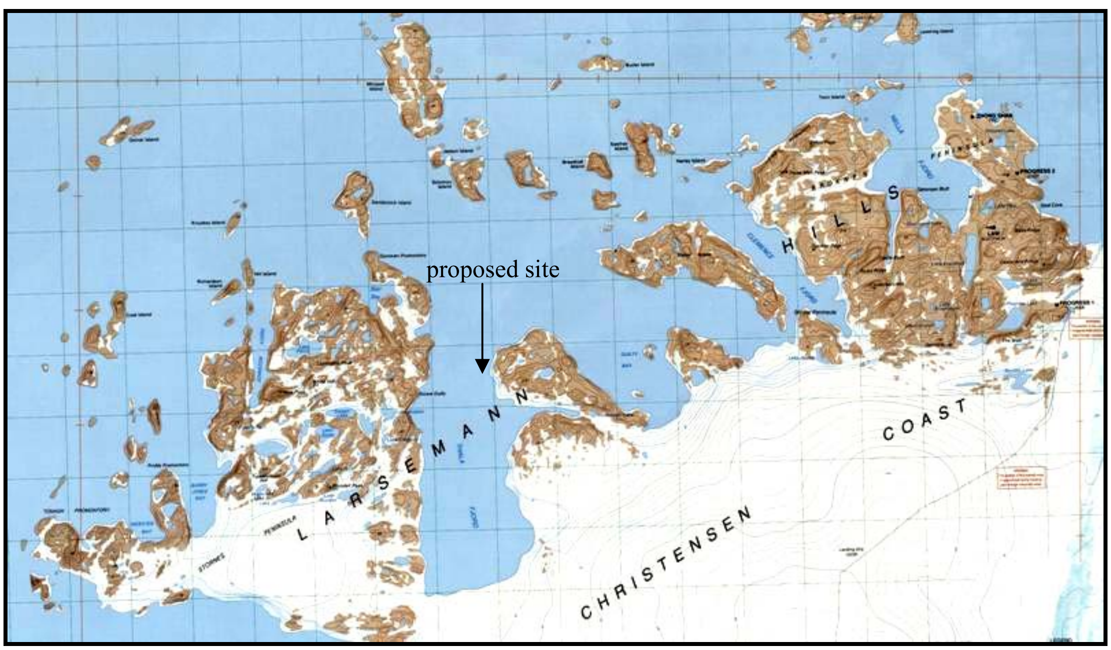
5. INITIAL ENVIRONMENTAL REFERENCE

5.1 Location

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

Four research stations namely the Progress I & Progress II (Russia), Law- Racovita (Australia-Romania) and Zhongshan (China) are located on the Larsemann Hills. The westerly oceanic currents break the fast ice during early summer facilitating the entry of the vessels quite close to these stations. The Indian Antarctic base is proposed to be located on an ice-free rocky area, situated between Quilty Bay on the east and Thala Fjord on the west (Figure 18).

Figure 18 : Larsemann Hills



(Source: AAD)

5.2 Geology

5.2.1 Geology of the Larsemann Hills

The local coastline has many indentations with fjords forming deep inlets. The highest point in the promontory where the station is being proposed is around 105 metres above msl. Geology of the area has been established by the detailed work of Sheraton and Collerson

(1983); Stuwe et al.(1989); Carson et. al. (1995); Zhao et al. (1995); Wang and Zhao (1997); Reading (2006) etc. The area is dominated by paragneisses which are more aluminous than similar rocks of the Rauer Group. Magnetotelluric deep sounding study in the region of Zhongshan station has established that the lithospheric thickness of Larsemann Hills is 140 km, and that the crustal high conductivity layer is situated at 22 km (Kong et al., 1994). The detailed bibliography concerning Larsemann Hills is available in the Working Paper No 8 submitted at XXIX ATCM, Edinburgh.

5.2.2 Geology at the Proposed Station Site

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

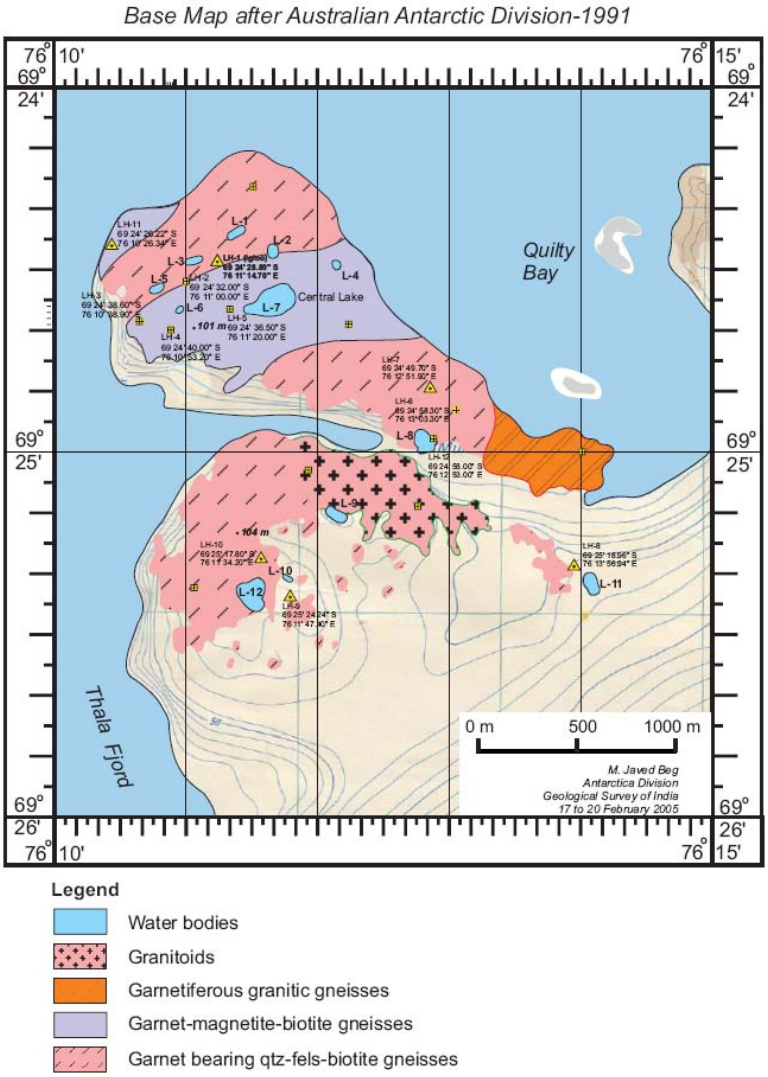
Granitoids: Exposed south-east of the intersection of 69^o 25' S & 76^o 12' E and north-east of Lake L-9 (Figure 19), the granitoids are medium to coarse grained with alkali feldspar as porphyroclasts. These granitoids are traversed by thin aplitic veins.

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

Garnet-magnetite-biotite gneisses: Trending NE-SW, 30 to 45 degrees due SE, this unit is exposed around the central lake (L-7), and extends up to lake L2 in the northwest and up to about 250 m southeast from the edge of the Lake L-7 (Figure 19). A small patch of the same unit is exposed at the northwestern extremity of the peninsula. The quartz-magnetite-biotite gneiss occupying the higher grounds is marked by the presence of small magnetite crystals evenly distributed throughout. At places small sized garnets are found in pockets. These gneisses are traversed by pegmatite, and aplitic veins have partly digested enclaves of older gneisses.

Garnet bearing quartz-feldspar-biotite gneisses: Most predominant litho-unit of the area, this unit is exposed in the northwestern part of the peninsula and north of lakes L-8 & L-12 (Figure 19). These gneisses consist of quartz and feldspar with biotite defining the foliation planes. Garnets occur as porphyroblasts within the gneisses. The size of the garnets varies from about 2 mm in the north-western side to less than 1 mm in the south eastern parts and is evenly distributed throughout. These are traversed by thin pegmatite and aplitic veins and have a few partially digested enclaves of older gneisses rich in melanocratic minerals.

Figure 19 : Geological Map of Grovnes Peninsula



5.3 Glaciology

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

5.3.1 Geomorphology

The area has a low, gentle and rolling topography merging with the polar ice cap in the south-southeast and surrounded by sea in other three directions. It is punctuated with small islands to the north & northeast. Starting from the mean sea level, it rises up to an elevation 150 m near the polar ice cap with the highest rocky outcrop exposed at 104 m above mean sea level.

The area is generally devoid of glacial morains but at a few places glacial striations are noticed. The area is dotted with small, perennial lakes.

5.4 Soil

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

5.5 Lake Water Characteristics

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

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

5.6 Climate

5.6.1 Overview

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

5.6.2 Snowfall

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

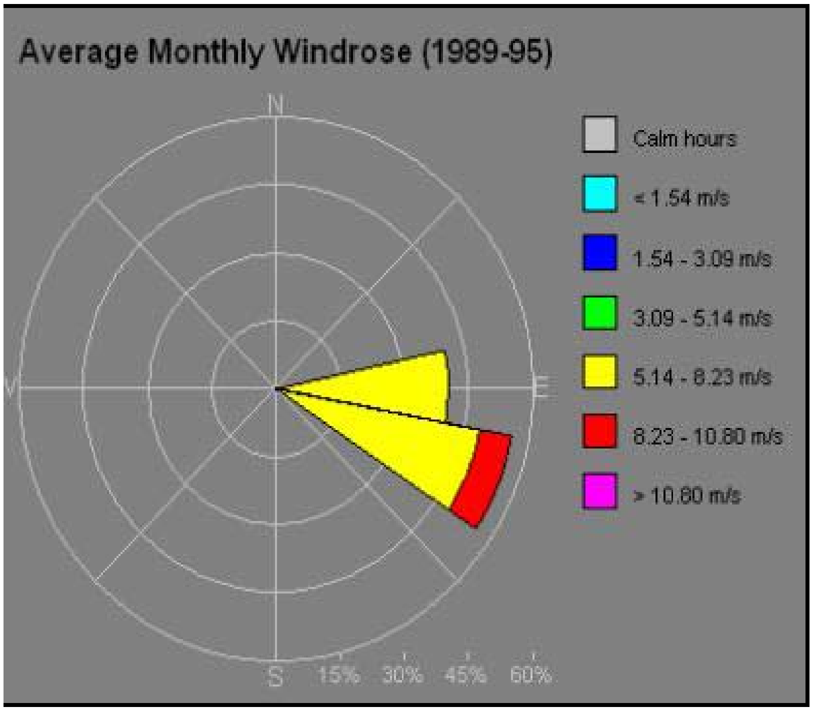
5.6.3 Katabatic Wind

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

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

At Zhongshan Station, easterly winds prevail all the year round (Figure 20). As seen from the monthly average wind direction record on an annual basis, east-northeast to east-southeast wind directions (67.5 – 112.5) have a frequency of 72%, of which 31% is due to the east wind and 27% for east-southeast winds (Appendix 4).

Figure 20 : Windrose at Larsemann Hills



5.6.4 Humidity

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

5.6.5 Sea Ice

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

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

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

5.7 Anthropogenic Impact - Background Information

Human occupation commenced in this area in 1986, with the establishment of four scientific bases by Australia (Law Base), Russia (Progress I and II) and China (Zhongshan) situated around 10 km away in NE direction from the proposed site. All these stations are situated within a radius of 2 km from each other. Ninety-three organic compounds including n-alkanes, lipidal isopentadienes, aromatic hydrocarbons, polycyclic aromatics, alcohols, aldehydes, ketones, esters, monocarboxylic acids and phthalic esters in the range of 0.027-4.79 mg/L have been identified in the Mochou and Heart lakes of the of Broknes area. Organic compounds like BHC, DDT and PCBs have also been detected in the water at concentrations of 0.012-0.356 mg/L (Li et al., 1997). Occasional ship-based tourist visits have also been made to the area since 1992.

5.7.1 Baseline Monitoring Information

5.7.1.1 Water Quality

Water samples collected from various lakes in the vicinity of the proposed site during the summer 2004 were analyzed for dissolved salts. Excepting the L-7 (Figure 19) which was saline in nature, the water quality from other lake was in general potable. Some of the important physico-chemical parameters of water of these lakes are provided in Table 1. The water bodies, L1, L2, L3, & L5 (Figure 19) besides being shallow reveal low hydraulic detention period/ high flushing rate.

Table 1 : Physico chemical Properties of Water Bodies at Larsemann Hills

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

The lake water samples were collected from two lakes in the McLeod Island located close to the proposed site for multi-parameter probe analysis.

The results of the physico-chemical analysis of same lakes numbered as 33 and 34 by Gillieson et al., 1990 are shown below in Table 2.

Table 2 : Physico chemical analysis of Lakes of McLeod Island

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

ND – Not Detected

5.8 Flora and Fauna

Extensive surveys have been carried out in this area. Seventeen species of rotifers (11 Monogononta and six Bdelloidea), three tardigrades, two arthropods, as well as protozoans, a platyhelminth and nematodes have been reported from 13 freshwater lakes (Dartnall, 1995). The benthic communities of the deepwater lakes are dominated by thick cyanobacterial mats (Ellis et al., 1998).

5.8.1 Flora

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

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

The bryophyte flora also comprises one species of liverwort *Cephaloziella exiliflora,* which is found on an unnamed outcrop south of Stornes and known from only four other Antarctic localities. Lichen coverage is considerable on north-eastern Stornes and Law Ridge on Broknes and the lichen flora of the region comprises at least 25 positively identified species. Although no systematic studies have been undertaken in the area, similar work conducted in nearby locations on the Ingrid Christensen Coast suggests that it would not be unreasonable to expect the Larsemann Hills to exhibit close to 200 non-marine algal taxa, and 100–120 fungal taxa (WP8, 2006).

5.8.1.1 Lake and stream biota

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

The most obvious biotic feature observed in almost all the lakes is an extensive blue-green cyanobacterial felt, which has accumulated since ice retreat and is consequently thickest on the islands and thinnest in young lakes adjacent to the polar plateau. These cyanobacterial mats are found to be of exceptional thickness of up to 1 m, not normally observed in other Antarctic freshwater systems, and are also widely distributed in streams and wet seepage areas (WP 8).

5.8.2 Vertebrate Fauna

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

Three species of seabird, South polar skuas, Snow petrels and Wilson’s storm petrels, breed within the Larsemann Hills . Approximate numbers and locations of breeding pairs are documented for Broknes, and particularly eastern Broknes, but their distribution throughout the remainder of the area is uncertain.

South polar skuas (*Catharacta maccormicki*) are present between mid-late October and early April, with approximately 17 breeding pairs nesting on Broknes and similar numbers of non-breeding birds.

Snow petrel (*Pagodroma nivea*) and Wilson’s storm petrel (*Oceanites oceanicus*) nests are found in sheltered bedrock fragments, crevices, boulder slopes and rock falls, and are generally occupied from October until February. Approximately 850–900 pairs of Snow petrel and 40–50 pairs of Wilson’s storm petrel are found on Broknes, with concentrations of Snow Petrels at Base Ridge and on rocky outcrops adjacent to the Dålk Glacier in the east and the plateau in the south.

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

5.8.2.1 Seals

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

5.8.3 Invertebrate Fauna

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

5.9 Protected Areas and Historic Sites and Monuments

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

5.10 Prediction of Future Environmental Reference in the absence of Proposed Activity

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

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