’ and $69^0$25’ and longitudes $76^0$10’and $76^0$14’ E, as the most suitable site for the new Indian base. This was reported by India in XXVIII ATCM (2005) at Stockholm in IP 80.

Proposed scientific studies at the new site

The new proposed research base is expected to cater to a critical scientific research in some of the frontier areas of earth science, environmental sciences, remote sensing, oceanography and coastal ecosystems of Antarctica.

Geoscientific studies

1) The Prydz Bay can be considered the key in the India-Antarctica link during Gondwanaland, as the area of Prydz Bay of Antarctica and the Eastern Ghat Mobile belt of India once formed a contiguous landmass. Geologically, therefore the area offers possibilities of detailed correlation between the rocks exposed all along the eastern coast of India (high grade granulite, charnockites, khondalites) with rocks of Napier and Rayner complexes of Prince Charles mountains as well as the rocks of Prydz Bay area. Only India is in a position to carry out such detailed correlation and directly verify the postulated correlation between Kerala Khondalite belt and rocks of Lutzow-Holm Bay area as also the correlation between the Eastern Ghat Mobile Belt Rocks with those of Prydz Bay region.
2) Integrated geophysical –geological studies aimed at understanding India-East Antarctic rifted margins and its role in the evolution of present Indian sub-continent. Such studies have not been attempted so far using high quality integrated geophysical data.
3) The study of Lambert Glacier, the fastest moving glacier in Antarctica, opens an exciting new vista in glaciological studies.
4) The history of late Quaternary glaciation in the Vestfold and Larsemann Hills areas remains a topic of intense academic debate.

5) The new research base offers an ideal location for yet another geomagnetic observatory in Antarctica, linking it with the Maitri research station as well as India.

6) Studies on the measurement of current drift of the Indian sub continent with respect to this region of Antarctica will complement similar studies being undertaken by the Indian scientists at Maitri.

Meteorological and Atmospheric studies

1) Setting up of a weather station

2) Aerosol Radiative Flux estimation; Aerosol size distribution, solar terrestrial effects, transportation of aerosols.

3) Establishment of geomagnetic observatory at Larseman Hill Site with deployment of instruments like DFM, DIM, PPM.

Biological and Environmental studies

4) Biodiversity of marine, terrestrial and aquatic biota of the area.

5) Determination of indicator fauna and their population trends and impact of biotic and abiotic factors on the coastal Antarctic ecosystem.

6) Wild life biology and conservation ecology

7) Environmental monitoring

Oceanography and Remote Sensing

8) Bathymetric and oceanographic surveys.

9) Establishment of a satellite earth station to facilitate remote sensing studies of the area, real time data transfer and communication between India, Larsemann Hills and Maitri.

The close proximity of the proposed Indian base to the Australian (recently reported to be jointly manned with Romania), Chinese and Russian stations would go a long way in fostering significant collaboration and co-operation in polar science.

Description of the proposed site

Location

The Prydz Bay represents an embayment along the Eastern Antarctic margin, lying between the East Longitudes 66^0 and 79^0. The Amery Ice Shelf on the southwestern side and Ingrid Christensen Coast on the southeastern end define its limits. The isolated islands, promontories, peninsulas and nunataks occurring along the continental ice describe the rocky terrain exposed in the area, which, from East to west, fall under Vestfold Hills, Rauer Group, Svenner Island, Larsemann Hills and Bolingen Islands respectively (**Fig. 1).**

The Larsemann Hills (69^0"23' S, 76^0"53 'E) named after Mr. Larsemann Christensen, is an ice-free coastal oasis fringing the Prydz Bay, located approximately midway between the eastern extremity of the Amery Ice Shelf and the southern boundary of the Vestfold Hills (Fig. 3). There are two main peninsulas on the two extremities of the Larsemann Hills, namely the Broknes Peninsula and the Stornes Peninsula. In between these two peninsulas, there are number of islands of varying dimensions and some unnamed promontories. The northern and western sides of Larsemann are dotted by a series of small islands. The satellite imagery of the area indicates open sea on the eastern edge of the Broknes Peninsula (**Fig.2**).

Westwards, the Clemence Fjord separates Broknes Peninsula from Stinear Peninsula and Fisher Island. The area north and westwards is marked by a number of islands, namely Harley, Easther, Breadloaf, Butler, Betts, McLeod, Jeason, Solomon, and Sandercock Island. The highest elevations on Larsemann Hills are around 180 m above sea level (ANARE 2000). The hills are dissected by steep valleys lying between the ice sheet and the coast. The shape of the land surface is controlled by the lithology and shape of geological structures, particularly joints and lineaments, as well as erosion by ice, water and salt. More than 150 freshwater lakes are found in the hills ranging from small ephemeral ponds to large water bodies such as the 3.8 m deep Progress Lake. Some of these water bodies are briefly ice-free or partially ice-free in the summer months. For the remainder of the year (8-10 months) they are covered with ~2 m of ice. The westerly currents break the fast ice during early summer facilitating the entry of the vessels quite close to these stations

Larsemann Hills have received considerable geological attention by several workers including Stuwe et al, 1989, Dirks et al, 1993, Thost et al, 1994, Zhao, 1993-94, Sheraton and Collerson, 1983, Harley and Hensen, 1990, etc. Four Antarctic stations viz. the Progress I & Progress II (Russia), Law Base of Australia (now jointly managed by Australia and Romania) and Zhong Shan (China) are located in the area.

Site of the proposed new base in the Larsemann Hills

The new Indian Antarctic base is proposed to be located on an as-yet un-named promontory situated between Quilty Bay on the east and Thala Fjord on the west. This particular site on the Larsemann Hills has been found to be most suitable for a research base. The pear shaped promontory with an available flat area, which is being considered as the site for the construction of the research base, has its broader end towards sea, trending NE-SW. The southern margin separates Polar ice margin and the hills thereupon, by a narrow bay. The northern and western slopes have a high gradient with the edge being exposed in the form of a steep cliff over the sea. There is however availability of an area of low gradient on the north-eastern part, where landing can be made by boats /barges for off -loading cargo. (**Fig**.**3)**

Accessibility of the site from the open ocean

The approach to the promontory is through the gap between the Solomon and Sandercock Islands. This area of the sea was found to be clear of sea ice during surveys conducted in the summer season of 2004, 05 and 06 with isolated icebergs on the outer periphery. Pack ice is extensive inshore throughout summer, and the fjords and embankments are rarely ice-free. Snow cover is generally deeper and more persistent on Stornes Peninsula than Broknes Peninsula. An isolated iceberg is grounded between the McLeod and the Sandercock islands but comparison of satellite imageries of past decade have shown that the said iceberg is reducing in size. The area is marked by persistent, strong katabatic winds that blow from the north-east on most summer days. which in conjunction with the ocean currents keep the sea relatively free of ice bergs **(Fig 4 & 5).**

During February 2006, preliminary multi-beam swath bathymetric surveys were undertaken along a corridor starting north of the grounded iceberg to the western face of the Larsemann promontory to define an approach channel for vessels. The NW-SE part of the corridor from the grounded iceberg to the promontory measured about 6 km and had a width of about 2.5 km. Bathymetric data totaling 122 line km was collected along 22 survey lines within the corridor. The minimum depth recorded in the channel was 10 m and the maximum 460 m. There is a deep channel in the corridor area with an observed minimum depth of 140 m and a maximum depth of 250 m Detailed analysis of the bathymetric results are currently being undertaken, which would facilitate delineating a proper and safe approach to the proposed site of the research base for vessel**s** (Fig. 6 & 7).

Availability of freshwater

In the vicinity of the proposed site, there is a fresh water lake situated at higher elevation, measuring about 300 m x 200 m. with water column height of 12m. The conductivity test confirms to the potable quality of water. Apart from the said lake, there are four main water bodies at lower elevations that store melt water and hence are also of good quality. The eastern most lake among these gets overflow from the other water bodies and the water ultimately seeps to sea. The water bodies L1, L2, L3, & L5 besides being shallow revealed low hydraulic detention period and high flushing rate. The variation of Temperature, density, salinity and conductivity along depth in the Prydz Bay lakes has been recorded.

Lake water sample from the McLeod Island were collected from the Lake-1 and Lake-2 (long lake) in 2006. A multi-parameter probe was used for in-situ measurement of certain parameters and the analysis result of both fresh water lake shows that the water is potable.

Existing Infrastructure

A temporary field camp was established in by the Indian scientists in the summer of 2005 by placing an Igloo hut with basic provisions for emergency needs near the proposed site. During the summer of 2006 this hut was found in good condition by the team of Indian scientists which landed on the shore using a boat. Indian scientists carried field observations and collected further data on various aspects of the site and its surroundings necessary for establishing a permanent research base. No further additions have been made at the temporary camp site during this year.

Proposed plan of future activities

India proposes to finalise in coming months the basic design and other infrastructural and logistic needs of the new research base. This will be done keeping in view the optimum requirement of scientific and logistic personnel to carryout the proposed scientific activities in Larsemann Hills, Pyrdz Bay and nearby areas. Based on the proposed layout of the research base and on the basis of available information on ecological, biological, physiographical, geological and other attributes of the area and the data which has been collected by the Indian scientists through surveys during the summer seasons of 2004, 2005 and 2006, a draft CEE will be prepared and submitted to the CEP as per the provisions of the Environmental Protocol of the Treaty. Collection of data on the proposed key areas of research and scientific programmes will be continued, both in the surrounding seas and around the site. Considering the requirement of additional logistic support and greater effort required from the polar science community during the International Polar Year in 2007, India would like to cooperate with nearby research stations in conducting joint research and sharing the infrastructure and logistics in the Larsemann Hills area.

India has also taken note of the Working Paper (WP 27 Rev 1) on the proposed ASMA in the Larsemann Hills area, jointly submitted by Australia, Russia and China during the XXVIII ATCM, 2005 at Stockholm. Considering the specific scientific and logistic requirements and need for future research, critical for greater understanding of the Antarctic in general and various global environmental, ecological and geological processes in particular, which are proposed to be studied in the new research base; India would be looking forward to appropriate modifications in the proposed ASMA. India will continue to maintain the ecological integrity of fragile Antarctic environment. However there is a need to make a greater effort to sustain the scientific quest, which is necessary to understand the global ecological processes, climate change and related issues.

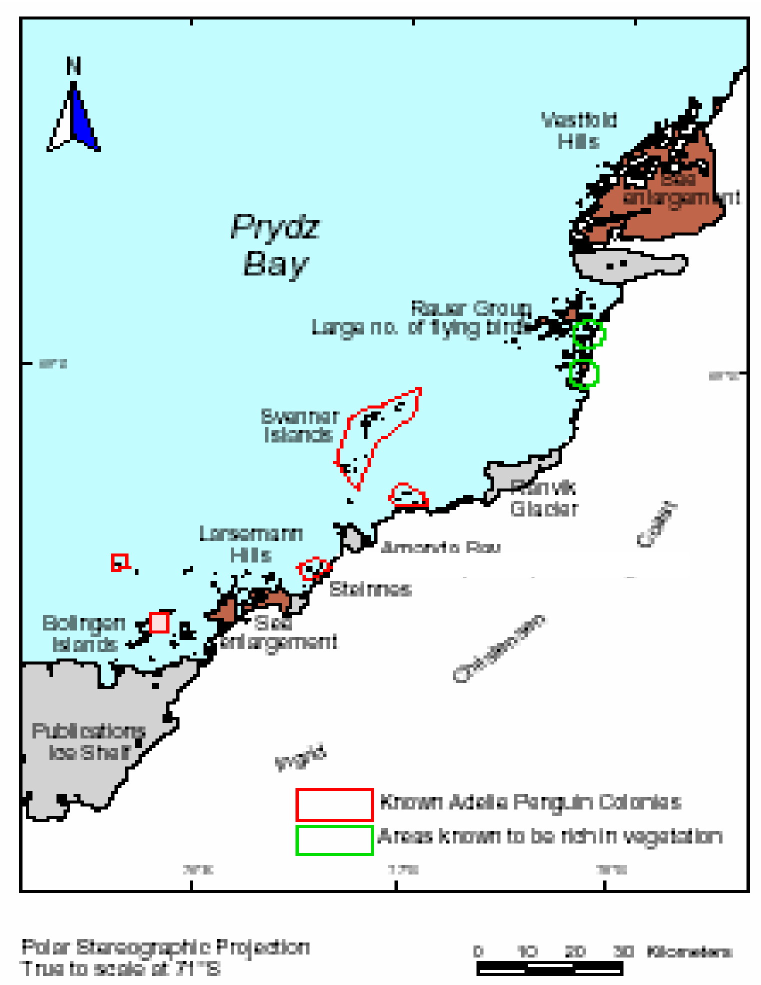

Figure 1. Larsemann-Vestfold Hills (

Source: Australian Antarctic Division

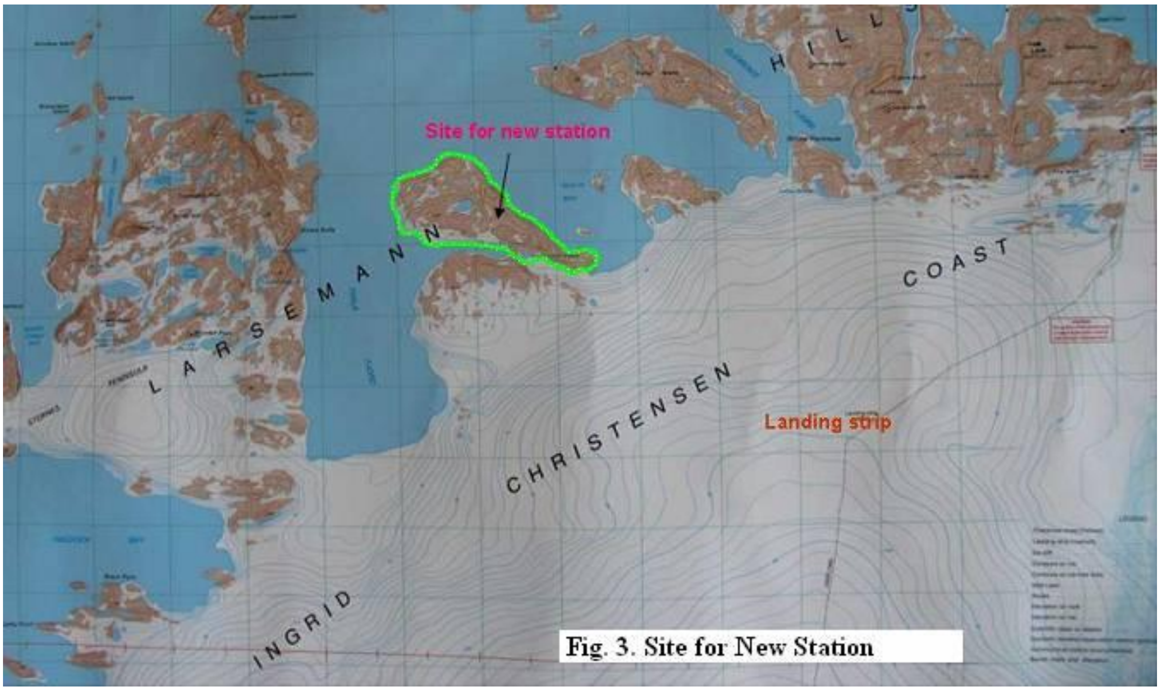

Figure 2. Site for New Station
Source: Australian Antarctic Division

Figure 3. Proposed site for Indian Research Base

Figure 4. Approach to the new Site

Source: Australian Antarctic Division

Figure 5. Approach to the promontory, a view from the promontory

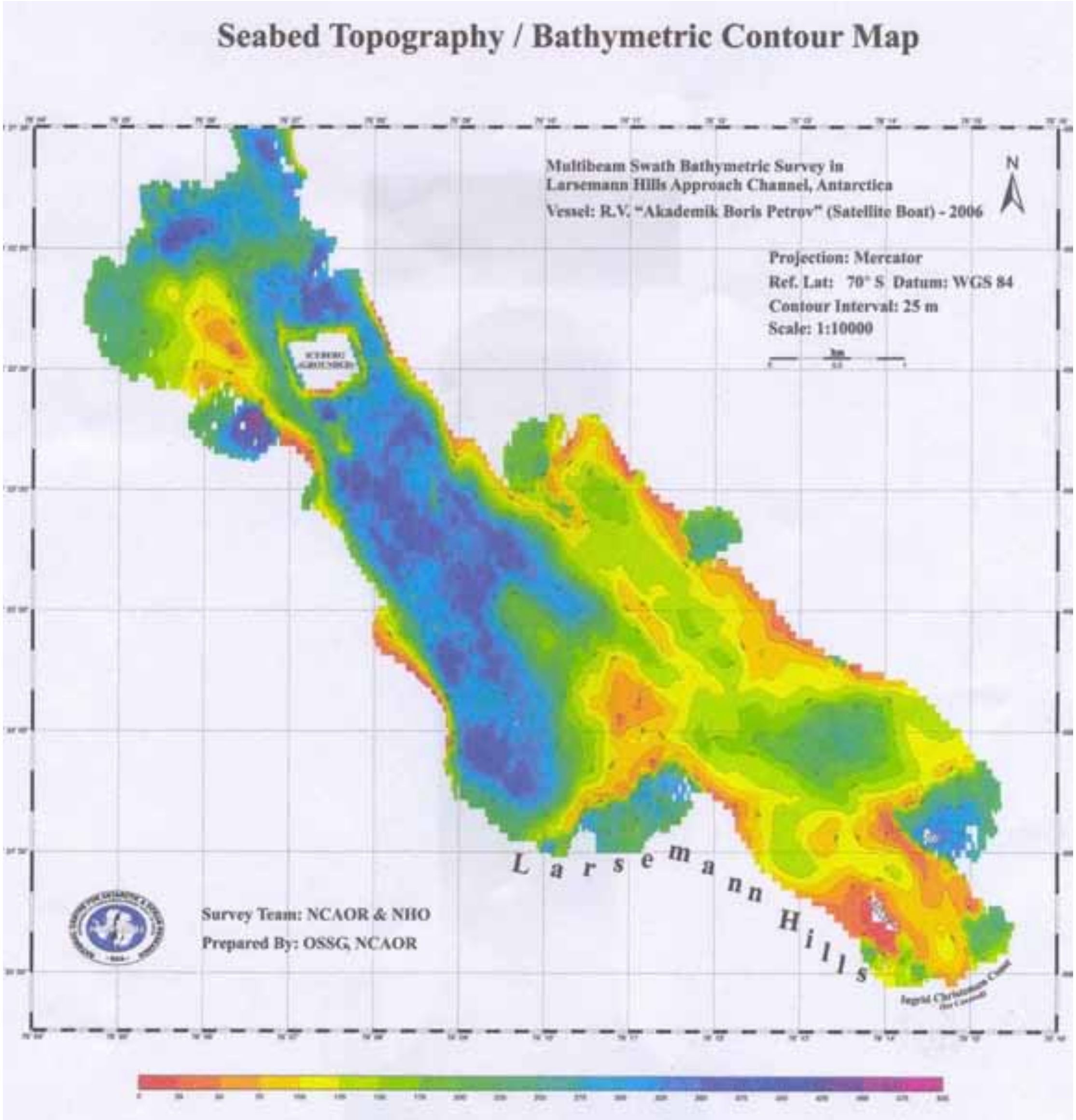

Figure 6. Bathymetry Contour Map at Larsemann Hill Area

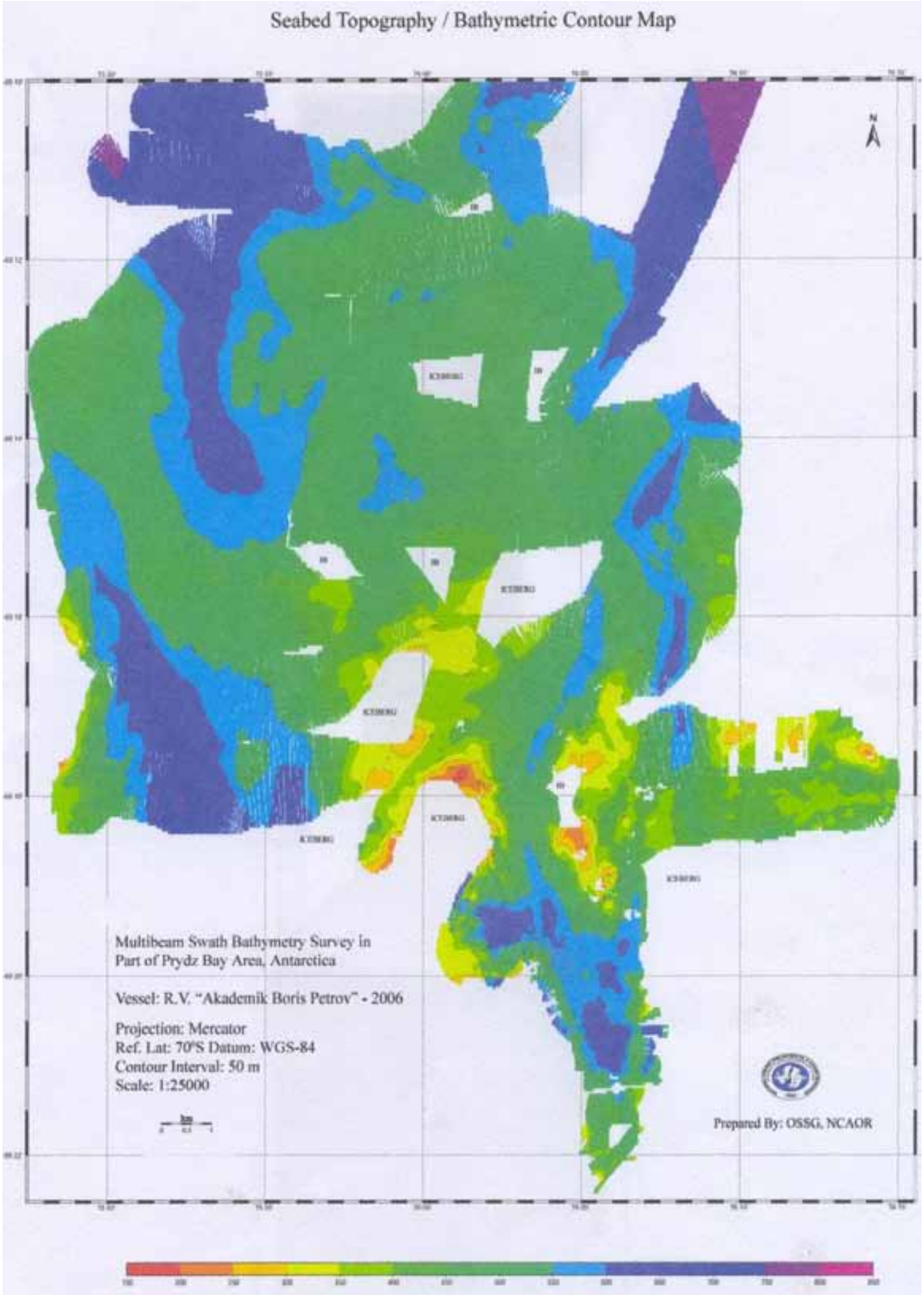

Figure 7. Multibeam Swath Bathymetry in parts of Prytz Bay Area

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