FINAL COMPREHENSIVE ENVIRONMENTAL EVALUATION

Construction and Operation of the Jang Bogo Antarctic Research Station, Terra Nova Bay, Antarctica

April 2012

Korea Polar Research Institute

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Non-technical Summary

I. Introduction

This final Comprehensive Environmental Evaluation (CEE) report aims to establish a plan that will minimize the adverse impact of the construction and operation of a new Korean research station in Antarctica. Comprehensive analyses on the environmental impact have been carried out in order to ensure that the station can be operated in a sustainable manner with minimal impact on the environment.

Considering the research programs including international collaboration, convenience of logistics, and its impact on the local environment, the site of Jang Bogo Antarctic Research Station (74°37.4′S / 164°13.7′E) was chosen through an evaluation process of six candidate sites in the Antarctic region from 2007 to early 2010. The proposed site is located near Cape Möbius, the coastal area of Terra Nova Bay in Northern Victoria Land along the Ross Sea.

The main purpose of Korean Antarctic research is parallel to the international efforts on predicting global climate change process through multidisciplinary research. As an independent station that will operate year-round, the Jang Bogo Station will develop the West Antarctic observatory network with Korea’s King Sejong Station and the icebreaker *ARAON*.

The key scientific programs based on the Jang Bogo Station include:

- Climate and atmospheric chemistry

  A WMO/GAW Global Station will be installed at the Jang Bogo Station. In connection with other stations in Antarctica, this large-scale monitoring of atmospheric components will cover the entire Antarctic region to strengthen the understanding of the interactions between the polar region and middle latitude of the southern hemisphere.

- Glaciology and snow chemistry

  Studies of snow and glaciers along the coast of West Antarctica will be conducted at the Jang Bogo Station as well as supported by the icebreaker *ARAON*, contributing to restoring the paleo-climate and paleo-environmental changes of the Pacific margin of Antarctica.

- Tectonics and geophysics

As various forms of glaciers developed near the proposed site, long-term monitoring of movement and mass balance of glaciers will be carried out in order to comprehend the relationship between tectonics and glacial changes. In addition, seismic, geomagnetic and GPS observation systems will be installed at the Jang Bogo Station as a part of the Polar Earth Observing Network (POLENET).

- Long-term monitoring for ocean and ecosystem

The Jang Bogo Station will accommodate year-round monitoring and research of the long-term impacts of climate change to ecosystem of the surrounding areas. A long-term monitoring program will be established in order to identify the major oceanographic and atmospheric parameters that are responsible for the rapid freshening in the Ross Sea.

II. Description of the Proposed Activity

The proposed site for the Jang Bogo Station is located on a small cape approximately 1.2km NNE of the Cape Möbius where Germany's Gondwana Station is located.

The main activities dealt with in the CEE include: construction, operation, and dismantlement of the station; installation and use of temporary facilities during the construction; and transportation of supplies and personnel to the station. The construction is planned to start in December 2012 and continue for two years during the Antarctic summer season. The station will begin to operate early 2014.

The station includes the main building, research facilities, and maintenance and operation facilities with a building area of 4,411.46m^2. The station is planned to be used for no less than 25 years. It will accommodate up to 15 personnel in the winter and up to 60 personnel in the summer.

The main building is designed to be an aerodynamic triple-arm structure elevated from the ground surface. The main building will work as the central hub, with other facilities being arranged like the spokes of a wheel. This type of layout is known to be reliable, has high functionality and efficiency, and causes minimal damages to the surrounding land. Moreover, the layout will minimize access time between buildings since all facilities will be directly accessible to the main building.

The main building is designed to withstand strong winds and fire. The compartmentation in the building will help prevent fire from spreading, and the stable aerodynamic structure will provide increased resistance against strong winds. Furthermore, the combination of the elevated and slanting structures helps to minimize the amount of snow pile-up around the building. Maximum use of natural lighting, as well as the double outer walls and five-time glazed windows in the current design plan of the building is intended to optimize its energy efficiency.

In an effort to minimize the construction period, a modular construction system will be adopted. The modular construction system will not only shorten the construction period but also minimize the number of workers required and construction wastes. This will also facilitate future dismantlement.

The use of Combined Heat and Power (CHP), solar and wind renewable energy, and waste heat will cover 100% as energy sources, thereby reducing the use of fossil fuels while the station is in operation. A comprehensive high-level treatment system will be installed and operated in order to prevent waste and wastewater from affecting the clean Antarctic environment. All wastes will be stored under an appropriate management plan until transported outside of the Antarctic region. Furthermore, the wastewater will be reused as much as possible by using the gray water reclamation and reuse system, and ultimately, will be treated and discharged with almost no pollutant.

III. Alternatives to the Proposed Activity

Various alternatives including no-action to the proposed activities have been compared and reviewed to select the best option in terms of the comparability of the site as well as for the design of the station.

Several alternatives examined to the proposed activities include:

- No-action alternative
- Six alternative locations in Antarctica (two in West Antarctica and four in East Antarctica)
- Three alternative locations in Cape Möbius region
- Three alternative designs of the main building
- Three alternative wind turbine types
- Five alternative means of transport (two for air transportation and three for marine + land transportation)
- Two alternative waste management plans

The proposed site was selected considering not only its compatibility in construction and operation, but also the research areas that Korea is planning. Minimizing any impact which the station would have on the natural environment was also considered.

For the main building, intensive triple-arm shaped design was selected because it is known to respond reliably to the extreme weather conditions of the Antarctic region, while maximizing energy efficiency, and could be operated year-round.

The vertically stacked modular type structure was selected for the final design of the wind turbine considering efficiency of power generation, noise, maintenance ease, and impacts on the ecosystem.

Marine transportation was selected over air transportation as the best means of transportation in consideration of cost, convenience, and on-time performance under uneven weather conditions.

All wastes will be transported outside of the Antarctic region in order to prevent any potential harm to its atmospheric environment.

IV. Initial Environmental Reference State of the Terra Nova Bay Region

The Terra Nova Bay region where the Jang Bogo Station will be located is one of the most biologically and ecologically diverse regions in Antarctica. It is a habitat to a diverse number of species, namely bryophytes, lichens, sea birds, marine mammals and invertebrates. However, the colonies and important habitats of organisms do not exist close to the proposed site.

The wind speed at Cape Möbius region is extremely high and variable. Strong westerly wind can reach a maximum speed of 56.4m/s. According to the previous long-term observatory data produced by Italy’s Mario Zucchelli Station, the annual average temperature and wind speed of the regions are -14.1℃ and 6.4m/s, respectively. According to the results of the data analysis by AWS (Automatic Weather System), westerly winds, together with northwesterly winds, develop at the proposed site predominantly due to topographical controls.

The proposed site is located in a small cape that is mainly composed of exposed bedrocks and glacial moraines. Most of the land gently slopes close to the coast.

Regional studies on flora and fauna show that only a few kinds of species inhabit the area. About 26 species of vegetation, primarily lichens and mosses, exist near the freshwater pond, approximately 1.2km north of the proposed site. A population of Weddell Seals was observed on an ice field near the proposed site and a colony of South Polar Skua was located in the east of Germany's Gondwana Station.

There are three Antarctic Specially Protected Areas (ASPA) and two Historic Sites and Monuments (HSM) in the vicinity of the Cape Möbius region.

V. Prediction of Impacts, Assessment and Mitigation Measures of the Proposed Activities

An impact assessment of the construction and operation of the station on the Antarctic environment was conducted through comprehensive analyses of the proposed activities based on the data acquired during the survey and accumulated knowledge on natural environment and weather conditions of the region provided by Italy and Germany. In addition, the environmental impacts caused by the construction and operation of the station were estimated for the major factors such as emissions of air pollutants, potential fuel and oil leakage, waste and wastewater, noise generation, and ecosystem. Optimal mitigation measures to reduce them were established accordingly (see section II in the above).

The main environmental impacts possibly caused by the proposed activities include:

- Unavoidable atmospheric emissions involved with fuel consumption
- Possibility of fuel and oil spills during fuel transfer and refueling as well as from damaged fuel pipelines and tanks
- Generation of hazardous and non-hazardous wastes such as construction waste, domestic waste, waste oil, and food waste
- Wastewater generation during the construction and operation of the station
- Noise generated from loading and unloading activities, equipment operations and other activities
- Possibility of disturbance to the local ecosystem of both marine and land biota (e.g., colonies of Weddell Seal and South Polar Skua, and lichens and mosses)

Waste heat from CHP system will be used to reduce the emissions of air pollutants. The use of fossil fuels will be minimized by increasing renewable energy and maximizing the indoor use of natural sunlight, and recycling the waste heat.

To prevent fuel spills, fuel tanks will be double-skinned and oil impermeable bund wall will be built around the fuel tank. For prevention and clean-up of spills, appropriate equipments and supplies will be prepared in the station in accordance with the associated regulations such as the guidelines of COMNAP/SCALOP (2003), etc.

Waste will be managed according to the Jang Bogo Station Waste Management Manual (KOPRI, 2011b). All wastes will securely be stored until transported outside of Antarctic region for disposal or recycling.

Wastewater will be treated using the high-level treatment system. The treated water up to the most stringent level of wastewater standards will be discharged (e.g., BOD less than 5mg/ℓ and COD less than 20mg/ℓ) accordingly.

Noise will be kept at a level not expected to disturb the South Polar Skua and Weddell Seal colonies by appropriately phased/distributed uses of construction equipment.

Given that there are no areas playing important role as habitats or colonies of a certain organism close to the proposed site, the station will not cause a significant impact on the surrounding ecosystem.

Environmental impacts and mitigation measures are summarized in an impact matrix, which evaluates possibility, range, period, and importance of the impacts.

VI. Environmental Monitoring and Verification

The Jang Bogo Station will implement an environmental monitoring program to continuously monitor environmental changes caused by its operation, and prepare systematic mitigation plans to respond to environmental accidents and other emergency. Activities that adversely affect the environment will be investigated and adjusted through monitoring of air emissions, fuel leakage, waste management, wastewater treatment and the ecosystem.

VII. Gaps in Knowledge and Uncertainties

The uncertainties and gaps in knowledge identified in the final CEE for the construction and operation of the Jang Bogo Station are as follows:

- Distribution of sea ice around Cape Möbius and climate conditions during construction period
- Future retreat of the Campbell Glacier Tongue near the proposed site
- Long-term climate change near the construction site
- Uncertainties in the knowledge and information of natural environment near the proposed site
- Status of a few South Polar Skua nests distributed close to the proposed site

- Items related to the future expansion of the station
- Changes in the activities of the station according to the change in future perspectives of research

VIII. Conclusion

The environmental impact of the construction and operation of the Jang Bogo Station is anticipated to be minimized by applying environmentally friendly technologies and optimal scientific mitigation measures. In addition, impacts of activities related to research and maintenance/management of the station on the ecosystem are also expected to be reduced by proper mitigation measures. The South Polar Skua colony near the proposed site is located at a safe distance from the station, and hence, the disturbance to skuas will not be significant by the construction and operation of the station. Furthermore, long-term monitoring of the potential environmental impacts will continue and the scope of site activities will be modified accordingly.

The Jang Bogo Station will be a multidisciplinary research hub of this region. It will fulfill its role of contributing to the international and multidisciplinary research activities by providing support not only to Korean scientists, but to foreign scientists and giving opportunities cooperating on international science projects.

The result of CEE suggests that the profits of knowledge and scientific information that will be obtained from the Jang Bogo Station will grossly outweigh the “more than a minor or transitory” impact on the Antarctic environment; thus, the establishment of Jang Bogo Station is highly recommended.

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1. Introduction

1.1. Purpose of the Jang Bogo Station

This final Comprehensive Environmental Evaluation (CEE) for the construction and operation of Korea's Jang Bogo Antarctic Research Station near Cape Möbius, the Terra Nova Bay of Northern Victoria Land in the Ross Sea area, estimates and analyzes the environmental impacts as well as lays out plans to minimize such impacts of the proposed activities so that its construction and operation are environmentally sound and sustainable (Fig. 1-1).

Global-scale environmental changes that have been surfacing since the end of the 20th century seem to pose a potential threat to human survival. Such alerting presence of environmental issues propelled the formation of an expansive agreement on the need to preserve the untouched environment of Antarctica and highlighted the importance of scientific research in the region. Antarctica provides a unique vantage point for observing the very first symptoms of climate change as it regulates the global climate system through constant energy and element exchanges with other regions. Preserved conditions of the Earth's past in the polar ice caps provide important clues to understand the current climate system and to better predict its future changes. The region is also geographically ideal for astronomical and aerospace studies.

In February 1988, the Republic of Korea constructed the King Sejong Station, a permanent base on King George Island near the northern Antarctic Peninsula. This station is actively undertaking a variety of research activities. However, given the distance from the main Antarctic continent, its current location has often been assessed as limiting the extent of in-depth research and of making a greater contribution to global efforts in tackling climate change. In this context, a proposal to construct the second research station in the mainland of Antarctica was initiated in 2004 (Ministry of Maritime Affairs and Fisheries, 2005), and six candidate sites were selected (KOPRI, 2007). Field investigations and assessment on those candidate sites were conducted from 2007 to early 2010 by a group of experts, including the Korea Polar Research Institute (KOPRI), organized by the Korean government (Kim *et al.*, 2008; KOPRI *et al.*, 2010). The findings of the assessment and three open hearings in Korea led to the final selection of the site approximately 1km north of Cape Möbius, which is a part of the coastal regions of Terra Nova Bay, Northern Victoria Land near the Ross Sea (74°37.4′S / 164°13.7′E) (Fig. 1-2). In this process, factors such as the planned research activities in the station, the level of environmental impact by the station, logistical convenience, and existing international research network were all carefully considered. Later, the international procedure on the construction of the station was initiated by the submission of the Information Paper (IP) on the establishment of Jang Bogo Station to the XXXIII Antarctic Treaty Consultative Meeting (ATCM) held at Punta del Este, Uruguay in May 2010. The draft CEE was circulated by the Korean government to other Antarctic Treaty Consultative Parties (ATCPs) more than 120 days before the ATCM XXXIV held in Buenos Aires, 2011.

The official name of the base, Jang Bogo Station, was chosen through a naming contest, which was held to boost nationwide interest on the construction of the second Korean research station in Antarctica. Jang Bogo is a distinguished figure in Korean history who built the marine Silk Road to enable international exchange of goods and cultures in the 9th century, an epitome of the Korean pioneer spirit.

Major research bases located near the Ross Sea area are as follows: The U.S. McMurdo Station, which has been in operation since the late 1950s on Ross Island along the Ross Ice Shelf of Southern Victoria Land; New Zealand's Scott Base located approximately 3km from the McMurdo Station (Fig. 1-1); and Italy's Mario Zucchelli Station and Germany's Gondwana Station, both operating approximately 370km north from the McMurdo Station (Fig. 1-2).

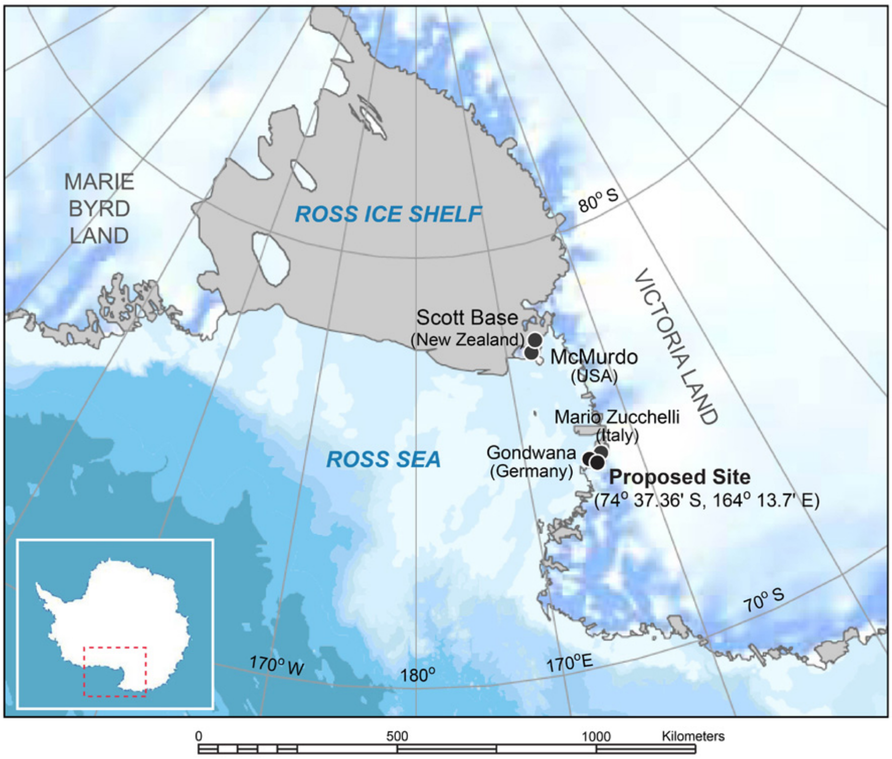


Fig. 1-1. Research bases near the Ross Sea and proposed site of the Jang Bogo Station. (Base map: adapted from Australian Antarctic Division, 2007)

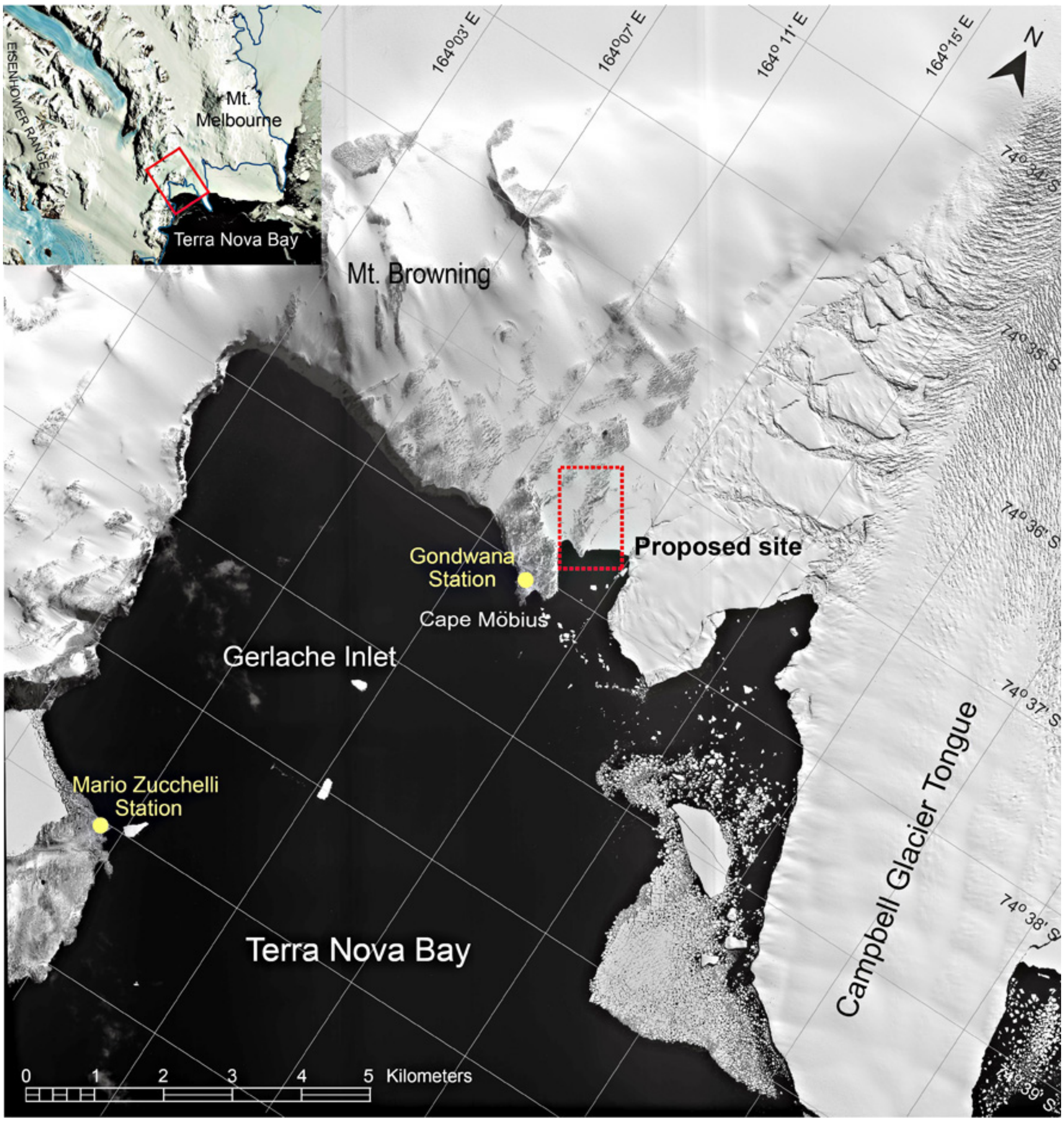


Fig. 1-2. Proposed site of the Jang Bogo Station. (Base image: adapted from KARI, KOMPSAT-2, 2010.02.08)

The Jang Bogo Station will be located on the boundary between East and West Antarctica. This position will allow comparative studies on climate change of both regions, filling the knowledge gap on the West Antarctic region caused by its limited accessibility. In close collaboration with the King Sejong Station (Fig. 1-3), the Jang Bogo Station will form West Antarctic observatory network using the icebreaker *ARAON*. In operation since 2009, the *ARAON* is an icebreaker, fully equipped with various cutting-edge research equipments and uniquely designed for research and logistics support in the Polar Regions (Fig. 1-4).

Fig. 1-3. King Sejong Station in King George Island. (Winter 2008)

Fig. 1-4. Icebreaker *ARAON.*

The Ross Sea surrounding Terra Nova Bay, the area selected to host the Jang Bogo Station, is known to form large-scale bottom currents. Recently, as the changes in the ocean circulations observed at the Ross Sea are being noted for their ultimate impact on climate change, the importance of monitoring distribution of sea ice as well as oceanographic and climatic natures is ever growing. Furthermore, the critical role of Terra Nova Bay in the formation of polynyas augments the importance of studying its impact on the marine ecosystem. Accessibility of the proposed site to the sea makes it an optimal location to study coastal ecosystems.

The Campbell and Priestley glaciers near the proposed site continuously drift towards the sea, and separating icebergs from glaciers further facilitate the movement. Thus, observations on changes of their movement will be a direct indicator of the increase and decrease in the size of the Antarctic ice sheet. It also provides an opportunity for researchers to go beyond Mt. Browning to the plateau and conduct studies on the continental glaciers of the East Antarctic region.

Once the Jang Bogo Station is constructed at Terra Nova Bay, the provided capacity, together with icebreaker *ARAON*, to conduct independent research on the broad region of West Antarctica will make a significant contribution to the international efforts of investigating global environmental change (Fig. 1-5).

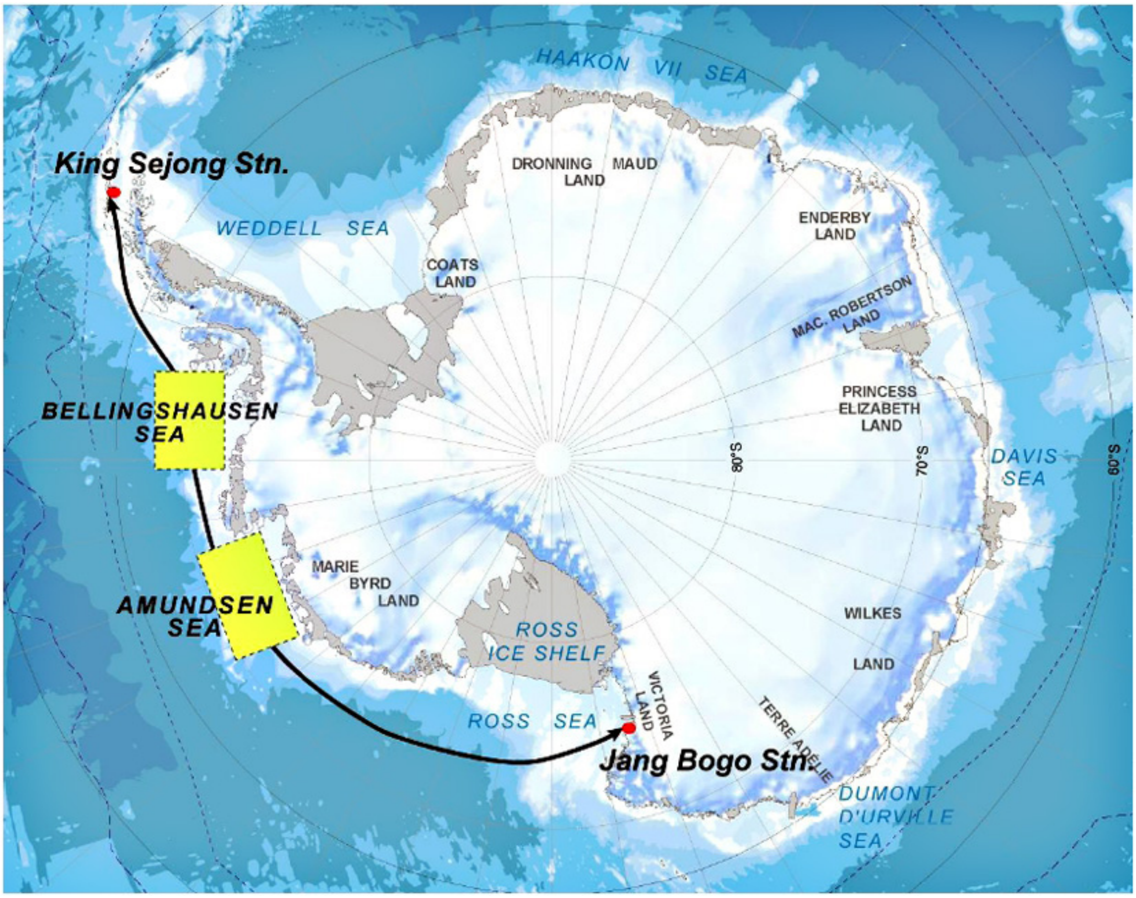


Fig. 1-5. Research sites in West Antarctica. (Base map: adapted from Australian Antarctic Division, 2007)

The Jang Bogo Station will be a sole permanent base operated throughout the year in Northern Victoria Land. It will also accommodate year-round monitoring and research of long-term impacts of climate change to ecosystem of the surrounding areas. Acting as the hub of various researches as well, the Jang Bogo Station will contribute to international collaboration and multidisciplinary studies in support of both Korean and foreign scientists.

The Jang Bogo Station is designed to minimize the impact of its construction and operation activities on the Antarctic environment. Combined Heat and Power (CHP) generation will reuse heat energy from generators and high efficient insulation panels are going to be placed. In order to minimize green house gas emission, the use of solar and wind renewable energy will contribute as much as 30% to the required energy need.

1.2. History of Korea's Antarctic Research

Recognizing the significance of the Antarctic research, Korea joined the Antarctic Treaty in 1986. Korea's history of research interest in the Antarctic reaches as far back as to 1978, when the investigation of krill in the Antarctic Ocean was initiated. However, the first step toward the full-pledged research activities in Antarctica began with the establishment of the King Sejong Station (62°13΄S / 58°47΄W) on King George Island, the South Shetland Islands, located northeast of the Antarctic Peninsula. The Korea Antarctic Research Program (KARP) based at the King Sejong Station has since been conducted for past 24 years on both land- and sea-sides of the South Shetland Islands, including King George Island and Bransfield Strait. The on-going program on the Antarctic Peninsula includes researches on meteorology and geology of the Antarctic Ocean and northern Antarctic Peninsula; long-term monitoring of the land and marine ecosystems in the region; and marine and benthic ecosystems of the Antarctic Ocean. These multidisciplinary studies included in the program are expected to broaden knowledge and enhance understandings on the environmental and ecological impacts of climate change in the Antarctic Peninsula, the most rapidly warming area in Antarctica.

The King Sejong Station was registered as an official weather station of the World Meteorological Organization (WMO) in 1989. The atmospheric observation system at the King Sejong Station is studying the exchange of energy between land and atmosphere, and monitoring changes of air chemistry in the polar region by analyzing aerosols.

Furthermore, in an effort to trace the paleo-climate change, studies on the geologic history of the South Shetland Islands as well as the sedimentary environments of both glacier in

Bransfield Strait and inner bays are ongoing. Korea is also actively participating in European Project for Ice Coring in Antarctica (EPICA), an international ice core drilling and research program on paleo-climates and paleo-environments. It began to collect meteorites in the ice fields of the Antarctic to study early history of the solar system from 2006 as well.

1.3. Scientific Research at the Jang Bogo Station

Continued legacy of scientific achievements of the International Polar Year (IPY) 2007-2008 evidently emphasizes the importance of the Antarctic in the Earth's system and the need for continuous post-IPY research activities to overcome limited human knowledge on climate change. In solidarity with the legacy, Korea further expanded the scope of the climate change research in its Antarctic Research Program pursuing to benefit humanity beyond borders through better understandings of the global-scale issue.

The coastal area of the Ross Sea where the Jang Bogo Station will be located provides an easy access to a variety of cryosphere (e.g., ice sheet, glacier, ice shelf, ice tongue), geosphere (e.g., Transantarctic Mountains) and hydrosphere (e.g., Ross Sea), accommodating a wide range of studies. The Ross Sea continental shelf represents a unique habitat and is substantially different from other areas of the Southern Ocean because of the extreme seasonality, numerous polynyas and extensive ice shelf. Along with the Weddell Sea, it is also one of the places with extensive bottom water formation in the Antarctic. This region is experiencing rapid freshening that may result in change in the rate of bottom water formation and in turn global climate change. The long-term and winter-over research program based on the Jang Bogo Station will contribute a great deal to understand the rapid climate change in the region and the Antarctic system response to it. The Jang Bogo Station is expected to provide an ideal platform for the research on climate change over the Pacific Ocean side of Antarctica and contribute to promoting scientific research of Northern Victoria Land.

In this context, the Jang Bogo Station is expected to boost multinational and multidisciplinary research collaborations in Northern Victoria Land while its infrastructure will remain open to all international researchers who wish to study the Antarctic. Currently, the United States, New Zealand, Italy and Germany run their research stations in the Ross Sea. International cooperation with these countries in operational support and logistics is expected to increase safety and efficiency in Antarctic activities.

☐ Climate and Atmospheric Chemistry: Establishment and Operation of WMO/GAW Global Station

In order to understand and predict the process of climate change, continuous observation of changing atmospheric compositions in various regions is highly important considering their vital role in radiative forcing.

There is currently no permanent observatory for the continuous observation, however, within at least 300km radius of the planned Jang Bogo Station site. There are two Global Atmosphere Watches (GAWs) and thirty local-level watches operating in Antarctica, only twelve of them measuring greenhouse gases. The nearest such station to the planned site is the McMurdo Station. The U.S. station, collaborating with New Zealand, measures a wide spectrum of greenhouse gases at aircraft cruising altitudes. The sea-level monitoring of greenhouse gases at the Jang Bogo Station operating as a permanent WMO/GAW, therefore, is expected to add valuable resource and complement current understanding of the regional changes of atmospheric compositions.

This will connect the Atlantic Ocean (Germany’s Neumayer III) and the Pacific Ocean regions, being centered on the South Pole (the U.S. Amundsen-Scott Base). This large-scale monitoring of atmospheric components covers the entire Antarctic region, thereby strengthening the understanding of the interaction between the polar region and the middle latitude of the southern hemisphere.

☐ Glaciology and Snow Chemistry: Reconstructing Paleo-climate and Paleo-environment in the Antarctic

Various proxy analyses using glaciers and snow samples in East Antarctica that will be conducted at the Jang Bogo Station are expected to restore the past climatic change record of the last hundreds of thousands of years and those of more recent decades, enabling a more complete understanding of the climate changes of the region. Furthermore, the Jang Bogo Station will undertake studies of snow and glaciers along the coast of West Antarctica, on which climate change study has been relatively rare. Supported by the icebreaker *ARAON*, these studies will contribute to reconstructing the paleo-climate and environmental changes of the Pacific margin of Antarctica. In the future, it is also expected for the Jang Bogo Station supporting a new ice core drilling program planned in Northern Victoria Land as part of the global efforts to restore paleo-climate changes in the Antarctic region. For the ice core drilling program, a separate environmental impact assessment will be carried out to see how the drilling activity will affect the local environment.

☐ Tectonics and Geophysics

Tectonics and geophysics are one of the essential areas of research for structural understanding of its cryosphere, geosphere and hydrosphere. Measurements of the tectonic and geophysical characteristics are sporadic due to limited number of permanent stations in the Ross Sea region.

Various forms of cryosphere are located near the proposed site, such as Aviator Glacier, Campbell Glacier, Priestley Glacier, Nansen Glacier, David Glacier and Drygalski ice tongue. This geographical set-up makes the site well qualified for monitoring the stability of ice sheet and tectonic evolution of the Antarctic. David Glacier, in particular, is known to be one of the fastest moving glaciers in the Antarctic region. Icequakes caused by this speedy motion have been observed while the low-velocity layer beneath the glacier indicates relatively high geothermal heat.

Currently, both a German and an Italian research teams are each collecting partial-year tectonic data in the Terra Nova Bay area. Therefore, with the year-round tectonic measurements at the Jang Bogo Station, long-term monitoring of movement and mass balance of the David Glacier will be carried out, and the moving mechanism of the terrestrial glaciers will be studied in order to comprehend the relationship between tectonics and glacial changes. Three-dimensional monitoring will be conducted employing ground, marine, and satellite data. The year-round, comprehensive sets of measurements obtained from the gravimeter, tide gauges, and GPS that are planned to be installed at the Jang Bogo Station will greatly facilitate and contribute to the regional geophysical and tectonic research.

Installations of seismic, geomagnetic and GPS observation systems at the Jang Bogo Station are planned as part of the Polar Earth Observing Network (POLENET), an international geophysical network working in the Antarctic area.

☐ Long-term Monitoring for ocean and ecosystem

The food web in the Ross Sea continental shelf is substantially different from those in the other areas of the Southern Ocean because of its extreme seasonality, numerous polynyas and extensive ice shelf. This ecosystem is also subject to all physiochemical changes occurring in the area. Accordingly, the physics of polynya formation will be studied and long-term monitoring of ecological impacts of polynya and ice shelves will be performed at the planned station.

For rapid freshening in the Ross Sea, it is of a great importance to identify major oceanographic and atmospheric parameters that are responsible for the freshening and to monitor the variability in the rate of bottom water formation. The observation of sea ice extent and physical processes is also important topics that need to be addressed collectively in a timely manner. As these physiochemical changes of the ocean can alter diversity of the marine ecosystem, its food web and functions, a long-term monitoring in this area is warranted. Continuous monitoring of physiochemical characteristics and its ecological impacts of the surface water near the construction site are also planned, which is expected to help understanding its seasonal changes and relationship with regional climate change.

In addition, the Jang Bogo Station will assist the exploration of meteorite in Northern Victoria Land; the paleo-climate study of the Ross Sea using marine sediments; and the observation of ionosphere using Dynasonde antenna with Vertical Incidence Pulsed Ionospheric Radar (VIPIR). A VIPIR will be installed to measure the altitudinal ionic strength distributions and occurrences of ionic wind for continuous atmospheric monitoring of Antarctic ionosphere and thermosphere. The collected data may be validated through comparisons with those from the Mario Zucchelli Station's Digisonde. Unlike the Digisonde, the VIPIR targets the ionic strength distribution of D-region (approximately 90km of altitude), and therefore is expected to further contribute to understanding the impact of high-energy solar particles on the ionic distributions at the bottom of the thermosphere as well as within the mesosphere.

1.4. Preparation and Implementation of the CEE for the Jang Bogo Station

The CEE of the construction and operation of the Jang Bogo Station has been carried out in accordance with the domestic law, Act on Activities and Preservation of the Antarctic Region, and internationally the Article 8 and Annex I (Environmental Impact Assessment) of the Protocol on Environmental Protection to the Antarctic Treaty.

A survey team of environment and construction experts led by KOPRI conducted a preliminary field study for the proposed site of Cape Möbius at Terra Nova Bay in February 2010, followed by more detailed field investigation efforts in February 2011 and also in January 2012. The locations of the dock and water intake points were selected based on the hydrographic data and measurements on tide and currents collected during the 2011 investigation and also considering accessibility and safety. Some complementary investigations of the currents and tides as well as potential environmental impacts are planned to follow.

The CEE was completed based on the results of the field study and data analysis as well as predictions and assessment of environmental impacts. The draft CEE written in Korean was submitted to the Korean Ministry of Foreign Affairs and Trade (MOFAT) in December 2010 and circulated to relevant ministries including the Ministry of Environment (MOE). MOE has officially organized an advisory committee to review the draft CEE. It was open to public for opinions on the environmental validity of the project. The draft CEE written in English was circulated by the Korean government to other ATCPs more than 120 days before the ATCM XXXIV held in Buenos Aires, Argentina during June 20th - July 1st, 2011. The draft CEE was considered by the Committee for Environmental Protection (CEP) at the ATCM.

Final CEE has been prepared incorporating comments and suggestions, officially received by national and international sources (MOFAT and CEP, respectively). The final CEE written in Korean was approved and endorsed by the Korean government in April 2012. Accordingly the final CEE written in English will be circulated by the Korean government to other ATCPs at least 60 days prior to proposed activities.

1.5. Regulations, Standards and Guidelines

In principle, the CEE of Jang Bogo Station follows the essential instructions of Article 8 and Annex I of the Protocol on Environmental Protection to the Antarctic Treaty. In this regard, the CEE has been prepared in accordance with the Guideline for Environmental Impact Assessment in Antarctica, which is a sub-guideline to the Principle of Antarctic Environment Protection, prescribed in Article 3 (Environmental Principles) Clause 2(c) of that Protocol (COMNAP, 2005a). In terms of transportation, oil spill countermeasures, waste management and contingency plans, the CEE is prepared following the guidelines for construction and operation of a station, suggested by COMNAP (Table 1-1).

Table 1-1. COMNAP and ATCM guidelines.

Operational Guidelines	
COMNAP Guidelines for Environmental Impact Assessment in Antarctica	2005
COMNAP Fuel Manual	2008
COMNAP Papers to Antarctic Treaty Meetings	
ATCM XXVII (IP012)-COMNAP's framework and guidelines for emergency response and contingency planning in Antarctica	2004
ATCM XXVII (WP010)-Guidelines for the operation of aircraft near concentrations of birds in Antarctica	2004
ATCM XXVIII (WP026)-Practical guidelines for developing and designing environmental monitoring programmes in Antarctica	2005
ATCM XXIX (IP088)-Practical biological indicators of human impacts in Antarctica	2006
ATCM XXX (IP098)-Waste management	2007
ATCM XXX (WP035)-Energy	2007
ATCM XXXI (IP098)-Survey on existing procedures concerning introduction of non native species in Antarctica	2008
ATCM XXXI (IP091)-The COMNAP Fuel manual, incorporating revised guidelines for fuel handling and storage in Antarctica	2008
ATCM XXXIV-CEP XIV (Resolution 6)-Non-native Species	2011

Korea enacted the Act on Activities and Preservation of the Antarctic Region in 2004 based on the Protocol on Environmental Protection to the Antarctic Treaty. This Act aims to contribute to the protection of the Antarctic environment and advancement in science technology in Antarctica by declaring the principles of activities in the region. Those who wish to commit to activities in Antarctica must consult with the MOE and obtain approval from the Minister of Foreign Affairs. The entire process of preparation, consultation, and approval of the CEE will comply with the enforcement ordinances and regulations under the Act.

For air quality, water quality and noise, domestic environmental standards were applied. The domestic environmental standards will be applied to the Initial Environmental Evaluation (IEE) for supplementary field investigations as well as to the CEE. The domestic environmental standards are considered as strict criteria of ecosystem and human health protection and well qualified for application to the Antarctic environment.

1.6. Project Management System

Once the Jang Bogo Station is constructed, KOPRI, the national operator of Antarctic activities, will coordinate the operation of the station and be in charge of Korea's overall research activities in Antarctica including the operation of the King Sejong Station and the icebreaker *ARAON*.

Under the supervision of the Ministry of Land, Transport and Maritime Affairs, KOPRI is responsible for the overall project for the establishment of Jang Bogo Station. Two other national research institutes, Korea Environment Institute (KEI) and Korea Institute of Construction Technology (KICT) were assigned to lead the generation of CEE and the construction master plan, respectively. Universities and private companies were also invited to participate in digital mapping, satellite image analysis, and other activities associated with the establishment of the station. In November 2010, a consortium led by Hyundai Engineering & Construction Co. was awarded the construction contract of the station. The company is in charge of construction of the entire station, including designing and planning the facilities.

The construction for the Jang Bogo Station is expected to start at the end of 2012 after circulating the final CEE to ATCPs at least 60 days prior to proposed activities. The construction will proceed for two Antarctic summers, and the station is expected to begin to operate early 2014. The design of the main station building should provide convenience, safety and energy efficiency. Renewable energy will be used in the station as much as possible. To ensure the best possible outcome in the planning and construction of the Jang Bogo Station, a group of consulting experts in environmental assessment, safety management, construction technology, and other associated areas will be summoned and provide necessary assistance to move the project forward.

2. Description of the Proposed Activity

2.1. Regional Overview

The Terra Nova Bay region is bordered by Cape Washington to the northeast and Inexpressible Island to the southwest in the western Ross Sea of East Antarctica (Fig. 2-1). Italy's Mario Zucchelli Station is located in the Northern Foothills in the west. The station mainly operates as a summer station, where quality research on various fields such as oceanography, geology and ecology is conducted. Cape Möbius lies approximately 7km northeast of the Mario Zucchelli Station, and the Germany's Gondwana Station is situated at the southern end of this cape. The station is a base that undertakes research in geology and geophysics only during the alternate summer seasons.

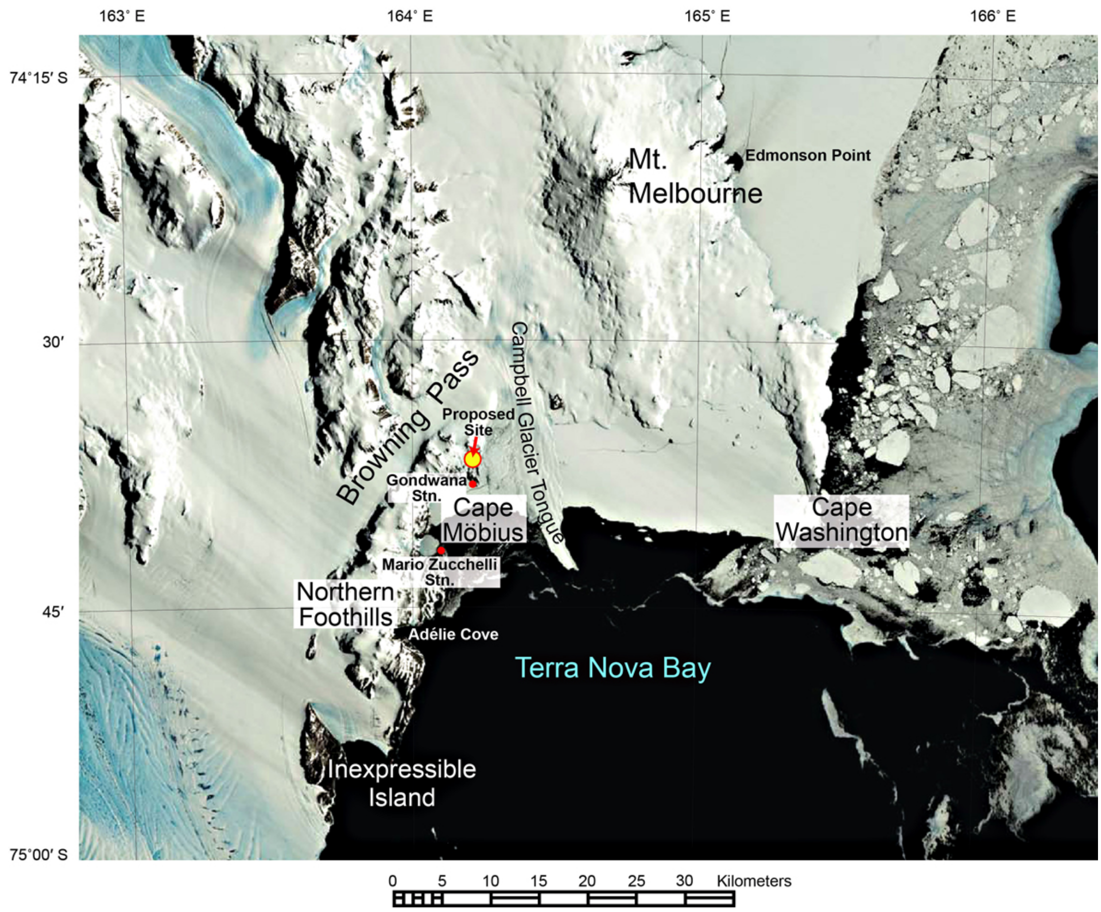


Fig. 2-1. Regional overview. (Base map: adapted from MUSEO NAZIONALE DELL'ANTARTIDE-Sezione di Scienze della Terra, Via Laterina 4-53100 SIENA-ITALY, 1996)

The proposed site for the Jang Bogo Station is located on the flat ground of a small bay 1.2km to the NNE of the Gondwana Station (74°37.4′S, 164°13.7′E, Fig. 2-1). Mt. Browning of NE-SW direction stands in the northwest rear of the proposed site, over which the 3km wide Browning Pass Glacier is developed in parallel. This ice valley is used as a runway by Italy. To the east of the small cape of the proposed site, the Campbell Glacier Tongue, which stretches from north to south, flows to the sea. About 30km NNE from the proposed site lays Mt. Melbourne.

A large colony of more than 150 South Polar Skuas resides in the eastern hills of Cape Möbius, but no penguin colonies were found in the region. There are two Adèlie penguin colonies near the Mario Zucchelli Station and a colony of Emperor penguins near Cape Washington approximately 20km to the east from the proposed site.

2.2. Proposed Activities

2.2.1. Main Activities

Main activities mentioned in the CEE include construction, operation and dismantling of the Jang Bogo Station and logistics to the station. The construction of the station is expected to commence in December 2012 and continue until March 2014 on during two consecutive Antarctic summer seasons. In principle, all activities related to the construction and operation of the station will adhere to the Protocol on Environment Protection to the Antarctic Treaty, and the impact of such activities on the environment has been planned to be restricted to a minimum level.

2.2.2. General Specification of the Jang Bogo Station

The Jang Bogo Station will be operated at least 25 years after being constructed. The station will be staffed with engineers, mechanics, an electrician, a doctor, and other managing staff members for its year-round operation. It will also accommodate researchers in various fields such as atmospheric science, astrometeorology, geophysics, oceanography, etc. The expected number of occupancy is 15 during the winter months while being up to 60 during the summer when more research staff and visitors are anticipated (Table 2-1). The number of winter-over staff doubles during the overlap in summer.

Table 2-1. Personnel for operating the Jang Bogo Station.

Type	Personnel	
	Winter	Summer
Staff	11	24
Researchers	4	Max. 36
Total	15	60

The station consists of the main building, power plant, maintenance building, emergency shelter, and observatory facilities with a building area of 4,411.46m^2. Other facilities such as antennas, fuel tank and heliports will additionally be installed (Appendix 1).

The design of the station includes a triple-arm shaped central main building, which connects to individual facilities such as the maintenance and power facilities in radial arrangement. As a result, all facilities will be placed close to each other. This station layout is intended not only to give the safety, functionality and efficiency that the operation of the station requires, but also to limit the land usage and minimize potential intrusion to the environment. Furthermore, as all facilities will be directly connected to the main building, the indoor traffic and associated energy loss will be minimized.

An aerodynamic design will be used for the main building in order to enhance its resistance against strong winds. Fire protection will be implemented with compartmentation in the building. The building will be elevated from the ground surface and be built with slanting walls and roofs to minimize snowdrift piling up around the building. Light shelves will bring in natural light from outside and double-layer walls and five-time glazed windows will maximize the energy efficiency.

Each facility will be in harmony with the natural landscape. The current design of the building foundation does not require driving piles or anchors into the ground, and hence, will not only shorten the construction period but also minimize the noise generated in the process. Modular construction system will be applied to most of the buildings in order to further decrease the total construction hours and thus minimize the cumulative impacts arising from each construction phase.

In order to minimize the use of fossil fuels required in the operation of the station, CHP system will be mainly used and the generators will fully utilize the waste heat. Solar and wind renewable energy system will be co-operated with at least 30% of the 275kW CHP capacity.

A comprehensive high-level treatment system will be used to treat wastes and wastewater during the operation of the station. All wastes will be stored under an appropriate management plan until transported outside of the Antarctic region. Using the gray water reclamation and reuse system, most wastewater will be reused, and the small amount of discharge water is expected to be near pollutant-free.

It is expected that activities related to logistics and transportation can be expanded depending on the changes of the station's operation plan, including cooperation with other stations and future research.

An environmental monitoring plan will be implemented in order to regularly monitor the environmental changes caused by the activities at the station. A systematic emergency plan has also been established (KOPRI, 2011a)

2.2.3. Transport and Logistics

All supplies for the station will be surface-shipped from Busan, Korea to Terra Nova Bay, via Christchurch, New Zealand. On the other hand, all personnel will be traveling by air from Incheon, Korea to Christchurch, arriving at Terra Nova Bay using the icebreaker *ARAON* (Fig. 2-2).

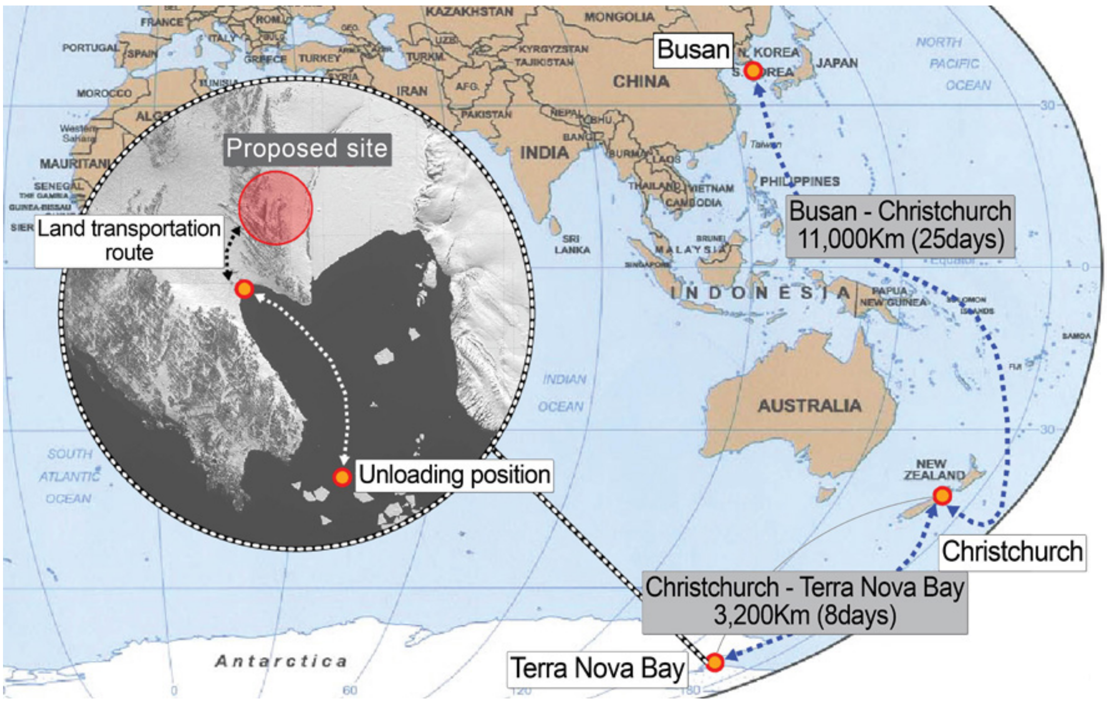


Fig. 2-2. Transportation route for shipping.

Given the geographical features of the proposed site, and the fact that there is no additional supply base in the area, the icebreaker *ARAON* will be providing main logistics support to transport supplies including the maximum 20ton food once each austral summer.

For the transportation of cargos and workers associated with the construction of the station, the *ARAON* and a chartered ice-strengthened cargo ship will be used. After they anchor near the proposed site, barge ships and helicopters will carry the workers and cargos from the ships to the land. Tracked vehicles will be needed for the additional 200m ground transport from the unloading point to the proposed site (see section 3.6 for more detail).

2.3. Station Design

The main demands for the design of the Jang Bogo Station were maximum energy efficiency and endurance to extreme weather conditions of the Antarctic region for the year-round operation of the station. Such demands prompted an aerodynamic triple-arm structure protective of strong winds in all directions (Fig. 2-3).

The concentrated radial positioning of facilities around the main building is intended to reduce the overall area usage of the station, thereby minimizing any possible intrusion into the surrounding environment. In order to reduce interferences between different programs in the station and to enhance functionality and efficiency in maintenance and management, each section of the building is clearly separated by its function in the design.

Energy plans of the station during the summer include installing light shelf and duct systems, and solar energy, which will encourage the highest level of activities by the largest number of personnel, to be engaged in during the long daylight hours. Furthermore, the double outer walls of the building will minimize energy loss by using the high-efficiency insulator, Polyisocyanurate Foam which is non-flammable, stable and non-deformable.

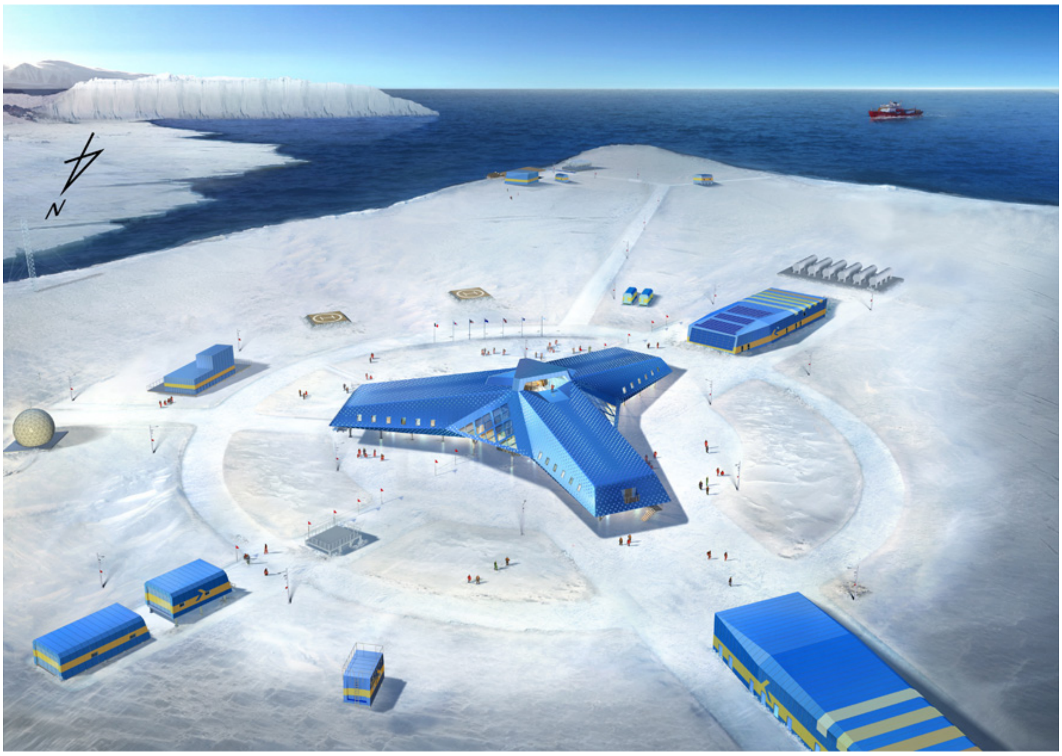


Fig. 2-3. Design image of the Jang Bogo Station.

☐ Station Layout Plan

The layout of the facilities in the station aims to provide the safety, functionality and efficiency required for the operation of the station. The facilities will be grouped into relevant sections and each section will be placed at the location that can provide optimal routes to other sections considering the inter-connectivity with minimal functional interference. With the main building acting as the pivot, facilities that will be used for similar comparable programs will be located within the same arm of the triple-arm structure. More specifically, most of the maintenance facilities will be located in the southern part, separated from the main building and the research facilities to minimize the noise disturbance. Research facilities for atmospheric science and geophysics will be located at a safe distance from the main building within the northwest and northeast arms, respectively, minimizing potential interferences by equipments in one facility on those in the other facility (Fig. 2-4(a)).

With the radial arrangement with the main building in the center, the layout plan provides direct access to the facilities from the main building. Major facilities include research facilities, power plant, maintenance and storage buildings, waste treatment facility, communication antennas and observatories. Renewable energy uses are planned with minimized potential environmental impacts: four 12kW vertically stacked modular type wind turbine structures, each composed of three 4kW capacity turbines, will be installed and Building Integrated Photovoltaic System (BIPV) and solar panels will be applied on the glass windows and building walls (Fig. 2-4(b)).

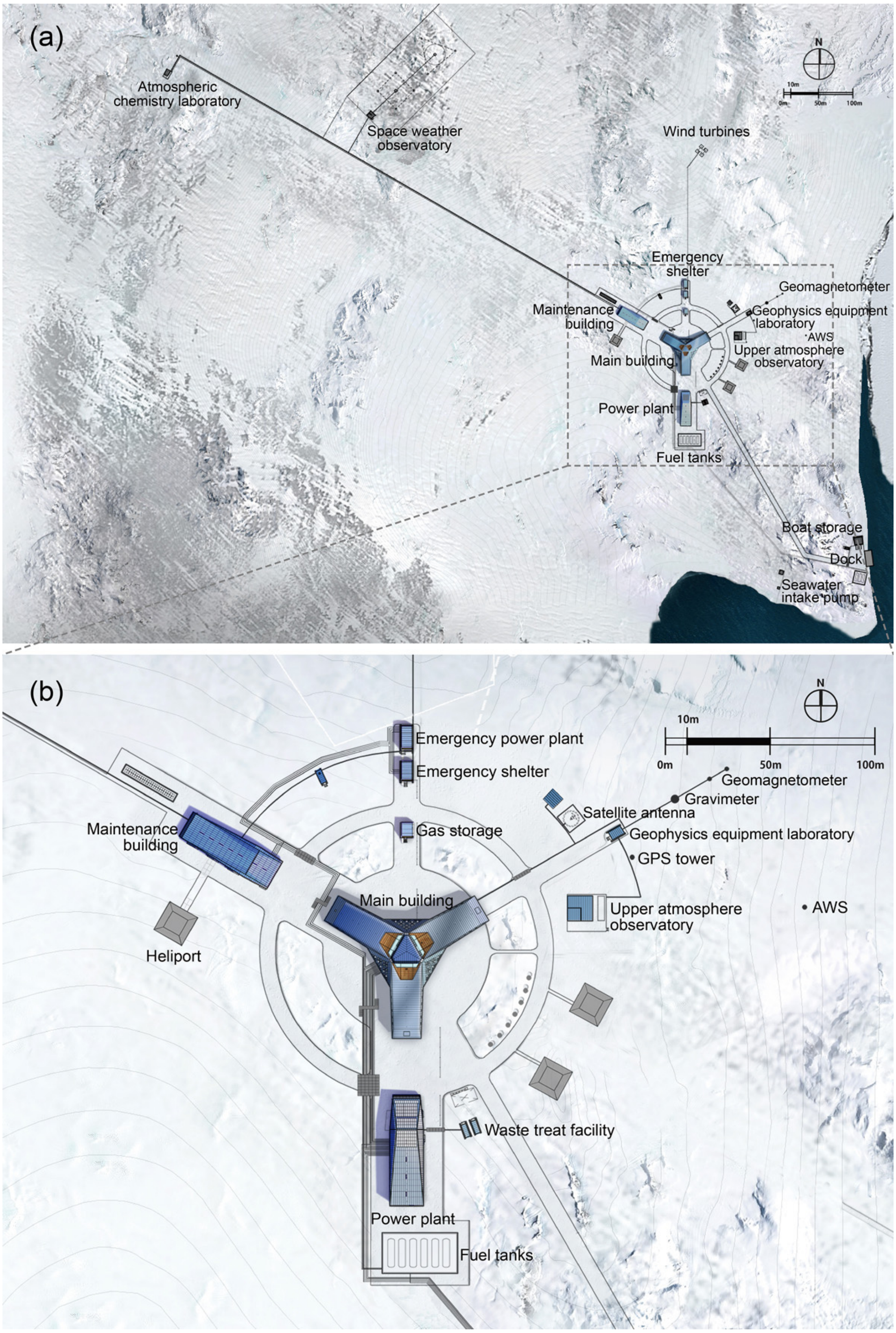


Fig. 2-4. Layout of the Jang Bogo Station. (a) Layout plan based on activities, (b) Arrangement of facilities.

☐ Main Building

The main building is designed to be an aerodynamic triple-arm structure elevated from the ground considering the strong winds and heavy snow in the region. Three main sectors of research labs, sleeping areas and residence supporting facilities are located on the elevated first floor of the main building. These sectors are laid out in the triple-arm structure, allowing each sector to be independent, at the same time making it secure, functional and efficient. The layout of the other floors in the building includes an Air Handling Unit (AHU) and emergency equipments on the ground floor, an office and meeting room on the second floor, and a communication room and observatory on the top floor (Fig. 2-5).

Fig. 2-5. Main building program.

Residence supporting facilities will have tall windows that allow as much natural light as possible into the facilities. A three-dimensional space plan has been devised for each floor and function area (Fig. 2-6).

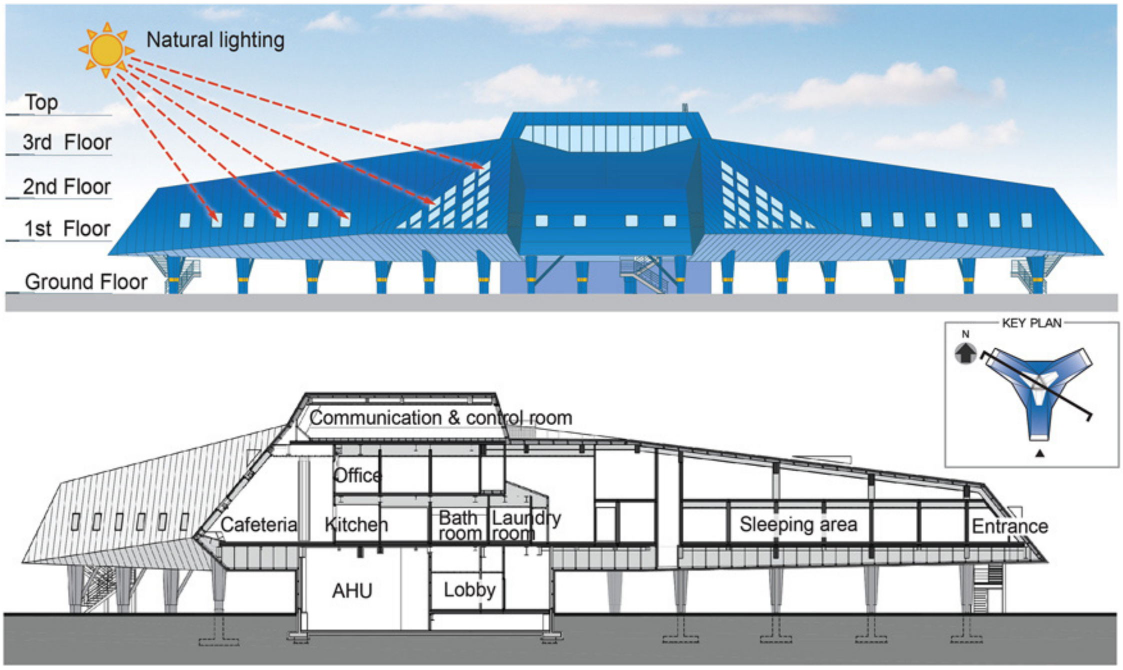


Fig. 2-6. Sectional view of the main building.

Furthermore, the working space and residence area will be separated through a division of both horizontal and vertical space. Facilities that may generate excessive noise will be grouped together, and separated from the sleeping areas and research labs with noise buffer zones to manage internally generated noise problems (Fig. 2-7).

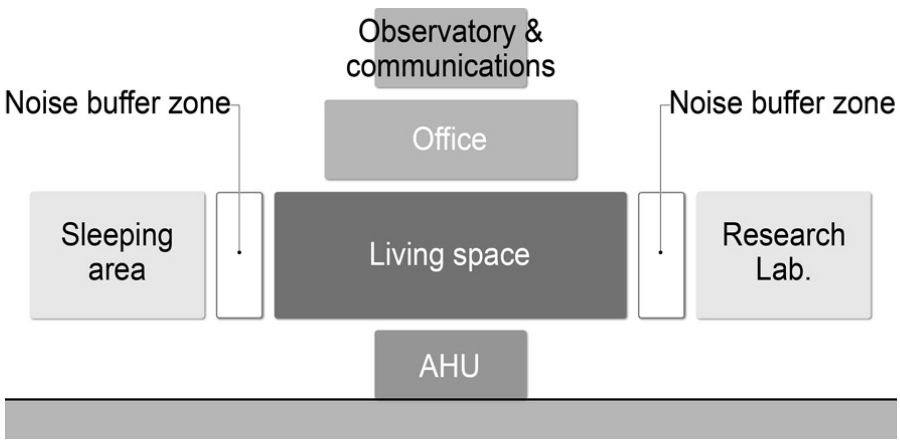
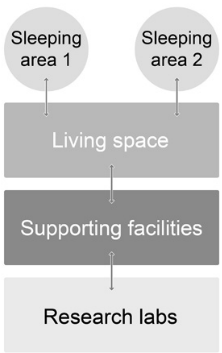
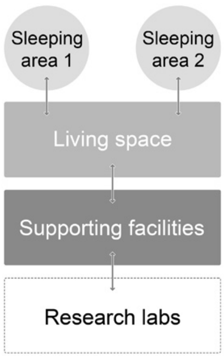
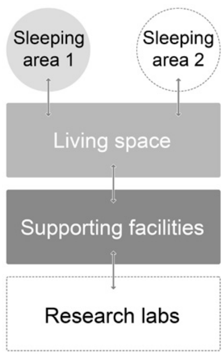
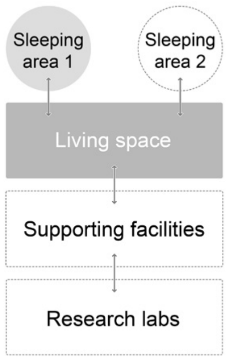


Fig. 2-7. Schematic diagram of noise buffer zone.

Also, an energy savings and efficiency plan was developed to plan sectioning of the main building into different operating areas by daily and seasonal changes in number of staff and facilities in operation. One of the residence areas and some research labs, for instance, will be closed during the winter to reduce the base operation down to 42% (Table 2-2). Closed areas will be partially heated at 5°C for preventing freeze. Meanwhile, cafeteria and convenience facilities will be installed with removable wall panels to be able to accommodate seasonally varying number of people they serve.

Table 2-2. Daily and seasonal operation plan of the main building.

Time	Summer day	Summer night	Winter day	Winter night
Personnel	60		15	
Main facilities in operation				
Operation ratio	100%	76%	65%	42%

The access passages for residential and research activities will be situated in close proximity to one another for both safety and accessibility reasons (Fig. 2-8(a)). In contrast, the access passages for vehicle, unloading, emergency and evacuation will be installed at locations to cause minimal disturbances to the passages for residential and research activities, and connected to the equipment facilities. The access passages for vehicle and unloading will also be connected to the dock facilities (Fig. 2-8(b)).

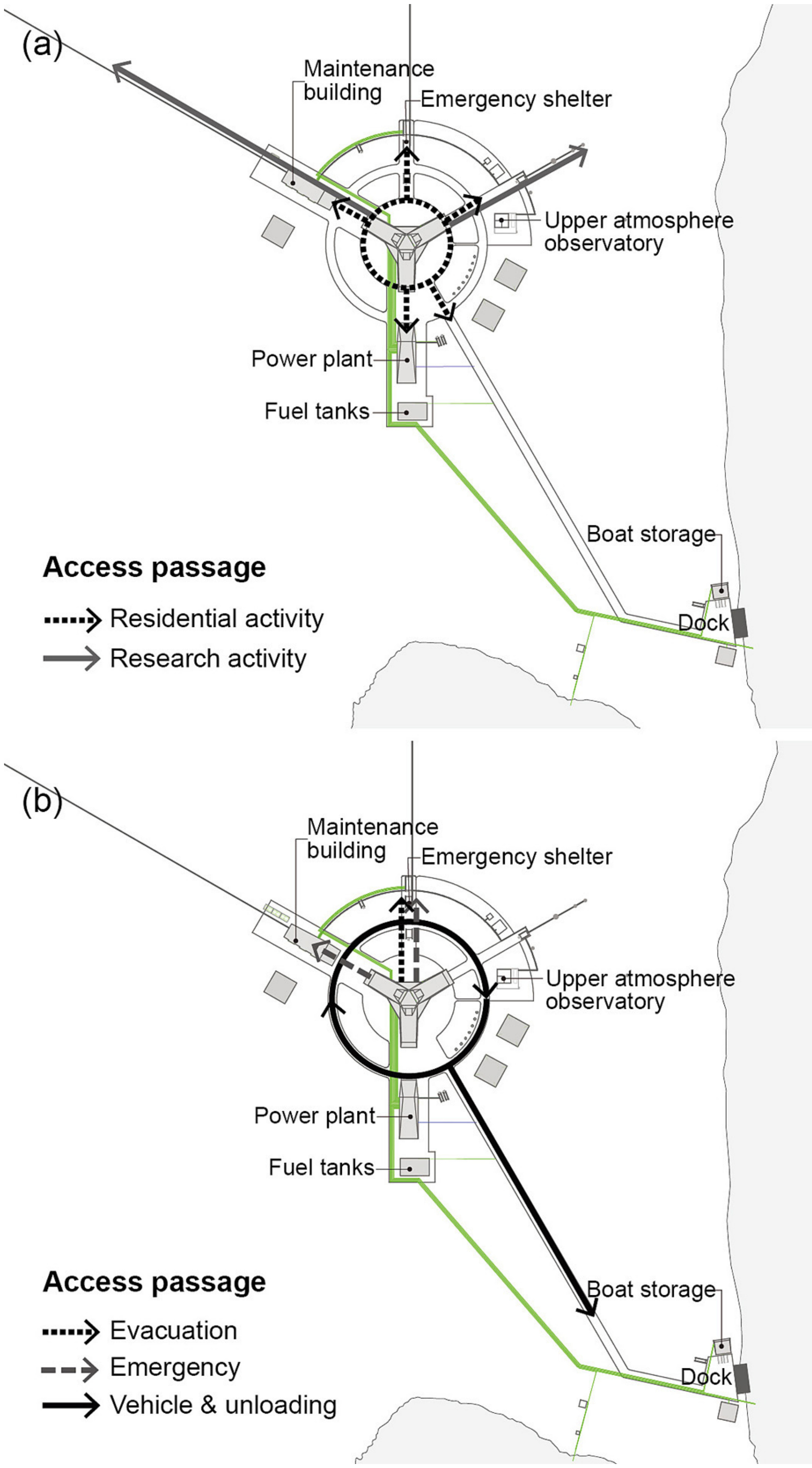


Fig. 2-8. Major access passages. (a) Residential and research activities, (b) Evacuation, emergency and vehicle.

☐ Fire Prevention Plan

An environmentally-friendly nitrogen extinguishing system, rather than a conventional sprinkler system, will be used in the Jang Bogo Station. The nitrogen system is automatically triggered if a fire develops and releases nitrogen gas which is harmless to health and environment. A fire door made of double layered steel plate will be installed at each wing. Fire alarms and eight indoor hydrants will be additionally installed in the main building and the power plant. A 20-ton supply will be rationed for firefighting from the water tank that will be in the power plant. In the event of a fire or emergency, all facilities will have two-way escape routes and the emergency shelter located considering prevailing wind direction will minimize the impact of flames and smoke caused by wind during escape (Fig. 2-9).

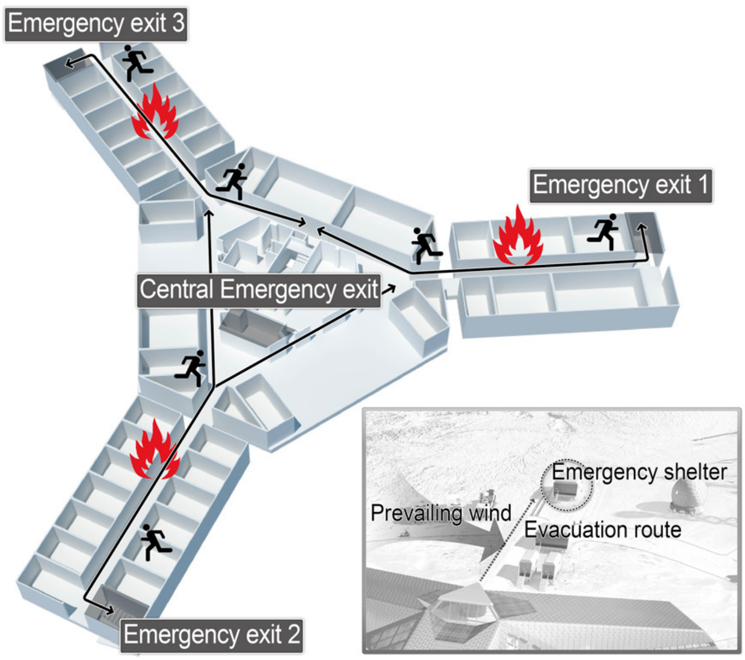


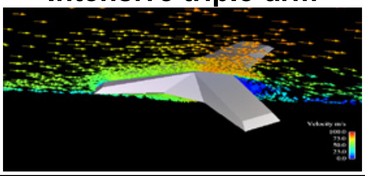
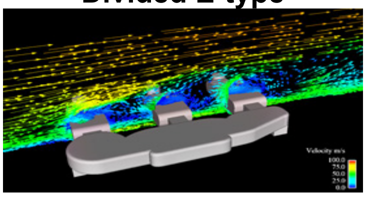
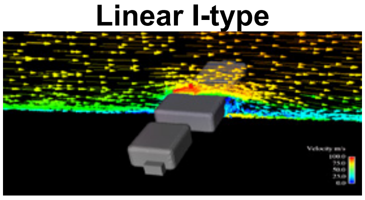
Fig. 2-9. Emergency evacuation plan.

☐ Safety from Winds and Snow

Some stations in the Antarctic region are suffering from snow pile-up that incurs considerable management costs of snow removal for accessibility and structure maintenances. A solution to this issue is the establishment of an optimal building layout plan based on an assessment of the changing patterns of wind speed and snow drift at the time of design and construction. Accordingly, a Computational Fluid Dynamics (CFD) numerical simulation on the hydrodynamics was conducted in order to evaluate the most appropriate design required to minimize the impact by the wind and snow pile-up.

First, the wind pressure indices of three different building designs, the intensive triple-arm design, divided E-type design and the linear I-type design, were compared to see how they respond to the strong winds. After calculating the basic wind speed using the data of weather conditions, wind pressure indices of construction standards were calculated with the CFD simulations. The wind pressure index of the intensive triple-arm design was 0.47, which showed that it is the least affected by strong winds as the indices for the E-type and the I-type structures were 1.14 and 1.26, respectively. Therefore, the intensive triple-arm design was evaluated as the most structurally sound design to withstand the impact of snowdrifts (Table 2-3).

Table 2-3. CFD simulations of three different types of building designs based on wind pressure index.

Type	Category	Drag Index	Lift Index
Intensive triple-arm 	Wind pressure index	0.47	0.04
Divided E-type 	Wind pressure index	1.14	0.29
	D	2.4	7.3
Linear I-type 	Wind pressure index	1.26	0.20
	L	2.7	5.0

Note) D and L: increasing/decreasing ratio of wind pressure index relative to intensive triple-arm type

Snowdrift damage caused by blizzards occurs due to the eddy flow at the rear of the structure. Drifted snow can accumulate up to more than five meters, causing extra work of clearing the snow.

Sometimes, the weight of the snowdrift may deform the structure. Combined with an elevated slanting structure, design of outer wall surface adopting the dimple effect can help minimize the damages of snowdrift. Majority of existing stations in Antarctica were built similarly for that reason. The elevated slanting structure enables the wind to circulate in the space between the structure and the ground, minimizing the exchange of heat between the relatively warmer building and the permafrost. Furthermore, the slanted design shades less area than the rectangular design, and hence, the ice formations near the main building will be also reduced (Fig. 2-10).

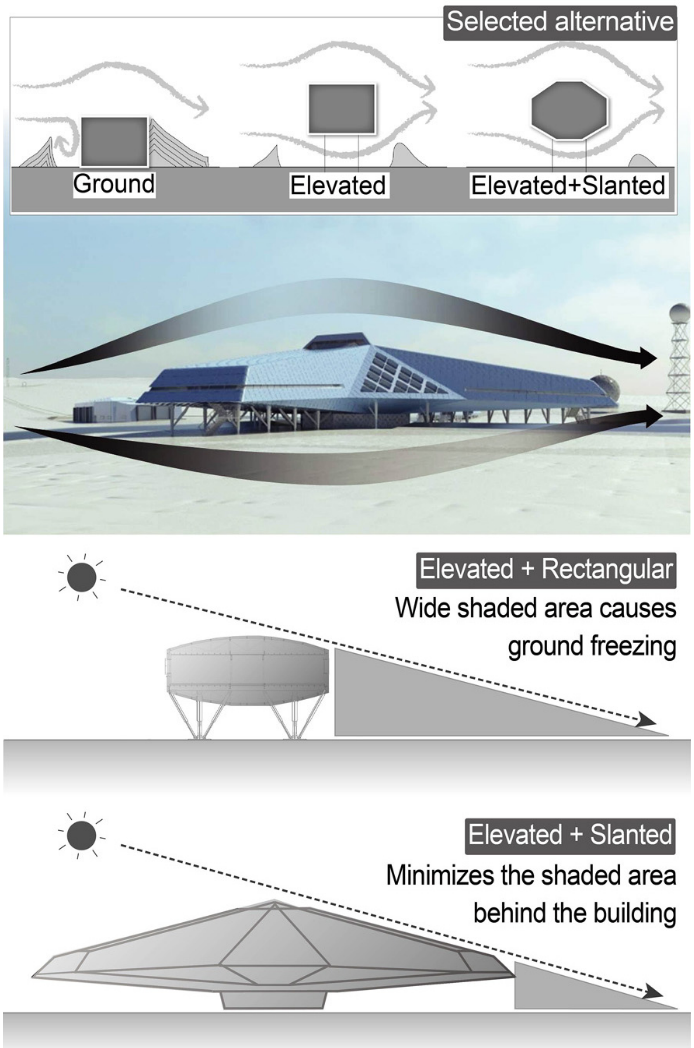


Fig. 2-10. Minimization of snowdrift and shading by adopting elevated and slanted design.

The result of the simulation on the main building elevated more than 2.5m above the ground surface indicates that there will be little snow pile-up in the surrounding area with the triple-arm design. Only a small pile of snow was created near the slipstream in the simulation (Fig. 2-11).

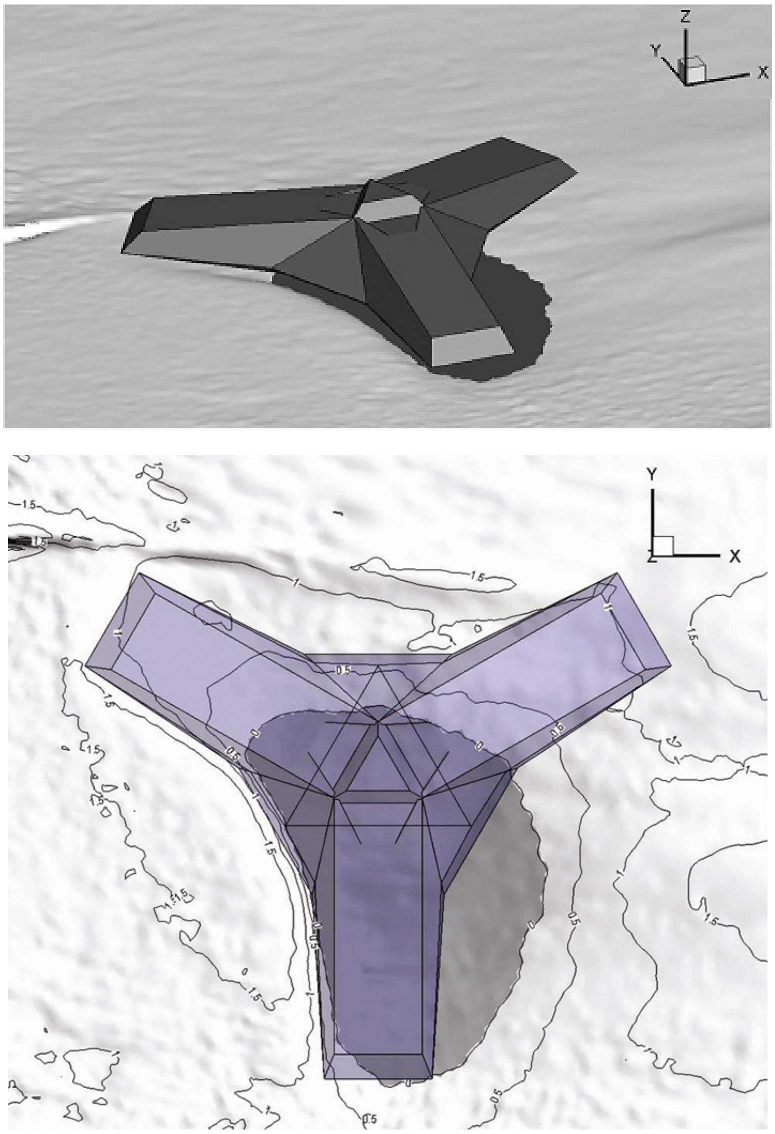


Fig. 2-11. Simulation of snow-piling up for the main building.

☐ Foundation type

For the foundation of the main building and facilities, the Precast Concrete (PC) was selected. Since PC foundation does not require pile or anchor driving into the ground, it will greatly reduce field work and construction time. PC foundation will be manufactured in and shipped out from Korea.

☐ Dock

A dock, indispensable for the construction as well as operation of the station, will be constructed at the eastern seashore of a small cape where the proposed site is located. The proposed dock area is wider and deeper than the western side of the station site according to the results of the hydrographic survey in February 2011 (Appendix 2). Docking facility will stretch along the shore approximately 30m-wide and 10m-long (Fig 2-4(a)).

In order to minimize its impact on the marine environment, the Gravity Wall type technique will be applied. This technique is one of the most secure structural methods as it can minimize resistance of external force and pack ice. By not using piles or anchors, it can minimize any impact to the natural landscape of the coast compared to other techniques.

A layout plan was developed to be less exposed to pack ice and strong wave and the secure and durable PC blocks with stainless steel panel will be used to minimize the impact on the marine environment. PC blocks will be used to further reduce construction time as they are easy to manufacture and install. The front of the PC blocks will be protected from ice drift with stainless steel panel. Rubble mound backfilling material will be supplied from Korea while excavated indigenous material is planned to be used for filling material (Fig 2-12). The backfilling material will be thoroughly cleaned in order to prevent invasive species migration.

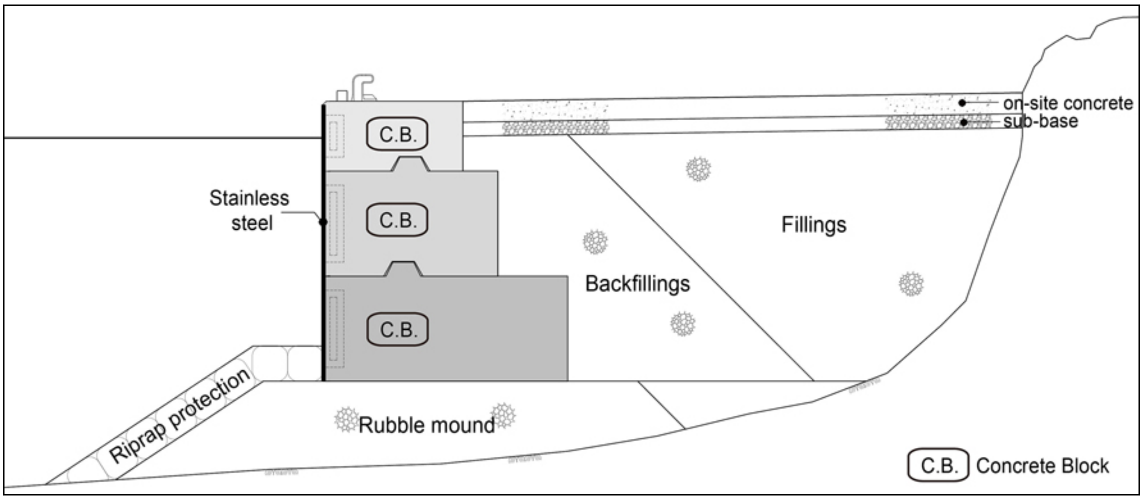


Fig. 2-12. Dock construction.

2.4. Construction of the Jang Bogo Station

2.4.1. Time Schedule and Duration

The construction of the Jang Bogo Station will commence in December 2012 to be completed by March 2014. It will be carried out in two phases over two consecutive Antarctic summer periods. If the cargo unloading or construction is obscured due to regional weather conditions, the construction period may be longer than initially planned.

The construction of the most of the major facilities surface grading and structures will be completed during the first phase. During the second phase, a step-by-step construction is scheduled for the supplementary facilities and installation of renewable energy equipments, and pilot operation of the station. Most of the major facilities will be assembled using modular units on site in the first phase (Fig. 2-13).

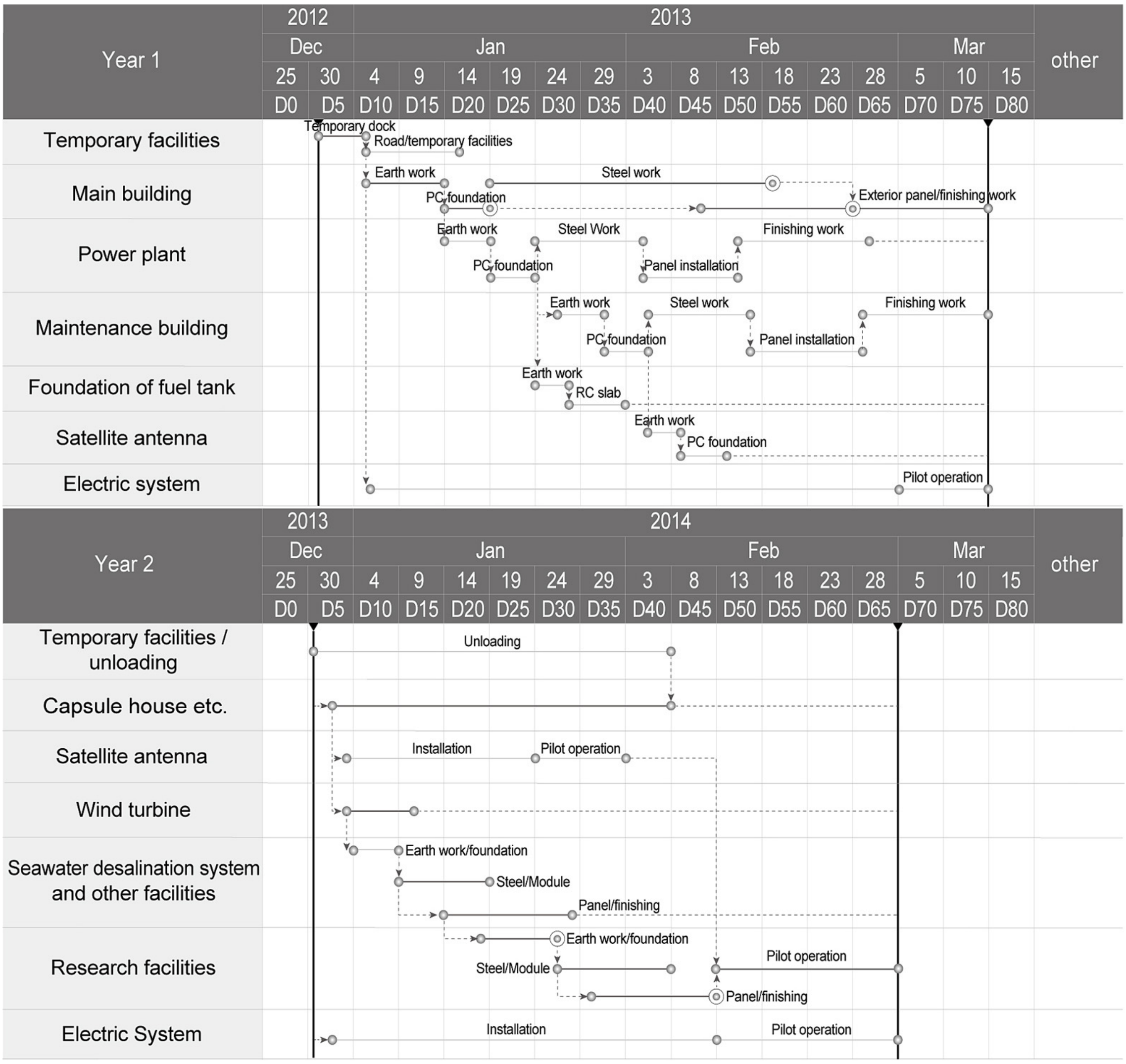


Fig. 2-13. Timeline of the construction phases.

2.4.2. Construction Workers and Accommodation

A total of 205 construction workers are expected to be required on a phase-by-phase basis (Table 2-4).

Table 2-4. Construction workers.

Phase	Personnel	Working period
Year 1	110	Dec. 2012 - Mar. 2013
Year 2	95	Dec. 2013 - Mar. 2014

Given the number of workers required in each phase, 29 containers (2.43m× 6.09m×2.58m) will serve as temporary accommodations for them. The total area of the accommodations is $429m^2$. A total of 110 workers will use the facility in the first construction year and 95 workers in the second construction year. The containers will be removed from the Antarctic region after the completion of construction.

Two 250kW power generators will be rotated as the main energy supply for the operation of accommodations and facilities during the construction period (Table 2-5).

Table 2-5. Plan of energy use during construction.

System	Purposes	Energy supply
Heating	Electric heating	Generators for electric power (2×250kW in rotation)
Sewage & wastewater	Sewage & wastewater disposal equipments	
Water supply (desalination system)	Desalination equipments	
Kitchen	Electric kitchen equipments	
Waste treatment	Recycling and treatment of wastes	-

The food required during the construction will be shipped from Korea and stored using two refrigerators and two freezers. An emergency shelter for the workers will also be installed.

The wastewater generated during construction will be treated at the wastewater treatment facility that will be installed in the temporary machine unit. Solid wastes produced during construction will be stored and treated in an appropriate manner based on a waste management plan pursuant to the Protocol on Environment Protection to the Antarctic Treaty. All solid wastes including construction materials will eventually be removed from the Antarctic after construction. Food wastes will be dried and compacted using a disposal equipment to minimize volume, which will then be stored in a separate place before the off-site removal.

2.4.3. Shipping

A transportation plan has been devised based on the estimated shipping needs for the materials, equipments and workers required for the construction of the station.

The expected gross combination shipping weight for Year 1 and 2 is of 15,638 ton (Table 2-6).

Table 2-6. Transport by ship during construction.

Phase	Construction cargos (ton)
Year 1	11,620
Year 2	4,018
Total	15,638

Note) Remove all wastes from the Antarctic region at the end of each construction phase.

Two 2000P non-powered barges, a 1000P non-powered barge, a tugboat and a 50-ton crane will be used to unload cargos safely from the ship. Furthermore, a number of (35 pieces during Year 1 and 28 Year 2) construction equipment will be used including a 30-ton dozer, and an 18-ton cargo truck for transporting cargos from the unloading site to the proposed site.

2.4.4. On-site Assembly of Facilities

In an effort to minimize the construction period, a modular construction system has been established through which unit modules will be pre-produced in Korea, and later assembled on site. This modular construction system will help streamlining the construction process, by minimizing the construction period, the number of on-site workers, and construction wastes. The system will also facilitate dismantlement of the station in the future.

Prohibited materials suggested in the regulation of Annex III of the Protocol on Environmental Protection to the Antarctic Treaty will not be used in either construction or assemblage of modules.

The size of the container for the unit modular was determined to be 3.3m×4.99m×3.29m by considering the overall volume capacity of the crane, and the working conditions at the site.

2.5. Operation of the Jang Bogo Station

2.5.1. Energy Management

The energy supply strategy during the station operation is to minimize energy loss and maximize energy efficiency. A CHP system will provide electrical power and heat for the platforms in the most efficient manner possible to minimize waste energy and, therefore, reduce fossil fuel consumption. Furthermore, the solar and wind renewable energy will be used in order to minimize CO_2 emissions.

☐ Energy use

Three types of utilities will be used for the operation of the station: electricity, waste heat and gas. The estimated total energy consumption includes an annual 1,603MWh of electric energy for the operation of research and residence facilities, waste disposal and wastewater treatment; 830MWh of waste heat energy for heating and hot water of main building; and 40.5Gcal of gas for the kitchens (Table 2-7).

Table 2-7. Estimated annual energy consumption in the Jang Bogo Station.

Source	Energy consumption
Electric power (CHP, Renewable Energy)	1,603MWh/year
Waste heat (CHP)	830MWh/year
Gas (Kitchen)	40.5Gcal/year

☐ Energy Supply Facility

Three 275kW CHP systems will be installed out of which two will alternate to be used as regular generators and one as a spare generator. Furthermore, another 275kW generator will be installed separately in the emergency power plant so that it will provide energy in emergency.

Solar and wind renewable energy will take up at least 30% (91.76kW) of the total capacity. A detailed installation plan of renewable energy system will be decided based on the factors such as the acquisition of a system that is durable in extreme conditions, efficiency, installation environment and the appropriateness of size. Renewable energy can be used to provide the emergency power supply to the major facilities in case all four generators fail.

☐ Renewable Energy

– Solar energy

Considering that the region's maximum solar elevation angle is 39.1° (*cf.*, NASA, 2008; Tin *et al.*, 2010), solar panels will be installed with the latest technology. The solar panels will be installed on the wall of the building to prevent damages from strong wind and blizzard as well as consider the solar elevation angle in this region. BIPV will be coated on the building windows.

– Wind energy

For wind turbine, four 12kW vertically stacked modular type structures, each composed of three 4kW capacity turbines, will be installed. The stacked-type design is space saving, convenient for transportation, construction and maintenance, while minimizing the noise generated by the turbine. The turbines will be located at a trade-off point between transmission loss and noise approximately 300m north of the main building.

– CO_2 reduction

When applying the equipment capacity for solar and wind energy as 43.76kW and 48kW, respectively, the total generation of renewable energy is expected to be 162,825kWh/yr, which will contribute to reducing fossil fuel by 50,722ℓ/yr. The use of renewable energy will eventually help to lower CO_2 emissions by a total of 72.3TCO_2/yr, of which 55.3TCO_2/yr will be reduced by wind energy and 17TCO_2/yr by solar energy (Table 2-8). These values, however, will be variable depending on the ratio of solar and wind energy.

Table 2-8. Fuel and carbon dioxide reduction by using renewable energy.

Source		Energy generation (kWh/yr)	Fuel reduction (ℓ/yr)	Carbon dioxide reduction[1)] (TCO_2/yr)
Solar energy	PV	36,285	50,722	16.1
	BIPV	2,124		0.9
Wind energy		124,416		55.3
Total		162,825		72.3

1) Carbon dioxide emission factor for power: 0.4448TCO_2/MWh (Korea Energy Management Corporation, 2009)

- Assuming solar and wind energy capacities, 43.76kW (PV: 41.36kW, BIPV: 2.4kW), 48kW respectively

2.5.2. Water Generation

The water supply required was calculated to be 150ℓ/day per person, which includes water needed for cooking, washing and personal hygiene.

☐ Water supply

Station-wide maximum daily water use was estimated to be 9,000ℓ (60 personnel) during the summer and 2,250ℓ (15 personnel) during the winter, based on the 150ℓ/day per capita use. A 7-day supply plus recycled gray water will be maintained as storage, 105,000ℓ for 100 people during the summer and 15,750ℓ for 15 people during the winter months (Table 2-9).

Table 2-9. Estimated water supply for the station. (seawater desalination + snow melting)

	Summer (60 personnel)	Winter (15 personnel)	Use
Daily Use (during operation)	9,000ℓ	2,250ℓ	Drinking, cooking, cleaning, sanitation, and others
Storage (during operation)	105,000ℓ	15,750ℓ	

☐ Water production and distribution system

A seawater desalination facility will work as the main water production for operating the station while a snow melting device will be utilized as needed during the winter months. The planned reverse-osmosis desalination system is easy to operate and energy efficient. An outside seawater storage tank of a 10-ton capacity will be installed with double-skinned for durability. Desalinated water will be stored in the two 10-ton tanks located in the power plant, which will be distributed eight 10-ton tanks in the station after treatment (Fig 2-14). Pipelines will be heat-wired so that being prevented from freezing.

Fig. 2-14. Seawater desalination facilities.

Using waste heat from the CHP plant, the snow melting facility can provide up to 10 tons of water during the winter months. The snow melting may be operated in parallel with seawater desalination when snow supply at the site remains sufficient. An emergency electric-based snow melting facility including a 15-ton water tank will also be constructed as a part of the emergency power plant. Seawater will be first transported to a seawater tank from the intake pump and temporarily stored there, and then pumped into the seawater desalination device in the power plant.

The planned intake point is situated on the western seashore of the small cape, opposite to and at sufficient distance from the dock facility and the discharge point (Fig. 2-15). The water pipes will be installed more than 1.2m above ground with heating wires and insulation to prevent freezing.

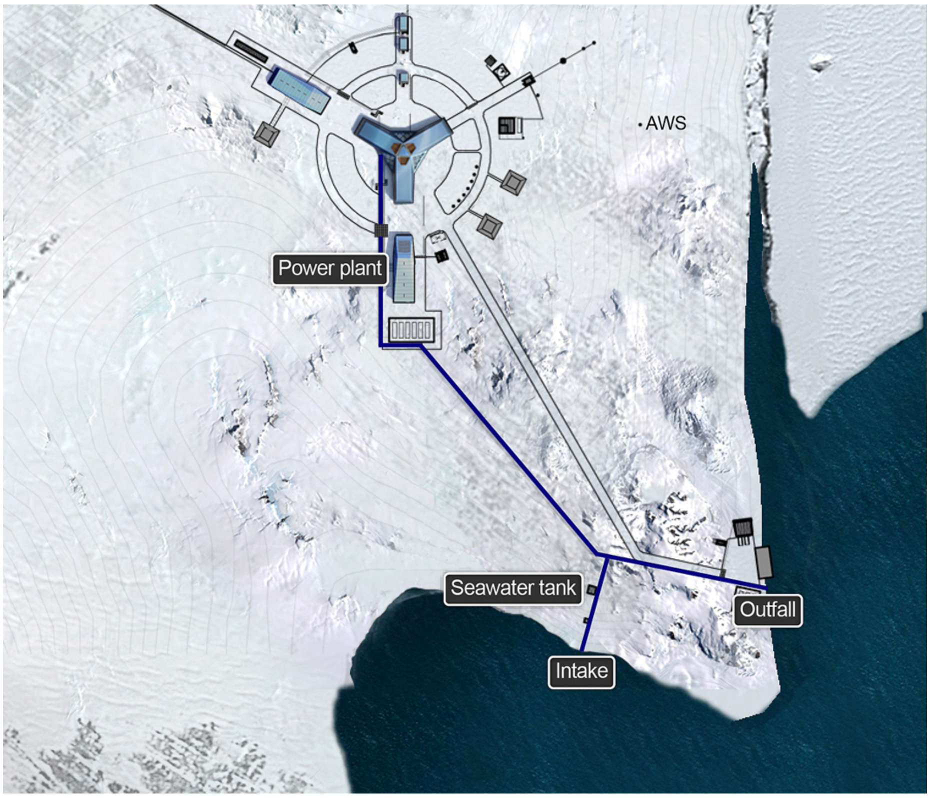


Fig. 2-15. Seawater intake structure and pipeline.

2.5.3. Fuels

The Antarctic Diesel required to operate the power generator and vehicles is expected to be a total of 328,724ℓ per year. The use of helicopters will require approximately 31,250ℓ of fuel, and the kitchens will require LPG of a total of 2,778Nm^3 per year (Table 2-10). Nine 100-ton fuel tanks and two 25-ton aircraft fuel tanks will be installed, and the LPG will be stored in a gas storage tank. At least two-year supply of fuel will be stored as the emergency fuel supply plan.

As a ship can approach up to approximately 200m to the coast, fuels will be transported using floating oil hoses to a pumping facility at the coast to be fed into the fuel tanks at the station through a pipeline.

Table 2-10. Fuel use. (per year)

Fuel type	Facilities	Total annual consumption
Antarctic Diesel	Generator	328,724ℓ
	Vehicles	
Aircraft fuel	Helicopter	31,250ℓ
LPG	Kitchen	2,778Nm^3

2.5.4. Waste Management

Waste generated from the station will be handled and stored according to Jang Bogo Station Waste Management Manual (KOPRI, 2011b). The British Antarctic Survey (BAS) Waste Management Handbook will also be used as an additional reference to manage waste (BAS, 2010).

Considering detailed site waste management alternatives, no incinerator will be installed. Waste materials will be classified into more than six types to minimize their environmental impact while maximizing recycling of them, and finally transported outside of the Antarctic region. A garbage compressor and a hydro-extractor will also be installed to reduce the volume of waste. A food waste reducer will be also used for wet garbage.

2.5.5. Wastewater Management

The comprehensive treatment system will be applied to wastewater to prevent any impact on the Antarctic environment. Wastewater generated from the station's various sources will be treated by an Internal Circulation in a Sequence Batch Reactor (IC-SBR). The basic concept of the IC-SBR is to maximize the reuse of water and to discharge relatively clean water through a high-level treatment. The discharge point will be located where sea current is active and the location is apart from the intake point near the dock facility. The pipeline will be attached to a guard structure to avoid ice drift damages.

2.5.6. Operation Manual and Training

The following items will be included in an operation guideline for effective management and maintenance/repair of the station.

- ☐ Guidelines for environmental protection including waste management, flora and fauna, protected areas, etc.
- ☐ Safety guidelines for fuel handling and contingency plan for fuel and oil spills
- ☐ A detailed guideline and step-by-step checklist about the usage of all major equipment and facilities
- ☐ A detailed information on procedures and step-by-step checklists for major maintenance and repair
- ☐ Tests devised from recommendations of the manufacturers who produce major equipment and systems
- ☐ A periodical inspection plan and guideline based on the maintenance/management and repairs
- ☐ A list of the standard specifications of spare parts
- ☐ A list of people responsible for the management and maintenance and of the manufacturers of the equipment and facilities and their contacting information

2.6. Range of Impacts

The general range of impact, produced by the construction and operation of the Jang Bogo Station, encompasses the areas that will be covered by the major facilities, wind turbines and unloading routes. The area is approximately 1.5km^2 and may increase if limited access to the temporary pool in the north is required (Fig. 2-16). The area may further be expanded if the spatial range should include the route to the Browning Pass. The routes toward the colonies of South Polar Skua and Weddell Seal shall be restricted for scientific purposes only. The eastern seashore of the small cape where the dock is planned would also be affected by the operations of cargo barges and boats for research activities and fuel transfer procedures. Therefore, the expected range of spatial impacts will be limited to buildings, research facilities, wind turbines, heliport, dock, associated unloading routes and surrounding regions.

The spatial range of scientific activities outside the station during the summer is expected to expand due to frequent activities within a several kilometer radius of the station through the Browning Pass to the north which may increase up to a several hundred kilometer radius at occasions.

The temporal impact on the region caused by the construction of the station is expected to at least three months each year during the two construction years. The temporal impact of the operation of the station is expected to be at least 25 years.

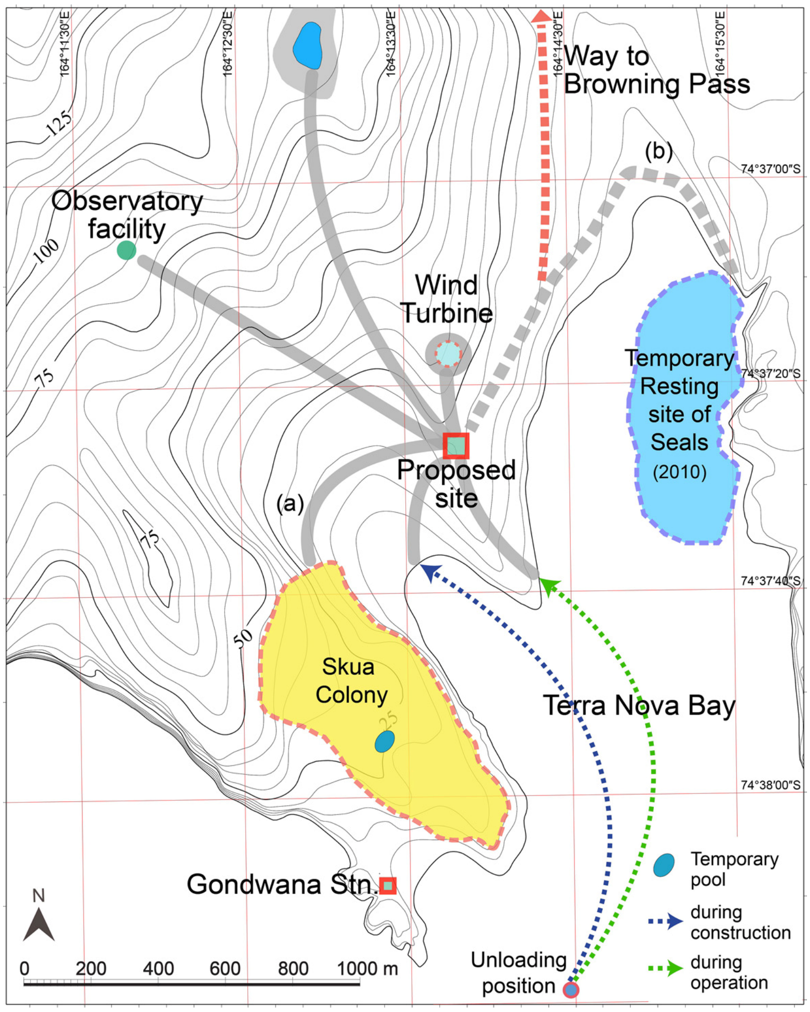


Fig. 2-16. The range of impact caused by construction and operation of the Jang Bogo Station. Visiting routes for (a) skua colony and (b) seal colony.

3. Alternatives to the Proposed Activity

3.1. No-action Alternative

Without the proposed activities at the Jang Bogo Station, the realization of the Korean commitment toward active Antarctic research is unlikely, and the demands for more information on the changes in the Antarctic environment by both Korean and foreign researchers will remain unmet. International collaborations in Northern Victoria Land with nearby research stations operated by countries such as the United States, New Zealand, Italy, and Germany are expected significantly synergistic for the Antarctic research.

Near the proposed site are Italy's Mario Zucchelli Station and Germany's Gondwana Station. However, Mario Zucchelli Station is being operated only in the summer and Gondwana Station, a relatively small-scale facility, every other summer. As such, they cannot provide sufficient support for the various Antarctic scientific research activities that Korea is planning to undertake.

Indeed the no-action alternative, being void of the temporary and cumulative impacts caused by the construction and operation of a base, guarantees full prevention of the Antarctic environment. However, advantages that the Jang Bogo Station would bring were assessed to prevail over the negative impacts on the Antarctic environment by the station, which will be minimized with the proposed construction and operational design of the station that highlights energy optimization. The Jang Bogo Station will provide comprehensive, in-depth understanding of the role of Antarctica in global environmental changes and enhance Korea's contribution to the conservation of the Antarctic environment as a member state of the Antarctic Treaty. Therefore, the establishment of the Jang Bogo Station is highly recommended.

3.2. Alternative Locations in Antarctica

In light of climate change as the main focus of Korea's future research on the Antarctic, Korea conducted preliminary surveys and evaluated six candidate regions for a new station in Antarctica for climate change research from 2007 to early 2010. Six candidate regions include: the Amundsen Sea coastal region including the Pine Island Bay and Cape Burks of Marie Byrd Land where Russia's Russkaya Station is located (both in West Antarctica);

Terra Nova Bay near the Ross Sea, the vicinity of Russia's Leningradskaya Station on Oates Coast, Ingrid Christensen Coast where China's Zhongshan Station is located, and Mawson Coast where Australia's Mawson Station is situated (all in East Antarctica) (Fig. 3-1).

Situated on the Canisteo Peninsula of the Amundsen Sea, Lindsey Island, the location recommended by many member states of the Antarctic Treaty, holds favorable physiographic conditions for constructing a new station. However, there is a large habitat of Adèlie penguins on the island as well as various colonies of sea mammals densely distributed nearby. This creates concerns about the impact of the construction on the environment, in particular natural habitats, requiring careful review of the various aspects of the construction and operation of the station.

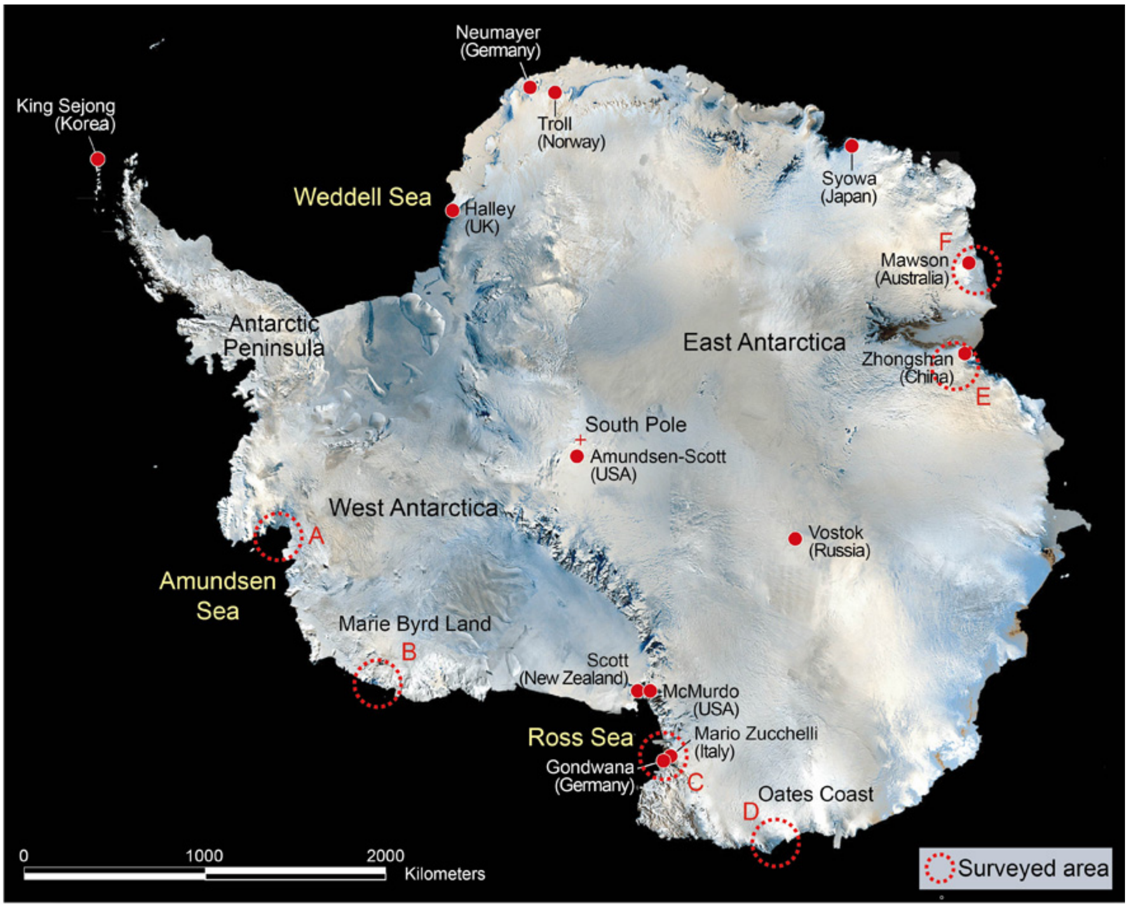


Fig. 3-1. Overview of alternative sites in Antarctica. A: Amundsen Sea, B: Cape Burks, C: Terra Nova Bay, D: Oates Coast, E: Ingrid Christensen Coast, F: Mawson Coast. (Base map: adapted from USGS, 1998)

The Mt. Hudson and Maish Nunatak located inland near the Amundsen Sea are basaltic volcanoes within the active volcanic region with a record of recent eruptions. This raises concerns about the safety and stable operations of the station. Furthermore, the station would be located a considerable distance from the coast, limiting its accessibility and restricting the construction and operation of the station as well as its research activities (Fig. 3-1. Region A).

The location of Russkaya Station, Cape Bucks is a good potential site in terms of gaining access into the West Antarctic ice field. Operating an independent station in this area could contribute to the research on climate change in the West Antarctic region. However, the distribution of exposed areas is limited, diminishing opportunities for research activities in the future. In addition, the coastal topography of the region with steep slopes and unstable ice cliff would cause difficulties for approaching the coast for unloading, compounded further by the extremely harsh weather conditions developed by the geographical features. Large colonies of Adèlie penguins along the northern coast also suggest possibilities of severe impacts on the ecosystem. Prompt responses to emergency situations would be very difficult as only long-range aircrafts can gain access to the site with a runway built on ice (Fig. 3-1. Region B).

Located in the Oates Coast region in East Antarctica, the area nearby Leningradskaya Station has distinctively uneven terrains, posing challenges to air and marine transportation required for an independent station operation. Finding a new inland route is also expected to be difficult (Fig. 3-1. Region D).

The Larsemann Hills region near the Zhongshan Station and the area near the Mawson Station in East Antarctica present favorable conditions for land and air transportation. This will enable future cooperation with nearby stations when necessary, but various research activities are already being performed at the existing stations in this area. Thus, Korea's contribution to the Antarctic research is likely to be much less here than in other potential areas. Besides, these areas feature some geographical disadvantages for providing full support to research activities in the Amundsen Sea using the icebreaker *ARAON* (Fig. 3-1. Regions E and F).

The five alternative locations mentioned above were ultimately evaluated inadequate on various decision factors for constructing the station and accommodating its research activities, such as accessibility, weather conditions, safety, logistics, and impacts on the ecosystem.

In contrast, the region surrounding Cape Möbius of Terra Nova Bay seems appropriate for the new station as it provides ample space for construction and relatively easy logistics with the absence of conspicuous local flora and fauna. The demand for a permanent station for year-round monitoring and research activities is also high in this region as two existing stations only operate during the summer. Therefore, the Jang Bogo Station, in cooperation with nearby stations, can play a key role providing the study of climate change in the Pacific region of the Antarctic (Fig. 3-1. Region C, Table 3-1).

Table 3-1. Alternative locations in Antarctica.

Type	(A) Amundsen Sea	(B) Cape Burks	(C) Terra Nova Bay (selected)	(D) Oates Coast	(E) Ingrid Christensen Coast	(F) Mawson Coast
Year investigated	2008	2008, 2010	2010	2008	2007	2007
Access	Limited	Limited	Easy	Limited	Easy	Easy
Climate	Inclement	Inclement	Fair	Inclement	Fair	Fair
Ground stability	Unstable	Unstable	Stable	Unstable	Stable	Stable
Logistics	Easy	Difficult	Easy	Difficult	Easy	Easy
Biodiversity	Very poor	Average (Adèlie penguin habitat)	Average (South Polar Skua colony)	Poor	Poor	Poor
Land	Limited	Available	Available	Limited	Available	Limited
note	AWS installed (Linsey Island)	AWS installed	AWS installed			

Source: KOPRI (2008) and Ministry of Land, Transport and Maritime Affairs (2009)

3.3. Alternative Locations in Cape Möbius Region

In the selection of the site, not only the effectiveness in construction and operation of the station, but also environmental impacts on natural environment including the habitat and breeding place of the avifauna in the area were taken into consideration. Three sites satisfying area requirements in the Cape Möbius region were considered: small gentle hill along the NW-SE axis just northeast of the Gondwana Station; an area near the access route to Browning Pass up north; and a southward small cape in the northeast, separated by a small bay. However, the first of these sites has proven to be unsuitable owing to a dense colony of South Polar Skuas. The option near the access route to Browning Pass is also unfavorable for the station because it is too far from the coast. As a result, the small cape about 600m to the northeast of the skua colony was selected as the best site for the new station. The region has only a few nests of skua and a low distribution of lichens and mosses, hence, an area of minimal potential impacts on its ecosystem.

As the coast of the small cape is mostly covered with bedrock outcrops, the construction of a base, especially grading, near the coast may extensively disturb the aesthetics of the coastal landscape. The proposed site, therefore, is located about 200m inland in flat terrain composed of glacial moraines.

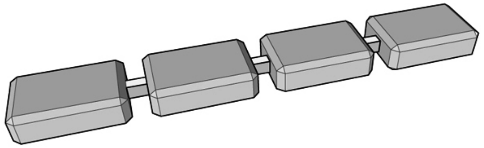
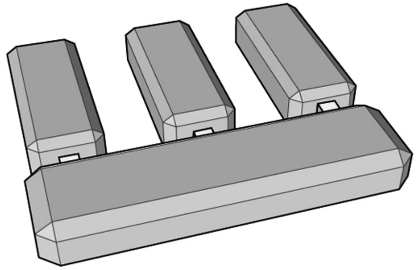
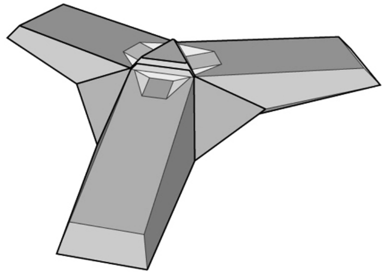
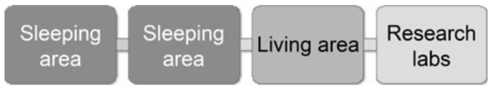
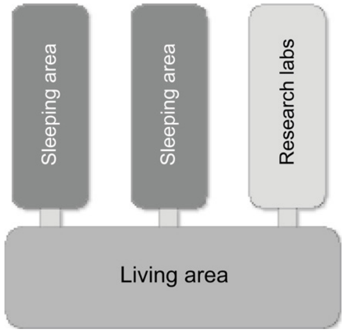
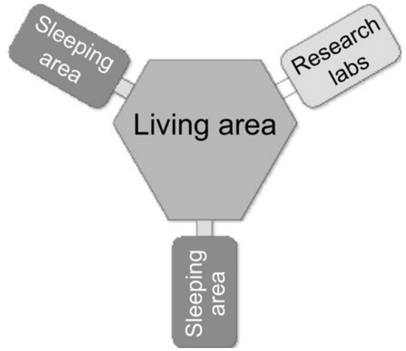
3.4. Alternative Designs

The main building of the station was designed not only to provide for the proposed scientific activities, but also to minimize environment impacts as well as to increase efficiency during the construction and operation of the station. In addition, the design paid full attention to the extreme weather conditions of Antarctica accompanied by high unpredictability, aiming to provide structural stability against all directions of wind at the same time minimizing energy requirements and increasing efficiency in staff and equipment traffic.

These considerations suggested three design options: linear I-shape, divided E-shape, and intensive triple-arm shape (Table 3-2). The first two shapes were evaluated to be too weak to withstand wind loads in some directions, too distant between facilities, and too high in energy demand with the large number of external panels required in the design. In contrast, the triple-arm shaped design was shown to provide good resistance to all directions of wind, provide better spatial efficiency through short inter-facility accesses, and energy efficiency through minimizing areas of the outer wall surface.

Consequently, the triple-arm shaped design was selected as the most appropriate and suited for the year-round operation of the station. This design incorporates Korea’s accumulated knowledge on the green building strategies such as double-layer walls, five-time glazed windows, and maximizes the penetration and use of natural sunlight.

Table 3-2. Design alternatives of main building.

Parameter	Linear I-shape	Divided E-shape	Triple-arm shape (Selected)
Type			
Division of the building			
Safety of structure	Low wind-resistance perpendicular to long axis	Low resistance to all wind directions	High resistance to all wind directions
Energy efficiency	Large surface area, High energy loss	Large surface area, high energy loss	Smaller surface area Low energy loss
Accessibility between activity areas	Low	Intermediate	High

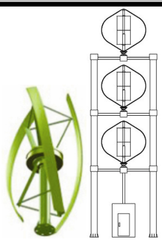
3.5. Alternative Wind Turbine Types

Three different types of wind turbines, the well-known horizontal and vertical types, and the vertically stacked modular type as a modified vertical type were evaluated and compared. Major parameters considered were efficiency of power generation, torque, noise, maintenance ease in extreme weather conditions, and impacts on the ecosystem.

Compared to the horizontal model, the vertical model has been proven to be easier to transport, construct, and maintain. Also, it can obtain high level of power generation efficiency in all directions. In particular, the low speed rotation of the vertical type is advantageous as it generates less low frequency noise when compared to the horizontal model, thus minimally affecting people and the surrounding ecosystem including the skuas.

The third option of the vertically stacked modular structure comes with all the advantages of the vertical model and more. This stack of 3 modules, each carrying relatively low power generation capacity of 4kW, can provide undisturbed power supply even in the case of failure of one of the modules, as the remaining two modules can still generate as much as other two types. Moreover, this modular structure demands less space in the installation and dramatically lowers noise (Table 3-3). Based on these advantages, the vertically stacked modular structure was selected as the final design of the wind turbine.

Table 3-3. Comparison of wind turbine types.

Type	Horizontal		Vertical		Vertically stacked modular (selected)	
		10kW		10kW	 4kW	12kW (3×4kW modules)
Efficiency	- Stable and high efficiency in power generation - Maximum efficiency only to a limited wind direction		- Efficient in all directions of wind - Not working under the low wind speed		- Efficient in all directions of wind - Continuous power generation in the event of one turbine failure	
Torque Maintenance	- Fluctuation of torque according to wind directions - Difficult to maintain in bad weather conditions		- Constant torque for all directions of wind - More convenient maintenance compared with the horizontal type in bad weather conditions		- Constant torque for all directions of wind - A low capacity turbine is easier to maintain in bad weather conditions	
Impacts on ecosystem	- Higher chance of bird strike - High level of noise produced		- Reduced chance of bird strike thanks to a smaller radius of rotation - Lower speed turbine with reduced noise		- Little chance of bird strike due to the visibility of tower shape - Lower speed turbine with reduced noise	

3.6. Alternative Transport

All construction material will be transported by surface from Korea to Christchurch, New Zealand first and then to the Jang Bogo Station together with people that join by air transportation. The alternatives of air and marine transportations were compared for the routes from Christchurch to the Jang Bogo Station.

☐ Air Transportation

In case of air transportation, the glacier runway at Browning Pass and the sea ice runway of Gerlache Inlet north of Mario Zucchelli Station can be used (Fig. 3-2(a)).

– Air transportation to Browning Pass
- Browning Pass can be used as a runway throughout the year.
- Only aircraft models with skis can be used, and access by large cargo planes is restricted.
- Snowmobiles and sleds will be needed for additional transport from the runway to the proposed site, involving approximately 10km of land transportation via east side of Mt. Browning.

– Air transportation route to Gerlache Inlet north of Mario Zucchelli Station
- When frozen layer in Gerlache Inlet is thick, large-size airplanes such as C130 can land as well. However, this is limited to the freezing season, not the whole summer.
- People and cargos are needed to be carried by snowmobiles and sleds for about 5km to the proposed site. If the sea ice does not extend to the proposed site, a means of marine transportation such as barge is additionally needed to be used.
- According to the currently available data, thick sea ice rarely forms in this region during the austral summer when most of the transportation will be made.

☐ Marine Transportation

U.S. National Snow and Ice Data Center (NSIDC) provides ice drift distribution data near the proposed site between 2002 and 2010. The data show that an icebreaker can gain access to the Terra Nova Bay area between mid-December and late-February, and hence availability of the cost-effective marine transportation of construction staff, material and equipment during the period.

According to the expedition result of the icebreaker *ARAON* from 2010 to 2012, ships can approach up to 1km near the coast of the proposed site. The ships may then be anchored at appropriate distances from the coast, and barges can be hired to relay the cargos and equipments to land vehicles for the final hundred meters to the site. A helicopter can be used as a contingency option if ice drift impede access during this period. This option of limited cargo capacity, however, may eventually require barges and slow the overall construction rate.

Three land transport routes from the unloading position were considered as shown in Fig. 3-2(b) from the perspective of ease of access. However, both route A, in which the unloading position is right next to Gondwana Station, and route C, in which the unloading position is nearest to the east coast of the proposed site, seem to have a potential to cause negative environmental impacts because they are near the colonies of South Polar Skua (route A) or of Weddell Seal (route C). Therefore, route B is considered to be the most appropriate option.

☐ Evaluation of means of Transportation Alternatives

Disadvantages of people and cargos being transported by aircraft in this region during the summer time include aforementioned limitations of sizes and types of aircraft depending on the conditions of the runway as well as the limitations on takeoff and landing time on sea ice runways. Furthermore, uneven weather conditions of the Antarctic region increase the uncertainties of scheduling, causing aircraft delays.

Besides, small cargo capacities of aircrafts may not be suitable in carrying heavy equipment such as cranes. Aircrafts are also not as cost effective as ships. Therefore, marine transportation was selected over air transportation in consideration of cost, convenience, and on-time performance under uneven weather conditions.

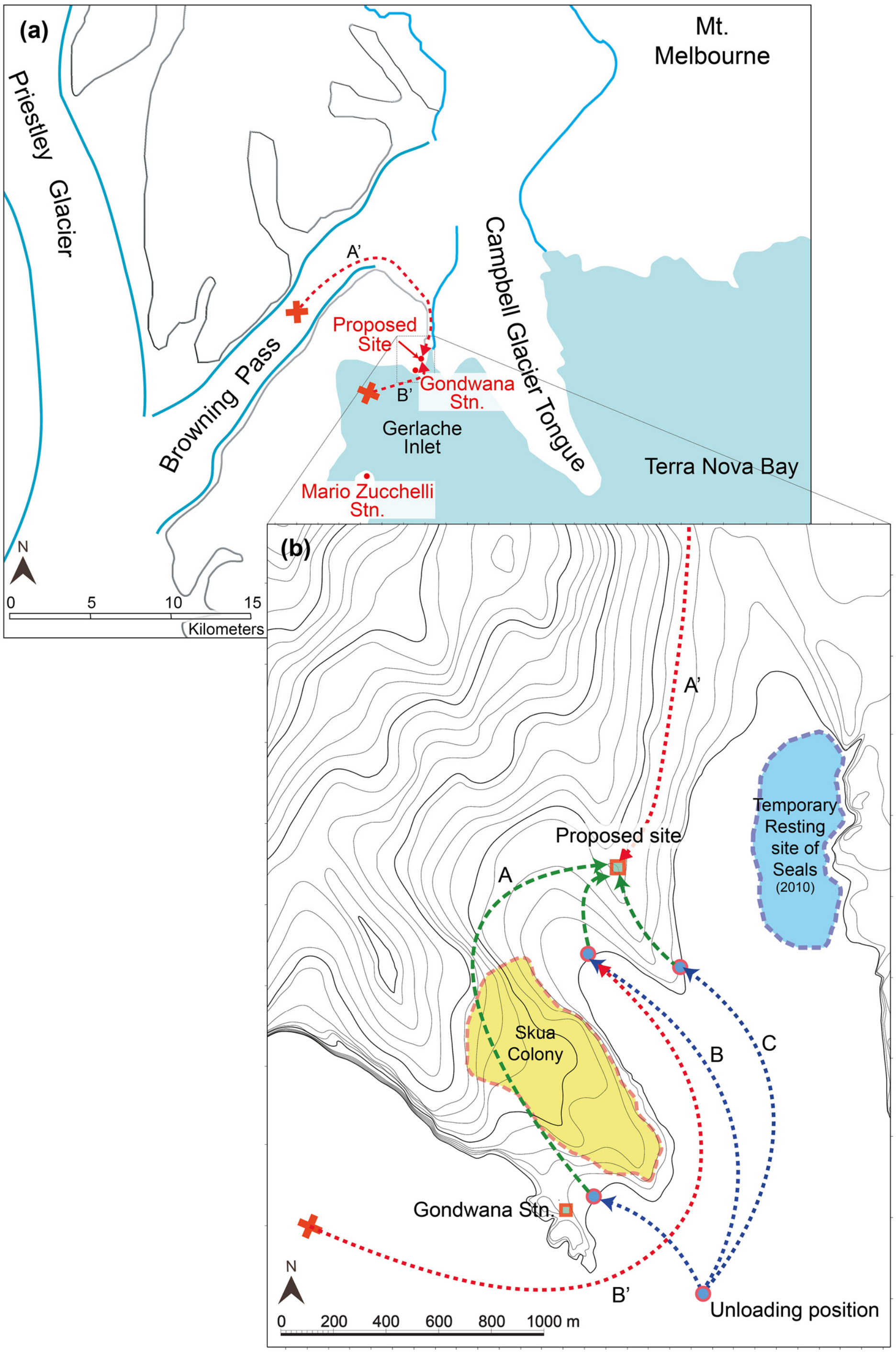


Fig. 3-2. Transport alternatives by (a) aircrafts (A' and B') and (b) ships during construction (A, B and C). Route B with the least ecological impact was selected.

3.7. Alternative Waste Management Plans

Waste management alternatives for the site construction and operation were compared considering potential impact to Antarctic environment, particularly to atmospheric environment, as well as the operation and management costs (Table 3-4).

☐ Incineration

On-site treatment of combustible waste with an incinerator accompanied with ash retrieval can effectively reduce the overall volume of waste. It can also prevent possible scavenging by South Polar Skua inhabiting near the proposed site.

However, gas emissions from an incinerator are expected to adversely impact the Antarctic air quality. Its operation will also increase the fuel use. A high temperature combustion method and multi-filtering system will minimize pollutants such as dioxin to be generated, but the additional cost associated with the operation of such systems on top of the incinerator itself is expected substantial.

☐ Off-continent disposal

Waste produced during construction and operation of the station, after necessary treatment, can be stored and transported outside of the Antarctic region. This alternative is desirable as it does not adversely impact the air quality and is also cost effective compared to the on-site incineration. The on-site treatment for storage including sorting, compacting, drying and packaging can be done with appropriate work area and an operation manual provided.

Table 3-4. Waste management alternatives.

	On-site incineration	Off-continent disposal (selected)
Method	On-site incineration of combustible waste in an incinerator	On-site storage after treatment (sorting, compacting, drying and packaging) and off-continent disposal
Advantage	- Easy storage with minimal waste volume	- No emission - Less fuel use - No construction and operation cost of incinerator
Disadvantage	- Impact on air quality - More fuel use - Construction and operation cost of incinerator - Emission control such as multi-filtering system required	- Storage area and management manual required - Off-site transportation, disposal and associated agency cost - Possible scavenging by South Polar Skua

On-site incineration has been favorable considered in the draft CEE but the final CEE selects the off-continent disposal option putting further weight on its advantage of keeping the clean Antarctic environment.

4. Initial Environmental Reference State of the Terra Nova Bay Region

4.1. Location

In the northwestern region of Terra Nova Bay, the proposed site is located in one of the two ridges along the NW-SE direction that originate from Mt. Browning (Fig. 4-1).

The two ridges correspond to Cape 1 and Cape 2 of Fig. 4-1, respectively. A small bay is placed between the two capes and a relatively flat ground of less than 100m in altitude is extended up to 1km from the coast toward the inland. Most of the area investigated including the proposed site has gentle slopes of less than 10º (Figs. 4-2, 4-3).

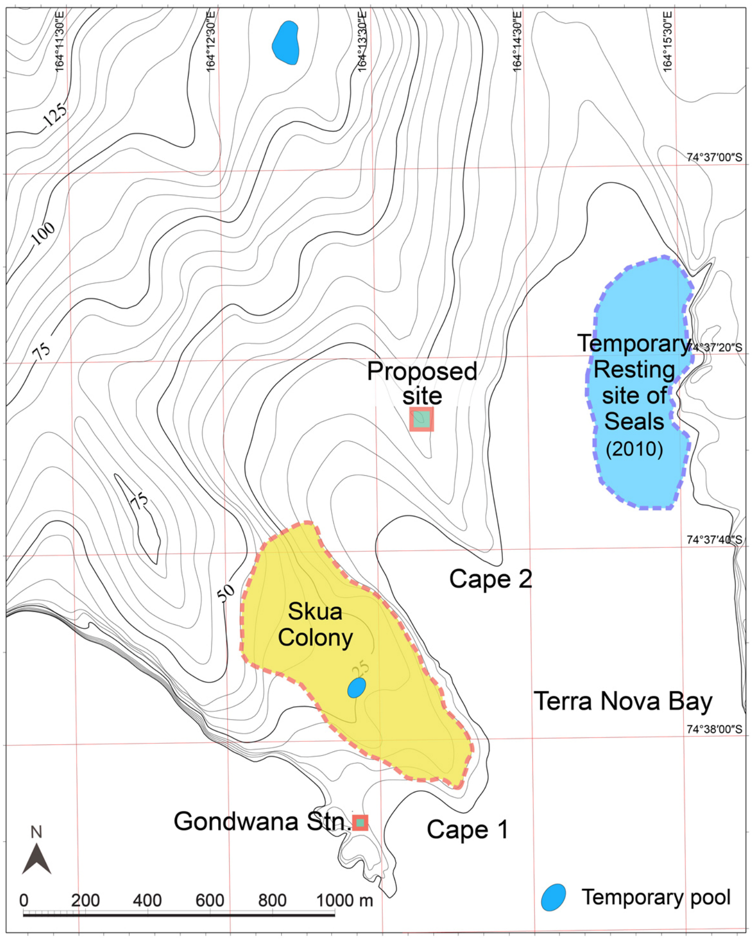


Fig. 4-1. Proposed site and surroundings.

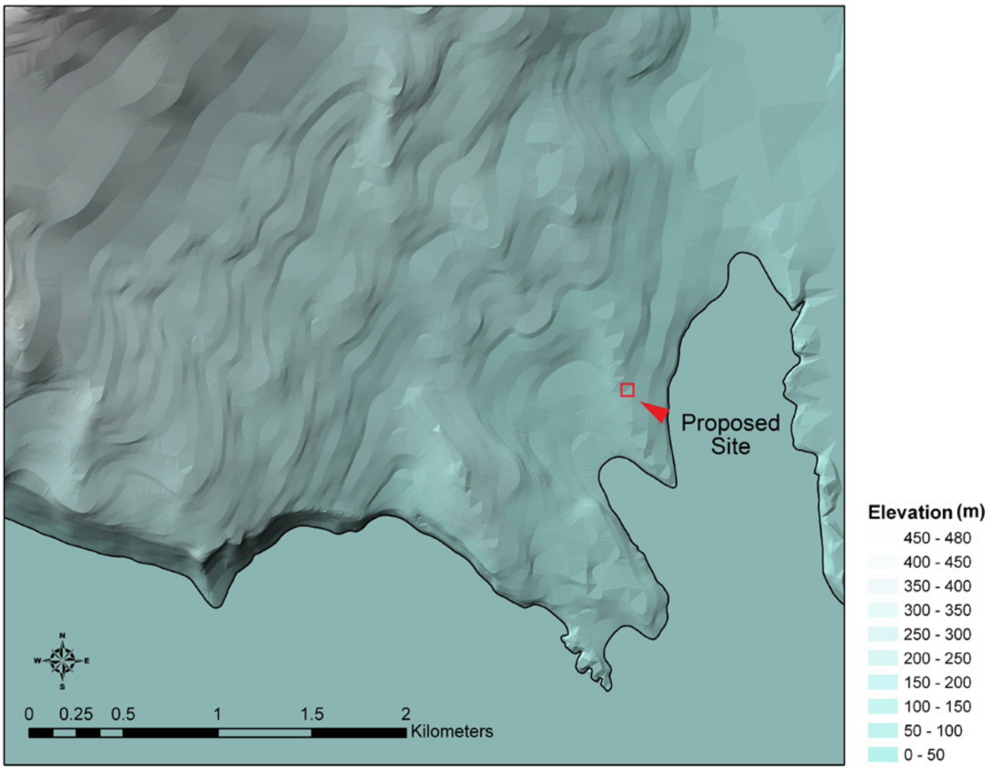


Fig. 4-2. Elevation analysis of Cape Möbius area.

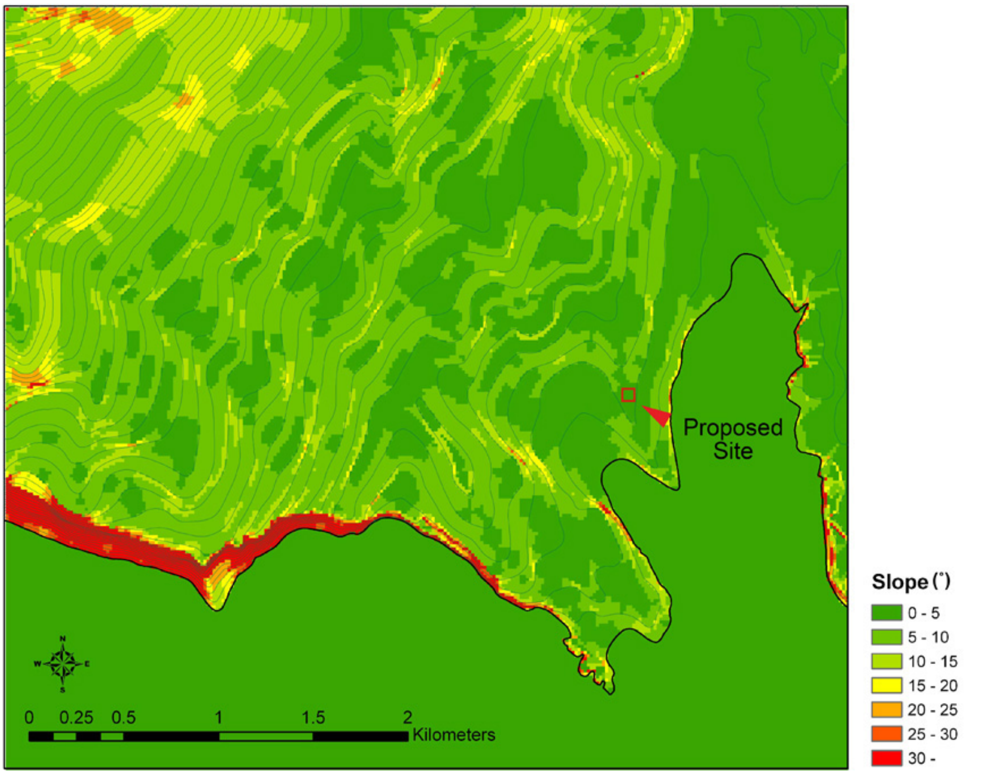


Fig. 4-3. Slope analysis of Cape Möbius area.

The Terra Nova Bay region is home to a wide range of living creatures with Woody Bay, for example bryophytes, lichens, marine birds, mammals and invertebrates. Located in Antarctica, it is one of the regions with the highest levels of diversity in terms of biology and ecology.

Colonies of birds and seals are distributed across Edmonson Point, Adèlie Cove, and Inexpressible Island, and Emperor penguin colonies are dispersed across the Cape Washington region approximately 20km from the proposed site (Fig. 2-1). Emperor penguins were not observed during either the 2011 or the 2012 visits as sea ice had been mostly melted.

Weddell Seal can be easily observed in this region. South Polar Skuas also inhabit the area, with their largest colony located in Victoria Land. Marine birds such as Snow Petrels and Wilson's Strom Petrels can also be seen in this region. At least 7 species of bryophytes and 30 species of lichens were discovered at Edmonson Point, and more than 120 kinds of algae and cyanobacteria were identified, according to a literature review. In addition to the 24 species of lichens, various unidentified species were also found in the area (Cormaci *et al.*, 2000).

Three temporary pools, formed with the thawing of ice, were found during the 2010 survey. They were located on the bedrock east of the Gondwana Station, near the proposed site for the station, and 1.2km north from the proposed site, respectively. The temporary pool near the Gondwana Station has an area of 25m×12m, with an average depth of 20cm. The temporary pools near the Gondwana Station as well as the proposed site were observed dry during 2011 survey (Fig. 4-1).

The largest temporary pool located to the north of the proposed site covers an area of 110m×72m, with an average depth of 50cm (75cm at most), and is estimated to hold about three thousand tons of water (Fig. 4-4). The pool was formed with ice melt during the summer. The bottom of the pool may be frozen during the winter due to its shallow depth.

Fig. 4-4. Temporary pool located approximately 1.2km to the north of the proposed site.

Biota is scarce in the region of 2-3m in depth in the tidal zone of Terra Nova Bay due to the influence of floating ice. Thus, blue green algae, diatom, and amphipod, such as *Paramoera walkeri* have been often reported in the region (Cattaneo-Vietti *et al*., 2000). However, marine algal colonies formed a distinct belt and Rhodophyta, consisting of shade-adapted species such as *Iridaea cordata, Phyllophora antarctica* and *Clathromorphum lemoineanum* is dominant at depths ranging from 2-4m to 70m (Cormaci *et al*., 2000). The marine algae provide food sources as well as shelters for various and abundant vagile fauna such as *Sterechinus neumayeri*, a species of sea urchin, and *Odontaster validus*, a species of starfish inhabiting this region.

It has been reported that both sponge and coral colonies are present abundantly in biomass and show a high species richness on the hard bottom at 70-120m in depth. Distinguishing colonies of polychaetes and bivalve such as *Latenula elliptica, Yoldia eightsi,* and *Adamussium colbecki* (Cattaneo-Vietti *et al*., 2000) were found on the soft bottom which commonly starts from 20-30m in depth and is composed of coarse sand and gravel.

Fast ice of 2-3m thickness was observed at shore around the proposed site during the 2012 visit. The only observed benthic flora during the visit is an individual young *Iridea cordata* (Rhodophyta) plant at 5m depth. No *Phyllophora antarctica* groups were observed. Bryozoans, *Cuthona* sp., soft coral and bivalves (*Adammussium cobeki, Latenula eliptica*) and starfish *(Odontaster validus*) were observed at depths 8-10m below the surface. Diverse and abundant benthic organisms were observed from approximately 20m below the surface. The dominant species of the investigated area are sponges. Four different species of sponges were identified during the investigation.

4.2. Topography and Geology

Located in the northern quadrant of Terra Nova Bay, Cape Möbius is mainly composed of exposed bedrock crops and forms the shape of a small peninsula. Most of the land close to the coast has a relatively gentle slope of less than 5º. The glacial deposits, bedrock crops, and other geological features govern the topographical characteristics of the area. In about 3km inland in the northwesterly direction, Mt. Browning (700m) lies along the NE-SW axis (Fig. 4-5).

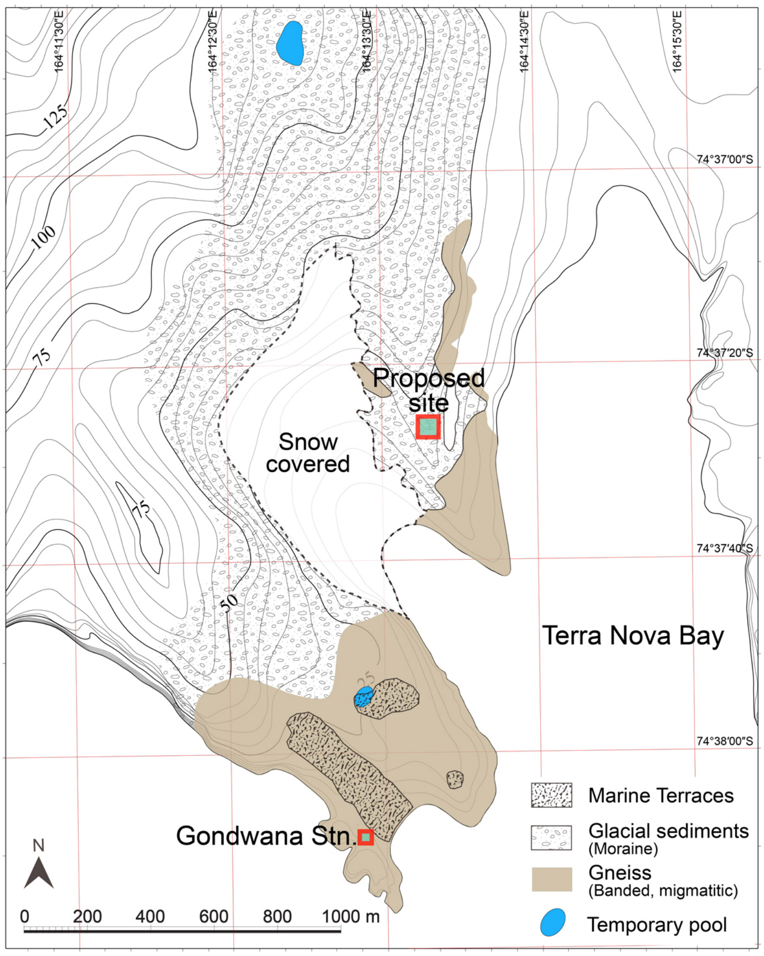


Fig. 4-5. Geological map of Cape Möbius area. (data from field survey and Kantor (1993))

The topography near the altitude of 80m along the southern part of Mt. Browning is very gentle all the way down to the coast. From the mountain, two parallel sets of gentle hills along the NW-SE direction extend to form small cape-shaped topography (Fig. 4-2). The major hill in the southwest is 600m wide and 1.5km long, while the other hill in the northeast is of a smaller size, 300m wide and 1km long. A small bay exists between the two capes. The proposed site for the Jang Bogo Station is in the center of the eastern cape (Fig. 4-6).

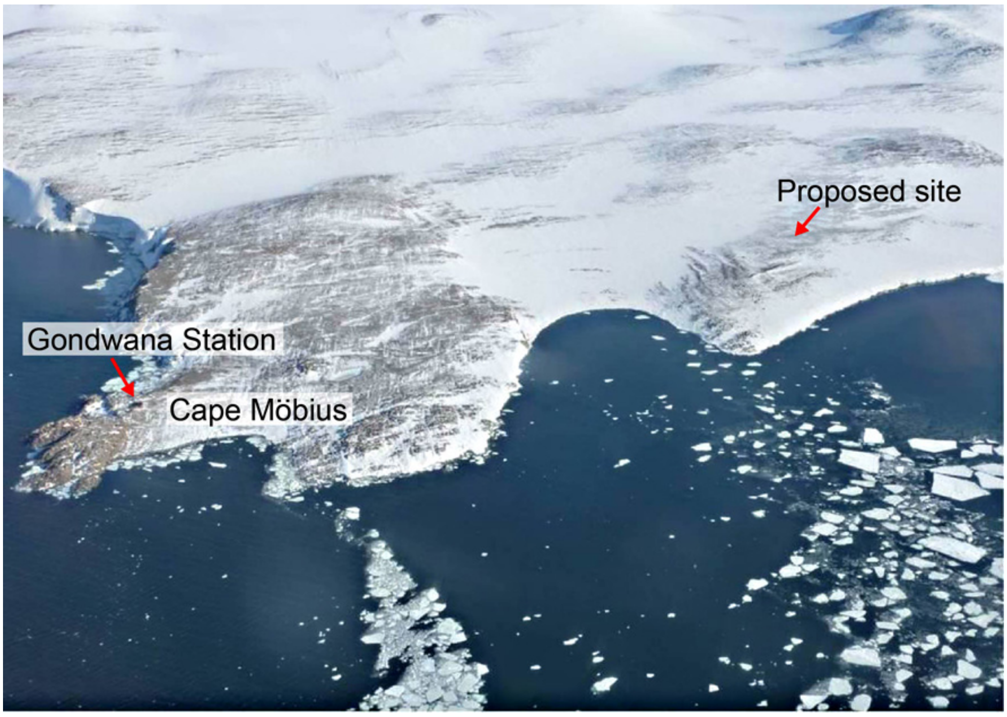


Fig. 4-6. Aerial image showing the proposed site.

In the west, Cape Möbius abuts Campbell Glacier, which is slowly moving from north to south, and in the west, coastal cliffs exist along the E-W direction corresponding to geologic fault scarp (Fig. 1-2).

The bedrock of the Cape Möbius region is predominantly composed of Precambrian gneiss. It is locally overlain by horizontal sedimentary layers of glacial moraine. The sedimentary layer forms glacial terraces at intervals of 1m to 2m in thickness (Fig. 4-7). Moraines are mainly composed of bedrock debris ranging in size from a few centimeters to tens of centimeters with intermediate roundness and poor sorting (Fig. 4-8).

Glacial deposits are weakly developed in the western cape where the Gondwana Station and the skua colony are located (Cape 1 in Fig. 4-1). However, the small cape where the proposed site is located is mostly covered by glacial deposits (Cape 2 in Fig. 4-1) except for along the coast. The glacial deposits were identified up to 100m in altitude. The temporary pool located in about 1.2km north of the proposed site is also overlaid by glacial deposits combined with thin layers of fine-grained soil (Fig. 4-4).

Fig. 4-7. Layered structure of glacial moraines.

Fig. 4-8. Moraines composed of bedrock debris.

Gneiss shows either banded or massive texture with NW-SE trending foliations. The foliations usually dip with an angle of higher than 70º to SW and NE repeatedly (Fig. 4-9). Because of the disturbance by migmatitic metamorphism, it is not easy to define the overall structural features of the gneiss, mostly quartzofeldspathic in composition.

In outcrops of gneiss, fold structures are observed with a near-horizontal fold axis (Fig. 4-

10). The dominant joint set is parallel to the foliation of the gneiss at a 10-50cm interval. Perpendicular to the first one, a vertical joint set is also well developed at a 0.5-1m interval.

The coastal cliffs observed in this region are controlled by large-scale geological structures such as fault. About 30km NNE of the proposed site is Mount Melbourne, estimated to have developed in the Cenozoic era. Its activation has been stopped, but intermittent steam disgorging has been reported (Fig. 2-1).

Unconsolidated layers are only locally found and seem to be related to the formation of glacial deposits, being composed of various sizes of particles from fine to coarse. However, it is difficult to identify typical soil types in regional scale.

Fig. 4-9. Banded gneiss.

Fig. 4-10. Migmatitic gneiss.

4.3. Sea Ice

Stretching approximately 64km along the coast between Cape Washington and Drygalski Ice Tongue, the Terra Nova Bay region is a part of the Ross Sea. Frequently the melting sea ice creates a large polynya in the Ross Sea throughout the year, which develops from the rim of the Ross Ice Shelf and extends to the north (Franda *et al*., 2000). The formation of large polynya in the region is extremely significant in terms of Antarctic coastal environment and ecology as it reveals the unique environmental and ecological features formed by highly variable sea ice dynamics.

The sea ice covers Terra Nova Bay from September to October with a thickness of 2-2.5m (Stocchino and Lusetti, 1988 and 1990). Utilizing the Gerlache Inlet sea ice of Terra Nova Bay, Italy operates an ice field runway from October to early December. During the 2010 investigation, the area was completely free from sea ice in the early February, and only small area of fast ice connected to the land remained. According to the estimated data released by the Italian researchers, the ocean currents in the region slowed down and generally flowed from north to south during the summer.

According to a recent study, sea ice has been repeatedly generated and disappeared in Terra Nova Bay due to the katabatic wind blowing from the continent, the reason behind the inconsistency and variety of the distribution of polynyas (Fig. 4-11).

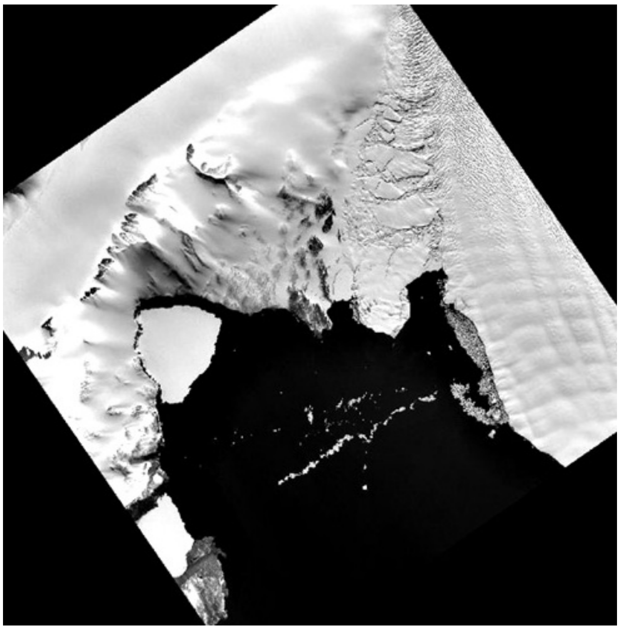


Fig. 4-11. Satellite image showing the distribution of sea ice in Terra Nova Bay. (Base image: adapted from KARI, KOMPSAT-2, 2010.02.03)

4.4. Glaciology

Three sets of large-sized glaciers with NW-SE trending are situated in Northern Victoria Land. The Reeves Glacier, Priestley Glacier, and Campbell Glacier are located parallel to each other. The Reeves Glacier and Priestley Glacier merge together with the Nansen Ice Sheet to the west of Mario Zucchelli Station (Fig. 4-12).

The Cape Möbius region is on the edge of the Deep Freeze Range located between the Priestley Glacier and the Campbell Glacier. Northwest of this region, a relatively stable and small-sized Browning Pass Glacier stretches from northeast to southwest. The Campbell Glacier extends over 100km to the north, and covers an area of 4,000km^2, including the névé of the Southern Cross Mountains and Deep Freeze Range. The glacier flows into the sea in the south and creates a glacier tongue stretching out to many kilometers across.

The flow velocity of the glacier tongue was estimated between 140±20m/year and 240±20m/year (comparative analysis results of SPOT 1 XS images of December 19, 1988 and December 2, 1989, Frezzotti, 1992). The amount of ice falling off into an iceberg is almost consistently compensated by the filling of glacier flow, and the extended area of the glacier tongue from 1963 and 1989 was also reported to be almost consistent.

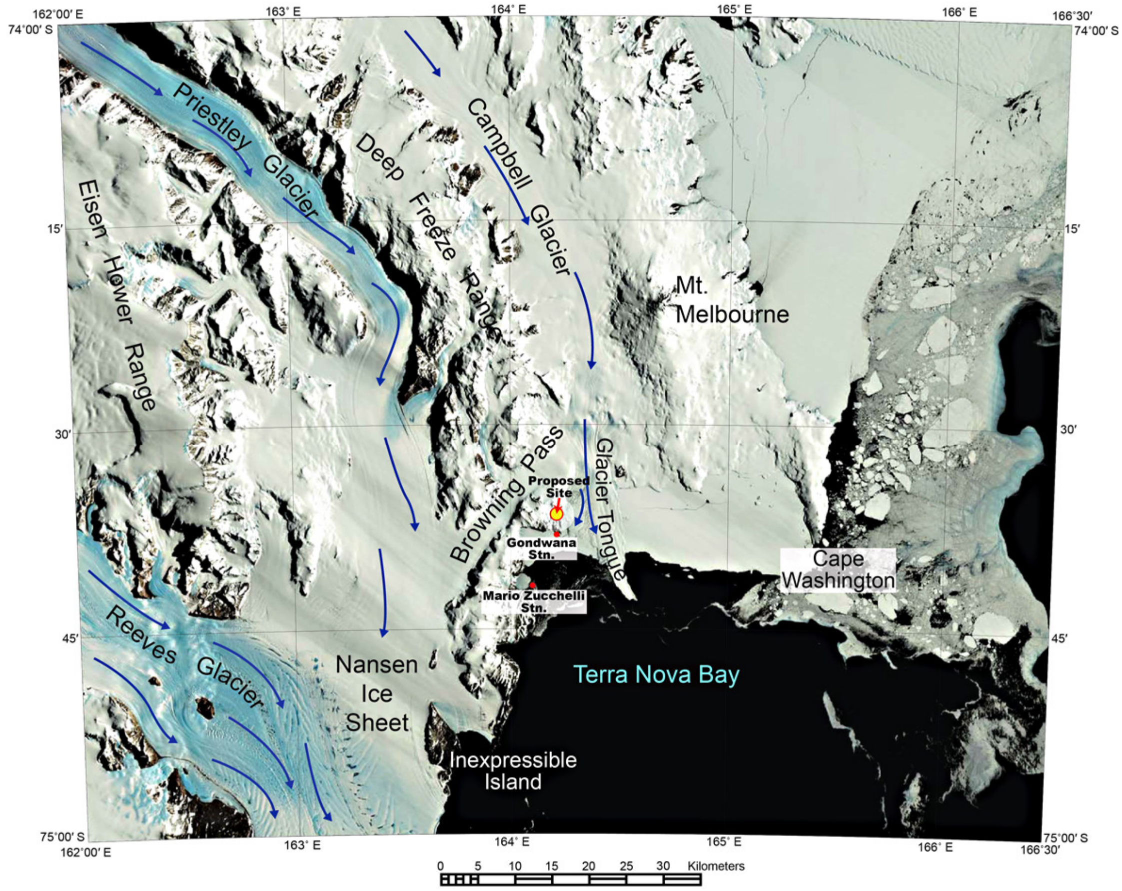


Fig. 4-12. Glaciological map. Arrows mean glacier flows. (Base map: adapted from MUSEO NAZIONALE DELL'ANTARTIDE-Sezione di Scienze della Terra, Via Laterina 4-53100 SIENA-ITALY, 1996)

4.5. Climate

Katabatic winds dominate in Terra Nova Bay due to steep topography from the inland to the coast, with increasing intensity toward the coast with the combination of channel flows from several glacial valleys. In this geography, a strong horizontal and vertical wind shear is developed, imposing severe limitations on aircraft operation. The strong wind in Terra Nova Bay will be one of the most defining climate factors in the operation of the proposed station. The wind speed is known to be highly variable even within short distances and the maximum wind speed has been measured as high as 56.4m/s with the influence of katabatic winds.

According to the analysis of the observed data over twenty years (1989-2009) at Mario Zucchelli Station, the annual mean temperature was -14.1°C, the annual mean wind speed was 6.4m/s, and prevailing wind direction was westerly. The temperature will have no impact on the operation of the station which will be the most active during Antarctic summer. With the wind chill, temperature may be felt as low as -50°C, and diurnal temperature variations reach as high as 15°C in clear sky conditions, particularly in October and February. From November to January the maximum daily temperatures are well above 0°C, having been recorded as high as 7-9°C, and daily variations decrease to 4-8°C (Turner and Pendlebury, 2004). The 22-month period data collected in the Automatic Weather System (AWS) between February 2010 and November 2011 show that the most frequent and the second most frequent wind directions are west and northwest, respectively. The overall average temperature was -13.8°C, with the highest monthly average being 7.2°C, and the lowest monthly average -34.0°C. The average of measured wind speeds was 4.7m/s, and the maximum average monthly speed was 35.9m/s (Figs. 4-13, 4-14, Appendix 3)

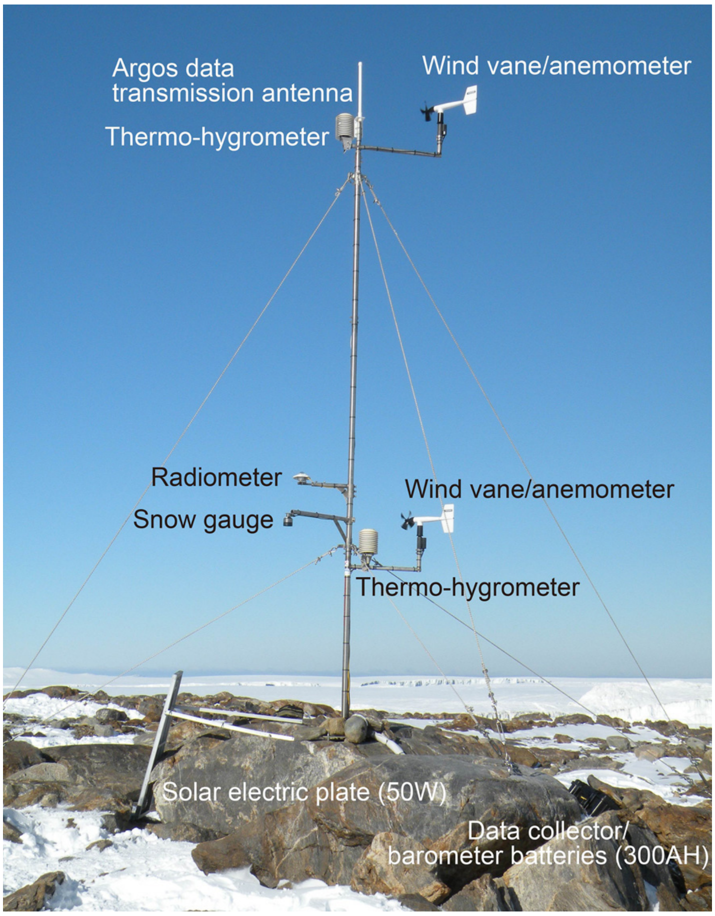


Fig. 4-13. Automatic Weather System installed at the proposed site.

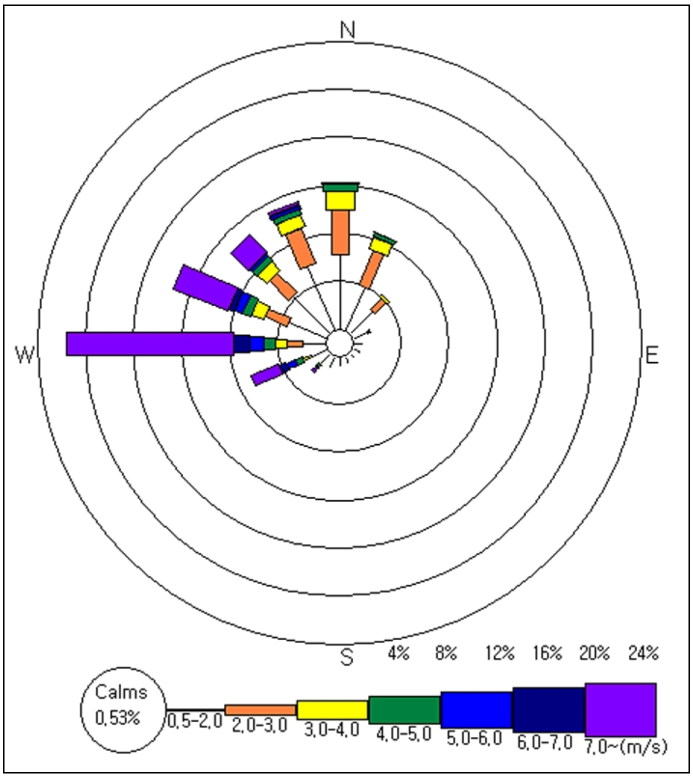


Fig. 4-14. Windrose of the proposed site.

4.6. Flora and Fauna

According to a study of the flora and fauna at the proposed site and nearby regions, there are not many living creatures that inhabit the area.

About 26 species of lichens and mosses including *Buellia* spp. and *Umbilicaria* spp. were found, and based on Kantor (1993), some 35 species of flora have been confirmed to be distributed across the region. Lichens and mosses showed the highest density near the largest temporary pool located about 1.2km to the north of the proposed site, but lower density in other regions.

As for marine mammals, colonies of Weddell Seal were found resting on a crevasse of Campbell glacier tongue as well as on the fast ice near bay area to the east of the proposed site. A breeding place of South Polar Skuas is located in the eastern hill of the Gondwana Station, and Adèlie penguins were spotted in shores and on the ice field individually or in groups of up to 5.

Two types (Nematoda and Tardigrada) of mesoinverterbrates were observed in the temporary pool near the proposed site. Twelve different species of zooplanktons, including Copepoda, Mysidacea, and Ostracoda, as well as eleven species of mesoinverterbrates including *Tigriopus japonicus*, Polychaeta, and Oligochaeta were identified in seawater.

4.6.1. Flora

The proposed site and surrounding regions correspond to coastal areas. Due to low temperatures, humidity is relatively low and little vegetation is found in the area (Kantor, 1993). The area shows topography composed of diverse moraines, and vegetation can be observed mainly in the northern side of the bedrock outcrops between cracks or underneath the rocks where soil layers have been developed.

Lichens are the key vegetation, among which crustose lichen adhering tightly to the rocks are most common. In particular, foliose lichens are abundant nearby the temporary pools, as the areas surrounding the pools are relatively rich in moisture with supply of snowmelt runoff (Fig. 4-15). The largest temporary pool in the north has relatively rich vegetation. The main types that dominate the area are *Umbilicaria* spp. and *Buellia* spp. *Bryum* spp. is distributed mostly in places where moist soil layer exists, but its biomass is small.

In the environmental impact analysis for the construction of Germany’s Gondwana Station in 1988/89, 22 species of lichens were reported (Kantor, 1993). During the 2010 investigation, 26 species of lichens were found. The proposed site and surrounding regions have been confirmed to have a total of 35 species of vegetation, including 30 species of lichens, 4 species of mosses and one species of freshwater algae (Appendix 4).

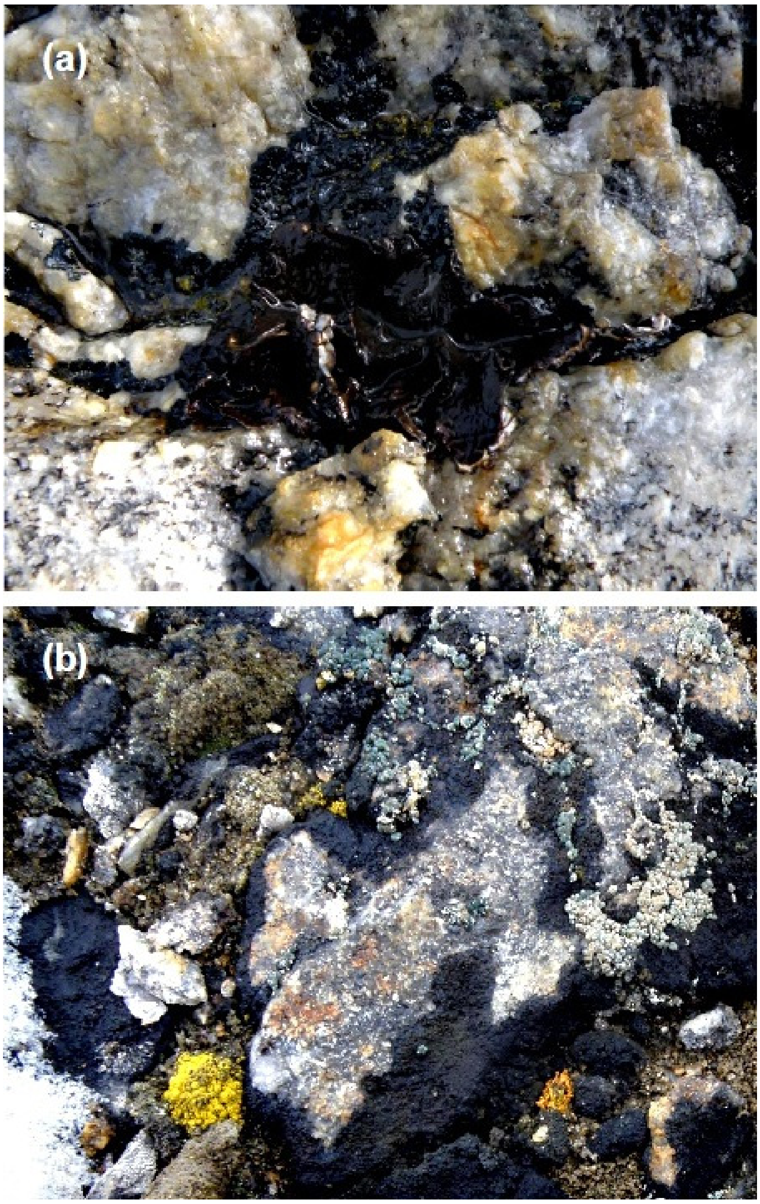


Fig. 4-15. (a) *Umbilicaria antarctica*, (b) *Buellia* spp. *Candelariella flava*, *Rhizoplaca* sp. *Bryum argenteum.*

4.6.2. Fauna

A couple of Adèlie penguins have been observed resting and feeding on the ice field in the west coast of Gondwana Station during the 2010 survey. Two habitats of Adèlie penguins were also reported near the Mario Zucchelli Station, but no such habitat has been discovered near the proposed site.

A habitat of Emperor penguins is known to exist near Cape Washington, more than 20km away from the proposed site.

Six Adèlie penguins were spotted at the western shore area near the Gondwana Station during the 2011 survey. Up to two Adèlie penguins were also spotted in other shore areas during the visit, as well as Emperor penguins (1 at 500m distance to the northwest from the proposed site; 2 at 300m to the east; and 3 at 1.5km to the east). Their visits were transitory lasting less than a couple days.

Individual Adèlie penguins have been spotted near the northwestern shore areas of the Gondwana Station and other sea ice areas during the 2012 survey. Two nests and three chicks were also observed in the northwestern shore areas of the Gondwana Station. No Emperor penguin was observed.

South Polar Skuas represent the largest portion of the bird population that was found near the proposed site. The main habitat was found on the eastern hill of Gondwana Station (Fig. 4-16).

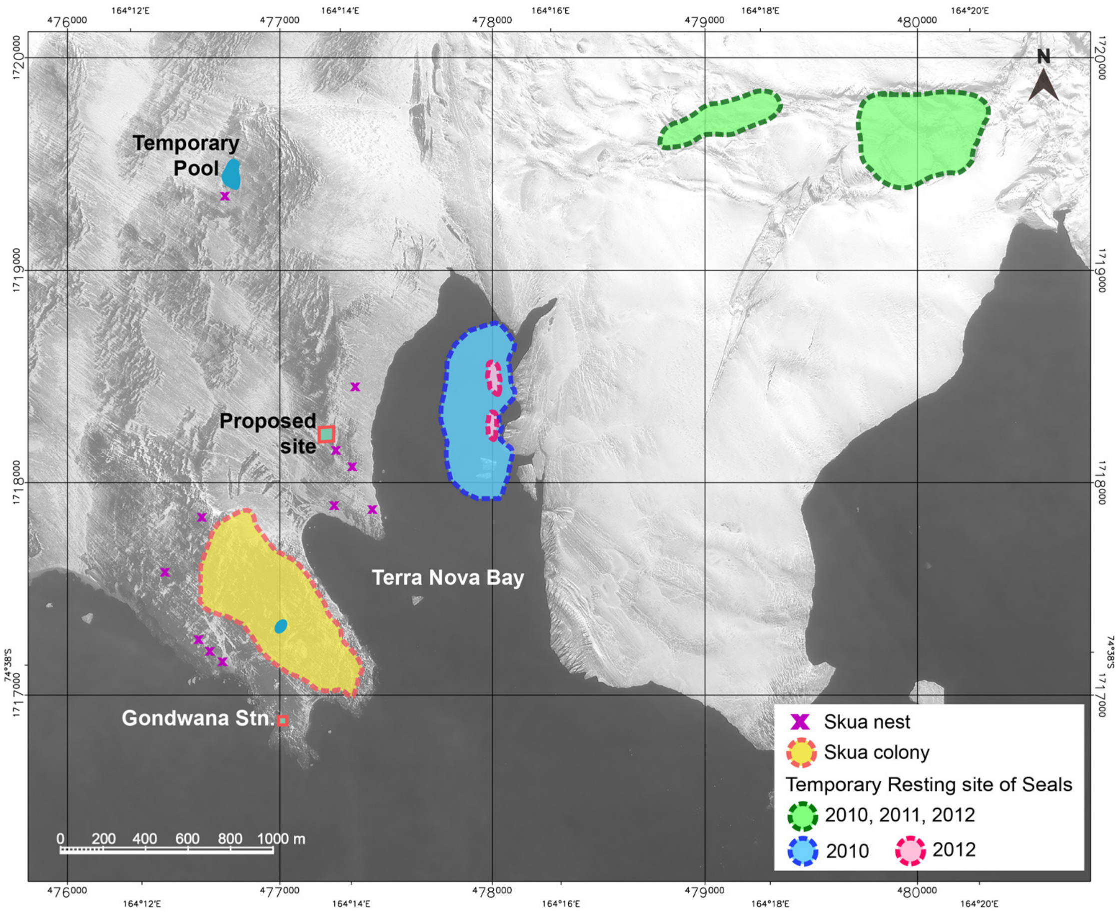


Fig. 4-16. Distribution of fauna near the proposed site. (Base image: adapted from KARI, KOMPSAT-2, 2011.02.21)

In 2010, the area of the habitat was measured approximately 800m×400m, and during the on-site investigation, 147 skua individuals, including 64 pairs and 19 chicks, were counted. Considering that chicks often hide between cracks in rocks, the number of skua inhabiting the area may be about 150-200 individuals.

84 South Polar Skua nests, including 10-20 new nests, were counted during the 2011 investigation. The new nests were mostly observed in the northwestern rocky area, except for the one found 200m to the northeast from the easternmost nest identified during the 2010 survey. No new nests were found formed near the proposed site.

78 South Polar Skua nests were identified during the 2012 survey. The decrease of six nests seems due to seasonal variation (Fig. 4-17).

Fig. 4-17. South Polar Skuas.

In 2010, Weddell Seals were observed during the on-site investigation. Three groups of the seal were observed resting on the fast ice in the east side of the proposed site. More than 85 seals in the fast ice were counted. Considering hidden individuals resting in the ice cracks, there could have been more than 100 seals inhabiting the area at the time of the investigation (Fig. 4-18(a)).

No Weddell Seal was observed during the 2011 survey as the eastern sea ice of the site had entirely melted. Aerial observations confirmed migrated seals over the eastern small glacial tongue resting on cracks (Fig. 4-18(b)).

Weddell Seals were also found resting in groups on crevasses between Campbell Glacier Tongues during the 2012 survey. Some seals were observed at the proposed site in the remaining eastern sea ice cracks, similarly as observed during the 2010 survey. They appeared as transitory small groups resting after fishing and unlikely to form permanent habitats at the area (Fig 4-16).

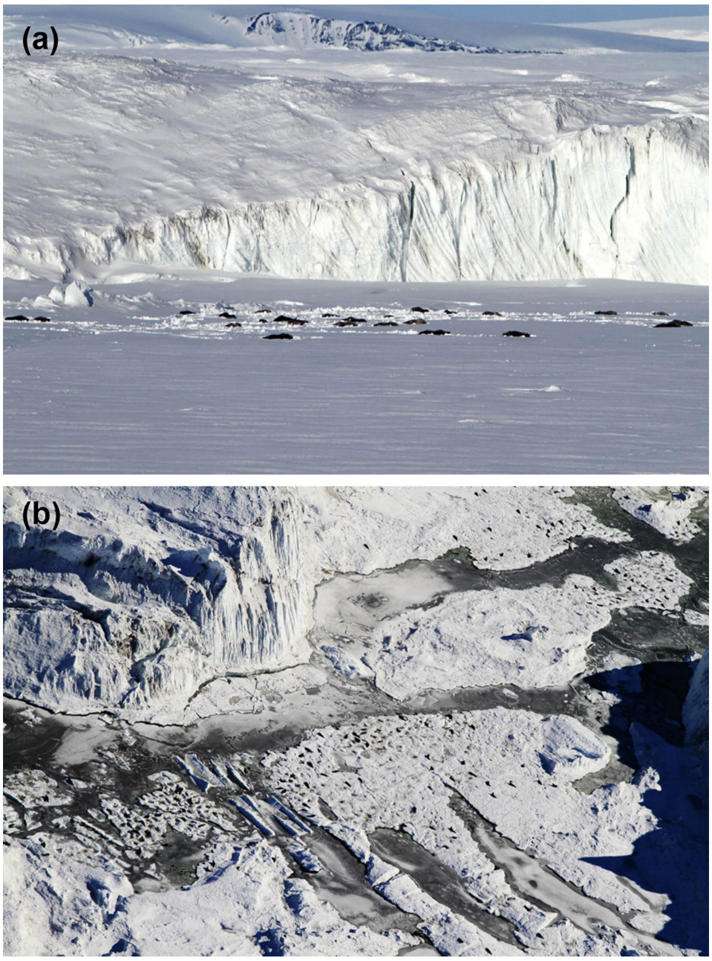


Fig. 4-18. Weddell Seals. (a) 2010 survey, (b) 2011 survey.

14.5% of mesoinverterbrates inhabiting the temporary pool near the proposed site were identified as Nematode at 18 indiv.10cm^{-2}, and 85.5% Tardigrada at 106 indiv.10cm^{-2}. The higher composition of Tardigrada mainly inhabiting lichen-rich soil reflects the site condition.

The dominant zooplankton species were identified as copepod and Gastropoda. Marine zooplanktons forms the basis of marine food chain and therefore, field investigation of the species is essential for any aquatic environmental impact studies. Gastropoda and Copepoda larva were dominant at 100-200m depth while copepod and Amphipoda were prevailing species above the depths. All larva generations are associated with phytoplankton masses (Innamorati *et al*., 2000).

Marine mesoinverterbrates compositions differed depending on the sampling locations. Nematoda, copepod, and Polychaeta were observed at all locations. Nematoda was the most dominant while Copepod, Polycheta and Oligocheta were found at a decreasing population density in order. Further studies are required to understand their community structure and diversity in relation with the benthic ecosystem and other environmental factors. Research on the regional marine benthic invertebrates prompted with the proposed Jang Bogo Station is expected to be valuable.

4.7. Human Activities

In 1985, Italy constructed Mario Zucchelli Station on the exposed land about 8km southwest from the proposed site across the Gerlache Inlet. The station has been actively conducting researches on biodiversity, changes in the ecosystem, geophysics, atmospheric science, and astronomy in the Ross Sea region. In particular, their marine ecology research has been focusing on understanding the marine communities in Terra Nova Bay. Based on the data accumulated through the research activities over the past 26 years, Italy recently proposed to designate the region across the Terra Nova Bay toward the northern Wood Bay as Marine Protected Area (MPA) in order to assure continued scientific research activities in the area while preserving ecological values of the area at IP 45 of the ATCM XXXIII (ATCM, 2010). In addition, the New Zealand-led Latitudinal Gradient Project (LGP) has been steadily promoted since the 2000s to understand the marine, land, and freshwater ecosystems of the coastal region of Victoria Land in the Ross Sea.

At Terra Nova Bay, research activities of Mario Zucchelli Station in conjunction with supply and transport activities are being vigorously conducted from November to February every year. Intercontinental and inner air flight routes connect from Christchurch, New Zealand to both McMurdo Station and Mario Zucchelli Station. The air routes are used to supply goods as well as to transport research and operating personnel. Furthermore, Italy's Programma Nazionale Ricerche in Antartide (PNRA) provides supplies and assists research activities using Italy's icebreaker *Italica.*

The Federal Institute for Geosciences and Natural Resources of Germany (BGR) began a research program titled German Antarctic North Victoria Land Expedition (GANOVEX) based in Terra Nova Bay in 1979. Under the program, being operated with two- to three-year interval projects (in 2009/10, the project GANOVEX X was completed), studies on the geology and geophysics of Northern Victoria Land have been conducted. BGR constructed the Gondwana Station right next to Cape Möbius in 1988/89 and has been operating the station temporarily only in the summer every two or three years. BGR cooperates with the programs of Italy, New Zealand, and the U.S. in order to provide assistance to the activities of Gondwana Station. It also undertakes joint researches with Alfred Wegener Institute (AWI) of Polar and Marine Research.

Antarctic tourist ships visit Terra Nova Bay to observe Cape Washington for a habitat of Emperor penguins, Inexpressible Island, and Mario Zucchelli Station. According to International Association of Antarctic Tour Operation (IAATO), the number of tourists that visited Cape Washington was the highest in 2005/06 registering 525 people. From 2003/04 to 2009/10, approximately 1,800 people visited the area. Cape Washington is the most popular destination for tourism in Terra Nova Bay, with 237 people visiting the region in 2009/10. During the same periods (2003/04 to 2009/10), a total of 1,144 people visited Mario Zucchelli Station.

4.8. Protected Areas, Historic Sites and Monuments

There are three ASPAs (Antarctic Specially Protected Areas) and two HSMs (Historic Sites and Monuments) in the vicinity of the Cape Möbius region.

☐ ASPA 118 (Summit of Mt. Melbourne, Northern Victoria Land)

ASPA (74°21′S, 164°42′E) proposed by New Zealand to protect the unique flora in a volcanic region (31.9km from the proposed site).

☐ ASPA 161 (Terra Nova Bay, Ross Sea)

ASPA (74°45′S, 164°10′E) proposed by Italy for preservation of coastal regions and long-term scientific research (15.7km from the proposed site).

☐ ASPA 165 (Edmonson Point, Wood Bay, Ross Sea)

ASPA (74°20′S, 165°08′E) proposed by Italy to protect diversity of the freshwater system and rich vegetation (40.9km from the proposed site).

☐ HSM 14 (An ice cave located on Inexpressible Island in Terra Nova Bay)

During the British expedition into the Antarctic from 1910 to 1913, Victor Campbell's northern exploration team created the ice cave in March 1912. They spent the winter of 1912 in this very cave, leaving signs, boards, and seal bones which still remain (74°54′S, 163°43′E). It was proposed by New Zealand and has been jointly managed by Italy and the U.K. (35.6km from the proposed site).

☐ HSM 68 (Location of storage on the moraine Hells Gate in Terra Nova Bay)

This emergency storage room was built in the form of a sled equipped with supplies and equipment on January 25, 1913 by the British expedition of the Antarctic from 1910 to 1913 (74°52′S, 163°50′E). It was proposed by New Zealand, Norway, and the U.K., and has been jointly managed by New Zealand and the U.K. (31.0km from the proposed site).

As mentioned previously, at the ATCM XXXIII held in May 2010, Italy submitted a proposal to designate the Terra Nova Bay-Wood Bay region as a MPA. This region covers an area of 6,000km^2 and includes the area south-southwestward from Kay Island (74°05′S), across Terra Nova Bay to Inexpressible Island (75°00′S), thus including the coastal region as well as part of the terrestrial land of 166°30′E and the entire coastal maritime land (ATCM, 2010).

The proposed site for the Jang Bogo Station is located within Terra Nova Bay, but is excluded from the proposed MPA (Fig. 4-19).

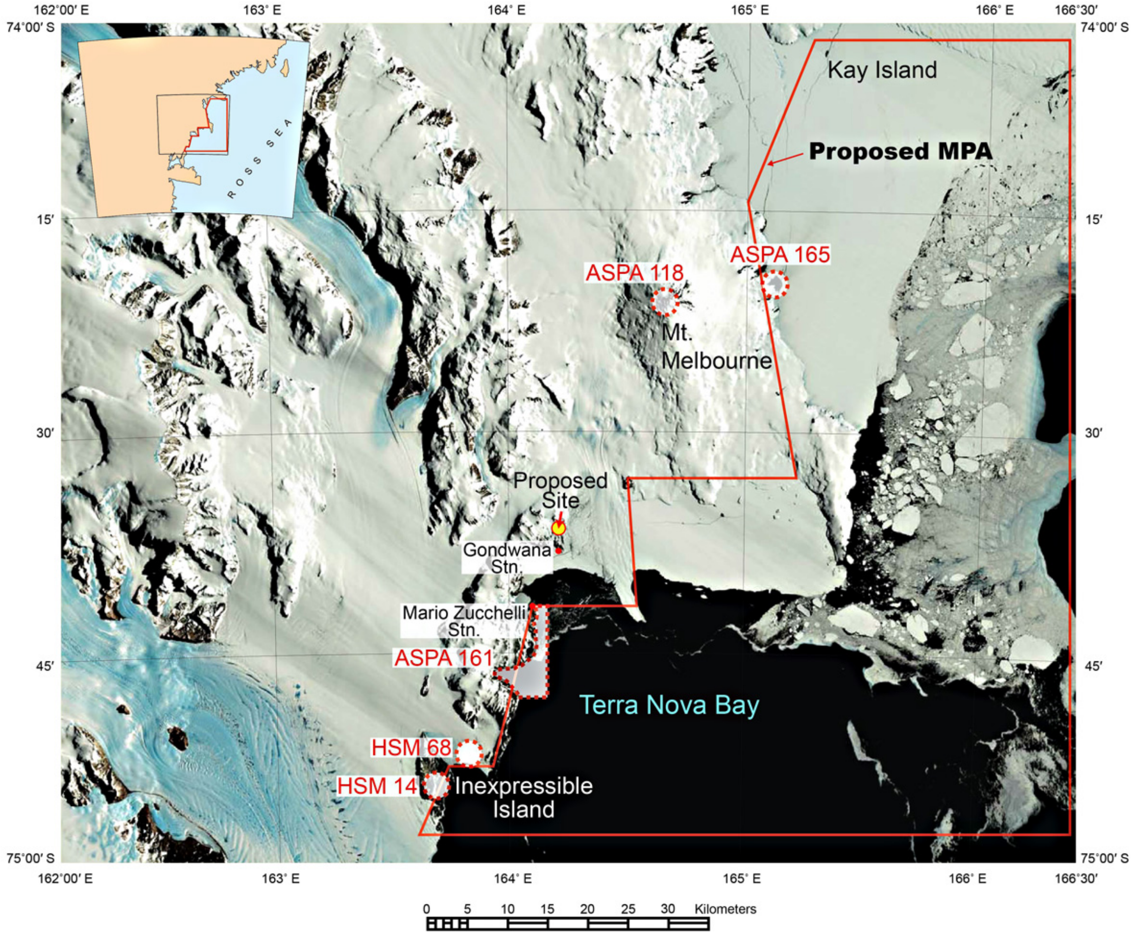


Fig. 4-19. Antarctic Specially Protected Areas (ASPA) and Historic Sites and Monuments (HSM) in Terra Nova Bay and Woody Bay regions. The red boundary indicates a proposed MPA by Italy. (Base map: adapted from MUSEO NAZIONALE DELL'ANTARTIDE-Sezione di Scienze della Terra, Via Laterina 4-53100 SIENA-ITALY, 1996)

4.9. Prediction of the Future Environmental Reference State in the Absence of the Proposed Activity

The proposed site of Jang Bogo Station is located on the way to Browning Pass from Mario Zucchelli Station and Gondwana Station. The environment of the proposed site is assessed free from any significant disturbances that may have been caused by past human activities.

Without the proposed activities being carried out, the current undisturbed environmental status will be preserved and the natural landscape will remain unchanged. In addition, there will be no topography change associated with the base construction. Individual nests of South Polar Skua will also be preserved as they are.

No impacts of the proposed activities on the environment, caused by either pollutants (such as noise, atmospheric pollutants and waste) or human interferences, will occur. If no dock for unloading is constructed along the coast, there will be little influence on marine environment either.

5. Prediction of Impacts, Assessment and Mitigation Measures of the Proposed Activities

5.1. Methodologies and Data

An Environmental Impact Assessment comprises three major phases: estimation of the current status of the environment, prediction of impacts, and suggestion of further assessment and mitigation measures. This final CEE for the construction and operation of the Jang Bogo Station is prepared in this phased process.

The preparation of the launch of the Jang Bogo Station is largely based on the Korea's experience of operating the King Sejong Station for more than two decades as well as the data acquired in Antarctica during the same period. It is also based on the knowledge on natural environment and weather conditions of the region accumulated by Italy and Germany. The data published by Italy and Germany (Faranda *et al*., 2000; Kantor, 1993; Orombelli, 1987) were particularly useful to better understand the environment and weather conditions at and near the proposed Jang Bogo Station site.

Three detailed surveys were conducted as part of the KARP for the proposed site from 2010 to 2012 using the icebreaker *ARAON*. These surveys provided data on the current environmental conditions at the proposed site, primarily the regional weather and ecosystem. The overall environmental impacts were assessed through comparison of the collected site survey data with the Italian and German data.

An AWS was installed at the proposed site to obtain continuous weather data during the survey in 2010 Thus, real-time data on the temperature, wind speed, wind direction, atmospheric pressure and snow fall have been accumulated since February 2010.

The intensity of a potential impact on Antarctic environmental media (atmosphere, glacier, sea, flora and fauna, etc.) can be classified into five different levels for each of its four different aspects: probability, extent, duration and importance of impact. The criteria of classification are based on whether the potential impact is direct/indirect, cumulative/temporary and inevitable/avoidable. A comprehensive impact assessment for the proposed activities associated with the establishment of the Jang Bogo Station was performed with the impact matrix provided by the EIA guidelines for Antarctic activities (e.g., COMNAP, 2005a)

5.2. Air Quality

For the prediction of unavoidable atmospheric emissions involved with the construction and operation of the station, the ISCST3 model, a Gaussian Dispersion Model, was applied as the proposed site features flat topography with the slope less than 10˚. The ISCST3 model predicted the impact on air quality based on topography and meteorology data collected between February 2010 and November 2011, measured by the AWS. With respect to the results of impact prediction, mitigation measures were prepared for the construction and operation phases per each source of the emissions.

5.2.1. During Construction

(1) Estimation of Emissions

The amount of atmospheric emissions is estimated based on the transportation plan per construction phase. The primary sources of the emissions during the construction are transportation, activities of the construction team, operations of temporary facilities, and the combustion of fuel by the construction equipments.

As shown in Appendix 5 and summarized in Table 5-1, total emissions from the construction were estimated at 10.66ton of CO, 37.32ton of NO_x, 297.71ton of SO_2, 2.93ton of PM10, and 8,250.4ton of CO_2.

Table 5-1. Predicted atmospheric emissions during construction. (unit: ton)

Emission / Source	CO	NO_x	SO_2	PM10	CO_2
Transportation (Ships & aircraft)	7.33	29.95	293.59	2.48	7,793.89
Construction camp & service facilities	0.10	1.46	0.09	0.13	61.15
Construction equipments	3.23	5.91	4.03	0.32	395.36
Total emissions	10.66	37.32	297.71	2.93	8,250.40

(2) Impact on Air Quality

The model-predicted 1-hour average PM10 concentration is 10㎍/m^3 and 24-hour average PM10 concentration 3㎍/m^3, which indicates that construction activities will have a minimal impact on air quality (Figs. 5-1, 5-2). Meanwhile, the emissions may partially contaminate snow, ice or rock surface causing adverse impacts on biota living in the rock cracks.

Most of the emissions will be originated from marine transportation except for during the anchoring periods. These emissions will rapidly disperse over wide areas. Therefore, their impacts will be limited, but they may contribute cumulatively to the air quality of Antarctica.

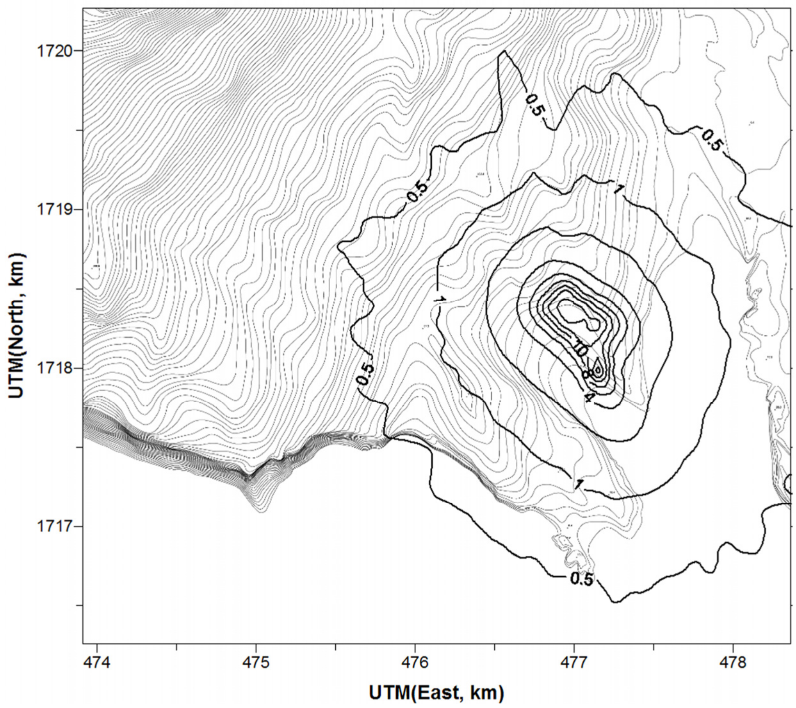


Fig. 5-1. Predicted 1-hour average PM10 concentration during construction. (㎍/m³)

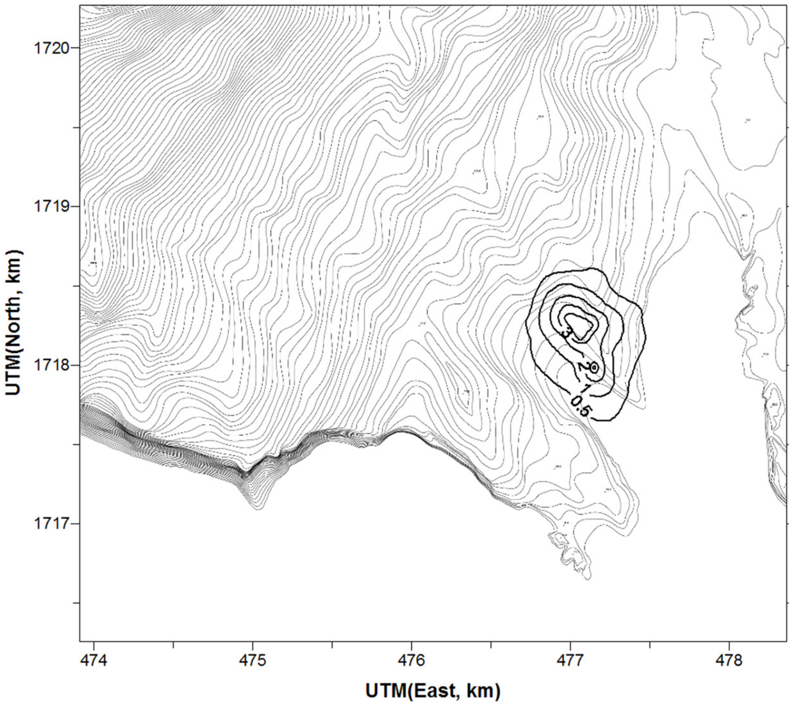


Fig. 5-2. Predicted 24-hour average PM10 concentration during construction. (㎍/m^3)

(3) Mitigation Measures

All ships in the area will be recommended to use high refined fuel such as Marine Gas Oil (MGO) with low-sulfur (lower than the 3.5% regulation by the MARPOL 73/78 if possible).

Equipments will be properly maintained to high standards to minimize atmospheric emissions. Equipment will not be left idling unless necessary and the operator will be advised to follow the routes selected for minimum fuel consumption.

Temporary facilities for construction workers are designed to use high quality insulation materials and maximum sealing to minimize energy loss.

5.2.2. During Operation

(1) Estimation of Emissions

Annual emissions coming from fuel consumption during operation of the station were estimated to be 1.12ton of CO, 10ton of NO_x, 0.29ton of SO_2, 0.46ton of PM10, and 893.9ton of CO_2 as shown in Table 5-2 (see Appendix 5 for more details).

Table 5-2. Predicted annual atmospheric emission during operation. (unit: ton)

Source \ Emission	CO	NO_x	SO_2	PM10	CO_2
Heating facilities	0.25	3.59	0.23	0.31	801.96
Vehicles	0.01	0.34	0.01	0.00	60.33
Helicopter	0.30	0.01	0.02	0.01	21.48
Kitchen facilities	0.56	6.06	0.03	0.14	10.13
Total annual emissions	1.12	10.00	0.29	0.46	893.90

(2) Impact on Air Quality

A simulation was conducted using the ISCST3 model to assess the air quality around the station in its operation phase, and the result indicates that there will be little impact on air quality due to the operation of the station. The result shows the maximum concentration of 30ppb for 1-hour average NO_x near the station and daily mean concentration of 10ppb and annual mean concentration of 3ppb which are much lower than standard levels of both the National Ambient Air Quality and the WHO standard (below 105ppb for 1-hour average and 21ppb for annual mean) (Figs. 5-3, 5-4, 5-5).

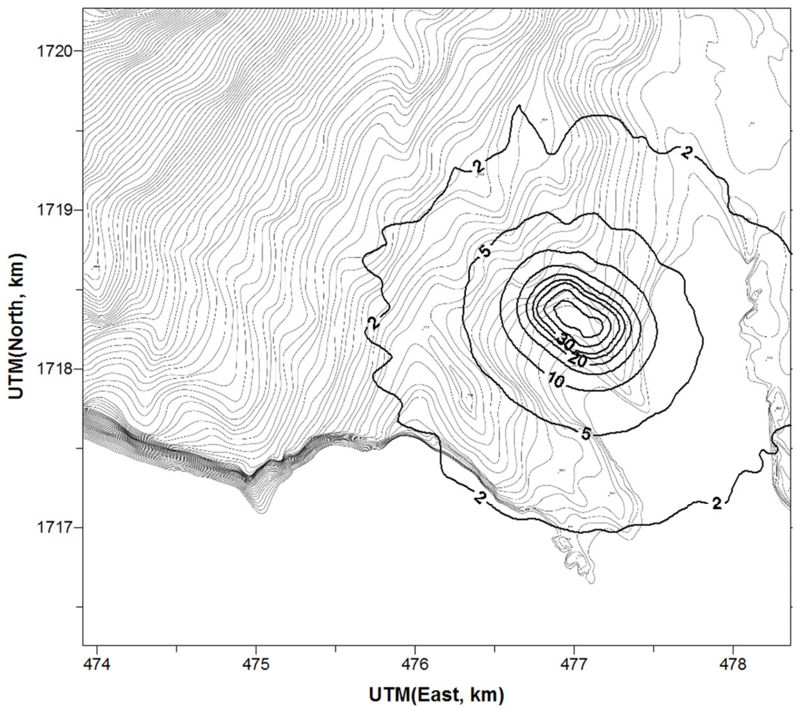


Fig. 5-3. Predicted 1-hour average NO_x concentration during operation. (ppb)

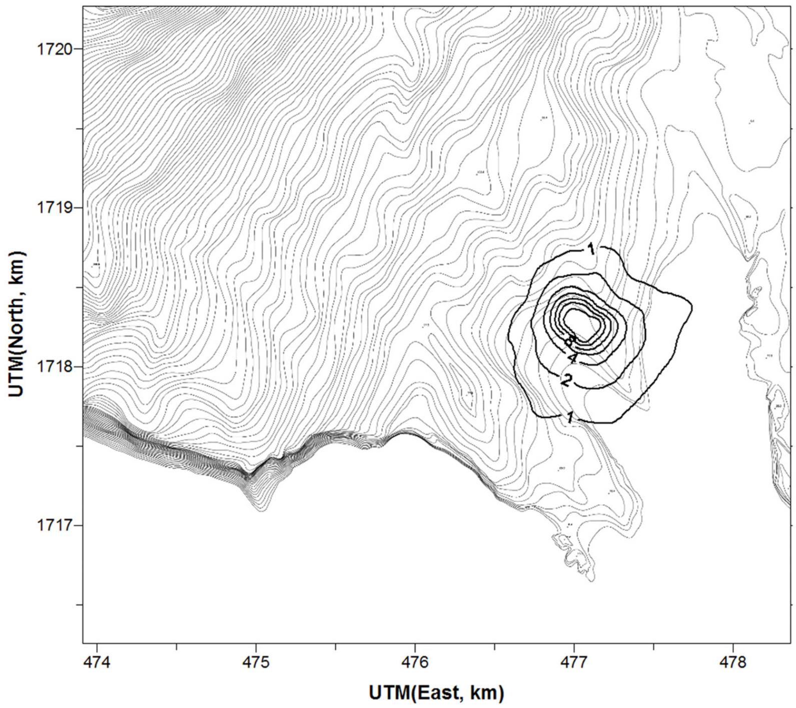


Fig. 5-4. Predicted 24-hour average NO_x concentration during operation. (ppb)

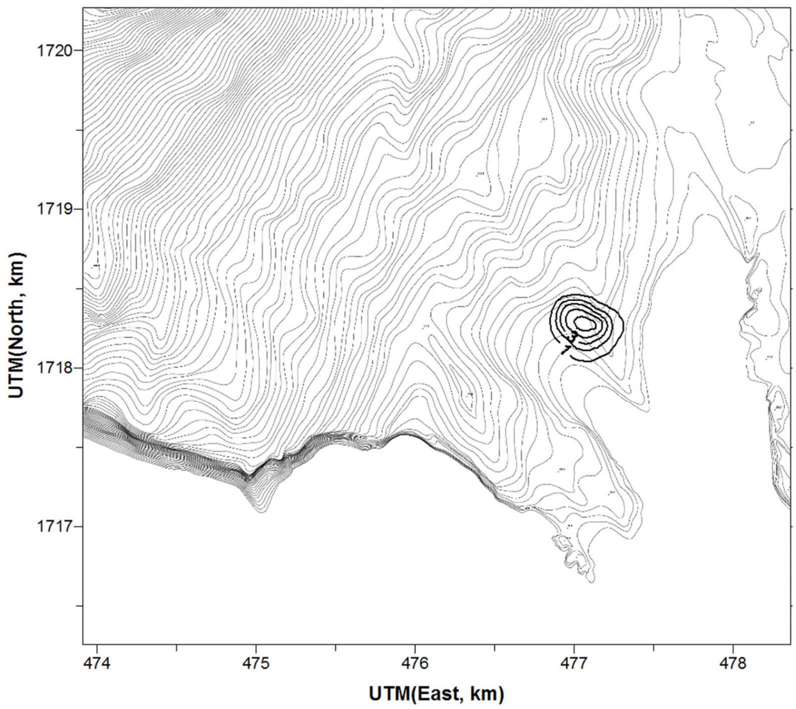


Fig. 5-5. Predicted annual average NO_x concentration during operation. (ppb)

(3) Mitigation Measures

Waste heat from CHP plant will be used to reduce heat loss and to minimize the use of fossil fuels and the emissions of air pollutants. Solar and wind renewable energy sources will be used to minimize the use of fuels, too. Energy consumption will also be reduced by removing all wastes from the Antarctic region without incineration. Table 5-3 shows the estimated reduction in carbon emissions.

Table 5-3. Estimated reduction of carbon emissions resulted from limit in use of fossil fuels.

Category	Annual reduction of CO_2				
	Solar energy		Wind energy	Natural sunlight	Recycled waste heat
	PV	BIPV			
Amount of electric power saved (kWh)	36,285	2,124	124,416	13,715	1,693,440
Annual carbon emissions reduction[1] (TCO_2)	16.1	0.9	55.3	6.1	753.2

1) Carbon dioxide emission factor for power: 0.4448TCO_2/MWh (Korea Energy Management Corporation, 2009)
- Assuming solar and wind energy capacities, 43.76kW (PV: 41.36kW, BIPV: 2.4kW), 48kW respectively

5.3. Fuel and Oil Spills

5.3.1. Possibility of Fuel and Oil Spills and Impacts

Various fuels and lubricants will be used during the construction and operation of the station.

Fuel and oil spills may occur during the processes of unloading construction materials and equipments, and fuel transfer procedures between transit and fuel tanks. Fuel spills may also occur during refueling aircraft, vehicles and generators. Cracked fuel pipelines and damaged fuel tanks are also potential sources of fuel spill, but the possibility of leakage from them is very limited. Ocean fuel spills can occur if a ship is stranded or collides with sea ice, but the probability of such occurrences is also very low.

Fuel or oil spills can seriously affect the environment. Spills, if occur in the station, are expected to be confined at the site. Besides, most of the fuel used in the station is relatively volatile and expected to vaporize quickly in case of spills, but a waxy residue may remain.

However, fuel spills may permeate through rock cracks or pore spaces of moraines. If permeated fuel spills do reach the sea, it will have an adverse impact on marine environment. Furthermore, inland fuel spills may contaminate the soil and also adversely affect the flora living in the cracks between rocks.

Spills during construction may indirectly affect the scientific values of the area and contribute the cumulative effects of the station in the future.

5.3.2. Prevention of Fuel and Oil Spills

The primary method of managing fuel and oil spills is the prevention of spills, thus the use of fuel and oil will be strictly managed during the construction and operation of the station. A contingency plan has been prepared to take immediate measures for unexpected oil spills (KOPRI, 2011a).

To prevent fuel spills, fuel tanks will be double-skinned, suitable absorbent mats will be used to underlay the pipelines, and oil impermeable bund wall will be built around the fuel tank (Fig. 5-6). Fuel pipelines for generators will be designed double-skinned to minimize the possibility of oil leakage.

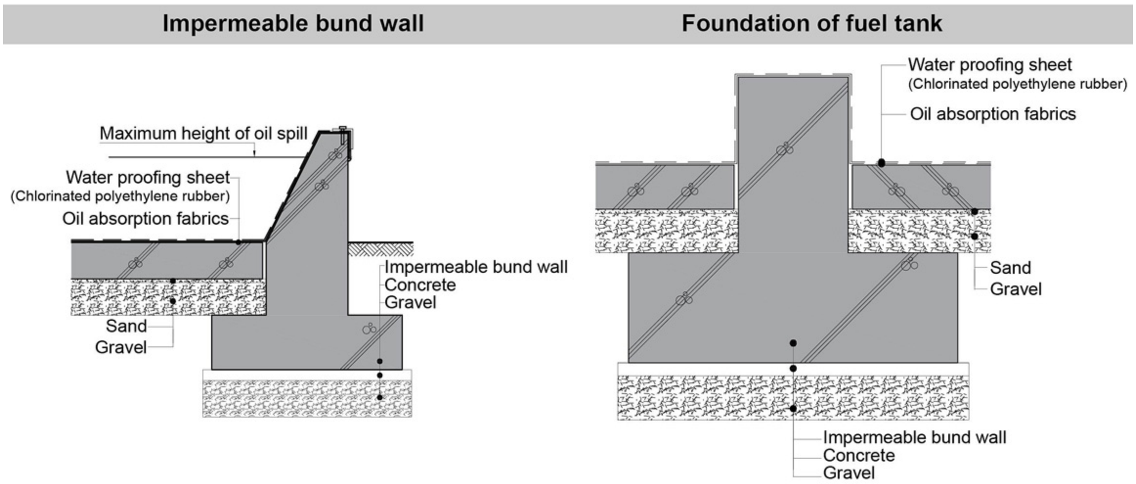


Fig. 5-6. Cross section of oil spill prevention facility.

The guidelines of COMNAP/SCALOP (2003), which describe actions to be taken in the event of different kinds of oil spills, will be strictly followed. Any incident, whether it involves casualties or any environmental damages, will be reported to the relevant authorities including the MOE, the Ministry of Land, Transport and Maritime Affairs, and the KOPRI.

Most of the oil spills are likely to be minor, but oil tank damages can create greater harm. For such rare but potentially catastrophic events, emergency equipments and supplies against large amount of oil spills as well as comprehensive plans against marine accidents has been prepared (KOPRI, 2011a). The station will also be provided with appropriate equipments and supplies for prevention and clean-up of spills in accordance with the associated regulations.

Furthermore, clean-up material and equipment at the station will be properly maintained for immediate emergency response. The maintenances will be scheduled at least once a year.

All staff members will be trained and refreshed once a year regarding immediate and appropriate response actions on the contingency action plan. The oil spill prevention and emergency response program will be regularly audited.

5.4. Waste

5.4.1. During Construction

(1) Waste Generation

The proposed construction activities are expected to mostly generate non-hazardous solid waste such as packaging materials, metal, plastic and wood. Some hazardous waste, including batteries, solvents and waste oil will also be produced.

The waste oil from construction equipments was calculated to be maximum 96.2ℓ/day.

The total amount of waste oil is estimated to be 2,410.9ℓ for Year 1, and 2,185.6ℓ for Year 2 during construction.

The amount of domestic waste and night soil during construction phases were estimated based on the data collected for the recent renovation of King Sejong Station: domestic waste 55kg/day (Year 1) and 47.5kg/day (Year 2); night soil 33ℓ/day (Year 1), 28.5ℓ/day (Year 2) (KOPRI, 2009, Appendix 6).

The modular construction method planned to be employed for the entire construction of the Jang Bogo Station, compared with the conventional construction method using piling and anchoring, substantially reduces the expected amount of construction waste: 20,765kg (Year 1), and 7,554kg (Year 2) (MOE, 2004).

If not securely contained, waste materials may be blown away by strong winds, buried under snow or scavenged by skua. Not properly managed waste may have other adverse biological effects on the fauna in the region. Waste may also have indirect effects on the future scientific value of the area.

(2) Mitigation Measures

Waste produced during construction will be managed according to Jang Bogo Station Waste Management Manual (KOPRI, 2011b) as well as the BAS Waste Management Handbook (BAS, 2010). The modular construction method will work to reduce substantial quantities of construction waste.

Storage of materials and waste will be carefully conducted in order to prevent wind dispersal or scavenging by skua.

Waste oil will be stored in storage facility until transported outside of the Antarctic region. Night soil will be packaged and stored until being transported outside of Antarctica.

Construction and domestic wastes will be separately collected for recycling and reuse if possible. All construction wastes will be properly stored, carefully managed and also removed from Antarctica.

5.4.2. During Operation

(1) Waste Generation

Operation of research, residential and maintenance facilities will generate hazardous and non-hazardous solid waste. If not properly stored and managed, some waste may be scattered by strong winds or buried by snowfall. Food waste could be scavenged by skua or contaminate exposed rock surfaces and flora if not thoroughly contained.

Total domestic waste including combustible, non-combustible and recycled waste may reach as much as 15.53kg/day during the winter and 62.1kg/day during the summer. Food waste as much as 4.52kg/day during the winter and 18.06kg/day during the summer are expected according to the daily food waste unit (MOE, 2009a, Appendix 6). However, given the living conditions in the Antarctic, the amount of food waste produced is expected to be significantly lower than the predicted value.

(2) Mitigation Measures

Waste will be managed according to Jang Bogo Station Waste Management Manual (KOPRI, 2011b) as well as the BAS Waste Management Handbook (BAS, 2010). Appropriate training and guidance on waste management for staff members will be provided.

All wastes will be sorted, compacted if possible, safely stored and removed from the station for reuse, recycling or disposal.

Food waste, containing approximately 80% water, is planned to be dried and reduced in volume before off-site transportation. Special care will be taken for the storage of food waste as any food waste items left outside may be scavenged by skua. Hazardous waste produced from laboratories and waste oil will be stored separately and eventually transported outside of Antarctica.

5.5. Wastewater

5.5.1. During Construction

(1) Wastewater Generation

The wastewater will be generated as much as 22m^3/day during the first construction year and 19m^3/day during the second construction year (Appendix 7). These are calculated based on the wastewater generation units provided by the MOE of Korea. However, wastewater is actually expected to be less than the calculated amounts given the energy and resource-conscious life style in Antarctica.

The direct on-site disposal of untreated wastewater may cause contamination of the marine environment as well as the land biota such as lichens and birds inhabiting the region.

(2) Mitigation Measures

Wastewater generated during construction will be discharged after treatment using an IC-SBR system installed in temporary equipment room.

5.5.2. During Operation

(1) Wastewater Generation

Wastewater will be generated from activities such as food preparation and washing during the operation phase of the station. A conservative estimation of the wastewater that will be generated is up to $2.14m^3$/day in the winter and $8.55m^3$/day in the summer (Appendix 7).

If the wastewater is discharged without proper treatment or in case of a failure of the treatment system, it could adversely affect the marine environment and the flora and fauna inhabiting the coastal region. In addition, if such discharge continues for a long time, cumulative impact on marine biota may occur.

There are also certain environmental concerns that must be addressed related to desalination of seawater. The disposal of concentrated residual brine into the sea may cause some environmental impacts on the marine ecosystem in nearby areas due to the changes in salinity, oxygen levels, and possibly temperature.

(2) Mitigation Measures

Methods of wastewater treatment and disposal will be based on the regulation of Annex III of the Protocol on Environmental Protection to the Antarctic Treaty.

The production of wastewater will be minimized in addition to the comprehensive treatment system that will be provided. The IC-SBR technique will be used to treat wastewater and the gray water reclamation and reuse system to maximize the reuse of wastewater. The gray water will be supplied for toilet flushing and cleaning which account for about 40% of total water use.

Wastewater will be treated and discharged based on the most stringent level in Discharged Water Quality Standard of Korea (BOD less than 5mg/ℓ, COD less than 20mg/ℓ, T-N less than 20mg/ℓ, T-P less than 0.2mg/ℓ), thereby minimizing the impact on the marine environment. The final discharge location of treated wastewater was selected as far as possible from the intake point.

The IC-SBR is unattended system so that a full-time specialist is unnecessary. It should be monitored regularly by a technician who takes minimal training by the provider. Even though this system is very reliable, sufficient spare parts will be supplied for contingency.

Wastewater produced with hazardous chemical component from laboratories will be contained, specially sealed and transported back to Korea. In addition, water-saving devices will be installed.

Several methods for an adequate and safe disposal of the concentrated brine produced by the desalination process will be considered to reduce the environmental impacts of desalination. The generated brine is expected to be relatively small in volume. A discharge point optimal for rapidly mixing and dilution was selected for the brine. Pre-discharge mixing of the brine with treated wastewater will be another alternative to reduce salt concentration.

5.6. Noise

Noise levels during construction and operation were estimated and associated mitigation measures were established.

5.6.1. During Construction

(1) Prediction of Level of Noise and Impact

Noise will be generated from loading and unloading activities, equipment operations and other construction activities.

Levels of noise arising from construction were estimated considering mainly the operation of equipments and other construction activities. The equation of point-sound source attenuation (Appendix 8) was used assuming the worst case scenario of full-capacity operation of heavy equipment. The estimated noise levels are expected to exceed 60dB temporarily at a distance of 300m. However, in real situation the noise levels will not exceed 50dB, the most stringent daytime noise limit applied in Korea, except for within the immediate proximity of the construction site (Fig. 5-7).

Noise disturbance may influence habitats of birds and mammals. However, the estimated noise levels are conservative as the model assumes flat topography, which is known to be the most preferable condition for the propagation of noise. Therefore the colonies of South Polar Skua and Weddell Seal, located approximately 1km away from the proposed site, will not be significantly impacted by the noise generated during the construction.

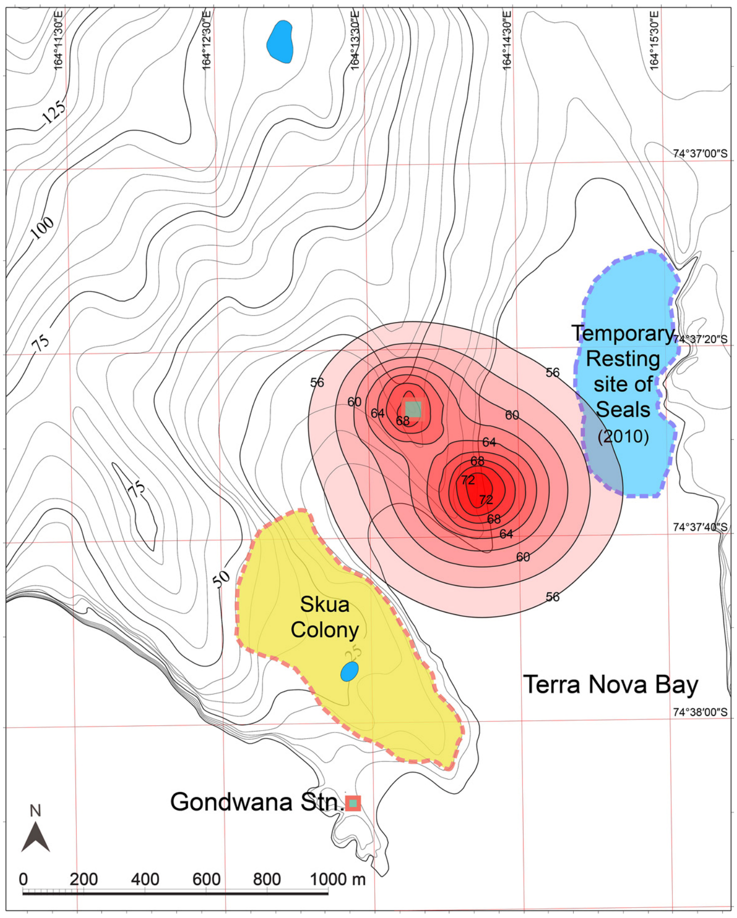


Fig. 5-7. Predicted noise level for the worst case scenario by equipment operation during construction.

(2) Mitigation Measures

Simultaneous operation of construction equipment will be limited in order to minimize impact of noise on the colonies of skua and seal, although predicted levels of noise under the simultaneous operation condition were insignificant. In addition, construction machines of low noise and vibration-reduction technologies will be used and idling of vehicles will be minimized.

5.6.2. During Operation

(1) Prediction of Noise Level and Impact

The noise generated from the station during its operation and associated scientific activities may cause an adverse impact on fauna such as skuas and seals. The operations of ships and aircrafts will also produce inevitable noise, but their impact is temporary and limited mostly during the summer.

Power generators and radiators will produce constant noise. However, their levels are expected to be significantly lower than 35dB, the indoor noise standard applied for the station in its operation phase.

The use of vertically stacked modular type wind turbines which combines three 4kW vertical turbines is also expected to significantly lower the noise levels than the equivalent single 10kW horizontal-type turbine. One such type wind turbine is calculated to produce about 35-38dB of noise. As the level of noise will be attenuated logarithmically by distance, impact of noise will be almost negligible for the station, and for the colonies of skua and seal.

(2) Mitigation Measures

Noise absorbing materials will be installed in the power generator facility.

The helicopters will maintain a flying altitude recommended by the ATCM guideline for aircraft operation to minimize the impact on the ecosystem (ATCM, 2004b).

5.7. Flora and Fauna

The construction and operation of the Jang Bogo Station may not affect the surrounding ecosystem significantly because no conspicuous colonies or breeding grounds of designated species have been found at the near proximity of the proposed site.

The flora, mostly lichens and mosses, is very sporadic with low distribution density and a coverage degree of less than 1% nearby the proposed site. They are expected to be disturbed during the construction of the station, especially by grading work. However, as there are very few lichen growths on the proposed site, the disturbance to vegetation will be transitory only for the construction and thus not be so significant.

The colony of South Polar Skua located in the eastern hill of the Gondwana Station will not be directly disturbed due to the construction and operation of the station, but indirect impacts are expected considering relative proximity of the colony, the shortest distance between the colony and the site being approximately 500 meters. Besides, in surveys from 2010 to 2012, about five individual skua nests have been observed within a 400m radius of the proposed site (Fig. 5-8). The distribution of individual nests, however, is expected to vary every year.

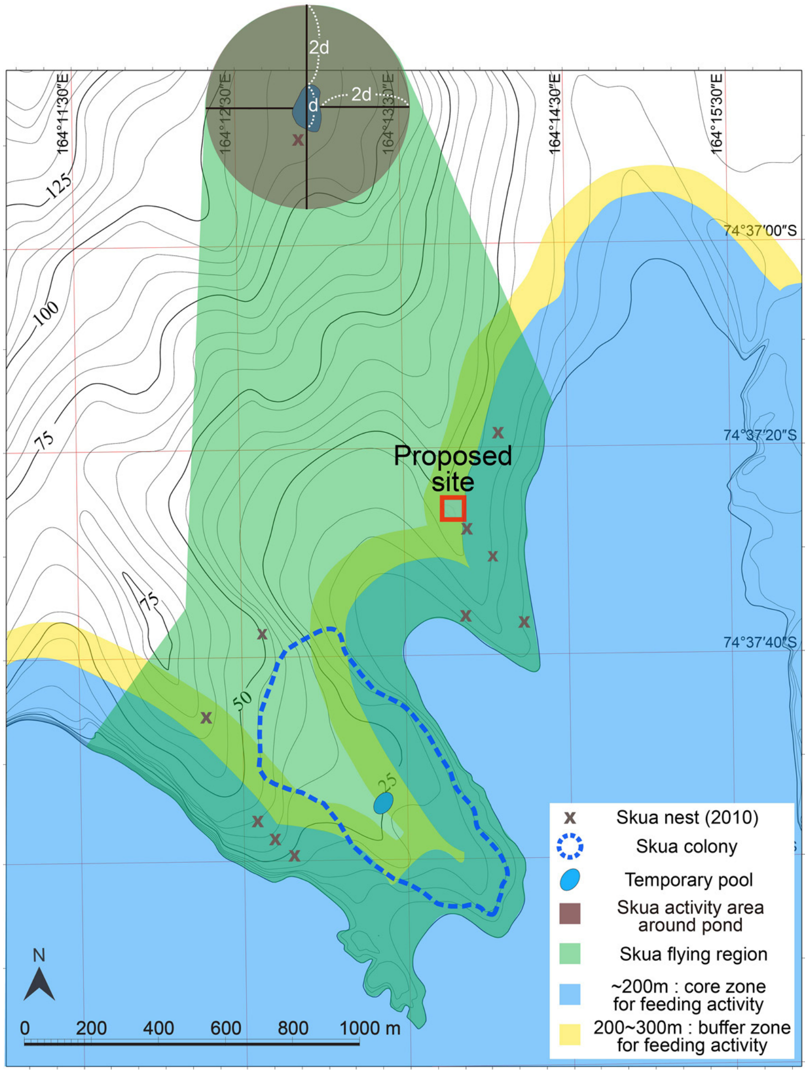


Fig. 5-8. Activity areas of South Polar Skua estimated based on the data of 2010 survey.

A number of Weddell Seal colonies were observed on sea ice 600m-2km to the east, and hence, with little potential impacts expected on the habitats by the construction and operation of the station. The access route selected to be used for the station, one through the small bay west of the proposed site, is expected to have little impacts on the habitats of skua and seal than the other alternative routes.

5.7.1. During Construction

(1) Prediction of Impacts

1) South Polar Skua

The proposed site was selected in a location approximately 500m away from the boundary of the skua colony, approximately 1km from the center of the colony, in order to minimize any disturbances caused by the construction.

A few scattered nests in or near the proposed site are unlikely to have chance to be developed as a large colony in the future due to the lack of bedrock outcrops, which are favorable for nests. However, currently existing skua nests within the site may be distressed during construction.

2) Helicopters

The selected unloading position and land transport route (route B) for construction cargos in Fig. 3-2(b) is expected to have a minimum potential to cause negative impacts on the skua colony. Therefore, helicopters will use the same flight route.

3) Marine transportation and unloading

Marine transportation may disturb the marine environment and ecosystem. Especially, it is likely that unloading from a barge to land has an impact on the benthic ecosystem along the coastal line as well as on marine mammals.

4) Marine ecosystem related to construction of dock

In construction of dock, pre-manufactured PC blocks and stainless steel panels will be used to shorten the construction period as well as to reduce potential impacts on the marine environment and preserve the natural coastal landscape. However, the benthic ecosystem near the shoreline may temporarily be impacted due to construction activities such as backfilling.

(2) Mitigation Measures

Impacts on the local ecosystem due to the construction and operation of the station can be reduced if mitigation measures are properly implemented.

1) South Polar Skua

As direct and/or indirect impacts on a few number of skua nests observed at the proposed site are inevitable during construction, additional protective measures to minimize the impacts, such as installation of barriers, are considered.

To conserve the skua colony at the western area apart from the proposed site, unnecessary visiting by either construction workers or other personnel will be strictly controlled and restricted during construction period.

In addition, all personnel will be given site specific guidance on minimizing anthropogenic disturbance to the skua colony. Biweekly monitoring on the skua colony will be taken by biologists to devise additional effective mitigation measures if unexpected impacts would occur.

2) Helicopters

In order to minimize the impact of helicopter operations on the colonies of skua and seal, a flight route which is able to minimize the impact on them will be taken into account. Moreover, guideline related to flying in the Antarctic, “Guideline for the operation of aircraft near concentrations of birds in Antarctica” will be followed (ATCM, 2004b). These guidelines will also be followed during the operation of the station.

3) Marine transportation and unloading

Impact of marine transportation on the marine ecosystem may vary depending on the alternative access routes to the station. Considering the distributions of the flora and fauna, a route through the small bay west of the proposed site, route B of Fig. 5-9, was estimated to be the best transportation route for the protection of biodiversity and the ecosystem. The transportation and unloading route B was selected to minimize environmental impacts (Table 5-4).

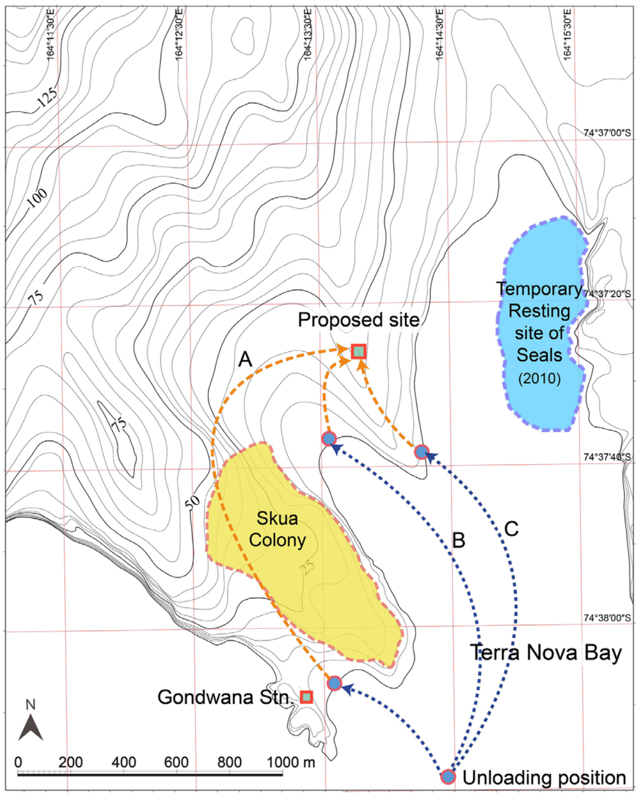


Fig. 5-9. Marine transport and unloading alternatives. A: through skua colony, B: through western bay of the proposed site (selected alternatives), C: through eastern seashore of the small cape

Table 5-4. Ecological impact of each transport alternative.

Category	Lichens/mosses	Birds	Marine mammals
Route A	Extremely low	Moderate	None
Route B	Extremely low	Extremely low	None
Route C	Extremely low	Extremely low	Moderate

4) Marine ecosystem related to construction of dock

Secure and durable PC blocks with stainless steel panel will be used to minimize the impact on the marine environment as well as further reduce construction time. It can also minimize resistance of external force and pack ice.

During the construction of the proposed dock, only the limited amounts of gravels and boulders, by-product of grading and excavation for the PC foundation of the building will be used for filling material to minimize the disturbance to nature of glacial topographic features in the area. In addition, the excavation site will be contained within a turbidity barrier that will be installed during the construction in order to avoid dispersion of suspended materials, and thus minimize impacts on the benthic ecosystem.

5.7.2. During Operation

(1) Prediction of Impacts

1) Research activities and visitors

Human disturbances can be induced by a variety of research activities and summer visitors, but the impact on lichens and mosses is almost negligible given their locations and densities of distribution. The impacts on skua and Weddell seal habitats will be indirect and minor during the operation of the station because the colonies are located at a safe distance from the proposed site.

2) Introduction of alien species

Alien species may be introduced through food items, equipment or other materials associated with personnel imports to the Antarctic. Non-native soil imports may also transfer alien species such as seeds and micro-organisms.

3) Transportation and unloading

In case of oil spill during transportation or unloading, the marine ecosystem may be subject to adverse impacts.

4) Wind turbine

The low speed rotation of vertically stacked modular type turbines is expected to generate noise less than 38dB, which will have almost no impact on the surrounding ecosystem as well as on people. It was predicted that bird strikes are highly unlikely because visibility of the tower is good and radius of the proposed type of turbine is relatively small, especially when compared with that of the horizontal turbine with big blades (Kikuchi, 2008, see Table 3-3).

5) South Polar Skua

Skuas are scavengers, and therefore food or food waste left outside of the station, if skuas feed on them, may disturb their dietary habits.

6) Temporary pools

If the temporary pool, located 1.2km to the north of the proposed site, is utilized as an emergency water source, the associated installation of pipe lines and facilities may render an adverse impact on the density of lichens and mosses as well as on the skua habitat.

(2) Mitigation Measures

1) Research activities and visitors

The impacts caused by research activities and activities of the summer visitors are expected mostly insignificant on the flora and fauna of the region. In particular, the major populations of skua and seal are not exposed to the direct impact during operation. However, as temporary indirect impacts are still expected, limits on the number and the scope of research activities and activities of the summer visitors will be planned in advance in the annual plans of operation of the station.

2) Introduction of alien species

In order to prevent the introduction or dissemination of alien species possibly transferred by people, equipment or supplies, the regulation of Annex II (Article 4) of the Protocol on Environmental Protection to the Antarctic Treaty and Resolution 6 - ATCM XXXIV-CEP XIV with Non-native Species Manual annexed to the resolution will be strictly followed (ATCM, 2011). Items such as shoes, clothes and organic matters will be thoroughly cleaned and sanitized before being imported onto Antarctica. In particular, tracked and wheeled vehicles will be carefully rinsed on the ship before unloading.

3) Transportation and unloading

For transportation and unloading, an oil spill contingency plan has been set up to protect the marine ecosystem (KOPRI, 2011a). Prevention and treatment materials such as oil absorption fabrics and recovery equipment will be prepared for immediate responses to oil spill accidents.

4) South Polar Skua

The main population of skua inhabiting a gentle hill between the proposed site and Gondwana station will be monitored as one of possible indicators responding any kind of impacts and changes in terrestrial ecosystem. During the operation, skua population fluctuation and dynamics will also be carefully analyzed to conserve the core spot of skua's habitats as well as to conduct scientific researches. In detail, the size and distribution of skua populations around the station will be monitored annually by establishing a post-monitoring program in order to investigate any changes in the ecosystem.

In consideration of skua's dietary habit as a scavenger, food and food wastes will be managed and treated according to a proper management plan.

All personnel including visitors will be given guidance on minimizing disturbance to the skua colony. Helicopter will not overfly the skua colony and its operation will follow the guideline related to flying in the Antarctic, "Guideline for the operation of aircraft near concentrations of birds in Antarctica" (ATCM, 2004b).

5) Temporary pools

As the flora and fauna in the northern temporary pool are diverse compared to those in other locations, the pool will not be used as an emergency water source to preserve the biota in this area. Skuas consistently use the pool as a freshwater source and resting area, too. Therefore, preservation of the temporary pool undisturbed will be more beneficial than using it as an emergency water source for the construction and operation of the station.

5.8. Changes in Topography

Partial grading is required for constructions of buildings, facilities and a temporary camp. Furthermore, the natural topographic features of the region should be modified for the unloading activities close to the coast and the installation of routes for the cargos and equipment to the proposed site. During the construction of the main building and other permanent structures, approximately $11{,}306m^3$ of excavated material by surface grading will be produced and $9{,}337m^3$ reused for refilling material. The remains will be used for filling material in dock construction as described in section 2.3.

Various activities related to the installation of wind turbines may also cause changes in the topographic features as well as the local landscape. The activities include transport of heavy equipment, construction of the foundation of the wind turbine towers, and installation of four

20m high towers. These changes will locally disturb the unconsolidated glacial sedimentary layers and bedrocks to some extent. However, it is expected that such change in topography is likely to be insignificant because the area is generally flat or only gently slopes.

5.9. Scenery and Aesthetic Natural Values

The proposed site is a region where its exposed bedrock outcrops and glacial moraines, in combination with the Campbell Glacier to the east and Mt. Browning to the northwest, command a stunning scenery.

Although horizontal glacial sedimentary layers develop relatively flat topography, the construction of buildings and routes may nevertheless result in, if minor and local, a visual disturbance of the natural landscape of the region. Installation of wind turbines may also cause an area-specific disturbance to the scenery as well. The uncontrolled use of tracked vehicles that mark disordered tracks on snow and land surface may create an undesirable visual impact, especially from a remote view.

The station layout is intended to have a minimum impact on landscape and maintain the aesthetics of the region. The buildings and facilities at the station will be contained within the proposed site to reduce an influence on the local scenery as much as possible. Tracked vehicles will only be used on designated routes to minimize disturbances of the land surface.

5.10. Cumulative Impacts

Cumulative impact refers to the combined impacts of past, present and future activities. The direct and indirect impacts should be evaluated and the temporal and spatial ranges of individual impacts must be taken into consideration to estimate cumulative impact.

The construction of the station is limited to the comparatively short time frame, and hence, contributing insignificantly to the cumulative impact on the environment. Impacts by the operation of the Jang Bogo Station will be combined with the impacts generated by the nearby Mario Zucchelli Station and Gondwana Station. Germany's Gondwana Station is located approximately 1.2km to the south and Italy's Mario Zuccelli Station, 8km to the southeast from the proposed site. Both stations are seasonal-the Italian station is being operated during summer only while the German station is open every other summer. Considering the 8km distance from the Jang Bogo Station, simultaneous operation of the Mario Zuccelli and Jang Bogo Station is not expected to amount to significant cumulative impacts on air quality, water quality, waste accumulation, and other environmental consequences. There is no significant cumulative impact because Gondwana Station has minimum operational facilities.

Some cumulative impacts are anticipated by research-related activities that will be sometimes performed simultaneously by the Jang Bogo Station and the existing stations, including marine research activities, route developments, glacial investigations and Browning Pass utilizations. Such impacts will be mitigated through cooperative logistic planning of supply and personnel. The impacts can be further reduced by avoiding duplicate research activities in the Terra Nova Bay region. As possibility of direct/indirect effects from increasing summer activities cannot be overlooked, a monitoring plan to observe cumulative effects will be set up.

Cumulative impacts will stem mainly from emissions air and discharge of wastewater during the construction and operation of the station.

The emissions generated by fuel consumptions will have direct impacts on air quality, and may further affect water and snow in the long term. Emissions may cumulatively affect regional/global air quality. However, these emissions will rapidly disperse with the strong winds of the area and the amount will be trivial relative to global emissions level. Therefore, the cumulative impacts are not considered significant.

The discharge of treated wastewater may cause some marine environment risks and adversely affect the flora and fauna inhabiting the coastal region if not properly treated. However the amount of discharge water will be reduced using the gray water reclamation and reuse system. In addition, a high-level treatment technology will be adopted to treat wastewater. Therefore the cumulative impacts on marine environment will not be significant.

5.11. Dismantling

The Jang Bogo Station will be constructed using the modular construction system. A detailed dismantling program, including plans to dismantle and reuse the station, will be established in accordance with the guidelines of the Protocol on Environment Protection to the Antarctic Treaty.

More specifically, a detailed work schedule will be planned including the time schedule of dismantling, packing and transportation of the station. For the environmental impacts estimated, relevant mitigation measures will be prepared for all tasks associated with the dismantling process.

When the Jang Bogo Station will be dismantled, all building modules and steel frames of the main building and other facilities are to be removed from Antarctica. Future considerations of the cost of complete removal may leave some structures with no potential environmental impact at the site. A comprehensive plan for phased dismantling will be established and implemented.

After the dismantling is completed, the region will be monitored for a certain period of time to assure minimizing the impact of the dismantling and determine whether additional measures are needed to recover the site.

5.12. Impact Matrix

Tables 5-5 and 5-6 illustrate the predicted impacts of the construction and operation of the Jang Bogo Station. Details of the activities were itemized by their environmental stressors, predicted impacts, and the levels of probability, extent, duration and importance of each stressor and impact were independently evaluated. The results of evaluation were incorporated into the mitigation measures per each stressor.

The criteria which categorize the impacts are as follows:

☐ Probability

- Unlikely
- Low
- Medium
- High
- Certain

☐ Extent

– Area-specific: Impact near the construction site
– Local: Around 1km radius from the proposed site
– Regional: Around 10km radius from the proposed site
– Continental: Antarctic continent, including the Ross Ice Shelf
– Global: Worldwide

☐ Duration

– Very short: - days
– Short: weeks to months
– Medium: years
– Long: decades
– Very long: centuries

☐ Importance

– Very low: almost no impact
– Low: very little impact
– Medium: average impact
– High: significant impact
– Very high: serious impact

Table 5-5. Impact matrix of construction activities for the Jang Bogo Station.

Activity		Stressors	Predicted impact	Probability	Extent	Duration	Importance	Mitigation measures
SHIPS	Shipping and cargo handling	Atmospheric emissions	-Cumulative impacts on local and global air quality	High	Regional	Long	Very low	-Strictly follow IMO regulations - Use of highly refined fuel such as MGO with low-sulfur (lower than 3.5% as regulated by the MARPOL 73/78)
			-Contamination of glaciers, snow and ecosystems	Low	Regional	Long	Very low	
		Fuel spills and generation of hazardous wastes	-Local marine pollution when anchored	Medium	Area-Specific	Short	Medium	-Care and attention when refueling -Oil absorbents to be kept on site in case of local oil spills and resulting marine pollution -Establishment of oil spill contingency plan
		Generation of wastes and wastewater	-Local marine pollution	Low	Area-Specific	Short	Very low	-Wastes discharged in accordance with MARPOL requirements after storing in containers -All vehicles and equipments to be cleaned before shipping
			-Introduction of alien species and diseases	Low	Area-Specific	Short	Very low	
HELICOPTERS	Taking off, landing, and operation of helicopter	Atmospheric emissions	-Cumulative contribution to local and global atmospheric pollution	Low	Regional	Short	Very low	-Efficient operation of helicopters -Use of high energy efficient fuel
			-Contamination of glaciers, snow and ecosystems	Low	Regional	Short	Very low	
		Flight	-Cumulative impact of helicopters flying over colonies of birds and mammals repeatedly	Medium	Local	Short	Medium	-Use of detour routes from colonies -Observe ATCM (2004b) "Guideline for the operation of aircraft near concentrations of birds in Antarctica"
			-Disturbance to ecosystem -Decrease in colonies of birds and mammals	Low	Local	Short	Very low	
			-Loss of biodiversity	Low	Local	Short	Very low	

Activity		Stressors	Predicted impact	Probability	Extent	Duration	Importance	Mitigation measures
	Refueling	Fuel spills	-Cumulative pollution on snow and glaciers	Low	Area-Specific	Long	Medium	-Refrain from refueling near station -Care and attention when refueling -Oil absorbents to be kept on site in case of local oil spills -Establishment of oil contingency plan
			-Loss of scientific value	Low	Area-Specific	Long	Low	
CONSTRUCTION ACTIVITIES	Construction of dock	Construction activities	-Disturbance of benthic sediments and ecosystem near the dock	High	Area-Specific	Short	Medium	-Limit the range of construction activities -Installing turbidity barrier during construction -Prohibit oil exchange and refueling near coast to prevent marine pollution
	Construction of station	Topographic change	-Land disturbance by foundation work	Medium	Area-Specific	Very short	Very low	-Application of foundation technique which does not use piles or anchors -Minimize impact by limiting site area
			-Land disturbance by land grading work	Low	Area-Specific	Short	Low	
		Route construction	-Land disturbance by land grading work	Medium	Local	Short	Medium	-Minimize damage by considering topographic features and scenery -Limit number of essential facilities contained within the site -Limit transportation within developed routes for tracked vehicle utilization
			-Disturbance to scenery and aesthetic natural values	Medium	Local	Long	Medium	
		Movement of equipments	-Disturbance to glacial sediment layers	High	Area-Specific	Short	Medium	-Limit expanding transfer routes of equipment
		Atmospheric emissions	-Contamination of glaciers, snow and glacial sediments	High	Regional	Short	Low	-Adopt low carbon techniques reducing the construction process (i.e., unit modular system for on-site assembling) -Consider both fuel efficiency and emission when choosing equipment -Limit operation of equipment and machineries -Use high quality heat insulating materials on temporary facilities and control the energy consumption efficiently -Use of low-sulfur fuel

Activity		Stressors	Predicted impact	Probability	Extent	Duration	Importance	Mitigation measures
		Fuel spills	-Contamination of snow, soil and rock surface	Low	Area-Specific	Long	Medium	-Prepare temporary oil storage and install Impermeable bund walls -Establishment of oil spill contingency plan -Care and attention when refueling -Oil absorbents to be kept on site to prevent spreading of an oil spill
		Generation of wastes and wastewater	-Contamination of snow, soil and rock surface	Low	Area-Specific	Short	Low	-Solid waste will be separately collected, reused if possible and completely removed out of Antarctica -Use toilets with suction system not requiring washing -Apply modular construction system to limit the generation of construction waste
			-Introduction of alien species	Low	Local	Short	Low	
		Generation of noise	-Decrease of colony size	Low	Local	Short	Medium	-Periodic use of equipment -Apply low noise and low vibration techniques -Installation of device to control idling while driving -Establish a monitoring plan considering reproductive and breeding seasons of birds and mammals near the station
			-Loss of biodiversity	Unlikely	Local	Medium	Very low	
		Impacts caused by construction equipments and workers	-Disturbance to soil and soil compaction	Medium	Local	Short	Medium	-Use cleaned construction equipment -Limit construction area and wear cleaned shoes and clothes
			-Introduction of alien species	Medium	Local	Short	Medium	

Table 5-6. Impact matrix of operation activities for the Jang Bogo Station.

Activity		Stressors	Predicted impact	Probability	Extent	Duration	Importance	Mitigation measures
OPERATION OF STATION	Operation of station	Atmospheric emissions	-Contamination of glaciers, snow and soil	Low	Local	Long	Low	-Minimal energy consumption by using waste heat from CHP and high efficiency lighting device -Extended use of recycled material -Use of renewable energy
		Generation of wastes and wastewater	-Contamination of snow, soil and rock surfaces	Low	Local	Long	Low	-Installation of recycling bins -Dry and compact food waste -Limit hazardous materials -Manage food waste not to be approached by skuas -Minimize amount of wastewater accompanied with IC-SBR treatment
			-Disturbance to skua's dietary Behavior	Medium	Local	Medium	Medium	
			-Behavioral change of skuas and infection of disease	Medium	Local	Short	Medium	
			-Potential impact of wastewater	Medium	Local	Medium	Medium	
		Fuel storage and oil spills	-Contamination of snow, soil and rock surfaces	Medium	Area-Specific	Long	Medium	-Prepare clean up equipment and audit once a year -Develop a training program for staff -For oil spills, activate oil removal process
			- Fuel leakage during fuel transfer in dock	Medium	Local	Medium	Medium	
		Operation of wind turbines	-Disturbance to ecosystem by noise	Low	Local	Long	Low	-Installation of vertically stacked modular type turbines which reduce noise and prevent bird strike
			-Disturbance to birds' behavior	Medium	Local	Long	Low	
			-Decrease of bird colony size	Unlikely	Local	Medium	Very low	
			-Bird strike	Low	Area-Specific	Long	Very low	

<table>
<tr><th colspan="2">Activity</th><th>Stressors</th><th>Predicted impact</th><th>Probability</th><th>Extent</th><th>Duration</th><th>Importance</th><th>Mitigation measures</th></tr>
<tr><td rowspan="6"></td><td rowspan="6">Research activities</td><td rowspan="2">Observation of flora and fauna</td><td>-Disturbance to habitat and breeding activities</td><td>Medium</td><td>Regional</td><td>Long</td><td>Medium</td><td rowspan="2">-Limit access to habitat
-Limit activities aside from those with scientific purpose
-Observe Recommendation XVIII-1 “Guidance for Visitors to the Antarctic” during operation
-Prevent disturbance by conducting preliminary evaluation of the sampling plans</td></tr>
<tr><td>-Disturbance caused by sampling</td><td>Medium</td><td>Local</td><td>Medium</td><td>Medium</td></tr>
<tr><td rowspan="4">Visitors</td><td>-Expansion of range by visitors</td><td>Medium</td><td>Regional</td><td>Long</td><td>Medium</td><td rowspan="4">-Observe Recommendation XVIII-1 “Guidance for Visitors to the Antarctic” during operation
-Limit access to breeding site
-Limit the number of visitors
-Establish visiting plan and conduct visitor training
-Clean clothes and shoes</td></tr>
<tr><td>-Disturbance to breeding birds</td><td>Medium</td><td>Regional</td><td>Short</td><td>Medium</td></tr>
<tr><td>-Damage of vegetation</td><td>Medium</td><td>Regional</td><td>Medium</td><td>Medium</td></tr>
<tr><td>-Introduction of alien species</td><td>Low</td><td>Regional</td><td>Medium</td><td>Low</td></tr>
<tr><td rowspan="4">USE OF TRANSPORTATION</td><td rowspan="2">Operation of transportation</td><td>Atmospheric emissions</td><td>-Cumulative impacts on snow, glaciers and soil caused by snowmobiles</td><td>Unlikely</td><td>Regional</td><td>Long</td><td>Very low</td><td>-Limited use of vehicles in the station
-Use energy efficient vehicles</td></tr>
<tr><td>Introduction of alien species</td><td>-Proliferation of alien species due to snowmobiles</td><td>Unlikely</td><td>Regional</td><td>Long</td><td>Very low</td><td>-Clean equipment and clothes</td></tr>
<tr><td rowspan="2">Refueling</td><td rowspan="2">Fuel spills</td><td>-Accumulation of contaminants on snow and glaciers</td><td>Medium</td><td>Area-Specific</td><td>Long</td><td>Medium</td><td rowspan="2">-Refueling only in designated place
-Care and attention when refueling
-Prepare oil spill prevention materials
-Establishment of oil spill contingency plan</td></tr>
<tr><td>-Loss of scientific value</td><td>Unlikely</td><td>Area-Specific</td><td>Long</td><td>Low</td></tr>
</table>

6. Environmental Monitoring and Verification

KOPRI will establish a monitoring and verification program for the effectiveness of source control, mitigation measures, environmental management and monitoring throughout the construction and operation of the Jang Bogo Station. Baseline data for the program have been set up from information collected during the 2010-2012 surveys as well as the meteorological data collected from the site AWS installed in 2010. This monitoring will be continued as a part of the major scientific research after the completion of construction of the station. The program will be continuously reviewed and modified in coordination with other post-construction research activities. The COMNAP guidelines will be followed by the monitoring program (COMNAP, 2005b).

☐ Implementation and management

- Implementation authority: KOPRI
- Monitoring and verification management
  - During construction: manager appointed by the constructor
  - During operation: manager appointed by KOPRI

☐ Plan

- Monitoring duration: Entire phase of construction and operation
- Establishment of a monitoring plan to identify adverse impacts of the proposed activities on environment and devise effective mitigation measures that are needed to reduce the adverse impacts if any
- Detailed monitoring plan: Tables 6-1, 6-2, 6-3 and 6-4

☐ Contingency plan

- Should any environmental quality level be not met, the field manager will have the authority to stop the construction until an appropriate mitigation measure is implemented.

☐ Reporting and notification

– Monitoring and verification personnel should report the results as scheduled and the manager will submit a comprehensive monitoring and verification report to the relevant authority.

– The report should be notified to stakeholders for reviews.

Table 6-1. Source management monitoring.

Parameter	Object	Reporting	Frequency
Construction equipment operation	Fuel supply and consumption for construction equipment	Fuel log	Once a month
	Oil change, waste oil and disposal for construction equipment	Motor oil log	Once a month
Construction staff	Wastewater and waste(recycle)	Wastewater and waste logs	Once a month
Construction material	Construction material used/disposed	Construction material log	Once a week
Operational staff	Waste(recycle)	Waste management log	Once a month
	Wastewater and gray water during operation	Wastewater treatment log -Generation and discharge -Treated volume -Amount of gray water	Once a week
Fuel use /operation	Fuel supply and use	Fuel log	Once a month
	Oil change, waste oil and disposal	Oil log	Once a month
Water production	Water intake, desalinated water production, water use	Desalination log -Production -Transport -Use	Once a week

Table 6-2. Mitigating facilities monitoring.

Parameter	Object	Reporting	Frequency
Wastewater treatment facility	Facility operation	Wastewater treatment operation log	Once a day
Waste facility	Recycling and storage of construction waste	Recycling and storage status	Once a week
	Recycling and monitoring of domestic waste	Recycling and storage status	Once a week
Noise protection facility	Temporary noise barrier	Barrier status	At installation
Oil storage facility	Oil and waste oil storage tanks	Oil leaks	Once a day

Table 6-3. Quality control monitoring.

Parameter	Object	Reporting	Frequency
Wastewater discharged	TSS, DO, BOD, COD, pH, Conductivity	Water quality analysis -Discharge point	Twice a year
Gray water	TSS, DO, BOD, pH, Colon bacterium, Total bacteria	Water quality analysis -Treated gray water -Discharge point	Twice a year
Brine	Salinity, temperature	Water quality analysis (brine)	Twice a year
Noise level (after installation of noise barrier)	Noise level	Noise level -Before/after barrier installation	At construction equipment in operation

Table 6-4. Monitoring of environmental changes.

Parameter	Object	Reporting	Frequency
Ecology	Alien species invasion	Invasive species	Once a year
	Changes in habitat (Lichen, South Polar Skua, Weddell Seals)	Habitat observation -South Polar Skua colony	Once per two weeks during construction
		Habitat observation -Lichen -South Polar Skua and Weddell Seal colonies	Once a year during operation
	Community structure changes	On-site Fauna/flora	Once a year
	Population dynamics	Esp. South Polar Skua	Once a year
Coastal Seawater quality	TSS, DO, COD, pH, Temperature, Salinity	Seawater quality -Intake point -3 points near discharge location -3 points near dock	Twice a year
Snow	TSS, pH	Snow quality -Main building -Comparison point	Twice a year
Soil	TPH	Soil analysis -4 points at oil storage sites -4 points at waste oil storage sites	Once a year
Air quality	PM10, NO_x	Air quality analysis -Main building -South Polar Skua colony -Atmospheric chemistry lab.	Twice a year
Noise	Noise level	Noise level -South Polar Skua and Weddell Seal colonies	At equipment in operation

7. Gaps in Knowledge and Uncertainties

The gaps in knowledge and uncertainties identified during the CEE on the construction and operation of Jang Bogo Station are as follows:

☐ Distribution of sea ice around Cape Möbius and climate conditions during construction period

– Associated transportation disruptions may affect the construction period.

☐ Future retreat of the Campbell Glacier Tongue near the proposed site

☐ Long-term climate change near the construction site

☐ Uncertainties in the knowledge and information of natural environment near the proposed site

– Validity of the collected data on a part of biological taxa as well as the hydrographic data of the sea currents near the proposed site

☐ Status of a few South Polar Skua nests distributed close to the proposed site

– Location and number of nests expected to change every year

☐ Items related to the future expansion of the station

– The station may be expanded depending on future research demands, although there is no detailed present plan of the expansion.

☐ Changes in the activities of the station according to the change in future perspectives of research

8. Summary and Conclusion

The Republic of Korea plans to construct the Jang Bogo Antarctic Research Station near Cape Möbius, the northwestern coastal region of Terra Nova Bay of Northern Victoria Land in the Ross Sea area, in order to conduct more in-depth research in Antarctica, the center of attention of international scientific community as well as the general public, and to contribute to the global efforts to address and respond to climate change.

A CEE was conducted in order to establish an environmentally sound and sustainable station with construction and operation plans to minimize any adverse impacts on the environment.

The station will be accommodating up to 60 personnel during the summer with estimated life expectancy of at least 25 years. A layout radially arranging structures from the central main building was selected for the station. This layout not only ensures safety, functionality, and efficiency, but also requires minimal disturbances to the natural topography at the site. The building will be constructed as a combination of elevated and slanting structures in order to efficiently respond to the extreme weather conditions of the Antarctic. Latest energy-saving technologies for buildings will be applied to maximize energy efficiency.

As an effort to minimize the use of fossil fuels during operation of the station, all waste heat will be fully utilized by a CHP. Solar and wind renewable energy will also be used as much as possible in the station.

The location of the proposed site for Jang Bogo Station at Terra Nova Bay is a region with high levels of biodiversity. However, based on yearly site surveys between 2010 and 2012, the colonies and important habitats of organisms do not exist close to the proposed site, and therefore, the station is not expected to have a significant impact on the ecosystem. The South Polar Skua colony near the proposed site is located at a safe distance from the station, and the degree of direct disturbance on the skuas by the station will not be significant.

Various reviews from national and international sources on the draft CEE resulted in revised selection of the off-continent waste disposal alternative. That is more protective of Antarctic atmosphere rather than the on-site incineration (Appendix 9). Mitigation measures were devised based on the quantitative and qualitative estimations on the major environmental consequences of construction and operation of the proposed station, including levels of noise, potential fuel and oil spills, generation of wastewater, and adverse environmental impacts on air quality and ecology. Furthermore, an environmental monitoring program will be administered to identify any environmental changes throughout the operation of the station. A systematic emergency response plan has been established for expedient and effective management of emergency situations.

The expected level of the environmental impact of the construction and operation of Jang Bogo Station is expected to be “more than minor or transitory.” In this regard, the Republic of Korea conducted a CEE on the proposed activities and proposed use of various cutting edge technologies and mitigation measures to minimize the potential environmental impacts that the construction and operation of the new station may have on the region.

The Jang Bogo Station will be operated year round and therefore, diverse scientific data on the surrounding environment and ecosystem will be continuously acquired at the station. It is our hope that the station will become a world leading contributor in prediction of future climate change. Furthermore, as a research hub supporting not only the activities of Korean scientists, but also partnerships with leading foreign experts on climate change in the Antarctic region, the Jang Bogo Station is expected to enable and inspire international collaboration and multidisciplinary research.

The results of CEE have led to the conclusion that the knowledge and information gained through the research activities held in the station will prove to be invaluable to the international scientific community and grossly outweigh the “more than a minor or transitory” impact on the Antarctic environment; thus, the establishment of Jang Bogo Station is highly recommended.

9. Preparers and Advisors

This final CEE was prepared by a team of researchers from Korea Environment Institute (KEI), Chungnam National University, and Korea Polar Research institute (KOPRI). PDF download is available from either KOPRI (http://eng.kopri.re.kr/home_e/contents/e_3330000/JangBogoStation.cms) or Ministry of Foreign Affairs and Trade (http://www.antarctica.go.kr).

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10. Acknowledgements

The authors wish to express their gratitude to the following people and organizations for the support in preparing this final CEE:

- Sohee Park of KEI for drawing and manuscript editing
- Young Soo Lee and Yun Sung Kim of KEI for their valuable comments and reviews
- Mindae Park of Dongrim Consultant Co. for proving emission and conversion factors as well as for technical comments on air quality, waste, and noise
- Hyundai Engineering & Construction Co. for providing information on the building design and station layout
- KICT for providing the construction master plan and comments on air quality and waste

The supports of the Ministry of Land, Transport and Maritime Affairs and the Ministry of Foreign Affairs and Trade are gratefully acknowledged.

The intersessional open-ended contact group (ICG) of CEP is gratefully acknowledged for providing valuable comments on the draft CEE.

The satellite image in Figures 2-1, 4-12 and 4-19 was used by permission of MUSEO NAZIONALE DELL'ANTARTIDE, Italy.

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12. Index

Acronym	Meaning
AHU	Air Handling Unit
ASPA	Antarctic Specially Protected Areas
ATCM	Antarctic Treaty Consultative Meeting
ATCP	Antarctic Treaty Consultative Party
AWI	Alfred-Wegener Institute
AWS	Automatic Weather System
BAS	British Antarctic Survey
BGR	Federal Institute for Geosciences and Natural Recourses
BIPV	Building Integrated Photovoltaic
BOD	Biochemical Oxygen Demand
CEE	Comprehensive Environmental Evaluation
CEP	Committee for Environmental Protection
CFD	Computational Fluid Dynamics
CHP	Combined Heat and Power
COD	Chemical Oxygen Demand
COMNAP	Council of Managers of National Antarctic Programs
DO	Dissolved Oxygen
EIA	Environmental Impact Assessment
EPICA	European Project for Ice Coring in Antarctica
GANOVEX	German Antarctic North Victoria Land Expedition
GAW	Global Atmosphere Watch
HSM	Historic Sites and Monuments
IAATO	International Association of Antarctic Tour Operation
IC-SBR	Internal Circulation in a Sequence Batch Reactor
ICG	Intersessional Open-ended Contact Group
IEE	Initial Environmental Evaluation
IPCC	Intergovernmental Panel on Climate Change
IMO	International Maritime Organization
IPY	International Polar Year
KARI	Korea Aerospace Research Institute
KARP	Korea Antarctic Research Program
KEI	Korea Environment Institute
KICT	Korea Institute of Construction Technology
KOMPSAT	Korean Multi-purpose Satellite
KOPRI	Korea Polar Research Institute
LGP	Latitudinal Gradient Project
MARPOL	Marine Pollution

MOFAT	Ministry of Foreign Affairs and Trade
MGO	Marine Gas Oil
MOE	Ministry of Environment
MPA	Marine Protected Area
NASA	National Aeronautics and Space Administration
NSIDC	National Snow and Ice Data Center
PC	Precast Concrete
pH	potential of Hydrogen
PNRA	Programma Nazionale di Ricerche in Antartide
POLENET	Polar Earth Observing Network
PV	Photovoltaic
SCALOP	Standing Committee of Antarctic Logistics and Operations
TPH	Total Petroleum Hydrocarbon
TSS	Total suspended solids
USGS	United States Geological Survey
VIPIR	Vertical Incidence Pulsed Ionospheric Radar
TPLMS	Total Pollution Load Management System
WMO	World Meteorological Organization

13. Appendices

Appendix 1. Building Area of the Jang Bogo Station

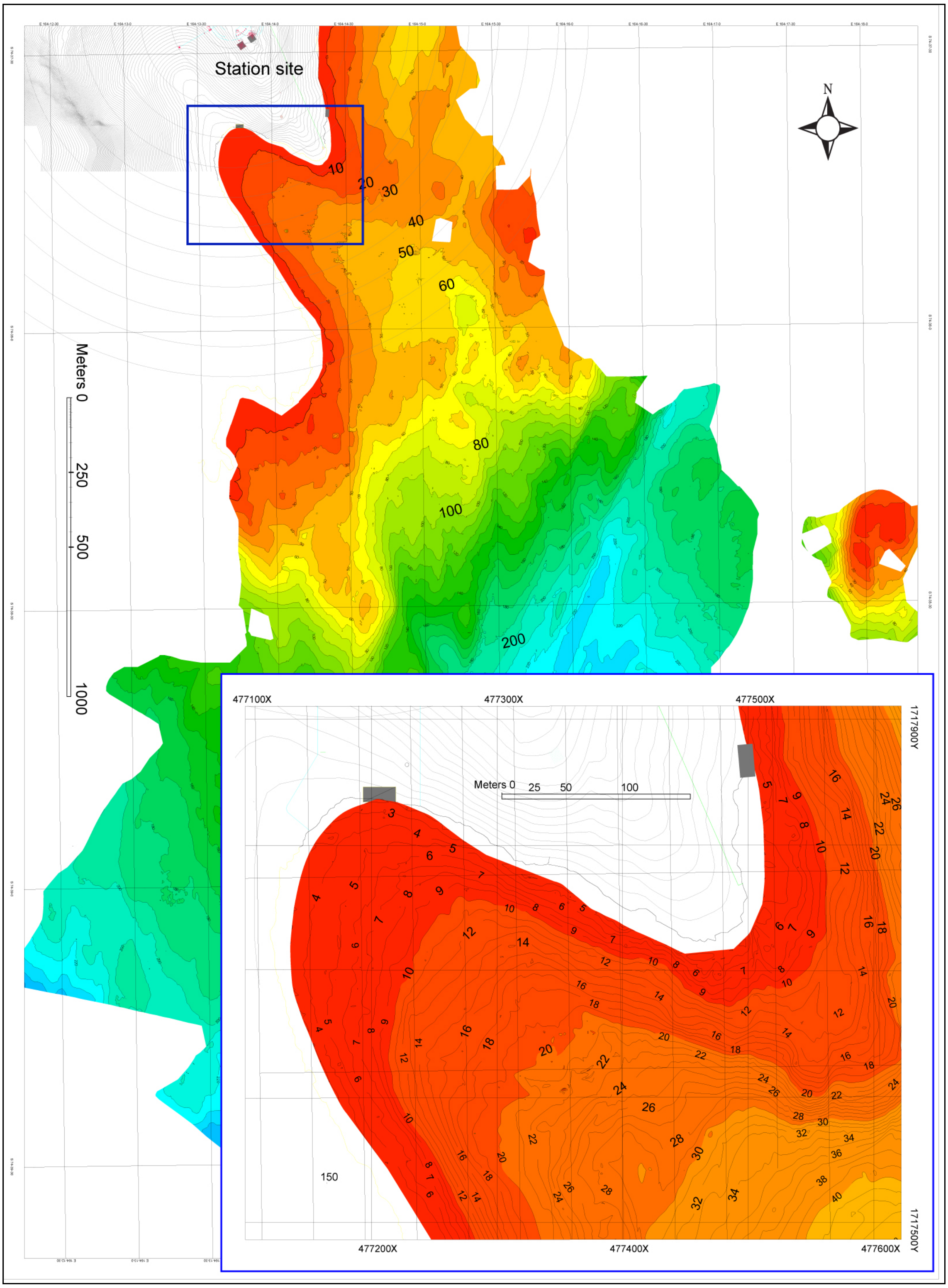
Main facilities of the Jang Bogo Station

Facilities		Area (m^2)	Specific facilities
Main building		1,777.29	Bed room, Communication room, Infirmary, Bathroom, Laundry room, Gym, Kitchen, Lounge, Library, Storage
Research facilities	Research labs.	304.77	Atmospheric chemistry lab., Bioscience lab., Geophysics lab., Geology/meteorite lab.
	Observatories	330.61	Space weather obs., Seismic obs., Geomagnetic obs., Boundary layer obs., Radiosonde obs., Upper atmosphere obs., Geophysical equipment test lab.
Maintenance /operation facilities	Power plant	866.00	Maintenance room, Office, Storage, IC-SBR, Sampling freezer
	Maintenance building	774.79	Heavy equipment maintenance room and storage, Office, Storage
	Boat storage	192.08	Rubber boat maintenance room
	Waste treat facility	37.82	Compactor, Food waste reducer
	Emergency shelter	54.29	Bed room, Office, Toilet, Kitchen, Water tank, Storage
	Emergency power plant	73.81	
Total area		4,411.46	

Ancillary facilities of the Jang Bogo Station

Facilities	Area (m^2)	Specific facilities
Fuel tanks	1,168	Six 100-ton tanks of double skinned stainless steel located next to the power plant and three tanks near the dock
Seawater tank	47	Seawater tank and pump
Dock	300	30m×10m gravity type with PC blocks
Heliports	900	Three heliports, aviator fuel tanks
Antennas and towers	125	Communication antennas, AWS, GPS tower, Brewer, wind turbines
Total area	2,540	

Appendix 2. Hydrograph Around the Proposed Site (2011)



Appendix 3. AWS Data at the Proposed Site

Site	Variables		Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Proposed site	T (°C)	Mean	-1.0	-6.2	-13.3	-18.7	-21.0	-21.4	-21.4	-20.3	-20.8	-15.0	-6.4	-0.6
		Max	4.9	0.7	-1.1	-2.8	-7.5	-4.9	-6.2	-2.7	-7.0	-2.4	2.5	7.2
		Min	-5.3	-12.6	-26.3	-29.1	-34.0	-31.3	-33.0	-33.7	-33.1	-26.3	-14.5	-9.3
	WS (m/s)	Mean	4.0	5.1	5.1	4.1	4.2	4.2	5.9	5.1	4.9	4.7	4.7	4.6
		Max	17.5	19.8	23.2	22.0	21.2	17.3	28.4	29.0	35.9	23.2	16.7	19.6
		Min	0.7	0.2	0.4	0.3	0.4	0.3	0.2	0.4	0.3	0.2	0.2	0.3
	P (hPa)	Mean	993.1	989.3	990.5	989.1	985.1	986.7	981.4	984.9	988.8	980.7	983.1	991.6
		Max	1,025.0	1,025.0	1,025.0	1,025.0	1,025.0	1,025.0	1,024.0	1,024.0	1,024.0	1,023.0	1,023.0	1,023.0
		Min	953.0	953.0	954.0	954.0	955.0	954.0	953.0	952.0	952.0	952.0	949.0	952.0

Note) 1-hour average data collected from February 2010 to November 2011

Appendix 4. A List of Flora Found in the Proposed Site and its Vicinity

Species name	Kantor 1993 [1)]	2010. 2
Lichens		
Acarospora gwynnii	+	+
Buellia frigida	+	+
Buellia pallida	+	+
Buellia papillata		+
Caloplaca sublobulata		+
Caloplaca citrine	+	
Caloplaca sp.	+	+
Candelariella flava		+
Candelariella sp.	+	
Carbonea capsulata	+	
Lecanora cf. expectans	+	
Lecanora fuscobrunnea	+	+
Lecanora sp.	+	+
Lecidella sp.	+	+
Leproloma sp.	+	+
Physcia sp.	+	
Pleopsidium chlorophanum		+
Pseudephebe minuscula	+	+
Pseudephebe pubescens	+	+
Psoroma cf.	+	
Rhiziplaca melanopthalma	+	+
Rinodina olivaceobrunnea		+
Umbilicaria antarctica		+
Umbilicaria decussata	+	+
Umbilicaria cf. rufidula	+	
Umbilicaria sp.		+
Usnea sphacelata	+	
Xanthoria candellaria	+	
Xanthoria elegans	+	+
Xanthoria mawsonii		+
Moss		
Bryum argenteun var. argenteum		+
Bryum argenteum var. muticum		+
Bryum pseudotriquetrum		+
Syntrichia magellanica		+
Algae		
Prasiola crispa		+
Total Number	**22**	**26**

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Appendix 5. Estimated Atmospheric Emissions

<Predicted emissions produced by transportation during construction>

Source	Total fuel		Type of emission	Emission factor (g/kg)	Total Emissions (ton)
	Volume (ℓ)	Weight (kg)			
Marine transportation - Icebreaker - Cargo ship - Tugboat - Rubber boat	10,387,751	8,777,650	CO	0.71	6.23
			NO_x	3.41	29.93
			SO_2	33.44	293.52
			PM10	0.28	2.46
			*CO_2	879.00	7,715.55
Air transportation - Helicopter	114,000	91,200	CO	12.00	1.09
			NO_x	0.19	0.02
			SO_2	0.72	0.07
			PM10	0.20	0.02
			*CO_2	859.00	78.34

・Source

1. Marine transportation: US EPA AP-42 (NO_2 fuel oil with uncontrolled burning)
   *CO_2: UK National Atmospheric Emission Inventory, 2008
2. Air transportation: UK National Atmospheric Emission Inventory, 2002

Note) Specific gravity: 0.845 for MGO, 0.8 for aircraft fuel

<Predicted emissions produced by generator operation during construction>

Source	Total fuel		Type of emission	Emission factor (g/kg)	Total Emissions (ton)
	Volume (ℓ)	Weight (kg)			
Generator used at camp (250kW)	82,728	66,182	CO	1.01	0.07
			NO_x	14.66	0.97
			SO_2	0.93	0.06
			PM10	1.28	0.08
			*CO_2	614.00	40.64
Generator used for construction of main building (250kW)	22,980	18,384	CO	1.01	0.02
			NO_x	14.66	0.27
			SO_2	0.93	0.02
			PM10	1.28	0.02
			*CO_2	614.00	11.29
Generator used for constructions of other facilities and dock (50kW)	18,792	15,034	CO	1.01	0.02
			NO_x	14.66	0.22
			SO_2	0.93	0.01
			PM10	1.28	0.02
			*CO_2	614.00	9.23

・Source

US EPA AP-42 (electric generator from internal combustion engine, uncontrolled operation)
*CO_2: UK National Atmospheric Emission Inventory, 2008

Note) Specific gravity: 0.8 for Antarctic Diesel (generator)

<Predicted emissions produced by equipments during construction - A>

Source	Number	Average declared power (kW)	Hours	Total fuel		Type of emission	Emission factor (g/kWh)	Total emissions (ton)
				Volume (ℓ)	Weight (kg)			
Mixer	1	470	200	2,600	2,080	CO	2.52	0.11
						NO_x	10.24	0.46
						SO_2	5.20	0.23
						PM10	0.35	0.02
						*CO_2	74,100	6.82
D/truck	2	470	160	5,088	4,070	CO	3.50	0.25
						NO_x	3.50	0.25
						SO_2	5.08	0.37
						PM10	0.20	0.01
						*CO_2	74,100	13.35
Cargo Truck	1	470	500	11,500	9,200	CO	3.50	0.39
						NO_x	3.50	0.39
						SO_2	5.08	0.57
						PM10	0.20	0.02
						*CO_2	74,100	30.17
H/Crane	1	226	720	6,912	5,529	CO	5.07	0.40
						NO_x	5.45	0.43
						SO_2	5.08	0.40
						PM10	0.40	0.03
						*CO_2	74,100	18.13
C/Crane	3	226	673	24,240	19,392	CO	5.07	1.11
						NO_x	5.45	1.19
						SO_2	5.08	1.11
						PM10	0.40	0.09
						*CO_2	74,100	63.58
R/Crane	1	226	160	3,824	3,059	CO	5.07	0.09
						NO_x	5.45	0.09
						SO_2	5.08	0.09
						PM10	0.40	0.01
						*CO_2	74,100	10.03
Bulldozer	1	127	300	11,700	9,360	CO	2.52	0.05
						NO_x	10.24	0.19
						SO_2	5.20	0.10
						PM10	0.35	0.01
						*CO_2	74,100	30.69

Wheel loader	2	153	400	5,920	4,736	CO	1.45	0.09
						NO_x	8.40	0.49
						SO_2	5.20	0.31
						PM10	0.18	0.01
						*CO_2	74,100	15.53
Backhoe	6	105	501	54,588	43,670	CO	2.52	0.38
						NO_x	10.24	1.55
						SO_2	5.20	0.79
						PM10	0.35	0.05
						*CO_2	74,100	143.19

- Source
  1. Korean National Emission Inventory, National Institute of Environmental Research, 2010
  2. Construction estimating standard, KICT, 2010

     Total emission:

     $E = N \times A \times k \times T \times EF$

     Where;

     E = emissions (ton)
     N = number of equipment
     A = average declared power (kW)
     T = hours of operation (hr)
     EF = emission factors (g/kWh)
     k = constant of the average output rate, 0.48

  3. For CO_2, 2006 IPCC Guidelines
     Net heating value: 35.4MJ/ℓ for Antarctic Diesel
     *: unit of emission factor: kg/TJ

<Predicted emissions produced by equipments during construction - B>

Source	Number	Hours	Total fuel		Type of emission	Emission factor (g/kg)	Total emissions (ton)
			Volume (ℓ)	Weight (kg)			
Forklift	1	300	1,710	1,368	CO	18.41	0.025
					NO_x	44.10	0.060
					SO_2	3.73	0.005
					PM10	3.61	0.005
					*CO_2	74,100	4.486
Trailer	1	700	11,550	9,240	CO	18.41	0.170
					NO_x	44.10	0.407
					SO_2	3.73	0.034
					PM10	3.61	0.033
					*CO_2	74,100	30.297
Roller	1	140	2,016	1,612	CO	18.41	0.030
					NO_x	44.10	0.071
					SO_2	3.73	0.006
					PM10	3.61	0.006
					*CO_2	74,100	5.288
Heater	3	1,008	9,072	7,257	CO	18.41	0.134
					NO_x	44.10	0.320
					SO_2	3.73	0.027
					PM10	3.61	0.026
					*CO_2	74,100	23.797

・Source

1. US EPA AP-42 (heavy-duty construction equipment)
2. For CO_2, 2006 IPCC Guidelines
   Net heating value: 35.4MJ/ℓ for Antarctic Diesel
   *: unit of emission factor: kg/TJ

<Predicted annual emissions produced by fuel consumption during operation>

Source	Fuel consumption		Type of emission	Emission factor		Total emissions (ton)
	Volume (ℓ)	Weight (kg)				
Antarctic Diesel (generators)	305,724	244,579	CO	1.01	g/kg	0.25
			NO_x	14.66		3.59
			SO_2	0.93		0.23
			PM10	1.28		0.31
			$^*CO_2$	74,100	kg/TJ	801.96

Source	Fuel consumption		Type of emission	Emission factor		Total emissions (ton)
	Volume (ℓ)	Weight (kg)				
Antarctic Diesel (vehicle)	23,000	18,400	CO	0.393	g/kg	0.01
			NO_x	18.664		0.34
			SO_2	0.6		0.01
			PM10	0.062		0.00
			$^*CO_2$	74,100	kg/TJ	60.33

Source	Fuel consumption		Type of emission	Emission factor		Total emissions (ton)
	Volume (ℓ)	Weight (kg)				
Helicopter	31,250	25,000	CO	12.0	g/kg	0.30
			NO_x	0.2		0.01
			SO_2	0.7		0.02
			PM10	0.2		0.01
			$^*CO_2$	859.0		21.48

Source	Fuel consumption		Type of emission	Emission factor		Total emissions (ton)
	Volume (Nm^3)	Weight (kg)				
LPG (kitchen)	2,778	-	CO	0.2	kg/kℓ	0.56
			NO_x	2.18		6.06
			SO_2	0.01		0.03
			PM10	0.05		0.14
			$^*CO_2$	63,100	kg/TJ	10.13

・Source

1. Antarctic Diesel (generators): US EPA AP-42 (electric generator from internal combustion engine, uncontrolled operation)
   $^*CO_2$: 2006 IPCC Guidelines
2. Antarctic Diesel (vehicle): vehicle emission factors, National Institute of Environmental Research, 2006
   $^*CO_2$: 2006 IPCC Guidelines
3. Helicopter: UK National Atmospheric Emission Inventory, 2002
   $^*CO_2$: UK National Atmospheric Emission Inventory, 2008
4. LPG (kitchen): National Air Pollutants Emission, National Institute of Environmental Research, 2000
   $^*CO_2$: 2006 IPCC Guidelines

Note) Specific gravity: 0.8 for Antarctic Diesel (generator)
Net heating value: 57.8MJ/Nm^3 for LPG

Appendix 6. Estimated Wastes

<Estimated waste oil used by equipments during construction>

Equipment		Capacity	Number	Hours	Fuel consumption		Conversion factor (%)	Waste oil (ℓ)
					(ℓ/hr)	(ℓ)		
Year 1	B/HOE	1.0m^3	2	576	19.50	22,464	0.55	123.6
		1.4m^3	1	576	20.20	11,635	0.55	64.0
		0.8m^3	1	576	16.30	9,389	0.60	56.3
		0.3m^3	1	200	5.00	1,000	0.00	0.0
	Vibration Roller	15ton	1	140	14.40	2,016	0.00	0.0
	Loader	15ton	2	400	7.40	5,920	0.53	31.1
	Forklift	5ton	1	300	5.70	1,710	0.93	15.8
	Dozer	20ton	1	300	39.00	11,700	0.40	46.8
	D/Truck	15ton	2	160	15.90	5,088	0.00	0.0
	C/Crane	50ton	1	700	12.00	8,400	0.50	42.0
		50ton	1	720	12.00	8,640	0.50	43.2
		50ton	1	600	12.00	7,200	0.50	36.0
	H/Crane	25ton	1	720	9.60	6,912	0.50	34.6
	Cargo Truck	18ton	1	500	23.00	11,500	0.95	109.3
	Trailer	20ton	1	700	16.50	11,550	0.98	112.6
	Mixer	2m^3	1	200	13.00	2,600	0.00	0.0
	Heater	-	3	336	9.00	9,072	0.60	54.4
	Generators	250kW	2	1,080	38.30	82,728	1.03	853.8
		250kW	1	600	38.30	22,980	0.60	137.9
		50kW	4	540	8.70	18,792	0.60	112.8
	B/HOE (L/BOOM)	1.4m^3	1	500	20.20	10,100	0.55	55.6
	R/Crane	120ton	1	160	23.90	3,824	0.00	0.0
	F/Barge	2000P	2	700	-	-	-	-
	F/Barge	1000P	1	700	-	-	-	-
	Tugboat	700HP	1	700	101.82	71,274	0.68	481.1
	Total		35	-	-	346,494		2,410.9

Equipment		Capacity	Number	Hours	Fuel consumption		Conversion factor (%)	Waste oil (ℓ)
					(ℓ/hr)	(ℓ)		
Year 2	B/HOE	$1.0m^3$	1	576	19.50	11,232	0.55	61.8
		$0.8m^3$	1	576	16.30	9,389	0.60	56.3
		$0.3m^3$	1	300	5.00	1,500	0.53	7.9
	Loader	15ton	2	400	7.40	5,920	0.53	31.1
	Forklift	5ton	1	400	5.70	2,280	0.93	21.1
	Dozer	20ton	1	300	39.00	11,700	0.40	46.8
	D/Truck	15ton	2	160	15.90	5,088	0.00	0.0
	C/Crane	50ton	1	700	12.00	8,400	0.50	42.0
		50ton	1	720	12.00	8,640	0.50	43.2
	H/Crane	25ton	1	720	9.60	6,912	0.50	34.6
	Cargo Truck	18ton	1	500	23.00	11,500	0.95	109.3
	Trailer	20ton	1	700	16.50	11,550	0.98	112.6
	Mixer	$2m^3$	1	200	13.00	2,600	0.00	0.0
	Heater	-	3	240	9.00	6,480	0.00	0.0
	Generators	250kW	2	1,080	38.30	82,728	1.03	853.8
		250kW	1	600	38.30	22,980	0.60	137.9
		50kW	4	540	8.70	18,792	0.60	112.8
	B/HOE (L/BOOM)	$1.4m^3$	1	300	20.20	6,060	0.55	33.3
	F/Barge	2000P	1	700	-	-	-	-
	Tugboat	700HP	1	700	101.82	71,274	0.68	481.1
	Total		28	-	-	305,025		2,185.6

・Source
Construction estimating standard, KICT, 2010

<Estimated domestic wastes and night soil during construction>

Type	Unit	Personnel		Total
Domestic wastes	0.5kg/person/day	Year 1	110	55.0kg/day
		Year 2	95	47.5kg/day
Night soil	0.3ℓ/person/day	Year 1	110	33.0ℓ/day
		Year 2	95	28.5ℓ/day

・Source

Initial Environmental Evaluation (IEE) for the eco-friendly renovation of King Sejong Station, King George Island, Antarctica, KOPRI, 2009

<Estimated domestic wastes during operation>

Period	Personnel	Unit (kg/person/ day)	Domestic waste (kg/day)			
			Total	Combustible waste	Non-combustible waste	Recycling waste
Winter	15	1.035	15.525	9.703	1.459	4.363
Summer	60	1.035	62.101	38.813	5.838	17.450

・Source

Domestic waste generation per person in Korea, 2008, MOE, 2009

Note) Ratio of domestic wastes:
Combustible (including food waste): 62.5%, noncombustible: 9.4%, recycling: 28.1%

<Estimated food waste during operation>

Period	Personnel	Unit (kg/person/day)	Volume of food waste (kg/day)
Winter	15	0.301	4.515
Summer	60	0.301	18.060

・Source

Domestic waste generation per person in Korea, 2008, MOE, 2009

Appendix 7. Estimated Wastewater

<Estimated wastewater during construction>

Period	Personnel	Unit (ℓ/person·day)	Wastewater (m^3/day)
Year 1	110	200.0	22.0
Year 2	95	200.0	19.0

- Source
  Wastewater generation unit, MOE, 2009 (Notification No. 2009-197)

<Estimated water usage during operation>

Period	Personnel	Consumption unit (ℓ/person·day)	Total consumption (m^3/day)
Winter	15	150	2.25
Summer	60	150	9.00

<Estimated wastewater during operation>

Period	Water consumption (m^3/day)	Conversion factor (%)	Wastewater (m^3/day)
Winter	2.25	95	2.14
Summer	9.00	95	8.55

- Source
  Guideline for Total Pollution Load Management System (TPLMS), MOE, 2006

Note) MOE, Korea provides 0.88 for wastewater conversion factor. However, 0.95 of wastewater conversion factor was applied with an assumption of minimal leakage in Antarctica

Appendix 8. Composite Noise and Point-sound Source Attenuation

☐ **Composite noise**

$$SPL = 10 . \log [A . 10^{(SPL1/10)} + B . 10^{(SPL2/10)} + \ldots\ldots + N . 10^{(SPLn/10)}]$$

Here, SPL: Composite noise [dB(A)]

A,B,…,N: No. of equipment in operation

SPL1,2,…,n: Noise of each equipment [dB(A)]

☐ **Point sound source attenuation**

$$SPL = SPL_0 - 20 . \log(r / r_0)$$

Here, SPL: Level of noise [dB(A)] r (m) away from the point-sound source

SPL_0: Level of equipment noise [dB(A)] r_0 m away from the point-sound source

r : Distance from point-sound source (m)

r_0: Distance from point-sound source to measurement point (m)

・Source

Reasonable Estimation and Assessment Method of Environmental Impact, KEI, 2002

Appendix 9. Comments Received on the Draft CEE and Response to Comments

CEP advice to ATCM on the draft CEE contained in ATCM XXXIV Final Report. (p103-105)

Item 6: Environmental Impact Assessment (EIA)

6a) Draft Comprehensive Environmental Evaluation

(53) The Republic of Korea introduced WP 42 *The Draft Comprehensive Environmental Evaluation for the construction and operation of the Jang Bogo Antarctic Research Station, Terra Nova Bay, Antarctica* and IP 19 containing the full draft CEE. Highlighting the main scientific objectives of the project, which include the study of climate change issues and long term studies of the ocean and different ecosystems, Korea noted that the draft CEE was intended to show clearly how the impact on the Antarctic environment would be minimised, and to share the benefits of construction and research with the wider international community, by promoting international global scientific cooperation.

(54) The Republic of Korea was grateful for the valuable work of the ICG in reviewing the draft CEE. The Republic of Korea thanked Norway for its suggestion to source an alternative solution to waste incineration, which will save a projected 50 tons of fuel annually.

(55) Australia introduced WP 7 *Report of the intersessional open-ended contact group to consider the draft CEE for the "Construction and Operation of the Jang Bogo Station, Terra Nova Bay, Antarctica"*. It noted that the ICG had expressed strong support for the proponent's plans to minimise and mitigate the environmental impacts of the project, and had recognised that environmental considerations had clearly been a key consideration in the project planning. Australia briefly introduced the outcomes of the ICG, highlighting the opportunities that participants had identified to enhance the final CEE, in keeping with the objectives of the CEE process established under Annex I of the Protocol.

(56) Many Members supported the Republic of Korea's plans, highlighting the importance of future international collaborations that this project will bring for research in East Antarctica. Some Members also noted with approval the use of alternative energy sources in the operation of the station.

(57) China supported and congratulated the Republic of Korea's plan of constructing a new research station in Antarctica and believed it would serve the purpose of the Antarctic Treaty. China agreed with the ICG's conclusion regarding the draft CEE for Jang Bogo station and expected the final CEE would have good considerations of the comments from other Parties.

(58) The proposed station will lie only 10km from the Italian Mario Zucchelli Station and will be close to the German Gondwana Station. France and Germany reported that Republic of Korea had visited their Antarctic research centres after completing the draft CEE to discuss many of the technical comments. Italy had proposed potential collaboration with Korea for the establishment of a marine protected area in Terra Nova Bay. The United States commended Korea for addressing questions and concerns raised in WP 7, through the timely submission of IP 76 and through additional information contained in its presentation to the CEP. The US offered to share pier building experiences at McMurdo Station with Korea.

(59) Belgium pointed to the necessary collaboration between the new Korean station and the existing stations in the surrounding areas so as to reduce the cumulative impact on the environment. It showed interest in collaborating with the Republic of Korea on undertaking long-term monitoring of the terrestrial and marine ecosystems in the region, including in the Amundsen Sea where few studies have yet been conducted; it indicated that the fact that the station will be constructed on the border of the Ross Sea will put Korea under a special responsibility should the Ross Sea or part of it receive a protection status.

(60) ASOC noted that since the station will operate year-round, its environmental impacts will be substantive. However, ASOC expressed appreciation for the decisions taken by the Republic of Korea to minimise environmental impacts since the first draft was circulated, such as by eliminating incineration and by using precast concrete foundations. ASOC expressed hopes that now that Korea will be active in that part of Antarctica it will collaborate with Italy on the establishment of marine protection in the Ross Sea.

(61) The Republic of Korea expressed its appreciation for the Committee's support of its draft CEE.

CEP advice to the ATCM

(62) The Committee discussed in detail the draft Comprehensive Environmental Evaluation (CEE) prepared by the Republic of Korea for "Construction and Operation of the Jang Bogo Station, Terra Nova Bay, Antarctica" (WP 42 and IP 19). It also discussed the report by Australia of the ICG established to consider the draft CEE in accordance with the *Procedures for intersessional CEP consideration of Draft CEEs* (WP 7), and additional information provided by the Republic of Korea in response to issues raised in the ICG (IP 76). Those discussions are summarised in paragraphs 56 and 57 above.

(63) Having fully considered the draft CEE, the Committee advised ATCM XXXIV that:

- The draft CEE generally conforms to the requirements of Article 3 of Annex I to the Protocol on Environmental Protection to the Antarctic Treaty.
- The information contained in the draft CEE supports the proponent's conclusion that the construction and operation of Jang Bogo station is likely to have more than a minor or transitory impact on the environment. The information provided also supports the proponent's conclusion that these impacts will be outweighed by knowledge and information to be gained through the research activities that will be supported by the station.
- When preparing the required final CEE, the proponent should consider, and address as appropriate, the comments raised by Members. In particular, the ATCM's attention is drawn to the suggestions that the final CEE should provide further detail regarding: the possible cumulative impacts of activities by multiple operators in the Terra Nova Bay region; the ancillary station infrastructure; the wastewater treatment system; the management of sewage and food wastes; oil spill prevention; measures to prevent impacts on the skua colony; measures to prevent the introduction of non-native species; and plans for decommissioning the station.
- The draft CEE is clear, well structured, and well presented.

(64) The CEP recommended that the ATCM endorses this view.

Significant comments raised by CEP

Section	Comment	Response addressed in Final CEE
Cumulative impacts	Several participants noted that the proposed site for Jang Bogo Station is in close to existing facilities operated by Germany and Italy. They suggested that the 'consideration of cumulative impacts or the proposed activity in light of existing activities and other known planned activities' (as required by Article 3.2(f) of Annex I) in the final CEE should be expanded to address the potential cumulative impacts associated with the conduct of science and operational activities by multiple operators in the Terra Nova Bay region.	See section 5.10.
Description station infrastructure	Some participants asked that the final CEE should provide further information about the full complement of station infrastructure, including: other major structures (e.g. power plant, maintenance facility, storage buildings, emergency shelter, boat storage; scientific facilities; other ancillary station infrastructure (e.g. heliport, antennae); and the site services (e.g. wires, pipe work) that will run between the station facilities.	Suggestion incorporated in appendix 1 See also section 2.2.2 (p15-16).
Waste water treatment, re-use and discharge	Many participants suggested that the final CEE could usefully describe the water treatment system in greater detail; whether the same system will be used during the construction and operational phases; the percentage of treated water that will be re-used on station, and for what purposes; the volume of effluent to be discharged (daily / annually); the likely quality of the 'near pollutant-free' effluent to be discharged; whether the waste treatment plant will require a full-time specialist operator; and what contingency arrangements will be in place if the plant fails.	See sections 5.5.1 (Mitigation Measures) & 5.5.2 (Mitigation Measures), chapter 6 (Table 6-3) and appendix 7.
Management of sewage and food waste	Many participants suggested that the final CEE should provide further information to the Korea's plans to incinerate food waste and sewage sludge (Section 2.5.4, page 37), including: the likely volume and moisture content of these waste streams; and the method of reducing moisture content (particularly in sewage sludge) to a point where incineration would be efficient and effective.	Considering detailed site waste management alternatives, no incinerator will be installed. See sections 2.5.4, 3.7 & 5.4.2 (Mitigation Measures).

Section	Comment	Response addressed in Final CEE
Oil spill prevention	Several participants commented that the description of measures to prevent fuel and oil spills (Section 5.3.2, page 78) focuses on spills from the bulk fuel tanks and pipelines connecting facilities on the station.	Jang Bogo Station Fuel Spill Prevention and Contingency Plan (KOPRI, 2011a) have been developed. See section 5.3.
Measures to prevent impacts to the skua colony	Many participants suggested that the final CEE should provide further information to clarify the predicted impacts on the skua colony, and the planned mitigation measures.	Correction incorporated in section 5.7.1 (Mitigation Measures) See also chapter 6 (Table 6-4).
Measures to prevent the introduction of non-native species	Many participants suggested that the final CEE should describe in greater detail the mitigation measures to minimise the risk of introduction of non-native species during the operation of the station (Section 5.7.2, page 90) should be described in greater detail in the final CEE.	Suggestion incorporated in section 5.7.2 and chapter 6 (Table 6-4) based on Non-native Species Manual (Resolution 6) (ATCM, 2011)
Decommis-sioning	Several participants ask to describe more clearly in the final CEE specifically what is expected to be removed from the site and what will be left in place after decommissioning.	Suggestion incorporated in section 5.11 (p101-102)

Additional comments in appendix A

Section	Comment	Response addressed in Final CEE
Introduction	1. The scientific justifications for establishing Jang Bogo Station (Section 1.3, page 7) could be improved in the final CEE to more clearly outline the importance of the new station, and to better support the proponent's conclusion that the scientific benefits arising from the station will outweigh the likely environmental impacts. For example, the document could more clearly identify how the proposed new research will differ from, or complement, a range of studies already undertaken at the existing research facilities in the Terra Nova Bay region. It could also emphasise the opportunities that arise to support research that can only be conducted at a year-round station (e.g. long term observation in the fields of geophysics, atmospheric science, meteorology). Furthermore, the final CEE could explain how the new station will be important for supporting planned research in the region (e.g. ice drilling, exploration for meteorites, paleo-climate studies on marine sediments) that might otherwise be conducted through field expeditions or with support from a ship.	Suggestion incorporated in section 1.3
	2. Section 1.3 could also be expanded to explain in greater detail the scientific research that will be supported by the *ARAON*, including during its passage between Jang Bogo Station and King Sejong Station. This could in part be addressed through a broader discussion of plans for long-term monitoring of the marine ecosystem.	In close collaboration with the King Sejong Station, the Jang Bogo Station will form the West Antarctic Observatory Network using the icebreaker *ARAON*. See sections 1.1 & 1.3.
	3. The final CEE should incorporate the results of the hydrographic survey undertaken in February 2011 (Section 1.4, page 10) because these data will be critical to ensuring the safety of shipping operations and to informing the specifications for the dock. If gaps in knowledge remain following the field survey, these should be noted in Section 7 Gaps in Knowledge and Uncertainties and preferably be addressed with further investigations before construction commences.	Correction incorporated in sections 1.4 & 2.3 (Dock) Suggestion incorporated in chapter 7 Hydrographic data added in appendix 2
	4. The last paragraph of Section 1.4 (page 10) could also note that, once completed, the final CEE will be circulated to all Parties at least 60 days before starting proposed activity.	Suggestion incorporated in section 1.4 (p11)
	5. In accordance with the provisions of Article 3 of Annex I, the ATCM will consider the draft CEE, but there is no mechanism for the ATCM to 'agree' with the proposed activity. The first sentence of the third paragraph in Section 1.6 (page 12) could be modified accordingly.	Correction incorporated in section 1.6 (p13)

Section	Comment	Response addressed in Final CEE
	6. It would be useful to identify whether the group of consulting experts referred to in Section 1.6 (page 12) will involve international participants.	For the new station construction project, we have consulted about those matters with other Antarctic operators (e.g., BAS, AWI, PNRA) and experts. The collaboration with international experts for this project will continue to get better results.
Description of the proposed activity	7. To better demonstrate the importance of the new station for science, Section 2.2.2 (page 14) could explain the rationale for the station composition during winter (11 staff, 4 researchers) and whether the researchers are expected to manage one or more projects. Some other stations have roughly equal numbers of technical staff and researchers during winter.	Suggestion incorporated in section 2.2.2
	8. Section 2.2.2. (page 15) notes that other ancillary station infrastructure will be installed and refers to Appendix 1, but the appendix provides no further details about such infrastructure.	Suggestion incorporated in appendix 1 See also section 2.2.2 (p15-16).
	9. The amount of food to be delivered to Jang Bogo annually (6,000kg) is low compared to experience elsewhere.	Correction incorporated in section 2.2.3 (p18) (6,000kg to 20ton)
	10. Although Section 2.2.3 (page 17) notes that barges will be used to transport personnel and cargo ashore, the final CEE could clarify whether the barges will be unloaded at the proposed dock, or whether a separate landing site will be used. If the latter, the document should discuss any construction or earthworks that will be required.	Only Route B in Figure 3-2(b) will be used during the construction period. The proposed landing site is relatively gentle and requires minimum earthwork. The dock is scheduled to be constructed in the second phase. See section 3.6 (Marine Transportation).
	11. Further details could be provided regarding the materials to be used in the state of the art insulation (Section 2.3, page 17).	High-efficiency insulator, Polyisocyanurate Foam will be used. See section 2.3 (p18).
	12. The caption for Figure 2.3 (Section 2.3, page 17) could clarify that the image represents a conceptual model of the proposed station, and that the station will be situated in an ice-free area.	Correction incorporated in Figure 2-3
	13. Noting that the main sectors of the main station building will be located on the elevated first floor (Section 2.3, page 20), it would be useful to describe how cargo will be transferred from the ground surface into the main building.	See the positions of entrances in Figures 2-5 & 2-6.
	14. Consideration could be given to whether locating the heliport and maintenance upwind (i.e. to the west) of other facilities will have an impact on scientific observations (Section 2.3, page 18).	The location of heliport and other facilities were arranged for not interfering with observation. See Figure 2-4.

Section	Comment	Response addressed in Final CEE
	15. In addition to describing the ability to close particular portions of the main station building during winter, Section 2.3 (page 22) could also explain whether it is possible to shut down ('winterise') and then restart the whole station if required.	Complete isolation of a part of the main building during winter may not be proper for maintenance purpose. Closed section with minimum heating is more practical solution for maintenance. See section 2.3 (Main Building).
	16. Stating in Table 2.2 (Section 2.3, page 22) the total expected electrical load during summer and winter would assist with clarifying the identified energy savings for the winter period.	Operation ratio in Table 2-2 represents a ratio of operation area in the main building by daily and seasonal changes during operation. See Table 2-2.
	17. More detail could be provided regarding the 'access passages for residential and research activities (Section 2.3, page 22), including whether these will be enclosed, on the surface, or below the surface.	All passages are on the surface. See Figure 2-8.
	18. The description of the station design (Section 2.3, page 17) or another suitable section could specify the construction materials and confirm that no materials banned under the Environmental Protocol will be used.	Suggestion incorporated in section 2.4.4
	19. The description of the fire prevention plan (Section 2.3, page 24) could be expanded. It could explain how the fire blocking zones will be divided and what materials will be used (e.g. fire resistant barriers), whether fire alarms will be installed, and what provisions will be made to put out a fire (e.g. fire extinguishers, sprinklers, hoses). If water is to be used, this section could also describe the provisions for ensuring adequate water storage for normal operating conditions and emergency use. Figure 2.9 suggests that a mechanism similar to that used in aircraft will be used to facilitate exit from the building in the case of a fire, but this is not described in the text.	Section 2.3 (Fire Prevention Plan) has been updated based on final design.
	20. The Range of Impacts discussion (Section 2.6, page 39) should also address the dock, fuel transfer activities, and any small boat activities.	Suggestion incorporated in section 2.6 (p41)
	21. Consideration should be given to experience with the use of elevated buildings elsewhere in Antarctica when considering the likelihood of snow or ice accumulation under the main building, particularly due to the presence of the Air Handling Unit (Section 2.3, page 27).	See section 2.3 (Safety from Winds and Snow).

Section	Comment	Response addressed in Final CEE
	22. The description of the proposed dock (Section 2.3, page 29) could include a more detailed discussion of the proposed construction techniques, including where the material for the rubble mound and backfill will be sourced from, and how the 'Gravity Wall' construction (being unanchored) will withstand the affects of sea ice / icebergs.	Suggestion incorporated in section 2.3 (Dock)
	23. It would be good to clarify the approximate extent and volume of material that may be moved by the 'surface grading' for the construction of the main station, other permanent structures, temporary facilities (e.g. the 29 containers to be used during construction) and access routes, as mentioned in Section 2.4.1 (page 31) and also in Section 5.8 (page 91).	Suggestion incorporated in section 5.8.
	24. The discussion of support requirements for the construction workers (Section 2.4.2, page 32) could be expanded to identify what kind of wastewater treatment plant will be used during the construction period, and how the treated effluent will be stored or discharged. Section 5.5.1 (page 81) states that a state of the art treatment system will be used, but does not provide further details).	Suggestion incorporated in sections 5.5.1 (Mitigation Measures) & 5.5.2 (Mitigation Measures)
	25. Section 2.4.3 (page 33) could describe whether cranes will be used to offload cargo from the barges and, if so, how many will be used.	A 50-ton crane will be used to unload cargo. See section 2.4.3.
	26. In Section 2.4.3 (page 33) it would also be useful to indicate whether the 36 items of heavy equipment are fitted with wheels or tracks (as this will have a bearing on the level of physical disturbance), and how many of these items will remain on station after the construction phase.	A dozer, 50-ton cranes and 2 backhoes are equipped with tracks and other vehicles with wheels. All construction equipments will be removed after construction except a crane and a truck for maintenance use.
	27. Testing the assembly of the prefabricated building modules before delivery to Antarctica is strongly recommended (Section 2.4.4, page 33).	All modules will be assembled for testing before shipment.
	28. The discussion of Wind Energy (Section 2.5.1, page 35) notes that 20 kW vertically stacked modular turbines will be used, but does not explain how many towers will be installed. This section could be updated to reflect the statement in Section 5.8 (page 91) that the plan is to install three 20 m high towers.	Suggestion incorporated in section 2.5.1 (Renewable Energy)
	29. The discussion of Energy Management (Section 2.5.1, page 34) could explain whether waste heat will be recovered from the incineration process as well as from the diesel generators. It could also explain why gas, not electric power, will be used for cooking.	No incinerator will be installed.

Section	Comment	Response addressed in Final CEE
	30. The final CEE could clarify what technology will be employed in the desalination facility (Section 2.5.2, page 36) (e.g. reverse osmosis or evaporation), and why this is the preferred approach to producing fresh water (e.g. economic and/or energy benefits).	The part of seawater desalination facility has been updated in section 2.5.2 (Water production and distribution system).
	31. It is unclear whether the snow melting device will be used only in emergency situations (i.e. when the desalination facility is inoperable) or if the snow melting device and desalination plant will operate together (Section 2.5.2, page 36).	Snow melting system will be operated together with desalination unit. See section 2.5.2.
	32. The anticipated volume of fresh water required during operation (150 l/day/person) (Section 2.5.2, page 36) is large relative to the experience of another station at which water use is approximately (100ℓ/day/person, which is itself considered a large volume).	150ℓ/day includes recycled gray water, which accounts for about 40% of total water use. See section 5.5.2.
	33. It is unclear how the pipelines associated with the intake point for the water supply for the desalination plant (Section 2.5.2, page 36) and the wastewater outfall (Section 2.5.5, page 38) will be constructed and anchored to prevent damage by sea ice and icebergs.	Suggestion incorporated in section 2.5.5
	34. It is possible that the weight and volume of fuel required for incinerating food and sewage wastes (more than 50,000 kg) Section 2.5.3, page 37) will be greater than that of the wastes themselves. The use of this volume of fuel for incineration might also neutralise the benefits of the planned renewable energy generation.	No incinerator will be installed.
	35. The final CEE could describe how the discharge point for waste water effluent was chosen (Section 2.5.5, page 38) and whether this decision was based on a baseline survey of the marine environment.	Correction incorporated in sections 1.4, 2.3 (Dock) & 2.5.5
Alternatives to the proposed activity	36. The alternative of utilising existing stations in the Terra Nova Bay region (Section 3.1, page 41) could be discussed in further detail, including consideration of options for further developing these facilities for year-round operation. The advantages of such an approach would include: minimising the collective human footprint in the region; reducing the need for transportation and construction of new facilities; increasing international cooperation in Antarctic science; and enhanced overall cost and energy efficiency.	Both Mario Zucchelli Station and Gondwana Station cannot provide sufficient support for the various scientific research activities that Korea is planning to undertake. See section 3.1.
	37. The statement in Section 3.2 (Page 44) that the region surrounding Cape Möbius is absent of 'major flora and fauna colonies' could explain what is meant by 'major'.	Correction incorporated in section 3.2 (p46)
	38. Section 3.2 (page 41) could be restructured to more clearly identify the criteria used to select the station site (i.e. the 'various decision factors' – accessibility, weather conditions, safety, logistics, impacts on the ecosystem).	Table 3-1 added

Section	Comment	Response addressed in Final CEE
	39. The discussion of Alternative Transport in Section 3.6 (page 48) could be revised to clarify whether it is planned to use aircraft to transport personnel and/or cargo to the station. The first paragraph in this section states that aircraft and ships will be used, whereas the final paragraph states that marine transportation was selected over air transportation. If air transportation is to be employed, the impacts of the runway facilities and associated access routes should considered.	The two alternatives (air and marine transportations) were considered only for comparison purpose for transportation from Christchurch to the proposed site. Marine transportation is to be employed. Correction incorporated in section 3.6
	40. According to Section 3.6 (page 49) route B is the most appropriate option for land transport of supplies to the station, including because use of the other two alternative routes would have the potential to cause wildlife disturbance. The final CEE could explicitly state that these other land transport routes will not be utilised.	Only route B will be used for unloading purpose during construction. See sections 3.6 (Figure 3-2) & 5.7.1 (Mitigation Measures).
	41. Given that materials transported from the ship will be handled many times before arriving at the station (i.e. ship to barge, barge to dock, dock to vehicles, vehicles to station) (Section 3.6, page 48) further information could be provided on measures to minimise the risk of spills/leaks.	Jang Bogo Station Fuel Spill Prevention and Contingency Plan (KOPRI, 2011a) have been developed. See section 5.3.
	42. Section 3.6 (page 49) could identify the period (timing and duration) each year during which ice conditions will allow shipping access to the station, and whether the transport of personnel by ship will represent a time- and cost-effective approach.	Suggestion incorporated in section 3.6 (Marine Transportation) by adding new data from NSIDC
	43. The discussion of Alternatives to the Proposed Activity (Section 3, page 41) could also address accommodating construction personnel on the ship as an alternative to establishing temporary accommodation ashore.	Staying on the ship is not efficient in aspects of safety and travel distance to the construction site.
Initial environmental reference state of the TNB region	44. Consideration could be given to locating the description of the Initial Environmental Reference State (current Section 4) after the Introduction (Section 1).	Not considered
	45. In the final CEE the discussion of the Initial Environmental Reference State Section (Section 4) should incorporate the findings arising from the detailed field investigation undertaken after the draft CEE was circulated, in February 2011.	The results of three yearly site surveys between 2010 and 2012 were added in sections 4.1, 4.5 & 4.6.
	46. Section 4.1 (page 53) describes wildlife colonies at Edmonson Point, Adélie Cove and Inexpressible Island. The location of these sites in relation to the proposed station site should be shown on a map and described in this section (Section 4.8 notes that ASPA 165 Edmonson Point is 40.9 km from the proposed site).	Correction incorporated in Figure 2-1

Section	Comment	Response addressed in Final CEE
	47. If vegetation is present at the temporary pools in the vicinity of the station, this could be outlined in Section 4.1 (page 53).	This part was described in section 4.6.1.
	48. In discussing the wind regime at the proposed site (Section 4.5, page 61 and Appendix 2), it would be useful to clarify whether the maximum / minimum wind speed is an average or instantaneous speed. It appears that the proposed site may be subject to seasonality in wind speed which does not occur, and that the risk of high speed katabatic winds may also be higher.	The value of wind speed represents 1-hour average data. See note in appendix 3.
	49. The description of the initial environment reference state of flora and fauna (Section 4.6, page 63) could be expanded to address terrestrial and freshwater invertebrates. The impacts of the proposed activities on these types of organisms should also be assessed.	Suggestion incorporated in section 4.6.2 (p72-73)
	50. The discussion of Human Impacts (Section 4.7, page 67) should identify any infrastructure installed by Korea at the proposed station site prior to the preparation of the draft CEE (i.e. ATCM XXXIII/IP54 stated that a hut and automatic weather station had already been established). The proponent could also clarify how the installation of these items did not pre-empt the outcome of its consideration of alternative locations through the CEE.	IEE was conducted for the hut and AWS before installation at the sites. Three AWSs have been installed between 2008 and 2010 in different locations. Table 3-1 added
	51. As well as listing the Antarctic Specially Protected Areas and Historic Sites and Monuments in the vicinity of the proposed station (Section 4.8, page 68), consideration could be given to identifying the environmental reference state of these sites.	The ASPA and HSM mentioned in section 4.8 are too far from the proposed site. The nearest one is located 15.7km from the proposed site.
Prediction of impacts, assessment and mitigation measures of the proposed activities	52. The ethylene propylene rubber to be used for oil spill prevention (Figure 5.3.2, page 78) will need to be strong and reliable as it may otherwise degrade or develop holes over time.	Suggestion incorporated in Figure 5-6
	53. Although Section 5.4.1 (page 79) identifies the likely volume of construction waste, it is not clear what total quantity of waste is expected to be produced during the construction phase (i.e. including wastes generated by the presence of large numbers of construction workers).	See appendix 6.
	54. The predicted noise levels illustrated in Figure 5.7 (Section 5.6.1, page 83) do not appear to account for the prevailing westerly winds, which may result in greater potential for noise impacts to the seal colony located to the east of the station. An explanation of how the calculated maximum noise level (50 dB) was determined would be useful.	In the prediction method in appendix 8 wind effect is negligible. The method estimates noise level using statistical approach. See appendix 8.

Section	Comment	Response addressed in Final CEE
	55. The statement in Section 5.7 (page 86) that the seal colony is more than 1 km to the east of the station seems inconsistent with the separation distance indicated in Figure 5.7.	Correction incorporated in section 5.7 and Figure 4-16.
	56. The likely impacts on the temporary pool closest to the station, and relevant mitigation measures, should be discussed in Section 5.7.1 (page 86).	The temporary pool closest to the proposed site was observed dry during 2011 survey. See section 4.1.
	57. The mitigation measures identified in Section 5.7.1 (page 87) and Section 5.7.2 (page 90) could include steps to prevent, as far as possible, disturbance of the habitat for terrestrial vegetation.	A monitoring plan for terrestrial vegetation has been established. See chapter 6 (Table 6-4).
	58. The measures that will be employed to ensure that research activities and visitors do not have a direct impact on major bird and seal colonies should be described (Section 5.7.2, page 89).	Included in section 5.7.2 (Mitigation Measures).
	59. Section 5.7.2 (page 89) states that it is unlikely that birds will strike the wind turbine towers. Evidence to support this statement would be useful.	See section 5.7.2 (Wind turbine) and Table 3-3.
	60. If the wind turbine towers will be supported by guy wires, the potential for birds striking the wires should also be addressed in Section 5.7.2 (page 89). Appropriate mitigation measures could also be identified (e.g. installing impact diverters on guy wires if used, shutting down turbines if bird strike becomes an issue).	Guy wires will not be applied to support wind turbine towers.
	61. Figure 5.8 (Section 5.7, page 85) identifies a 200m core zone for feeding activity of South Polar Skuas, as well as a 200-300m buffer zone for feeding activity. The absence of a suitable terrestrial food supply (e.g. penguin colony) is likely to mean that the skuas will feed mainly in areas further offshore and by scavenging from the seal colony. The figure and related management provisions may need to be modified accordingly.	Management provision will be modified after years of observations.
	62. The assessment of impacts on Scenery and Aesthetic Natural Values (Section 5.9, page 92) should be expanded to also consider impacts on wilderness values. Such an assessment could take into account the current absence of significant human disturbance, the spatial extent of the area in which proposed new structures (including access routes to more remote locations) will be visible, and the duration and severity of impacts on wilderness values. This section could also describe in further detail how the buildings and facilities at the station will be arranged to minimise impacts on the local scenery. Impacts on intrinsic and wilderness values should also be addressed in the Impacts Matrix (Section 5.12, page 93).	Suggestion incorporated in section 5.9 and Table 5-5

Section	Comment	Response addressed in Final CEE
	63. The discussion of cumulative impacts (Section 5.10, page 92) should also address the impacts of planned and possible future operational and scientific activities to be supported by the new station (e.g. expansion of logistics and transportation, establishment of a new drilling program in Northern Victoria Land).	Suggestion incorporated in section 5.10 In case of a new ice drilling program, a separate EIA will be conducted.
	64. To better understand the possible cumulative impacts arising from discharge of wastewater (Section 5.10, page 92), a study of the dispersal environment could be undertaken and the results incorporated into assessment of cumulative impacts.	Cumulative impacts related to waste water was described in section 5.10. An additional monitoring plan has been established to investigate the possible cumulative impact on water quality in Table 6-3.
	65. The possible effects of ground disturbance from foot and vehicle traffic and other activities at the site over time could be considered in the discussion of cumulative impacts (Section 5.10, page 92).	Suggestion incorporated in section 5.10
	66. The following comments relate to the impact matrices presented in Table 5.5 and Table 5.6 (Section 5.12), pages 96-100: - Construction > Ships > Shipping and cargo handling > Fuel spills and generation of hazardous wastes: the 'Importance' might more appropriately be assessed as Medium or High, to reflect the potentially significant impacts of a fuel spill on wildlife and coastal ecosystems. - Construction activities > Construction of station > Fuel spills: the 'Importance' might more appropriately be assessed as Medium, to reflect the significance of potential impacts on soil/rock communities. - Construction activities > Construction of station > Impacts caused by construction equipment and works: the probability of the predicted impact should be High. For clarity, it would be best to separate the assessment for physical disturbance impacts (e.g. soil compaction) from the assessment for biological impacts (e.g. arising from introduction of species). The probability of species being introduced, and the importance, may be greater than 'low'. - Operation of station > Generation of wastes and wastewater: the potential introduction of non-native species, and potential impacts arising from the discharge of brine from the desalination plant, should be addressed here. - Operation of station: additional stressors could be added related to the ongoing operation of the dock, ship to shore transfer of fuel, management of snow drift, aircraft operations and small boat operations., with the predicted impact 'contamination and disturbance of benthic habitat'.	Suggestion incorporated in Tables 5-5 & 5-6

Section	Comment	Response addressed in Final CEE
Environmental monitoring and verification	67. The environmental monitoring plan (Section 6, Page 101) could identify the parameters that will be measured for each item listed. It would usefully address further biotic parameters (e.g. a census of the seal colony before and after construction), measurement of noise levels during construction and operation phases, and monitoring of the marine environment to identify impacts arising from wastewater discharge.	A specific monitoring plan has been established. See chapter 6.
	68. It would be useful to consider reviewing the effectiveness of the CEE once the station is operational. For example, reporting on the accuracy of the impact assessment and on the effectiveness of the mitigation measures adopted.	Suggestion incorporated in chapter 6 by establishing a specific monitoring plan

Editorial comments in appendix B

Reference	Comment	Response addressed in Final CEE
1.3 (p8)	1. Under the heading 'Glaciology and Snow Chemistry', the reference to 'restoring' paleo-climate changes might be replaced with 'reveal', 'reconstruct, or similar.	Correction incorporated
Fig.4.11 (p59)	2. Please provide a reference for the image (date and satellite details)	Correction incorporated
4.7 (p67)	3. Suggest replacing 'astronautics' with 'astronomy'	Correction incorporated
12	4. Add the meaning of COD (used on pages vi and 82) to the Index	Suggestion incorporated

FINAL COMPREHENSIVE ENVIRONMENTAL EVALUATION

Construction and Operation of the Jang Bogo Antarctic Research Station, Terra Nova Bay, Antarctica

Korea Polar Research Institute

Korea Environment Institute