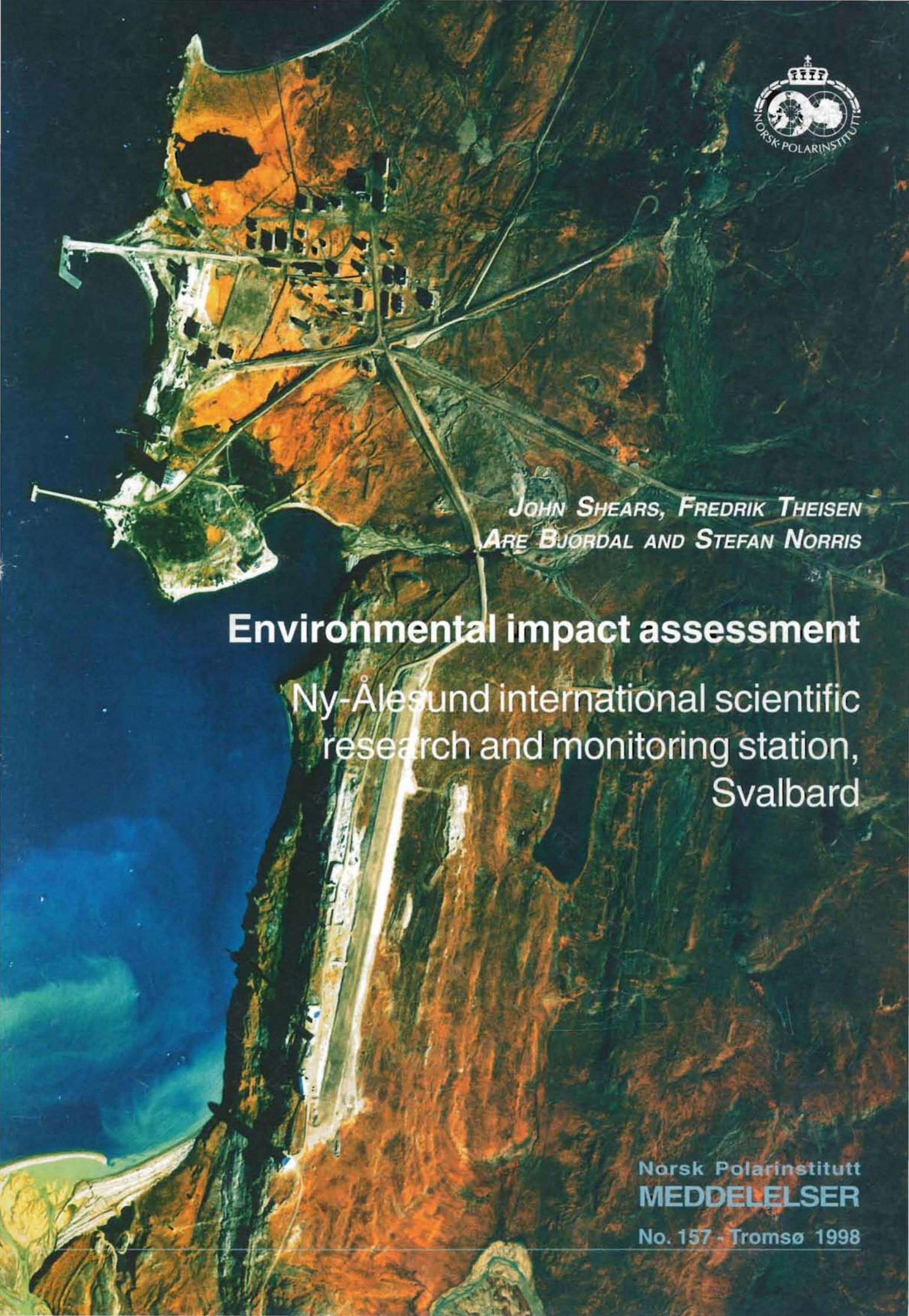

JOHN SHEARS, FREDRIK THEISEN
ARE BJORDAL AND STEFAN NORRIS

Environmental impact assessment

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NySMAC

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Norsk Polarinstitutt
Tromsø 1998

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PREFACE

Ny-Ålesund has been designated by the Norwegian Government as the principal centre of scientific research on Svalbard. The aim has been to develop Ny-Ålesund as a leading international scientific research and monitoring station in the Arctic. At the same time, the Norwegian Government considers that local human impacts must be kept at the lowest possible level to maintain the Ny-Ålesund area as a near pristine environment suitable as a reference site for natural science, and in particular research related to long range pollution, climate change and polar ecology.

In 1995, the Ny-Ålesund Science Managers Advisory Comittee (NySMAC) became concerned that the rapid expansion of human activity and facilities at Ny-Ålesund might be causing significant local environmental effects and conflicts with important scientific research. There was, however, a serious lack of systematic information regarding human impacts on the local environment and research and monitoring activities.

In early 1996, NySMAC therefore agreed that an Environmental Impact Assessment (EIA) was to be undertaken by the Norwegian Polar Institute (NP), on behalf of NySMAC. Shortly thereafter, the EIA project was approved by the board of Kings Bay Kull Compani (KBKC) A/S, the owner and technical operator of the Ny-Ålesund Scientific Station. The objectives of the EIA were to examine the impact of human activities on the environment at Ny-Ålesund, to examine the conflicts between the various activities and to recommend actions to reduce impacts and conflicts in order to maintain and restore the area as a near pristine site for environmental research and monitoring.

The EIA was managed jointly by NP and the British Antarctic Survey (BAS). The work was led by Dr John Shears (BAS) and Mr Fredrik Theisen (NP), who together formed the EIA team. The financial costs of the EIA were covered by KBKC, NP and the Norwegian Institute of Air Research (NILU). NP and NILU paid their own costs, while KBKC paid the costs of BAS and the other external consultants involved in the EIA.

The environmental issues were examined in a series of ten specially commissioned technical studies undertaken between May 1996 and April 1997. An EIA Reference Group was established and met regularly to determine progress, discuss results and receive comments. The group comprised representatives from NP, KBKC, NILU, the Norwegian Mapping Authority (NMA) and the Norwegian state Pollution Control Authority (SFT). The progress of the EIA was also regularly reviewed and assessed by NySMAC. In August 1997, NySMAC organised a one-day workshop to examine the results of the technical studies and the preliminary recommendations put forward by the EIA team.

The report at hand provides the final assessment and recommendations of the EIA team. Opinions and views expressed in the report are the sole responsibility of the EIA team and they are not necessarily those of NySMAC or any other institutions involved in the development of the EIA.

Olav Orheim
Director
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This report has been written and prepared by Dr John Shears of the British Antarctic Survey (BAS) and Dr Fredrik Theisen, Are Bjørdal and Stefan Norris of the Norwegian Polar Institute (NP).

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EXECUTIVE SUMMARY

This report summarises the findings of an Environmental Impact Assessment (EIA) of the Ny-Ålesund international scientific research and monitoring station, Svalbard (78°55'N, 11°56'E).

Background

Ny-Ålesund is one of the most northerly settlements in the world and is situated on Brøggerhalvøya on the southern coast of Kongsfjorden, north-west Spitsbergen. The settlement was built by the Kings Bay Kull Compani (KBKC) A/S in 1917 to support coal mining nearby. Mining stopped in 1962 after a major explosion. Since 1965, the major activity carried out at Ny-Ålesund has been scientific research and monitoring, although cruise ship tourism, commercial shrimp fishing and adventure expeditions also take place in the local area. Scientific research and monitoring has increased substantially at Ny-Ålesund during the last decade, particularly since the station was opened to foreign research institutions in 1990. In 1997, the maximum summer population at the station was about 150 people.

The Norwegian Government policy for the future of Ny-Ålesund is that it should be developed as a leading international scientific research and monitoring station in the Arctic , with priority given to science over other human activities. Also, the Norwegian Government has decided that local human environmental impacts at Ny-Ålesund should be kept at the lowest possible level so as to ensure the protection of nearby undisturbed high arctic ecosystems, and to avoid conflicts with science.

In 1996, the Ny-Ålesund Science Managers Advisory Committee (NySMAC) decided that an EIA should be undertaken for Ny-Ålesund. NySMAC were concerned that the rapid expansion of the station might be causing significant environmental effects and conflicts with important scientific research. The EIA was undertaken by the Norwegian Polar Institute (NP) and the British Antarctic Survey (BAS).

Objectives of the EIA

The objectives of the EIA were to:

i) Examine the impact of human activities on the environment at Ny-Ålesund;

ii) Examine the conflicts between the various activities;

iii) Recommend actions to reduce impacts and conflicts in order to maintain and restore the area as a near pristine site for environmental research and monitoring.

The EIA concentrated on the key environmental issues affecting Ny-Ålesund. These issues were examined in a series of ten specially commissioned technical studies which were undertaken between May 1996 and April 1997, as well as by a specially organised EIA workshop held by NySMAC at Ny-Ålesund on 23 August 1997.

Significant environmental impacts

The results of the EIA show that the current operation of Ny-Ålesund is having a significant impact on the local environment. Environmental impacts identified as having very high significance were damage and destruction of habitat, particularly tundra, from station activities, and the cumulative effects of the increased human "footprint" of the station which is causing fragmentation of habitats and disturbance to wildlife. The total area degraded by human activities has increased by almost 50% in the last decade, from 78 ha in 1986 to 116 ha in 1997. Most of this loss has occurred since 1990.

Other environmental impacts of concern are the widespread disturbance of marine soft sediments and benthic communities in the deeper waters of Kongsfjorden by shrimp trawling, and pollution of the fjord by polycyclic aromatic hydrocarbons (PAHs) leaching from the station rubbish dump and other abandoned dumps nearby. There has also been a significant decline in the species and numbers of waders breeding at Ny-Ålesund since 1981 due to habitat loss as a result of station activities and reindeer overgrazing. Major diesel fuel spills occurred at the station in 1986 (110 m^3) and in 1990 (35 m^3), and contamination of soils from the 1986 spill persists. The potential for further fuel pollution remains high as little has been done to prevent or prepare for possible future spills.

Significant conflicts

There are major conflicts between a number of the activities being undertaken at Ny-Ålesund. The conflict identified as having the highest significance is the serious disturbance to global atmospheric monitoring undertaken at the Zeppelin station because of local air pollution from station operations at Ny-Ålesund and from vessels in Kongsfjorden. At present, around 5% of the atmospheric monitoring data are definitely being influenced by local sources. However, it is impossible to resolve all the episodes of local pollution from the atmospheric data alone and this casts doubt on around 20% of the data. If local air pollution continues to increase then global atmospheric reference measurements taken from the Zeppelin station will become unreliable and this unique site will no longer be able to be used.

Commercial shrimp trawling also causes conflicts with marine scientific research by preventing the deployment of moored instruments, and reduces the value of Kongsfjorden as a scientific research and monitoring site. There is also a potential problem of electromagnetic radiation generated by active emitters (e.g. radars, radio transmitters) at the station interfering with scientific instruments that require a very quiet radio environment (e.g. the Very Long Baseline Interferometry undertaken by the Norwegian Mapping Authority).

Conclusions and recommendations

The EIA has shown that the policy of the Norwegian Government to give priority to scientific research over other activities and to minimise human impacts at Ny-Ålesund has not been properly enforced or implemented. It is concluded that a

The view over Ny-Ålesund and Kongsfjorden from Zeppelinfjellet. Photo: B. Frantzen (NP)

"business-as-usual" approach to the management of Ny-Ålesund is no longer acceptable and comprehensive action needs to be taken to protect scientific research and monitoring and stop further degradation of the local environment.

The EIA recommends a twelve point Environmental Action Plan (EAP) for Ny-Ålesund and prioritises the actions that need to be taken. The twelve recommendations are:

1) Prepare a "mission statement" for Ny-Ålesund.
2) Set a precautionary upper limit on the total activity/numbers of people at the station.
3) Stabilise and reduce local emissions, and stop any open burning.
4) Protect flora and fauna, and revegetate degraded tundra areas.
5) Increase and improve the information provided to all visitors and residents of Ny-Ålesund, giving them guidance as to how they can reduce environmental impacts and minimise conflicts.
6) Incorporate the key results of the EIA into the Land Use Plan for Ny-Ålesund.
7) Prevent fuel spills and establish a station fuel spill contingency and clean-up plan.
8) Improve waste management by closing the rubbish dump at Thiisbukta, and reducing contamination from this dump and others in the Ny-Ålesund local area.
9) Reduce the number and size of tour ships calling at the station.
10) Establish the Kongsfjorden area, including Brøggerhalvøya, as a combined terrestrial and marine "scientific research area".
11) Employ a senior scientific/environmental manager at the station.
12) Introduce stricter controls over activities.

Parts of the EAP, most notably the station "mission statement", have already been agreed and adopted by NySMAC. A wide-ranging environmental monitoring programme is also recommended so that the effectiveness of the EAP can be judged. It is suggested that this programme should include not only the monitoring of key ecosystem indicators (e.g. breeding success of birds), but also monitoring of station environmental performance (e.g. waste production).

If the mitigation measures in the EAP and the monitoring programme are implemented properly by NySMAC and Kings Bay A/S, it is considered that human impacts and conflicts will be reduced to the minimum. The establishment of these environmental management procedures will help Ny-Ålesund to regain, and then enhance, its reputation as a leading scientific research and monitoring station in the Arctic.

1. INTRODUCTION

1.1 Background

Ny-Ålesund is one of the most northerly settlements in the world and is situated on north-west Spitsbergen, the largest island in Svalbard. Today the main role of Ny-Ålesund is as an international arctic scientific research and monitoring station.

Svalbard is located in the high Arctic and is one of the last and largest remaining wilderness regions in Europe (Hansen *et al.*, 1996). The total land area of the archipelago is 63,000 km^2, of which about two thirds is covered by a permanent ice sheet and glaciers. The largest island is Spitsbergen, with an area of approximately 39,000 km^2 (Figure 1).

Ny-Ålesund has been designated by the Norwegian Government as the principal centre for scientific research on Svalbard, and also as a centre for Norwegian Arctic research (White Paper to the Norwegian Parliament No. 42, 1992-93). The aim is to develop Ny-Ålesund as the leading scientific research and monitoring station in the Arctic, where scientists from many different nations and organisations collaborate to undertake high quality research programmes utilising common facilities and infrastructure (see Box 1). Both Norwegian and foreign research organisations have therefore been encouraged to locate in Ny-Ålesund.

At the same time, the Norwegian Government has decided that local human environmental impacts at the settlement should be kept at the lowest possible level. This is to ensure that there is no disturbance to the near pristine high arctic terrestrial and marine ecosystems which surround Ny-Ålesund, and also to protect the scientific research and monitoring which is carried out there.

Ny-Ålesund is a unique arctic research site. The combination of the area's high-latitude position, relatively undisturbed ecosystems, access to foreign scientists, easy accessibility, and well developed scientific facilities and logistical infrastructure have made the station one of the best sites in the Arctic for scientific research.

1.2 Ny-Ålesund international scientific research and monitoring station

Ny-Ålesund was built as a coal mining settlement by the Kings Bay Kull Compani A/S (KBKC) in 1917. The company, renamed Kings Bay A/S in 1998, retains ownership of the buildings at Ny-Ålesund and is responsible for maintaining and developing the site's infrastructure. Coal mining stopped in 1962 after a major explosion at the mines killed 21 people.

Scientific research began at Ny-Ålesund in 1920 when the Norwegian Geophysical Institute operated a small geophysical station at Kvadehuken on Brøggerhalvøya for a year. However, it was not until 1965, when the European Space Research Organisation (ESRO) opened a satellite telemetry station at the settlement, that scientific research began to establish itself as a major activity. In 1968, the Norwegian Polar Institute (NP) established a research station at Ny-Ålesund and the Norwegian Institute for Air Research (NILU) started scientific research in 1977. Scientific activities have increased substantially

The central area of Ny-Ålesund. Photo: J. Shears (BAS)

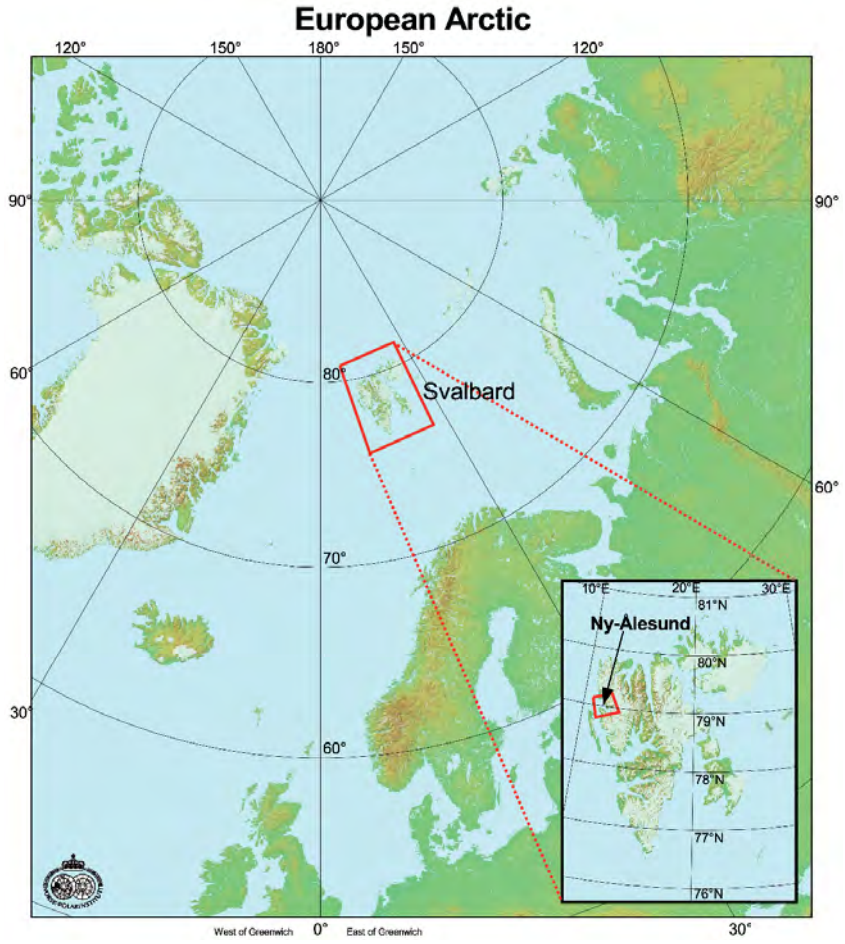


Figure 1. Map of the European Arctic showing the location of Ny-Ålesund.

during the last decade, particularly since Ny-Ålesund was opened up to foreign research institutions in 1990. In 1990 and 1991, the German Alfred Wegener Institute for Polar and Marine Research (AWI), the UK Natural Environment Research Council (NERC) and the Japanese National Institute of Polar Research (NIPR) all established small separate research stations. In 1995, the Norwegian Mapping Authority (NMA) opened a new high precision space geodesy observatory at Ny-Ålesund, and the station as a whole was designated as a European Commission large scale research facility. In 1997, expansion continued with the Italian Consiglio Nazionale delle Ricerche (CNR) opening an atmospheric research laboratory, and the Norwegian Space Centre (NSC) starting operation of a launch facility for scientific sounding-rockets (the Sval-Rak project). The total number of overnight stays spent at the station increased from 16,451 in 1994 to 24,168 in 1997 (Figure 2).

Each year a small number of scientific meetings and courses are held at Ny-Ålesund. For example, each summer a group of Norwegian civil servants and politicians visits the station as part of a special Svalbard course organised by the University of Trondheim and NP.

Although scientific research and associated logistical support is now the major activity at Ny-Ålesund, cruise ship tourism, shrimp fishing and commercial and private adventure expeditions also take place in the area.

The increasing number of scientists from many different countries working at Ny-Ålesund has led to a need for close co-ordination of research activities and associated logistics to prevent conflicts and unnecessary duplication of effort. To answer this need the Ny-Ålesund Science Managers Advisory Committee (NySMAC) was established in 1994. The committee comprises representatives of all the organisations which have permanent research facilities or large research programmes located at Ny-Ålesund.

In 1995, NySMAC became concerned that the rapid expansion of human activity and facilities at Ny-Ålesund might be causing significant environmental effects and conflict with important scientific research (NySMAC, 1995). However, it was clear that there was a serious lack of information regarding human impact on the local environment (Theisen, 1996). The only previous environmental impact study was carried out in summer 1986 (Krzyszowska 1988, 1989). NySMAC therefore approved an Environmental Impact Assessment (EIA) of Ny-Ålesund in early 1996 to determine the current state of the local environment, and the EIA was undertaken by NP on behalf of NySMAC (NySMAC, 1996). This report summarises the findings of the EIA.

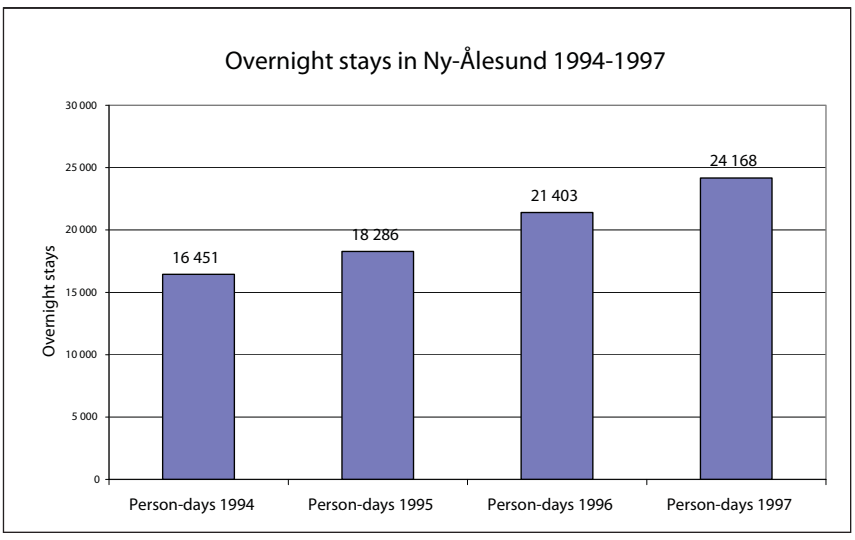


Figure 2. Increase in total number of person-days spent at Ny-Ålesund between 1994 and 1997. Source: KBKC.

Box 1

Norwegian Government policy for the development of Ny-Ålesund

The Svalbard Treaty of 1920 gave Norway sovereignty over Svalbard, and since 1925 the archipelago has been part of the Kingdom of Norway. Signatory countries to the Treaty have equal rights of residence for their nationals and equal rights to exploit the resources of Svalbard. Norway is obliged under the Treaty to ensure the preservation and, if necessary, the reinstatement of the natural environment of the archipelago. The provisions of the Treaty are administered and implemented on Svalbard by the Sysselmannen (Norwegian Governor of Svalbard).

The Norwegian Government's environmental policy for Svalbard is that it shall be one of the best managed wilderness areas in the world, and this requires the protection and maintenance of the archipelago's near pristine environmental and wilderness qualities (White Paper to the Norwegian Parliament No. 22, 1994-95). This policy emphasises the high value of Svalbard's extensive wilderness areas because of their natural beauty and importance for scientific research and monitoring, and as a natural heritage for future generations. The Norwegian Government has therefore decided that it should have high standards of environmental management in Svalbard.

Norway has prepared special environmental regulations for the archipelago - *The Environmental Regulations for Svalbard and Jan Mayen* - to protect both the natural environment and the cultural heritage (Norwegian Ministry of Environment, 1995).

The Norwegian Government put forward its policy for the future development of Ny-Ålesund in White Paper No. 42 to the Norwegian Parliament, 1992-93. This states that Ny-Ålesund is to be developed as an international station for research in the natural sciences, and priority is to be given to research activities which are dependent on the unique qualities of the local area. As a prerequisite for Ny-Ålesund continuing to attract both Norwegian and foreign scientists, the Norwegian Government considers that local human impacts on the environment are to be kept at a very low level. Moreover, science is to be given priority over other human activities at Ny-Ålesund. Other activities must adapt to the requirements set by scientific research and monitoring.

The NP research station, Ny-Ålesund. Photo: A. Brekke (NP)

2. OBJECTIVES OF THE EIA

The overall goal of the Norwegian Government is to make Ny-Ålesund the leading scientific research and monitoring station in the Arctic. To achieve this goal the Norwegian Government recognises that human impacts in the local area must be kept to the lowest possible level so as to ensure the protection of the local near pristine ecosystems and to avoid disturbing scientific research and monitoring.

The objectives of the EIA were therefore to:

i) Examine the impact of human activities on the environment at Ny-Ålesund;

ii) Examine the conflicts between the various activities;

iii) Recommend actions to reduce impacts and conflicts in order to maintain and restore the area as a near pristine site for environmental research and monitoring.

The aim of the recommendations was to set tough, but achievable, objectives and targets based on the precautionary principle.

The boundary of the area examined by the EIA is shown in Figure 3. This extended from Engelskbukta in the south to Kapp Guissez in the north, and included Brøggerhalvøya and Kongsfjorden.

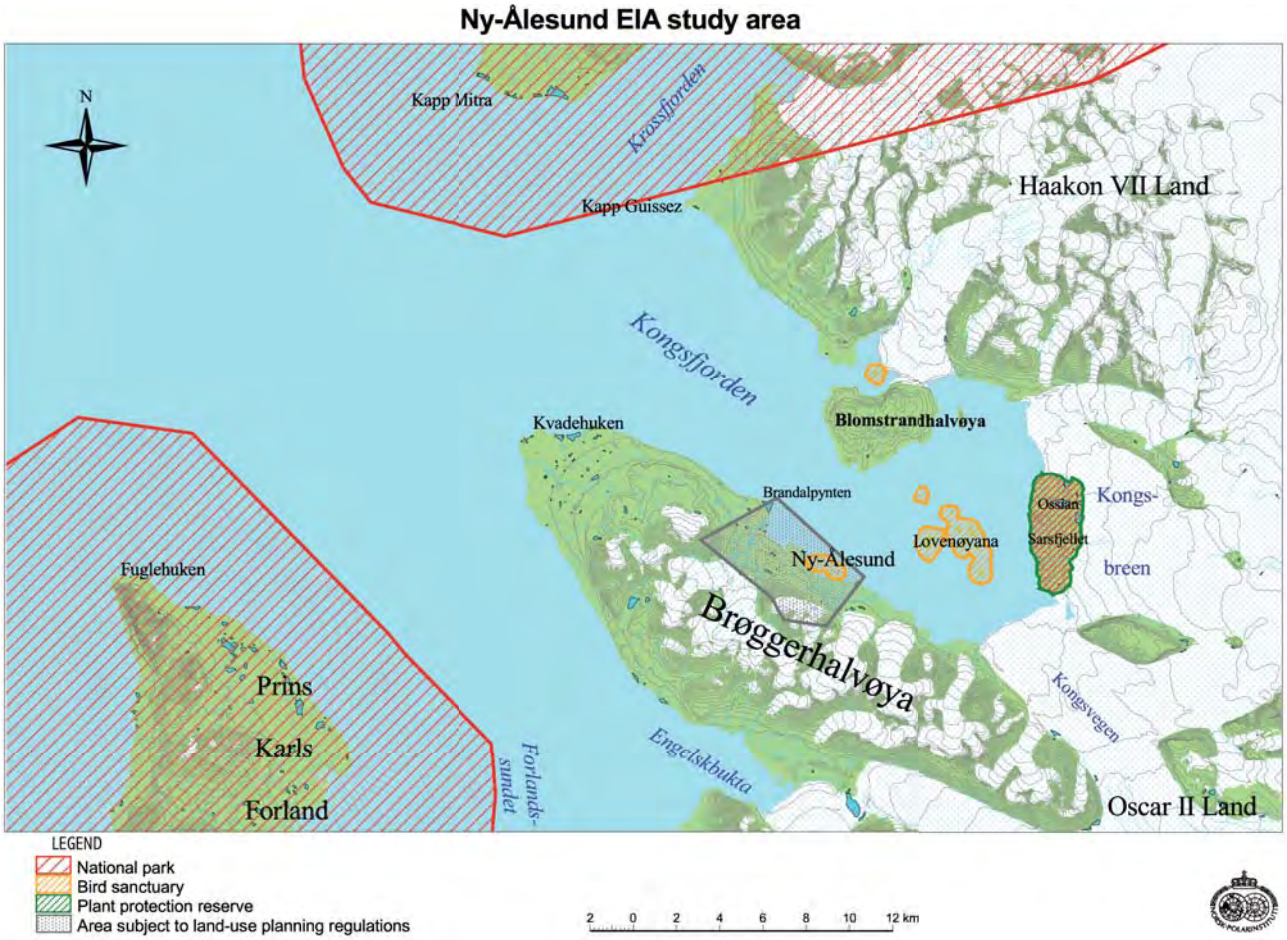


Figure 3. General map of the EIA study area. The boundary of the land use plan area is also shown.

3. METHOD STATEMENT

The concept of the EIA was first discussed by NySMAC at the 2nd NySMAC Meeting on 3 May 1995. The project description for the EIA (Theisen, 1996) was presented by NP to the 4th NySMAC Meeting on 27 February 1996, and at this meeting NP offered to co-ordinate the production of the EIA on behalf of NySMAC. NySMAC agreed to this proposal. At about the same time the EIA project was approved by the KBKC board.

The EIA was managed jointly by NP and the British Antarctic Survey (BAS). The BAS were invited to participate in the project because of their substantial expertise in the environmental management of polar research stations. The EIA was led by Dr Fredrik Theisen (NP) and Dr John Shears (BAS), who together formed the EIA team. The financial costs of the EIA were covered by NP, NILU and KBKC. NP and NILU paid their own costs, and KBKC paid the costs of BAS and the other external consultants involved in the EIA.

From the outset, the EIA team decided that the study should not try to identify every single impact or conflict, but instead would concentrate on the key environmental issues affecting Ny-Ålesund itself, as it was at the station where most of the significant effects were thought to occur. These issues were examined in a series of ten specially commissioned technical studies undertaken between May 1996 and April 1997 (Table 1). Fieldwork was carried out at Ny-Ålesund during July and August 1996, and in August 1997.

3.1 EIA Reference Group

Throughout the EIA there was close and continuous consultation by the EIA team with NySMAC, KBKC and other interested parties to ensure the effective exchange of information. An EIA Reference Group was established and met regularly to determine progress, discuss results and receive comments. The Group comprised representatives from NP, KBKC, NILU, NMA and the Norwegian State Pollution Control Authority (SFT).

3.2 Review of the EIA by NySMAC

The progress of the EIA was also regularly reviewed and assessed by NySMAC. A short progress report on the EIA was submitted to the 5th NySMAC Meeting on 24 August 1996. A full status report was presented to the 6th NySMAC Meeting on 8 April 1997 by the EIA team. As a result of this presentation, NySMAC organised a one-day workshop to discuss the EIA. This was held at Ny-Ålesund on 23 August 1997.

The aim of the NySMAC workshop was to examine the progress of the EIA, assess the results of the technical studies and examine the practical implementation of the recommendations put forward by the EIA team. All NySMAC members and observers were invited to the workshop. A total of 22 people attended from six different countries, representing ten different organisations. The conclusions and the majority of the recommendations from the workshop were subsequently adopted at the 7th NySMAC Meeting on 24 August 1997. The proceedings of the workshop (NySMAC, 1997) were distributed by the NySMAC Secretariat to all the participants on 26 September 1997.

The EIA team prepared the final draft EIA report during November and December 1997. The EIA was presented by NP to the 8th NySMAC Meeting on 4 March 1998 for discussion and comment. The final EIA report was subsequently published on 10 September 1998 both as a printed report and in digital form on the NP Web site on the Internet: http://www.npolar.no/nysmac/.

Table 1. Technical studies undertaken as part of the EIA.

Topic	Title	Author(s)
Waste management	Environmental Impact Assessment of Ny-Ålesund, Svalbard - Waste Management	John Shears (BAS)
Effects of oil spills and traffic	The Effects of Oil Spills and Traffic in the Vicinity of Ny-Ålesund, Svalbard.	Anna Krzyszowska-Waitkus (University of Wyoming)
Fuel spill prevention	Environmental Impact Assessment of Ny-Ålesund, Svalbard: Fuel Spill Prevention and Contingency Planning	John Shears (BAS)
Census of local birdlife	Birdlife at Ny-Ålesund, Summer 1996	Georg Bangjord and Fridtjof Mehlum (NP)
Impacts on local birdlife	The Impact of the Increased Human Activities on the Bird Populations in the Ny-Ålesund Area, Svalbard.	Fridtof Mehlum and Georg Bangjord (NP)
Terrain Vulnerability	Ny-Ålesund, Terrain Vulnerability Map 1:10 000.	Kirsti Høgvard (NP)
Spatial analysis of sensitivity	Environmental Impact Assessment Ny-Ålesund: Spatial Analysis of Sensitivity to Human Impacts.	Fredrik Theisen (NP), John Shears (BAS), Are Bjørdal (NP) and Stefan Norris (NP)
Local air pollution	Local Influences on the Zeppelin Station, Ny-Ålesund, Svalbard.	Harry Beine (NILU)
Energy supply	The Energy System of Ny-Ålesund.	KanEnergi
Conflicts between activities	Environmental Impact Assessment of Ny-Ålesund, Svalbard - Conflicts Between Activities.	John Shears (BAS)

4. DESCRIPTION OF NY-ÅLESUND

4.1 Location

Ny-Ålesund (78°55' N, 11°56' E) is located on Brøggerhalvøya on the southern coast of Kongsfjorden, north-west Spitsbergen. KBKC owns the land and buildings at Ny-Ålesund, as well as about 300 km^2 of land around Kongsfjorden (Figure 3). KBKC is a state owned limited company under the control of the Norwegian Ministry of Commerce and Trade.

The air ship "Norge" at Ny-Ålesund 7 May 1926. Source: Hanoa (1993)

4.2 History

Early activities 1917 - 1962

The early history of Ny-Ålesund is dominated by coal mining (Hanoa, 1993). The Bergen Spitsbergen Kullgrubekompani constructed the first building at the settlement in 1901.

Large-scale coal mining did not start at Ny-Ålesund until KBKC began operations in the summer of 1917 when 143 people were employed. By 1918, coal production had reached 15,000 tons and employed 300 people during the summer. A range of surface facilities were built between 1917 - 1920 to support the mining operations, including a railway, wharf, houses, power station and a hospital. A sketch map of Ny-Ålesund in 1919 is shown in Figure 4. In 1920 - 21, coal began to be mined all year. The population of the settlement reached a maximum in the summer of 1923 when 319 men, 29 women and 8 children were living there. The mines did not reach peak output until 1927 when 98,700 tons were excavated. However, this output was short-lived as the mines quickly became uneconomic and were closed down temporarily in 1929 (Hjelle, 1993).

During the 1920s, Ny-Ålesund became the starting point for a series of expeditions to the North Pole. The Norwegian explorer Roald Amundsen led two of these expeditions. In 1925, Amundsen tried to reach the North Pole using two sea planes, N-24 and N-25, but this attempt failed. In 1926, Amundsen, together with fellow explorers Lincoln Ellsworth and Umberto Nobile, finally reached the North Pole by flying the airship "Norge" from Ny-Ålesund to Nome in Alaska. The mooring mast used by "Norge" still stands to the east of the settlement, although the airship's large hangar has been removed. In 1928, Umberto Nobile returned to Ny-Ålesund in an attempt to fly another airship, "Italia", to the North Pole, but it crashed on the sea-ice north of Svalbard. Several of the expedition members were killed, as was Amundsen in the rescue attempt. However, Nobile survived along with several of his crew and they were eventually found and rescued.

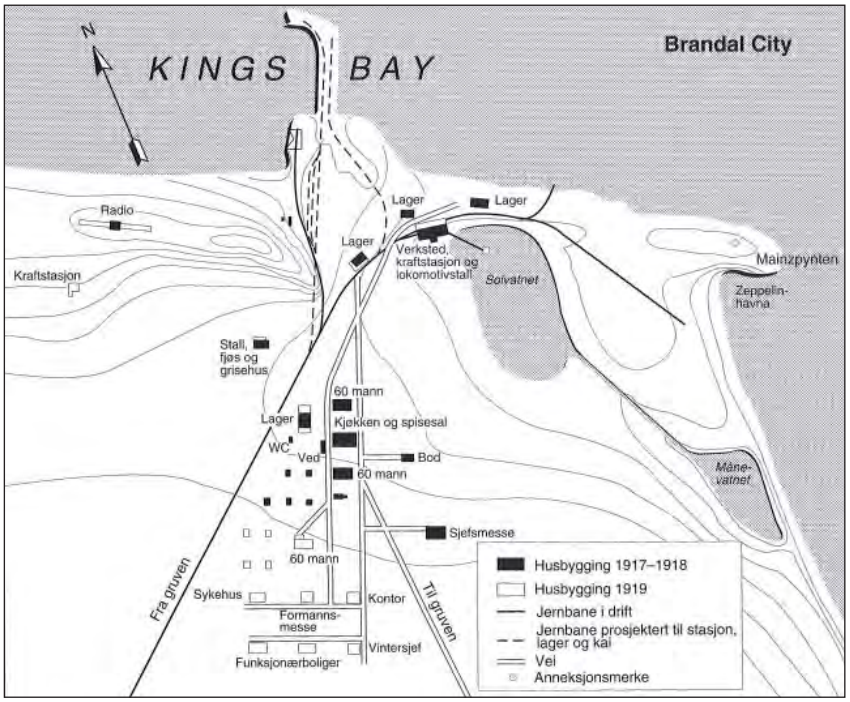


Figure 4. Sketch map of Ny-Ålesund in 1919. Source: Hanoa (1993).

The Norwegian Government took over control of KBKC in 1933. At that time attempts were made to diversify activities at Ny-Ålesund. A fishery station was built in 1935 to support the Norwegian cod fishing fleet, and in 1936 the "North Pole Hotel" ("Nordpolhotellet") was opened. Today the hotel is still in use for accommodation purposes.

In August 1941, Ny-Ålesund was evacuated because of the threat of German invasion and all activities were stopped. The Norwegians living on Svalbard were brought to Britain by the Royal Navy and Canadian

Coal mining at its peak at Ny-Ålesund in 1927. Source: Hanoa (1993).

Armed Forces. The mines and associated facilities at Ny-Ålesund were destroyed and the stockpiles of coal were set on fire to prevent their use by the Germans.

Mining began again at Ny-Ålesund in 1946 when 20,000 tons of coal were produced and a population of 172 people lived at the settlement. Output increased rapidly, reaching 61,000 tons in 1948. However, production never reached the levels of the late 1920s as the mines were hit by a series of major accidents. A map of Ny-Ålesund from 1960 is shown in Figure 5. Mining finally stopped after a major explosion on 5 November 1962 when 21 people died (Hanoa, 1993).

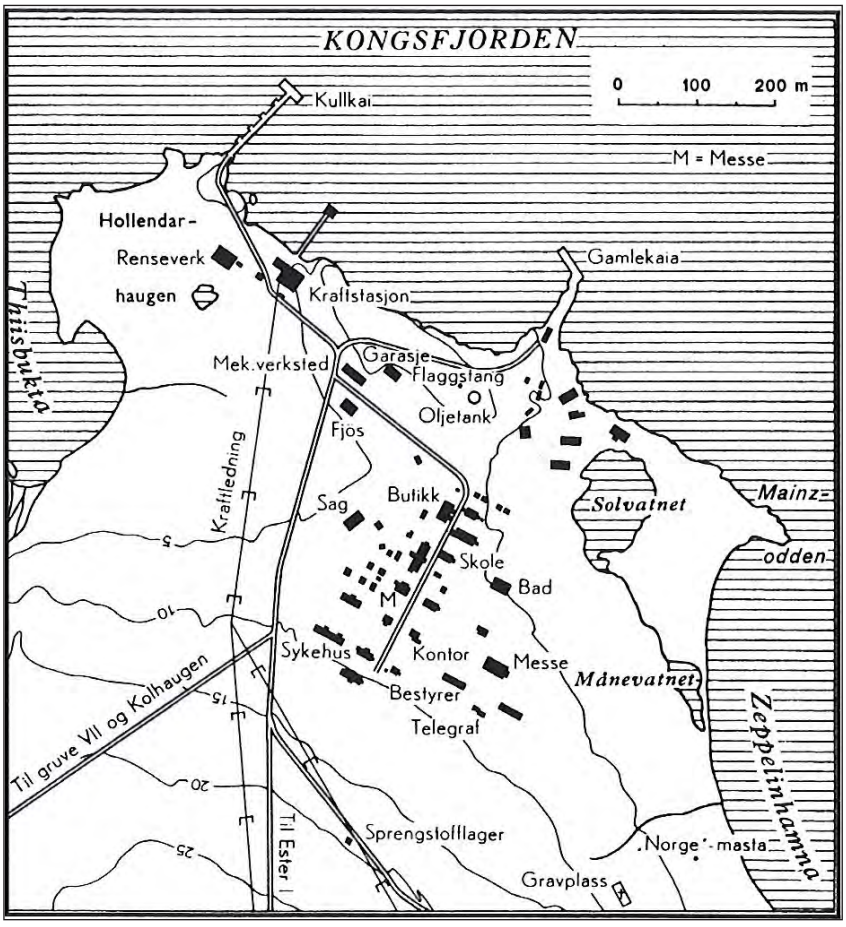


Figure 5. Map of Ny-Ålesund in 1960. Source: Hanoa (1993).

Many of the buildings built during the mining period remain in Ny-Ålesund, including most of the houses, the old wharf, old power station and coal sorting plant. Outside of the settlement there are also coal spoil heaps at the entrances to the mines, as well as the remains of iron and timber scaffolding, the railway system and other associated debris. The houses and other buildings, as well as mine workings, which were built before 1945 are now protected as Cultural Monuments under Norwegian law in Svalbard (see Section 6.3).

Scientific research 1965 - to present

In 1965, ESRO began operating a satellite receiving station at Ny-Ålesund and a gravel airstrip was built to the west of the settlement. In 1971, the British Cambridge Arctic Shelf Programme (CASP) started to use the settlement as a summer base for its geological investigations on Svalbard. Further scientific research activity followed when the Norwegian Government decided that NP should establish a research station at Ny-Ålesund in 1968. The ESRO station closed in 1974, and the small NP research station and the summer geo-

Old coal spoil heaps and mining debris at Ny-Ålesund. Photo: J. Shears (BAS)

logical research carried out by CASP were the only remaining activities, apart from maintenance work which was undertaken by KBKC. In 1975, the maximum summer population of Ny-Ålesund had decreased to only about 30 people (Cox, pers. comm. 1998), and of these only seven people wintered there (Hisdal, 1976).

Since the low point of 1975, scientific research activity at Ny-Ålesund has increased significantly. In 1982, NP moved into a new research station. An atmospheric monitoring station was built at the top of Zeppelinfjellet (460 m a.s.l.) by NP, in co-operation with NILU, in 1989 (Braathen *et al.*, 1990). Foreign research organisations began to open permanent research facilities at Ny-Ålesund in 1990 and this has led to further sustained growth. In 1992, KBKC completed a new wharf capable of taking large vessels and in 1997, the airstrip was enlarged significantly. By 1997, the maximum summer population was about 150 people.

For further information about the history of KBKC and Ny-Ålesund between 1917 - 1992 see Hanoa (1993).

4.3 Present size and scale

Ny-Ålesund is now a major international scientific research and monitoring station. The settlement consists of some 60 separate buildings, of which nearly half are protected as Cultural Monuments. A map of Ny-Ålesund as recorded in 1997 is shown in Figure 6. As well as the modern research laboratories and stations, Ny-Ålesund also has an air facility with an 800 m long gravel airstrip, harbour facility with a 110 m long wharf, power station, bulk fuel tanks, accommodation buildings, administration buildings, shop and post office. The central area of the settlement covers about 25 ha. From the central area roads and other infrastructure facilities extend about 2 km towards the north-west, 1.5 km to the south-west and 1.5 km to the south-east.

4.4 Duration and timing of activities

Currently, Ny-Ålesund is at its busiest during the summer months of July and August, and at peak periods the population can reach a maximum of 150 people. In winter, particularly in December and January, the settlement is much quieter and the population falls to 25, most being employed by KBKC to maintain essential services. Activity is concentrated in the summer months because of the continual sunlight, warmer temperatures and lack of snow, which make scientific fieldwork and construction work much easier. Figure 7 shows the marked difference in the level of activity at Ny-Ålesund between summer and winter, as measured by overnight stays per month for the years 1994 - 1997.

In winter 1997, launches of scientific sounding-rockets began at Ny-Ålesund as part of NSC's Sval-Rak project. This is a new activity. It involves the launching of a maximum of four rockets between November and March every two years. In winter 1997 there were only three launches. The opening of the rocket facility and subsequent launches led to a substantial increase in the number of overnight stays at the station in November 1997 compared to previous years (see Figure 7). Each rocket campaign requires eight people and takes about 21 days. An environmental assessment of the Sval-Rak project was undertaken by Aerospace Corporation (1994). This concluded that it would have no significant effect on the environment because of the small size of the rockets and the relatively infrequent launches.

There are aircraft flights from Longyearbyen to Ny-Ålesund six to seven times a week in July and August,

The NP/NILU atmospheric monitoring station, Zeppelinfjellet. Photo: B. Frantzen (NP)

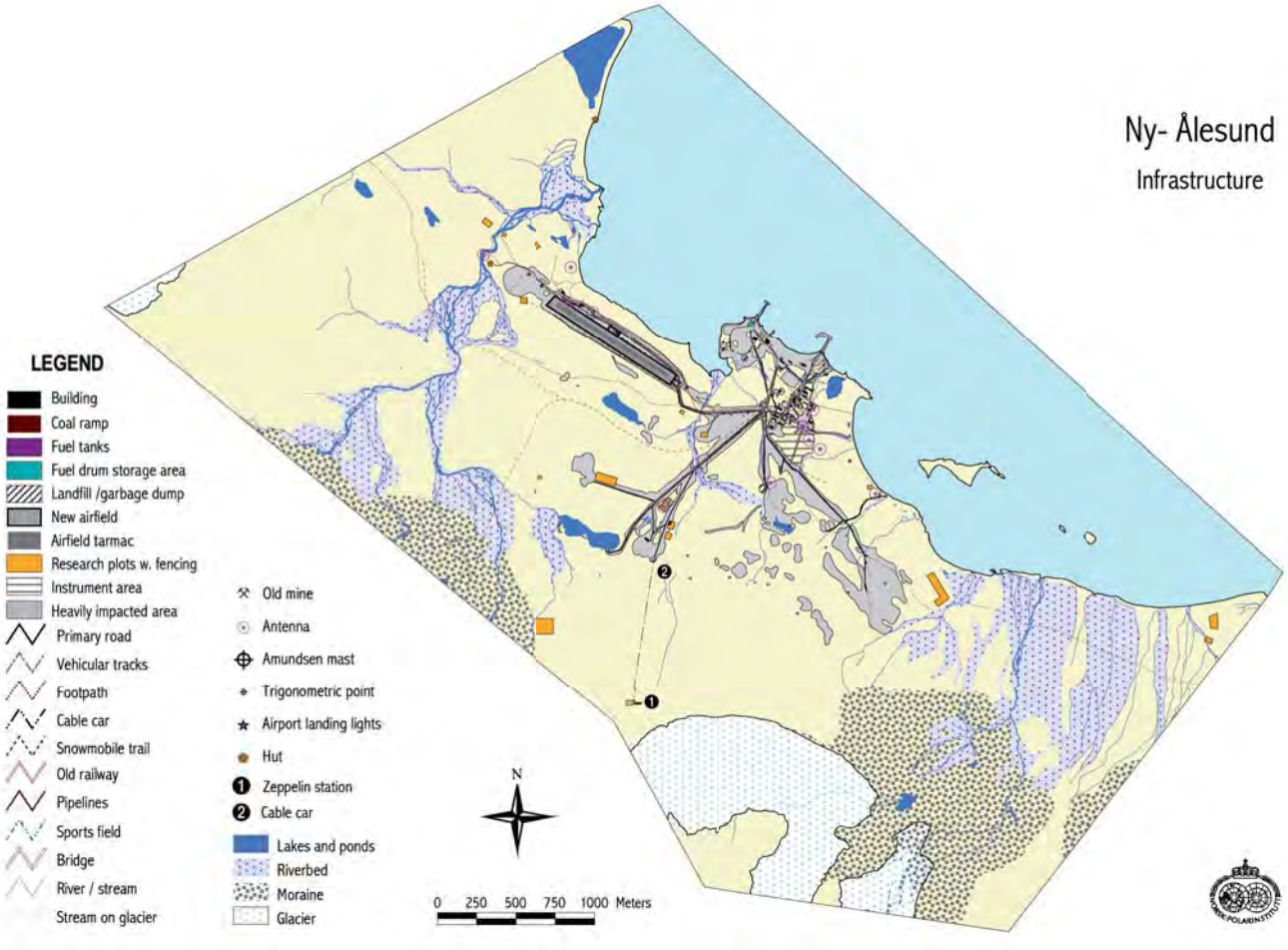


Figure 6 a. Map of Ny-Ålesund in 1997.

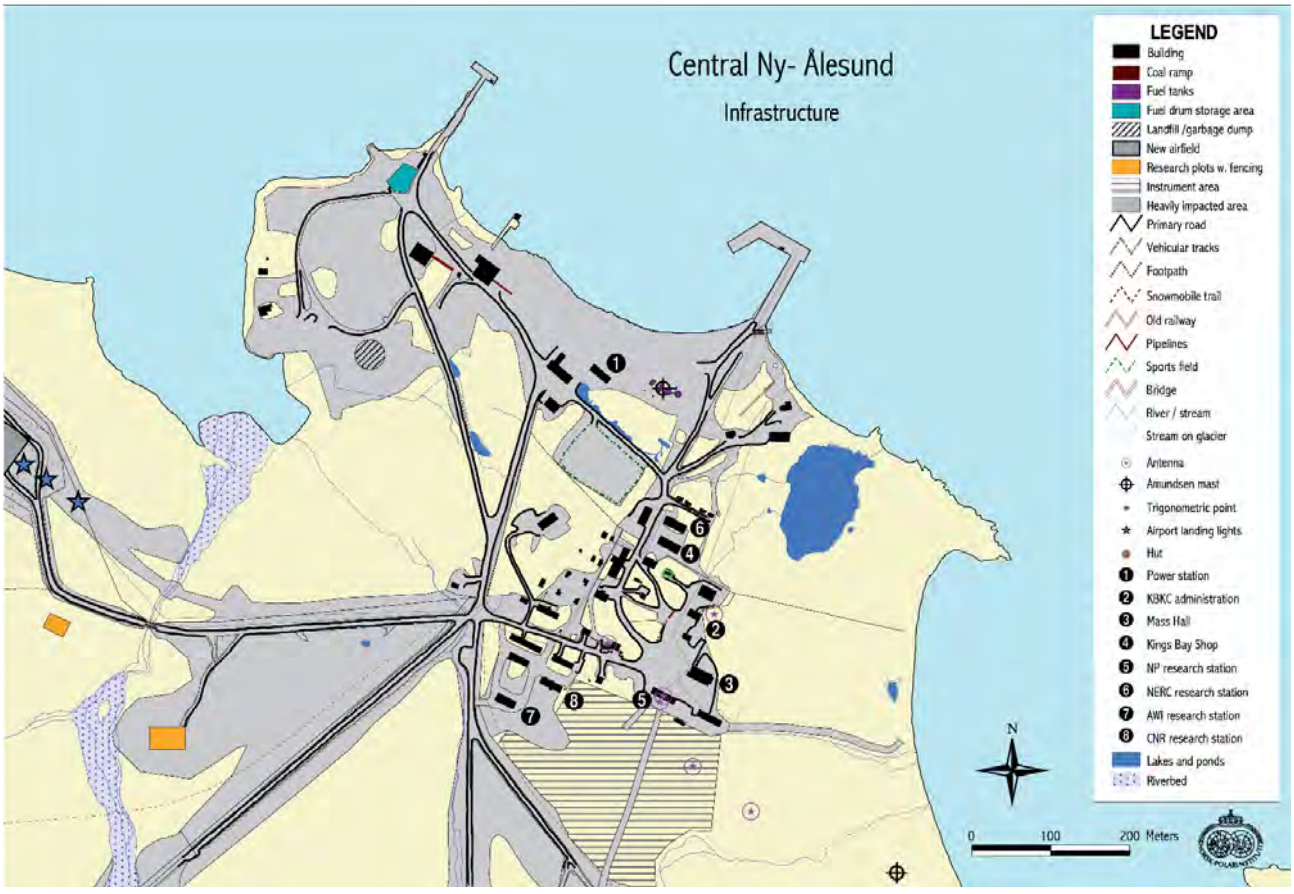


Figure 6 b. Map of Ny-Ålesund in 1997.

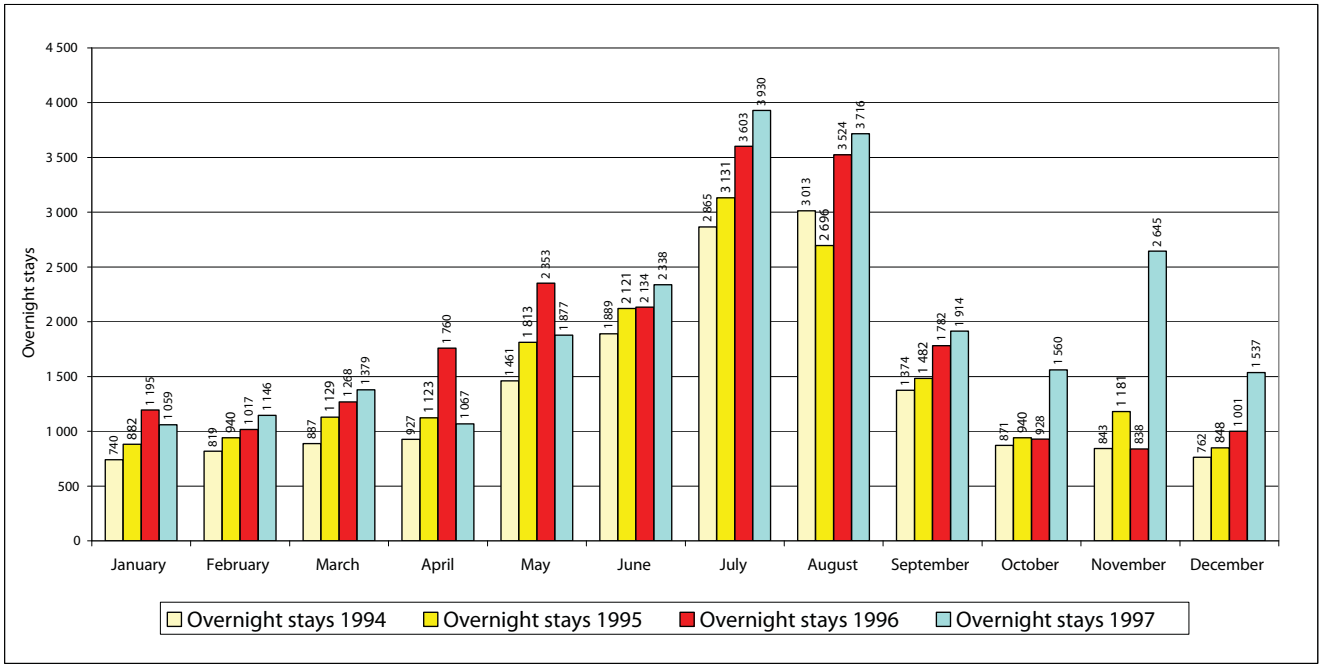


Figure 7. Number of overnight stays per month at Ny-Ålesund for the years 1994 - 1997. Source: KBKC.

and twice a week in May, June and September, and once a week in winter. The aircraft used is an 18 seat Dornier 228-202, which replaced a smaller seven seat Partonavia aircraft in 1994.

In June, July and August the harbour at Ny-Ålesund is usually ice-free and there are frequent ship visits, including regular boat services from Longyearbyen and a weekly boat service from Tromsø. In winter, the accessibility of the harbour is dependent on sea-ice conditions.

There is considerable vehicular activity at Ny-Ålesund all year round, but particularly during summer when the population reaches its annual maximum. In summer 1996, there were 10 heavy vehicles, 5 lorries, 8 pick-ups, 7 vans, 3 motorbikes and 21 snowmobiles at the settlement (Krzyszowska-Waitkus, 1997). This compares to only about 2 lorries, a single VW van and a small number of snowmobiles in 1991 (Cox, pers. comm. 1996).

Large numbers of tourists visit Ny-Ålesund in June, July and August, almost all arriving by cruise ships or on regular boat services. Tour ship passengers usually spend between two to four hours at the settlement. In 1994, over 9,000 passengers were landed at the station (Kaltenborn and Hindrum, 1996), and by 1997 this had increased to over 10,000 (Sjorner, 1997).

Commercial fishing for the deep-water shrimp (*Pandalus borealis*) is undertaken in Kongsfjorden. Up to five fishing boats were reported to have been active in the fjord at any one time during 1996 (Forsberg, pers.

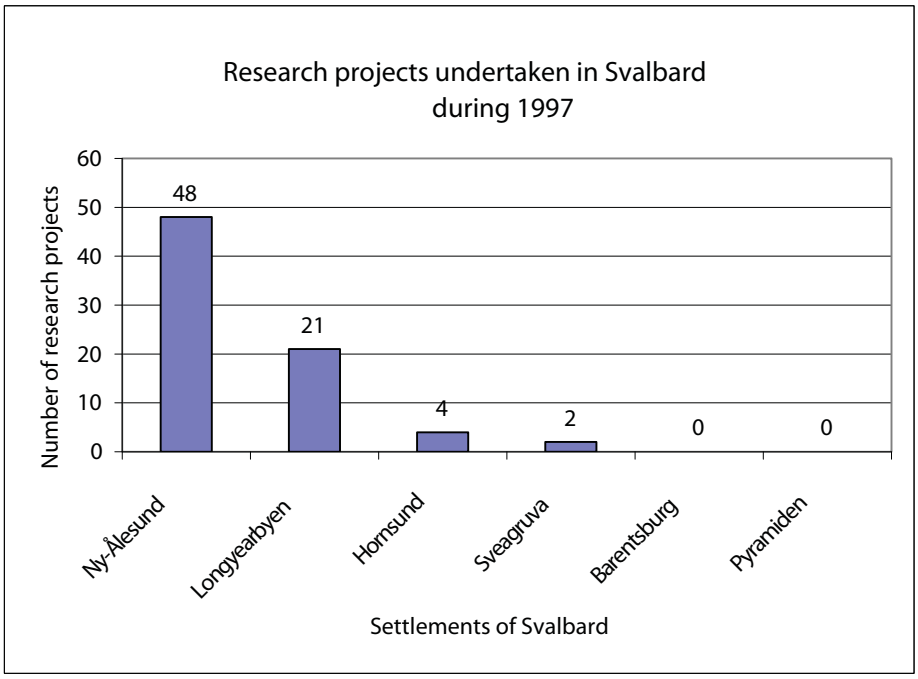


Figure 8. Number of research projects carried out at the six settlements in Svalbard in1997. Source: NP (1997).

comm. 1996). These boats often call at Ny-Ålesund to refuel and pick-up supplies. The highest annual catches were taken between 1985 and 1990 (Hop, pers. comm. 1997). A maximum of 775 tonnes were taken in 1985, and a minimum of only 11 tonnes in 1992.

4.5 Scientific research and monitoring

The station currently has two main scientific objectives. First, it acts as an international observatory for long-term measurements of the physical and biotic environment. Second, it provides laboratory and research facilities for visiting scientists (Prestrud, 1996). Many of the research projects undertaken at Ny-Ålesund are important, long-term studies investigating problems of global relevance, such as climate change, and are being undertaken as part of large international research programmes. These studies are therefore of considerable importance.

At present, NP is notified each year of approximately 150 different scientific projects which are planned for Svalbard, of these about 75 (50%) are carried out in the field away from any settlement, and 50 (33%) are located in Ny-Ålesund (NP, 1997). Figure 8 shows the number of scientific projects carried out during 1997 at the six settlements on West Spitsbergen. Ny-Ålesund had about twice as many projects as all the other five settlements combined. Projects at Ny-Ålesund cover a very wide range of scientific disciplines, including meteorology, geophysics, geodesy, geology, glaciology and biology. Ny-Ålesund is a major international centre for polar auroral studies, geodetic research, climate and atmospheric studies, and the monitoring of the long range atmospheric transport of pollutants.

Launching of monitoring balloons. Photo: B. Frantzen (NP)

Instrument platform on the roof of the NP research station. Photo: J. Shears (NP)

5. DESCRIPTION OF THE ENVIRONMENT

5.1 Climate and atmosphere

The climate at Ny-Ålesund is influenced by the warming effect of the North Atlantic Current flowing along the west coast of Spitsbergen. This brings warm water and raises the average water temperature of the area. Prevailing low pressure fronts bring warmer air from the Atlantic to the Barents Sea which also has a heating effect.

Figure 9 shows the monthly average temperature at Ny-Ålesund. The average temperature in February (the coldest month) is -14° C and in July (usually the warmest month) 5° C. Precipitation is low and is about 400 mm/year (measurements from 1975), and falls mainly as snow in the winter (Førland *et al.*, 1997). Snow usually begins to accumulate at the end of September each year and disappears by mid-June. The sun is continually above the horizon from 18 April to 24 August (the midnight sun), while the polar night lasts from 25 October to 17 February.

Svalbard's remote location means that it is far enough removed from anthropogenic pollution sources (located in Europe, Russia mainly) to permit scientific studies and monitoring of the background air in the high arctic troposphere. The location is unique in that it displays a seasonal cycle of airflow patterns and source regions of air not usually found at other sites in the Arctic. This means that at different times of the year Svalbard can experience either extremely clean background air or polluted air, which has undergone long distance transport from Europe.

5.2 Geology and geomorphology

The underlying geology around Ny-Ålesund consists of sedimentary rocks of Middle and Upper Carboniferous and Permian age (Hjelle, 1993). Reddish mid-Carboniferous sandstones can be found exposed along the coast between Brandalpynten and Kongsfjordneset, and near Brøggerbreen. Permian limestone and dolostone are exposed along the rocky shore east of Kolhamna. Lower Tertiary beds are found in a small area (4.5 km^2) just south and west of Ny-Ålesund (Hjelle, 1993). They consist mostly of sandstones with some scattered conglomerates, but there are also shales and coal seams. Faults cut the coal seams, which cause them to lie at several different levels and they also dip 12 - 35° towards the south-west. To the south and east of Ny-Ålesund pre-Devonian metamorphic rocks occur. These comprise mostly schists, marbles and quartzites.

Ny-Ålesund itself is located on a strandflat. This is a lowland plain, partly covered by marine deposits, carved out by the sea when sea levels were higher than they are today. Near the coast, postglacial marine terraces are common and they contain sand and gravel, with a very small amount of organic material (Orvin, 1934). Soils on Brøggerhalvøya vary considerably in thickness, and humus is generally scarce. On the mountain ridges and plateaus the soils are almost entirely residual deposits. Radiocarbon dates on whale bone and shell fragments found in a soil profile on Brøggerhalvøya show ages between 9,000 - 12,000 years B.P. (Mann *et al.*, 1986).

To the west of Ny-Ålesund at Brandalpynten, and at Kvadehuksletta, there are raised shorelines. The best preserved beach ridges are found at an altitude of 0 - 40 m a.s.l., and were formed during the last 12,000 years. Some ridges at higher levels are known to be considerably older (Hjelle, 1993). Kvadehuksletta also has many excellent examples of periglacial features, including stone-sorted polygons and circles. On slopes there are solifluction stone

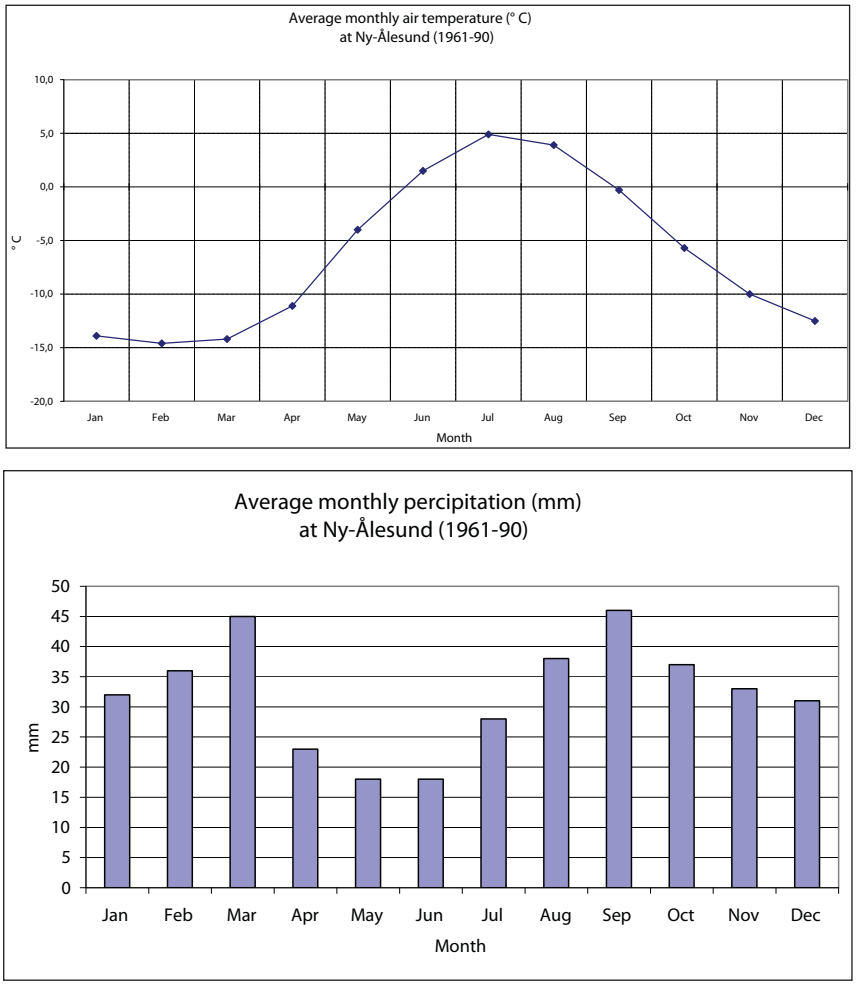


Figure 9. Average monthly air temperature (° C) and precipitation (mm) at Ny-Ålesund. Source: Førland et al. (1997).

Tomentypnum nitens moss tundra at the lake Solvatnet. Photo: F. Theisen (NP)

stripes. The stone-sorted circles are considered to be particularly well developed and are very important for geomorphological research (Sollid, 1995).

5.3 Terrestrial ecosystems

Ny-Ålesund is located within the Middle Arctic Tundra Zone (Elvebakk, 1994). Five major vegetation types surround the settlement: *Tomentypnum nitens* moss-tundra, *Deschampsia alpina* snow bed, *Saxifraga oppositfolia* heath, *Luzula confusa* heath and *Carex rupestris* - *Dryas octopetala* heath. Names used for vegetation types follow Brattbakk (1981).

In low-lying (< 10 m a.s.l.), very wet areas there is peat-producing moss-tundra, dominated by the mosses *Tomentypnum nitens* and *Calliergon richardsonii*. Moss-tundra can be found adjacent to the bay at Thiisbukta and around the lake Solvatnet. These two areas are particularly lush, probably due to fertilisation from human sewage and domestic animal manure during the coal mining period, and contain several grass species, mainly *Poa arctica* and *Festuca vivipara*. In wet areas, or areas that are water-logged early in the summer by melt from snow drifts, there are tundra mires dominated by the tussock grass *Deschampsia alpina*, and the mosses *Scorpidium cossonii*, *Scorpidium revolvens* and *Loeskypnum badium*. On the higher (>10 m a.s.l.), flat terraces above the settlement with an alkaline substrate and moderate winter snow cover there is heath, dominated by the purple saxifrage *Saxifraga oppositifolia*, and the brown fruticose lichen *Cetrariella delisei*. The polar willow *Salix polaris* is also a common species of this vegetation type. Terraces with an acidic substrate and moderate winter snow cover support another type of heath, dominated by the northern wood-rush *Luzula confusa* along with lichens. The final vegetation type is rock sedge *Carex rupestris* - mountain avens *Dryas octopetala* heath. This is found on neutral or calcareous soils on dry or exposed slopes, or other areas where snow melts early in the summer.

One of the most significant insect herbivores is the arctic aphid (*Acyrthosiphon svalbardicum*), which feeds only on mountain avens. Its patchy distribution in the Ny-Ålesund area appears to be due to microclimate and microtopography. Chironomids (Diptera) swarm during July and August. In total, there are some 200 insect species recorded on Svalbard (Sømme, 1979).

5.4 Freshwater ecosystems

The freshwater biota has been little studied at Ny-Ålesund.

Most of the streams are short, and are fed by glaciers during summer. These streams therefore have limited animal life. However, well developed benthic algal communities, including cyanobacteria (blue-green algae), are found in lakes and ponds, such as the lake Solvatnet.

Freshwater ecosystems comprise mostly plankton communities, dominated by diatoms, and zooplankton that feed on them, such as the taxa *Copepoda* and *Daphnia.* Fish are rare or absent. The bottom-dwelling communities are dominated by chironomid midges and other taxa of insects and crustaceans.

The arctic char (*Salvelinus alpinus*) has not been found in any of the lakes or streams on Brøggerhalvøya. However, both migratory and stationary populations of the fish are found to the north of Kongsfjorden in freshwater systems on Kapp Mitra.

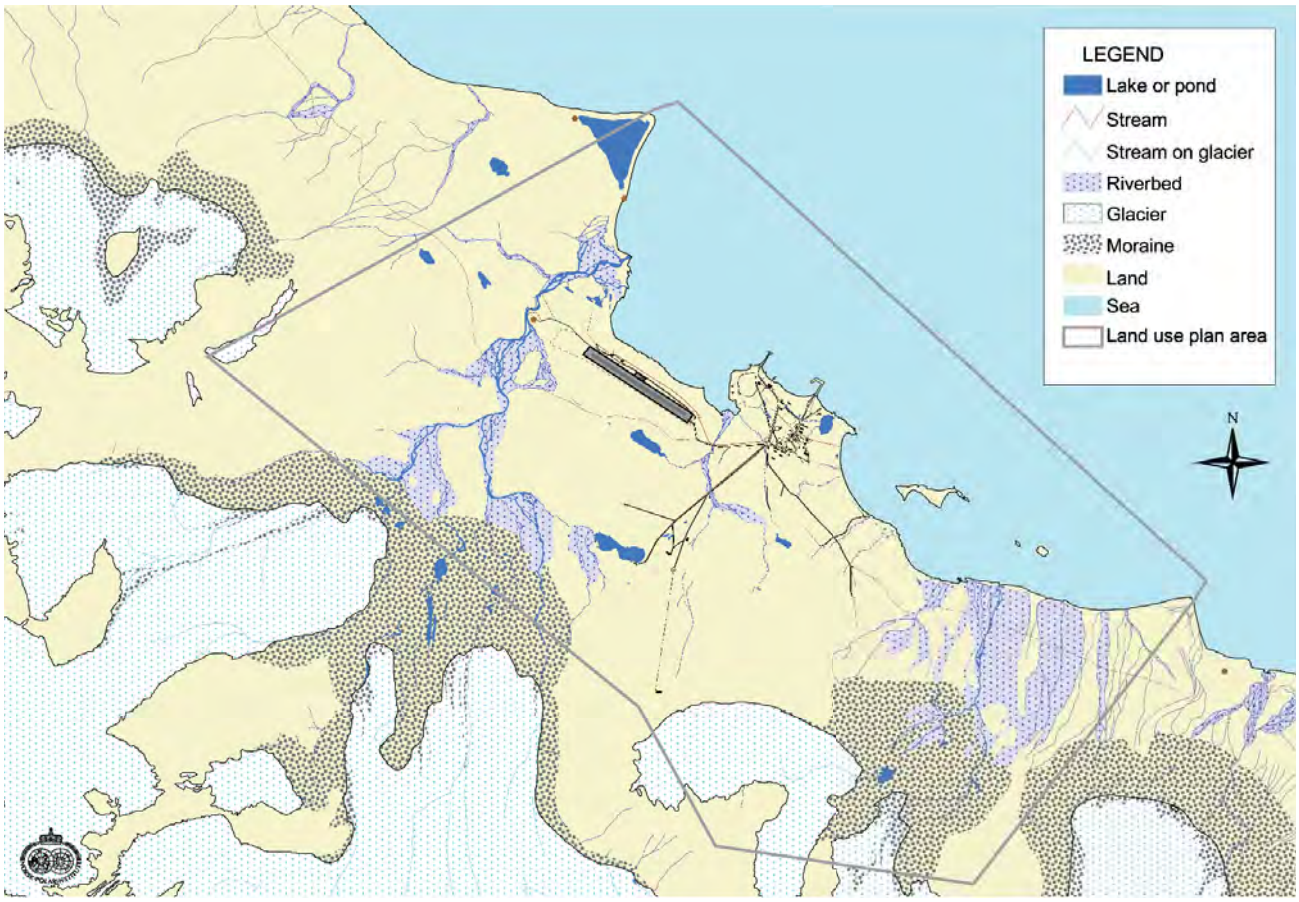


Figure 10. Fresh water systems arround Ny-Ålesund.

Figure 10 shows streams and lakes around the settlement.

5.5 Marine ecosystems

Kongsfjorden is approximately 23 km long and 8 km wide. It has an inner basin, which is separated from the main basin by a shallow sill around the small islands at Lovénøyane. Along most of the length of the fjord water depths vary from 100 - 330 m. Kongsfjorden is usually covered by sea-ice during winter, which usually breaks up at the end of April. Between mid-May and September the fjord is usually ice-free.

There is a strong vertical stratification in Kongsfjorden during the summer with warmer and less saline water contained in the top 20 m (Ushio *et al.*, 1995). Summer sea water temperature ranges up to 4.5°C in the upper surface layer, where the salinity is about 31 - 32 psu. At the bottom of the fjord local cold bottom water (< 0°C) is found, and water exchange at this depth is hampered by the sill around Lovénøyane.

In Kongsfjorden the diversity of the marine communities is low. About 1,200 species of fish and marine invertebrates are found around Svalbard, but only about 200 are found in Kongsfjorden (Hop, pers. comm. 1997). This is because the marine ecology of Kongsfjorden is greatly influenced by glacier ice, sea-ice and the very high deposition of silt and sediment resulting from glacier run-off.

The sea-ice and icebergs in the intertidal and shallow subtidal zones disturb benthic communities by repeated scouring, and larger icebergs can plough several metres into sediments in deeper water down to 60 m. Sediment load from glacier melt water streams entering the fjord is very high. Sediment concentrations in the plume adjacent to the Kongsvegen glacier can reach 300 - 500 mg/l (Elverhøi *et al.*, 1980), decreasing to 1 - 5 mg/l in the central and outer parts of the fjord (Elverhøi *et al.*, 1983). A 5 - 20 m layer of muddy and sandy sediments covers the bottom of the fjord.

In the intertidal zone of Kongsfjorden exposed rocky shores are low in biodiversity because of ice scouring (Hansen and Haugen, 1989). They are dominated by the bright green filmy algae *Ulothrix* spp. and *Urospora pencilliformis*. Dwarf individuals of the brown algae *Fucus distichus* and *Pilayella littoralis* can be found in crevices and sheltering under rocks.

The subtidal areas from a depth of about 5 - 30 m where there is hard substrate, support dense and rich macroalgae communities. At the most exposed sites, such as Kapp Mitra, Kapp Guissez and Hansneset there are large kelp forests of the brown algae *Alaria esculenta* and *Laminaria* spp. In the inner sheltered part of the fjord, and on soft substrates, the diversity of algae is lower, and the algal zone rarely extends below 10 m.

The benthic fauna associated with hard substrates is relatively rich, particularly in the more exposed areas in the outer fjord. Here, decorator crabs (*Hyas araneus*), whelks (*Buccinum undatum*), sea urchins (*Strongylocentrotus droebakiensis*), sea anemones and seastars can all be found, as well as more than 50 species of bryozoans. There are rich communities of sea anemones and sponges on the rock walls around Kvadehuken,

making this a very valuable scientific research area and an attractive dive site.

Sheltered intertidal mud and sandflats in the middle and outer parts of Kongsfjorden support substantial infauna populations. Ambrose and Leinaas (1988) found infaunal densities as high as 8,500 - 9,500 individuals/m^2 at Thiisbukta.

Subtidal soft sediments in Kongsfjorden are increasingly dominated by infaunal deposit-feeders, such as *Chaetozone/Tharyx* sp., *Scolopos armiger* and *Capitella capitata*, with decreasing distance from glacier meltwater sources. Biomass is low because of the high sedimentation rates, particularly near the glacier fronts. Biomass in the outer and middle part of the fjord can be greater than 100 g/m^2, but less than 10 g/m^2 near the glaciers (Hop, pers. comm. 1997). However, there is relatively high faunal abundance. The fauna in the deeper part of the fjord is dominated by molluscs, crustaceans and polychaetes. The shrimp (*Pandalus borealis*) is the most abundant crustacean in deep water (> 150 m depth), but other shrimp species (e.g. *Sclerocrangon* spp.) are also found.

There are 15 - 20 fish species in Kongsfjorden (Hop, pers. comm. 1997). In shallow areas (< 20 m depth) the most abundant species are sculpins (*Gymnacanthis tricuspis*, *Myxocephalus scorpius*), lumpsuckers (*Eumicrotremus derjugini*) and snailfishes (*Liparis liparis*). In some of the rocky areas in the middle and outer part of the fjord there are wolf fish (*Anarhichas lupus*) and Atlantic cod (*Gadus morhua*). The most abundant pelagic fish species in the fjord is the polar cod (*Boreogadus saida*), and capelin (*Mallotus villosus*) may be present in warm years. In deep water there is a diverse community of benthic fish, including large species such as Atlantic cod, Greenland halibut (*Reinhardtius hippoglossoides*) and American plaice (*Hippoglossoides platessoides*).

Benthic fish in shallow water are prey for diving birds, such as terns. In deeper water, fish are taken by bearded seals (*Erignathus barbatus*), and by whales which enter the fjord, but the predation pressure is probably low (Hop, pers. comm. 1997).

5.6 Birds

A major survey of the bird populations at Ny-Ålesund was undertaken by Mehlum and Bangjord (1997) as part of the EIA. This showed that there are 27 breeding species found within Brøggerhalvøya and Kongsfjorden, of which 16 have been recorded as breeding at some time within the Ny-Ålesund settlement area (Table 2). The only bird that over-winters on Brøggerhalvøya is the Svalbard ptarmigan (*Logopus mutus hyperboreus*). The others are all summer visitors.

The most numerous breeding bird in Kongsfjorden is the kittiwake (*Rissa tridactyla*), although none nest at Ny-Ålesund. Birds recorded as breeding in the Ny-Ålesund settlement area in 1996 were: the common eider (*Somateria mollissima*), arctic tern (*Sterna paradisaea*), barnacle goose (*Branta leucopsis*), long-tailed duck (*Clangula hyemalis*), grey phalarope (*Phalaropus lobatus*) and red-throated diver (*Gavia stellata*) (Mehlum and Bangjord, 1997). The locations of the major bird breeding colonies in Kongsfjorden are shown in Figure 11.

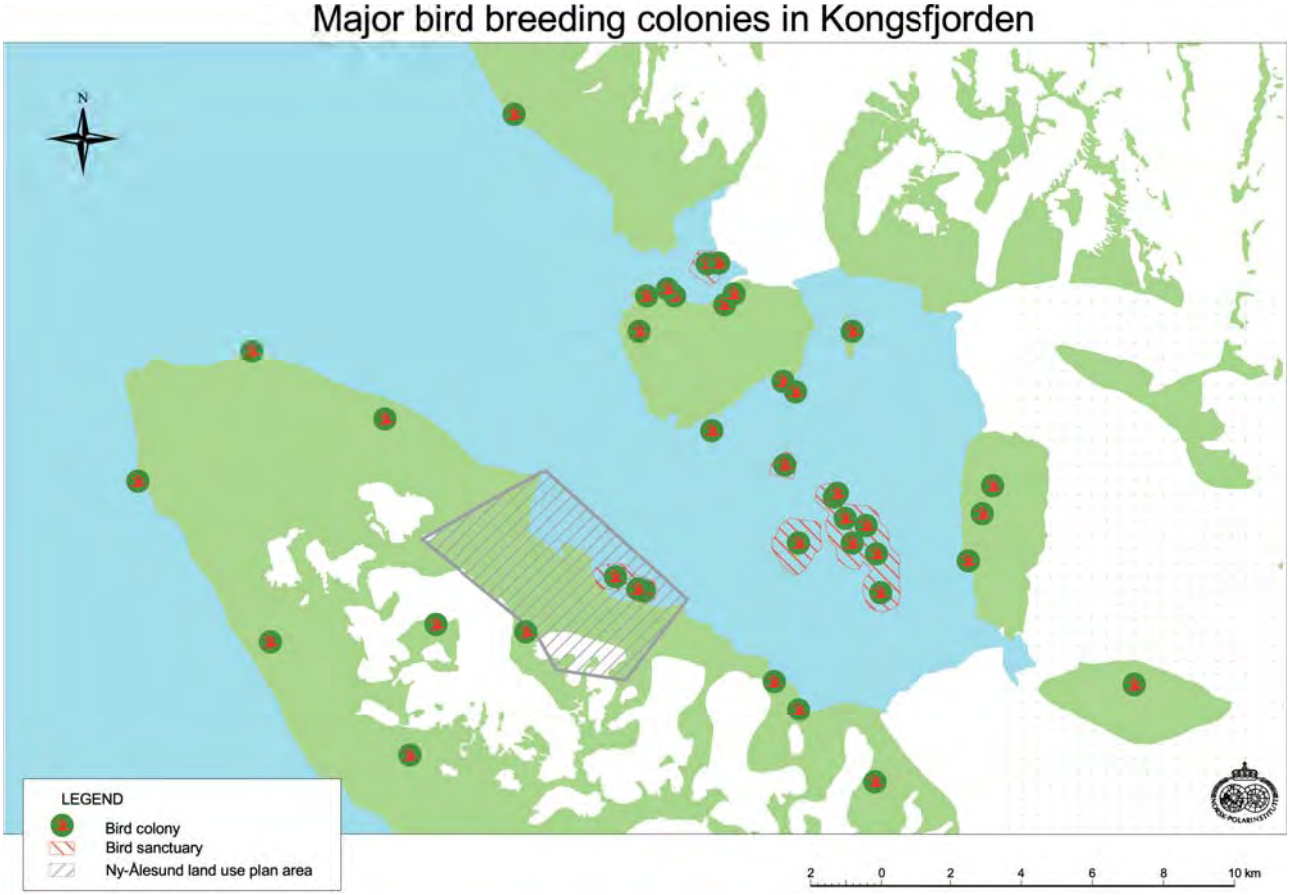


Figure 11. Map of the major seabird breeding colonies in Kongsfjorden.

Cliff-nesting seabirds

The kittiwake has a total estimated population of over 4,100 pairs in Kongsfjorden (Mehlum and Bangjord, 1997). Numbers of these birds appear to have increased over recent years. The largest colony of kittiwakes nests on the cliffs at Ossian Sarsfjellet. Other seabirds nesting at this site are fulmars (*Fulmarus glacialis*), Brünnich's guillemots (*Uria lomvia*), puffins (*Fratercula arctica*), little auks (*Alle alle*), black guillemots (*Cepphus grylle*) and glaucous gulls (*Larus hyperboreus*). Most of these bird species feed in waters outside of Kongsfjorden, but black guillemots and glaucous gulls feed mainly within the fjord. There are no cliff-nesting seabird colonies at Ny-Ålesund.

Common eider

Within Kongsfjorden the most numerous breeding species of waterfowl is the common eider, with a total estimated population of 4,000 breeding pairs. Numbers have increased over recent years, although there are large variations between years (Mehlum and Bangjord, 1997). The largest breeding colony is on the island of Storholmen. The common eider prefers to nest on low-lying islands in Kongsfjorden rather than on the mainland so that it can escape predation by the arctic fox (*Alopex lagopus*). Eiders also nest within the Ny-Ålesund settlement area, with 40 pairs breeding there in 1996. Eiders are one of the primary consumers in the marine ecosystem of Kongsfjorden and feed on various benthic animals, particularly mussels, as well as small crustaceans in the intertidal zone.

Nesting common eider. Photo: B. Frantzen (NP)

Table 2. List of birds that have been recorded as breeding in the EIA study area. Source: Mehlum and Bangjord (1997).

English/Latin names	Inner area	Outer area
Fulmar *Fulmarus glacialis*		x
Red-throated diver *Gavia stellata*	X	x
Common eider *Somateria mollissima*	X	x
Long-tailed duck *Clangula hyemalis*	X	x
Arctic skua *Stercorarius parasiticus*	X	x
Great skua *S. skua*		x
Long-tailed skua *S. longicaudus*		x
Glaucous gull *Larus hyperboreus*	X	x
Greater black-backed gull *L. marinus*		x
Kittiwake *Rissa tridactyla*		x
Arctic tern *Sterna paradisaea*	X	x
Brünnich's guillemot *Uria lomvia*		x
Black guillemot *Cepphus grylle*		x
Little auk *Alle alle*		x
Puffin *Fratercula arctica*		x
Pink-footed goose *Anser brachyrhynchus*	X	x
Barnacle goose *Branta leucopsis*	X	x
Svalbard ptarmigan *Lagopus mutus*		x
Ringed plover *Charadrius hiaticula*	X	x
Sanderling *Calidris alba*	X	x
Purple sandpiper *C. maritima*	X	x
Dunlin *C. alpina*	X	x
Turnstone *Arenaria interpres*	X	x
Red-necked phalarope *Phalaropus lobatus*	X	x
Grey phalarope *P. fulicarius*	X	x
Wheatear *Oenanthe oenanthe*		x
Snow bunting *Plectrophenax nivalis*	X	x
Total number of species	**16**	**27**

Arctic tern

At Ny-Ålesund itself the most common breeding bird is the arctic tern. The tern colony at the settlement has increased from some 80 pairs in 1967 (Bengtson, 1971), to about 300 pairs in 1981 and 1982 (Meltofte *et al.*, 1982), and to 366 pairs in 1996 (Mehlum and Bangjord, 1997). The colony is widely dispersed around Ny-Ålesund, with some birds nesting within a metre of buildings, footpaths or roads. The main predators of the arctic tern are the arctic fox, glaucous gull and the arctic skua (*Stercorarius parasiticus*). Arctic terns are highly aggressive towards predators, and people, who venture too near nests or chicks. At Ny-Ålesund, the terns provide protection for other ground-nesting birds, such as eiders, long-tailed ducks and several species of waders. Terns feed on fish, mostly sculpins and juvenile polar cod, and various crustaceans (Mehlum, 1990).

Waders

Waders are particularly common in the Kongsfjorden area compared to other parts of Svalbard. However, since 1981 there has been a significant decline in the numbers of most of the breeding species (Table 3). For example, grey phalarope breeding pairs have declined from 20 - 25 pairs in 1981 to 4 -5 pairs in 1996. Mehlum and Bangjord (1997) have suggested that the major reason for this decline is nest habitat loss. This has occurred because of overgrazing by reindeer, and physical destruction of habitat through the construction of new buildings, roads and pipelines at the settlement. The loss of vegetation within the station area may have benefited the arctic tern population and thus explain its population increase. Terns prefer to nest in open terrain

Grey phalarope. Photo: B. Frantzen (NP)

on bare, dry gravel, rather than in the tussocks of *Deschampsia alpina* preferred by many waders.

Barnacle goose

A relatively new breeding bird species in Kongsfjorden is the barnacle goose. The first record of a breeding pair of barnacle geese is from 1980 (Mehlum, pers. comm. 1997). Since then the breeding population within the fjord has increased rapidly from an estimated population of 180 birds in 1989 to 783 birds in 1997 (Loonen, 1997). The geese usually breed on the islands in Kongsfjorden, although in years without arctic foxes some nests have been found in Ny-Ålesund (maximum 22 nests in 1991). After the eggs have hatched, most geese leave the islands and move to the mainland to graze. The largest concentration in Kongsfjorden of both goose families and adults without goslings is around and within Ny-Ålesund, and these geese form a loose population of about 650 birds. The lake Solvatnet and the moss-tundra around Thiisbukta are the most important feeding and roosting areas. Here the geese prefer to graze on the grass *Poa alpina* protruding out of the moss carpet. The group of barnacle geese which summer at Ny-Ålesund are unique as they are used to the presence of people, and this enables detailed scientific observations of the birds to be made at very close quarters without disturbance. The geese normally feed within the settlement in the evening and at night when human activity is low and most people are asleep (Mehlum and Bangjord, 1997). During these times they will graze between buildings and at roadsides.

Barnacle goose. Photo: B. Frantzen (NP)

Table 3. Changes in the numbers of birds breeding around Ny-Ålesund between 1981 and 1996. Numbers represent breeding pairs. ( ) = pairs breeding within the settlement itself. Blank boxes = no data available. Source: Mehlum and Bangjord (1997).

English/Latin names	1981	1982	1987	1995	1996
Red-throated diver *Gavia stellata*	(1)	(1)		(1)	3 (1)
Common eider *Somateria mollissima*					ca. 100 (40)
Log-tailed duck *Clangula hyemalis*	(6)				16 (6)
Pink-footed goose *Anser brachyrhynchus*		(2)		0	0
Barnacle goose *Branta leucopsis*					7
Svalbard ptarmigan *Lagopus mutus*					
Ringed plover *Charadrius hiaticula*	4-5	2-3		0	1
Sanderling *Calidris alba*	0	0			3?
Purple sandpiper *C. maritima*	13-14	13-15	6		3
Dunlin *C. alpina*	(1)	(2)		0?	0
Turnstone *Arenaria interpres*	3-5	3		0	0
Red-necked phalarope *Phalaropus lobatus*	(1-2)	(1-2)		0	0
Grey phalarope *P. fulicarius*	(20-25)	(15-20)		(0-1)	(4-5)
Arctic skua *Stercorarius parasiticus*			6		6
Glaucous gull *Larus hyperboreus*			2		1
Arctic tern *Sterna paradisaea*	(300)	(300)			(366)
Snow bunting *Plectrophenax nivalis*					

Long-tailed duck

A small number of long-tailed ducks breed at Ny-Ålesund. Mehlum and Bangjord (1997) recorded six pairs breeding in the settlement area in 1996. All were nesting adjacent to breeding Aarctic terns. Male long-tailed ducks are known to be highly territorial and return to the same area to breed every year. Thiisbukta and the coastline around Solvatnet are important local feeding areas for long-tailed ducks, where they prey on mussels and crustaceans.

Red-throated diver

A single pair of red-throated divers (*Gavia stellata*) breed at Ny-Ålesund (Mehlum and Bangjord, 1997). They nest at the freshwater lake at Solvatnet, and the same pair return year after year.

Figure 12 shows the most important breeding, feeding and resting areas for birds around Ny-Ålesund.

5.7 Terrestrial mammals

Svalbard reindeer

In 1978, after an absence of about 100 years, NP reintroduced 15 Svalbard reindeer (*Rangifer tarandus platyrhynchus*) to Brøggerhalvøya. The fifteen reindeer comprised six males and nine females. By 1989 the population had rapidly increased to 200 animals (Staaland *et al.*, 1991), and by 1993 to about 360 (Øritsland, 1996). However, the population crashed in winter 1993 because of unusual weather conditions. Ice covered the ground surface and prevented reindeer from feeding. This, combined with heavy grazing pressure, meant reindeer could not find enough to eat and many animals starved or moved out of the area. The population fell to only 78 animals in 1994 and to 65 animals in 1996 (Øritsland, pers. comm. 1997).

Reindeer grazing has changed the plant composition on Brøggerhalvøya significantly. There has been

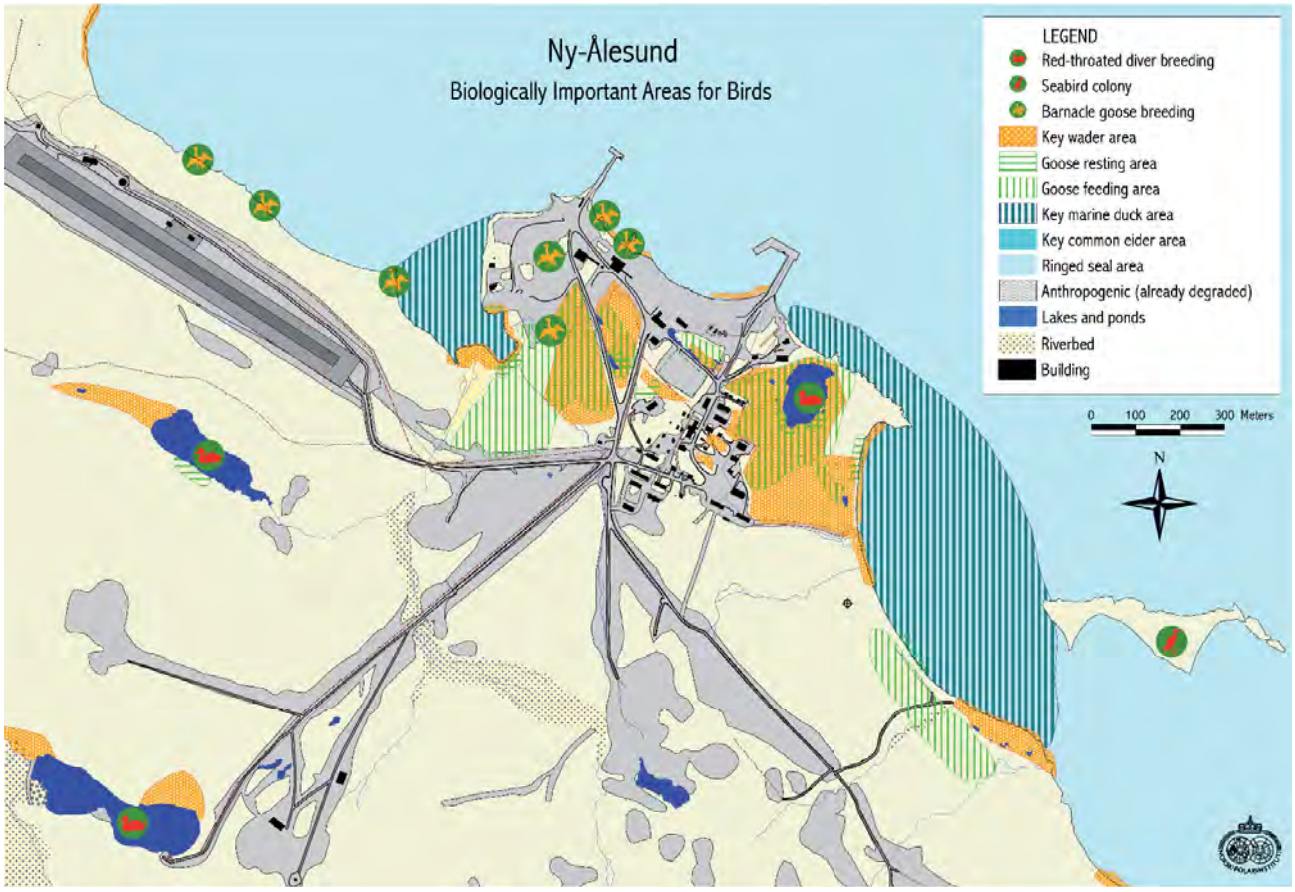


Figure 12. Important breeding, feeding and resting areas for birds around Ny-Ålesund.

a decrease in coverage of vascular plants and lichens which the reindeer prefer to mosses. In particular, highly preferred species such as tussock grass *Deschampsia alpina* and the lichens *Cetraria nivalis* and *Cladonia mitis* have almost disappeared. Tussocks of *Deschampsia alpina* are the main nest habitat of phalaropes and other waders (Mehlum and Bangjord, 1997).

Male reindeer often graze within the Ny-Ålesund settlement area, usually at night or in the early morning, when most people are asleep. In summer 1996 up to five male reindeer were observed in the settlement at one time.

Svalbard reindeer grazing in Ny-Ålesund. Photo: F. Theisen (NP)

Arctic fox

The arctic fox (*Alopex lagopus*) breeds on Brøggerhalvøya and can sometimes be seen in and around Ny-Ålesund. Dens are located in rock screes, usually near bird colonies where foxes prey on eggs and chicks. In years when there are large numbers of arctic foxes there can be heavy predation of seabirds, eiders and geese. For example in 1993, foxes took 91 of the 141 barnacle goslings (65%) which had hatched in Kongsfjorden that summer (Mehlum and Bangjord, 1997).

5.8 Marine mammals

Seals

Ringed seals (*Phoca hispida*) are by far the most common seal in Kongsfjorden, and are found there all year round (Gjertz, 1996). They live mainly on pelagic organisms and under-ice fauna, mainly small crustaceans and shrimps, as well as polar cod and other small fish. They can be found near fast ice or heavy pack ice where they maintain breathing holes, and haul-out lairs in the snow beside these holes. These lairs offer the seals protection from predators and cold, and pups are usually born in them. Adult ringed seals are territorial and return to the same breeding sites each year. Lydersen and Gjertz (1986) found 90 lairs in Kongsfjorden in spring 1984, all of which were located on fast ice in the inner part of the fjord, to the west of the Lovénøyane islands, and immediately east of the Kongsvegen and Conwaybreen glacier fronts (see Figure 13). The major predator of ringed seal pups in Kongsfjorden is the arctic fox. Lydersen and Gjertz (1986) found that foxes had attacked 19 of the 90 lairs they found, and six of these had resulted in a seal pup being killed. In comparison, polar bears (*Ursus maritimus*) had attacked 13 lairs with only one successful kill.

Bearded seals (*Erignathus barbatus*) are not as abundant as ringed seals in Kongsfjorden, but are the second most common seal and are also found year round (Gjertz, 1996). They are mainly benthic feeders preying on clams, shrimps, crabs and benthic fish. They avoid areas of fast ice, and can usually be found hauled out on relatively small ice floes (< 50 m

Ringed seal hauled out on an ice floe in Kongsfjorden. Photo: B. Frantzen (NP)

length) in the mid and outer parts of the fjord where they also give birth to their pups.

In the outer parts of Kongsfjorden, notably at Kvadehuken and Blomstrandhamna, there are small colonies of harbour seals (*Phoca vitulina*) (Gjertz, 1996). This is the least common seal species found on Svalbard. It is predominately found off the west coast of Prins Karls Forland, where most of the pupping is believed to occur in late June.

Walruses (*Odobenus rosmarus*) are not common, but are regularly encountered in the outer parts of Kongsfjorden, as are migrating harp seals (*Phoca groenlandica*) (Gjertz, 1996).

Whales

The most common species found in Kongsfjorden is the white whale (*Delphinapterus leucas*) (Gjertz, 1996). It feeds on polar cod, squid and benthic crustaceans. Between May and July each year large pods of white whales can be found in the fjord, often in shallow fresh water near the glacier fronts. Fin whales (*Balaenoptera physalus*) and minke whales (*Balaenoptera acutorostrata*) are both regularly observed in Kongsfjorden. Both species migrate into the seas and fjords around Svalbard during summer where they feed primarily on small crustaceans and a variety of fish. Killer whales (*Orcinus orca*) and white-beaked dolphins (*Lagenorhynchus albirostris*) are also sometimes seen.

Polar bear

Polar bears (*Ursus maritimus*) are not uncommon visitors to Kongsfjorden, particularly in spring. Lone bears have been observed wandering through Ny-Ålesund. The polar bears prey mostly on ringed and bearded seals that they catch on the ice, particularly in areas of moving pack ice and along the edge of the fast ice. However, Kongsfjorden is not regarded as important polar bear habitat and no bears are believed to breed in the area. They bears probably come ashore when the polar pack ice drifts into the fjord, and after a short stay they are thought to migrate to the north or east.

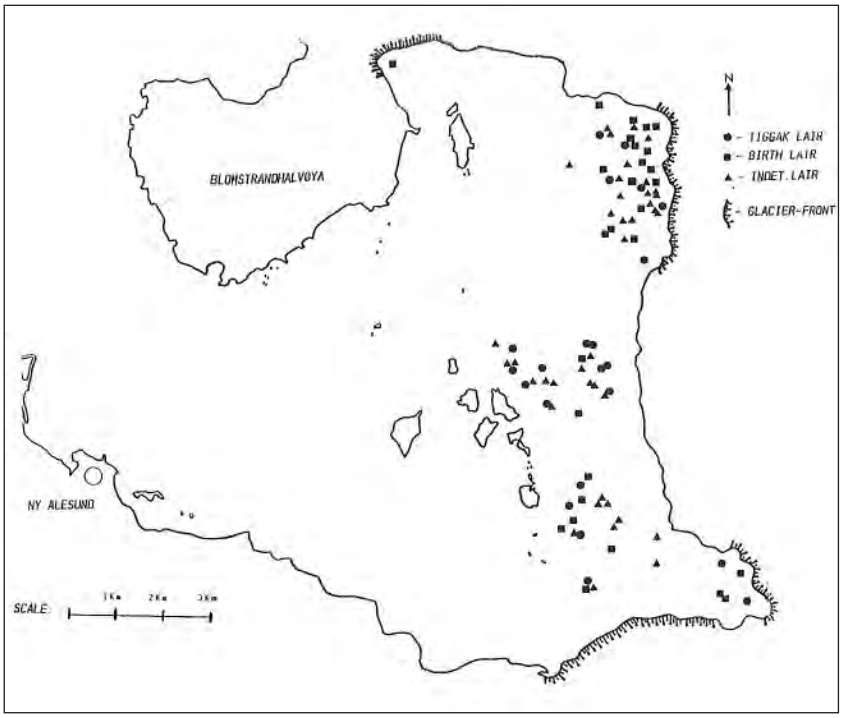


Figure 13. Ringed seal lairs in Kongsfjorden. Source: Lydersen and Gjertz (1986).

6. PROTECTED AREAS

The Norwegian Ministry of the Environment has officially designated three types of protected area in Kongsfjorden: Bird Sanctuaries, a Plant Protection Reserve and Cultural Monuments. There are also two types of local, unofficial protected areas: local bird protection areas and a restricted research area. All protected areas in the vicinity of Ny-Ålesund, whether officially designated or not, are shown in Figure 14. In addition, the area immediately to the north of Kongsfjorden beyond Kapp Guissez is protected by the North West Spitsbergen National Park. Forlandsundet, south-west of Kongsfjorden, is protected by Forlandet National Park.

6.1 Bird Sanctuaries

In Svalbard, Bird Sanctuaries are designated to protect areas, usually islands, which are important bird breeding sites. In Kongsfjorden, there are three Bird Sanctuaries: Kongsfjorden, Blomstrandhamna and Guissezholmen. They were established in 1973 to protect important breeding sites for eider and barnacle geese. The sanctuaries include both the islands themselves and the surrounding water out to 300 m off shore. No buildings can be erected on the islands, and fishing is prohibited. To prevent disturbance during the breeding season there is a ban on vehicles and boats from 15 May – 15 August each year. Visitors must remove all their waste. New plant species cannot be introduced. Also, plants and fossils cannot be removed. Entry to Bird Sanctuaries requires the permission of the Sysselmannen.

6.2 Plant Protection Reserve

Plant Protection Reserves are designated to protect areas that are exceptionally rich in vegetation, or contain rare plant species, and might be vulnerable to disturbance. There is one Plant Protection Reserve in Kongsfjorden, which is at Ossian Sars. This was established in 1994 to protect the rich vegetation on Ossian Sarsfjellet, which includes several rare and vulnerable plant species. The collection or destruction of plants at Ossian Sars is prohibited, as is the introduction of new species. Special care must be taken so as not to harm the flora and fauna or unnecessarily disturb the wildlife. Camping and dumping of litter is not allowed, and there are strict controls on the use of snowmobiles. Entry to Ossian Sars requires the permission of the Sysselmannen.

6.3 Cultural Monuments

The Norwegian Ministry of Environment may protect any fixed or moveable historical or cultural monument on Svalbard regardless of age. Moreover, all cultural monuments are also protected if they are thought to date from 1945 or earlier. The Directorate for Cultural Heritage (Riksantikvaren) is the authority within the Norwegian Ministry of Environment which has responsibility for protecting the cultural heritage, while the Sysselmannen is responsible for the day-to-day administration of the regulations on Svalbard. In Ny-Ålesund approximately 30 of the older buildings from the mining period are protected as Cultural Monuments, as well as the entrances to the mines and associated mining facilities, the airship mooring mast and remains of the foundations of the airship hangar. The cultural heritage regulations also protect the cultural heritage in a broader context as part of the landscape. This means that the local settlement landscape immediately around the historic buildings in Ny-Ålesund is also protected, and new buildings must be designed so that they fit in with the pre-1945 ones.

6.4 Local protected areas

Local bird protection areas

KBKC, in co-operation with NP and the other scientific organisations located at Ny-Ålesund, has established two local bird protection areas within the station. One area is to the west of the settlement and protects the moss-tundra around Thiisbukta, whilst the other is to the west of the settlement and protects the lake Solvatnet as well as the moss-tundra surrounding it. Both areas are very important for bird nesting, feeding and resting. Entry to these areas is forbidden during the summer, except for scientific research purposes.

Restricted research area

NILU and NP, in co-operation with KBKC, have established a restricted research area on the summit of Zeppelinfjellet where the Zeppelin atmospheric monitoring station is located. The monitoring equipment at the station is extremely sensitive to local pollution, such as snowmobile emissions and cigarette smoke. Entry into the restricted area is forbidden, except for access to the Zeppelin station for scientific research purposes.

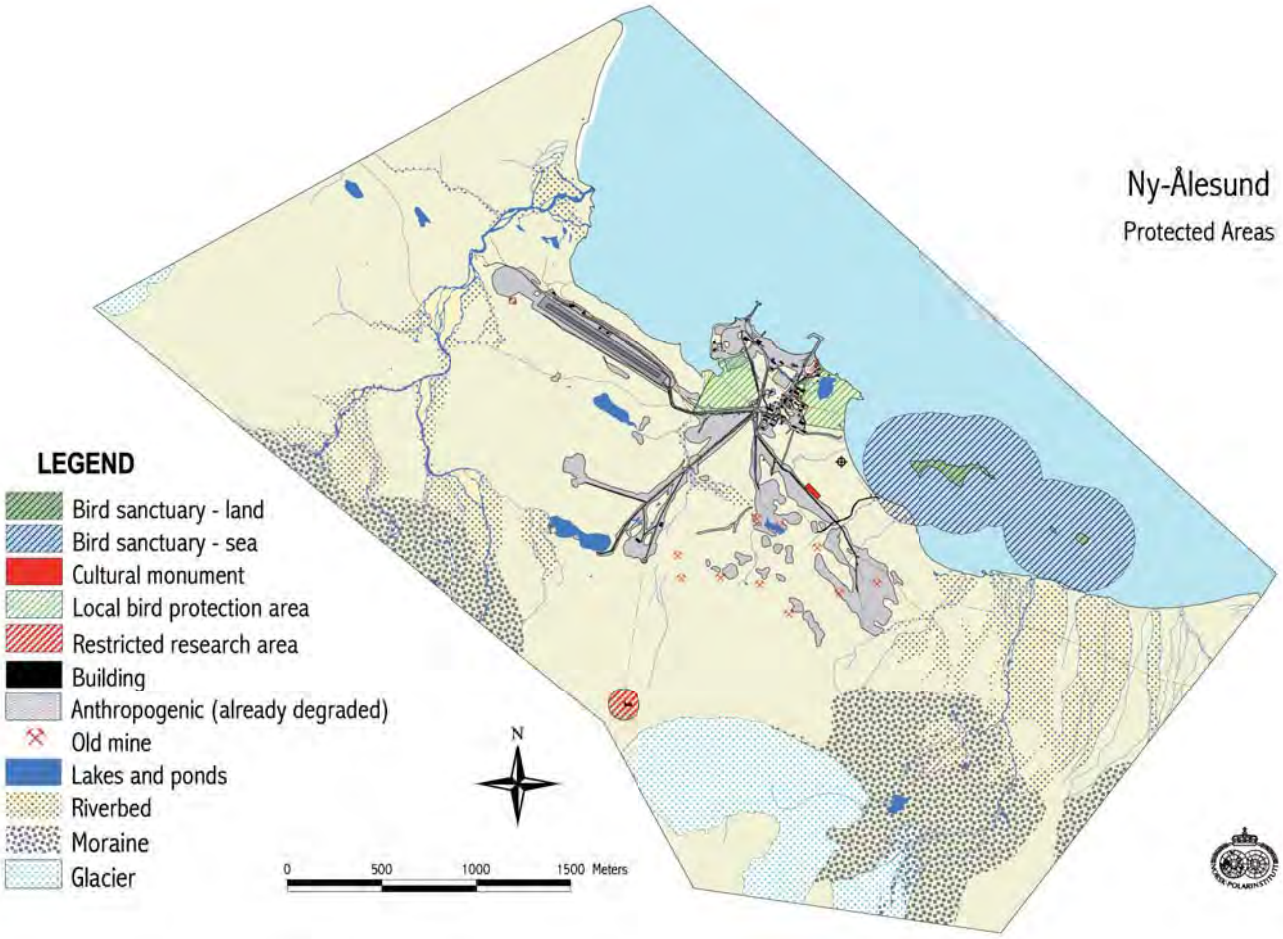


Figure 14. Protected areas in and around Kongsfjorden.

7. IDENTIFICATION OF SENSITIVE RESOURCES

7.1 Sensitivity mapping of the local area around Ny-Ålesund

As part of the EIA, key resources were identified that are particularly vulnerable to human impacts (Theisen *et al*., 1997). The resources were then digitally mapped into the Geographic Information System (GIS) developed by NP (Norris, 1995). The aim was to use the GIS to carry out a spatial analysis of sensitive resources, and to provide a visual demonstration of the vulnerability of the local environment.

Four key categories of sensitive resources were identified and mapped as a series of thematic maps. They were:

i) Important fauna habitats (e.g. key habitat for breeding birds);

ii) Terrain (see Box 2 and Figure 15);

iii) Scientific research and monitoring sites and scientific restricted areas (e.g. restricted area around the Zeppelin atmospheric monitoring station);

iv) Protected areas (e.g. Bird Sanctuaries).

In addition, a map showing the station facilities and infrastructure at Ny-Ålesund was produced. This category was subsequently superimposed on the other thematic maps to show the spatial relationship between the various resources and human activities at the station. All four maps also include a further category showing areas degraded by past human activity (e.g. coal mining).

The maps of terrain vulnerability and important fauna habitats were then superimposed using the GIS to produce summary maps displaying the overall environmental sensitivity of the Ny-Ålesund area to human disturbance in both summer (Figure 16) and winter (Figure 17). The two maps reflect the marked difference in vulnerability between the summer and winter seasons. For example, many sensitive biological resources, such as breeding birds, are only present at Ny-Ålesund in summer.

On the maps of overall sensitivity, the categories of terrain vulnerability and important fauna habitats are classified according to their degree of vulnerability. The classes of vulnerability used are:

- very high vulnerability
- high vulnerability
- medium to high vulnerability
- low vulnerability
- anthropogenic (already degraded)

For example, in the important fauna habitat category, the nesting sites of red-throated divers (*Gavia stellata*) were classified as having very high vulnerability, the resting areas for barnacle geese (*Branta leucopsis*) were considered as having high vulnerability, whilst ringed seal (*Phoca hispida*) territories were classified as having medium vulnerability.

Classification of the vulnerability of the various key resources required the use of expert judgement by the EIA team, as well as scientists at NP. In the sensitivity maps, human impacts and disturbances are used in a very broad and general sense and include physical impacts, as well as noise and pollution.

In the case of overlapping resources, the resource with the highest degree of vulnerability to human impacts was superimposed on other resources with lower degrees of vulnerability, and this is reflected in the final sensitivity maps.

7.2 Sensitivity mapping of Brøggerhalvøya and Kongsfjorden

A less detailed sensitivity map has been produced for the wider EIA study area, between Engelsbukta and Kapp Guissez (Figure 18). This map has not been converted into a map of generalised vulnerability, but the vulnerability of the various features of the map is indicated in the legend. The map includes natural features such as alluvial plains, moraines, glaciers and wetlands. Bird colonies, moulting areas and breeding and haul-out areas for seals are also displayed.

Red-throated diver. Photo: B. Frantzen (NP)

Box 2

Terrain vulnerability

The vulnerability of terrain on Svalbard depends on plant cover, surficial material, topography, permafrost and soil moisture content. All of these factors are strongly interrelated. Research has shown that it is possible to identify and predict areas which are particularly prone to terrain disturbance on Svalbard, particularly by vehicles (Råheim, 1992). A terrain vulnerability classification system for Svalbard was developed by Sørbel *et al.* (1990). This separates terrain into four classes:

1) Invulnerable areas
   This class includes active alluvial plains and fans, rocky shores, tidal flats, glaciers and areas of exposed bedrock. Also included are areas with no vegetation cover and coarse surficial materials, like talus slopes, ice cored moraines and stony material.
2) Moderately vulnerable areas
   This class includes dry, well drained areas with a discontinuous vegetation cover and relatively coarse surficial material, such as coarse gravel, weathered material and till with little fine-grained material.
3) Vulnerable areas
   This class is characterised by continuous vegetation cover, fine-grained material and relatively high ground moisture. Thick humus cover soils or peat commonly cover the surface.
4) Highly vulnerable areas
   This class is characterised by continuous, thick vegetation cover, fine surficial material and moisture saturation.

Høgvard (1997) prepared a terrain vulnerability map for Ny-Ålesund using this classification system (Figure 15). This shows that most of the areas with very high vulnerability are located immediately next to the settlement.

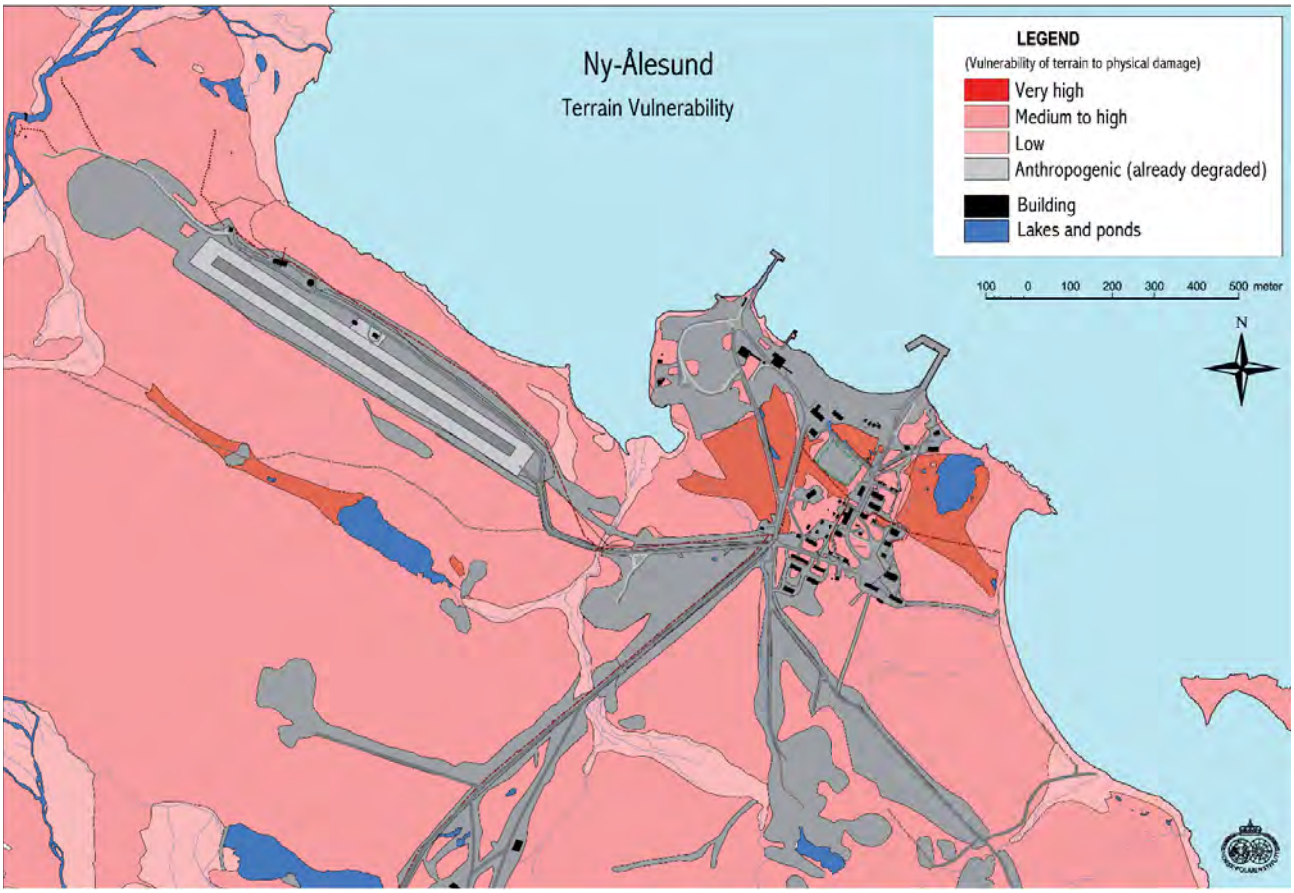


Figure 15. Terrain vulnerability map of Ny-Ålesund. Source: Høgvard (1997).

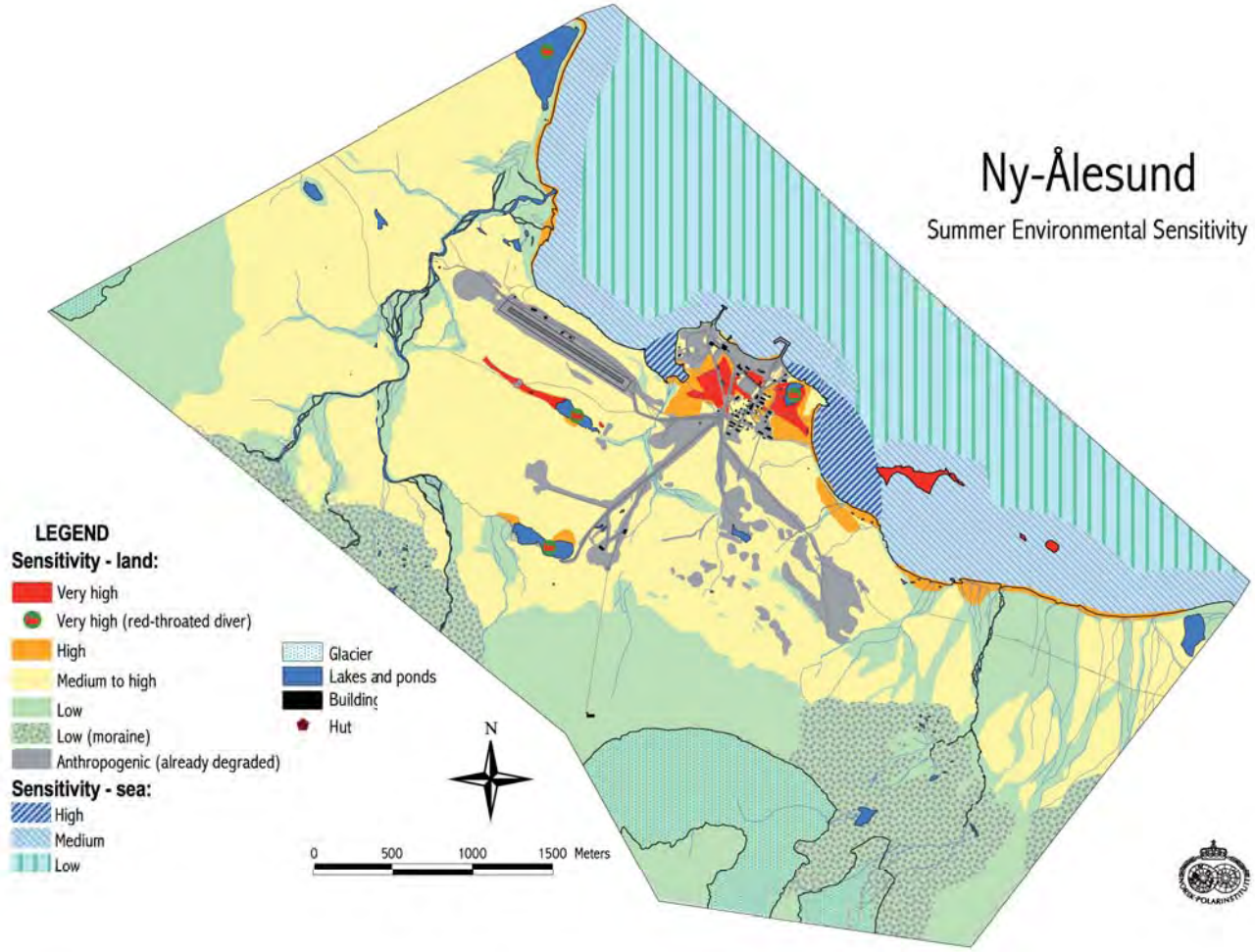


Figure 16. Summer environmental sensitivity at Ny-Ålesund.

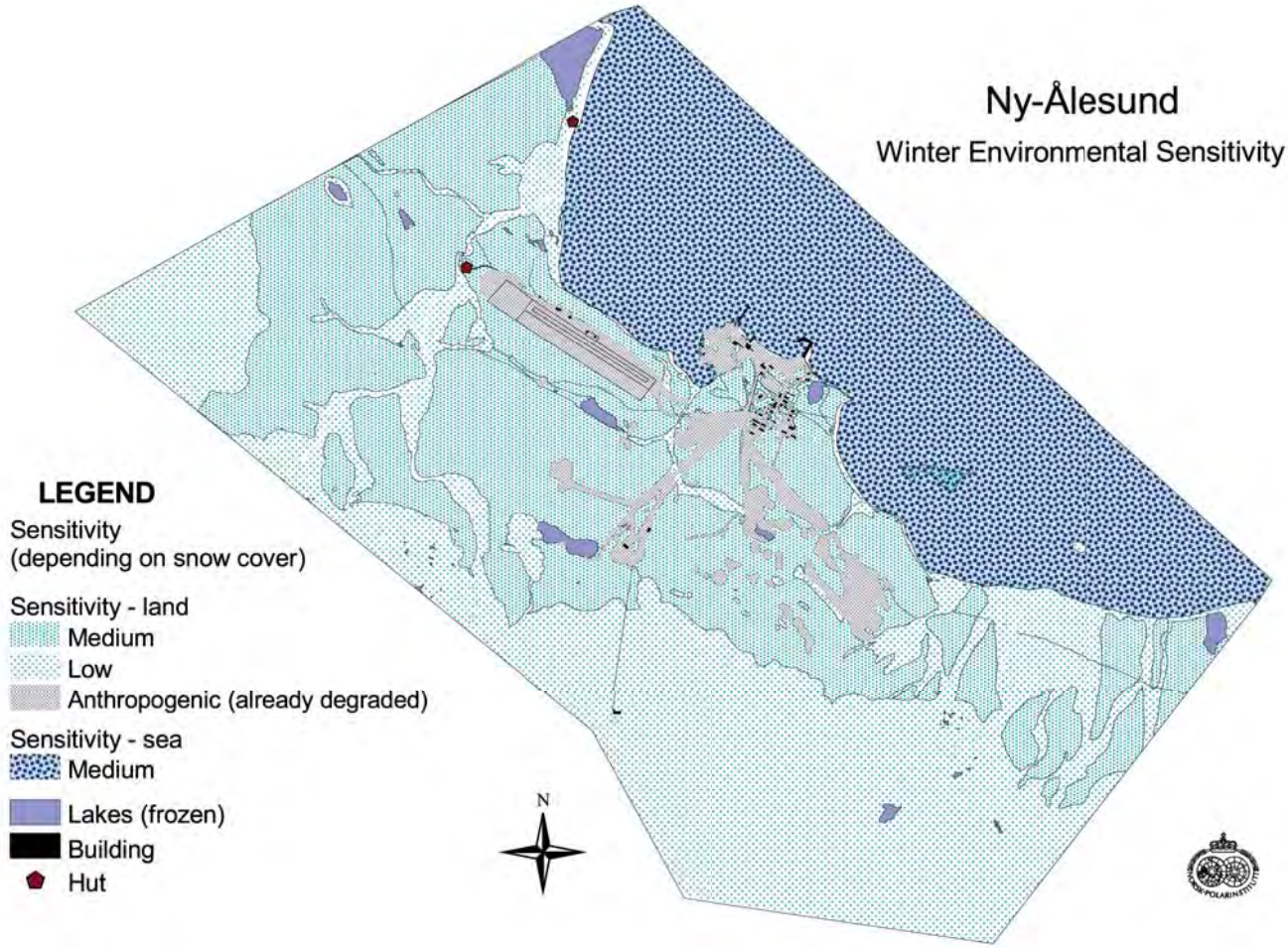


Figure 17. Winter environmental sensitivity at Ny-Ålesund.

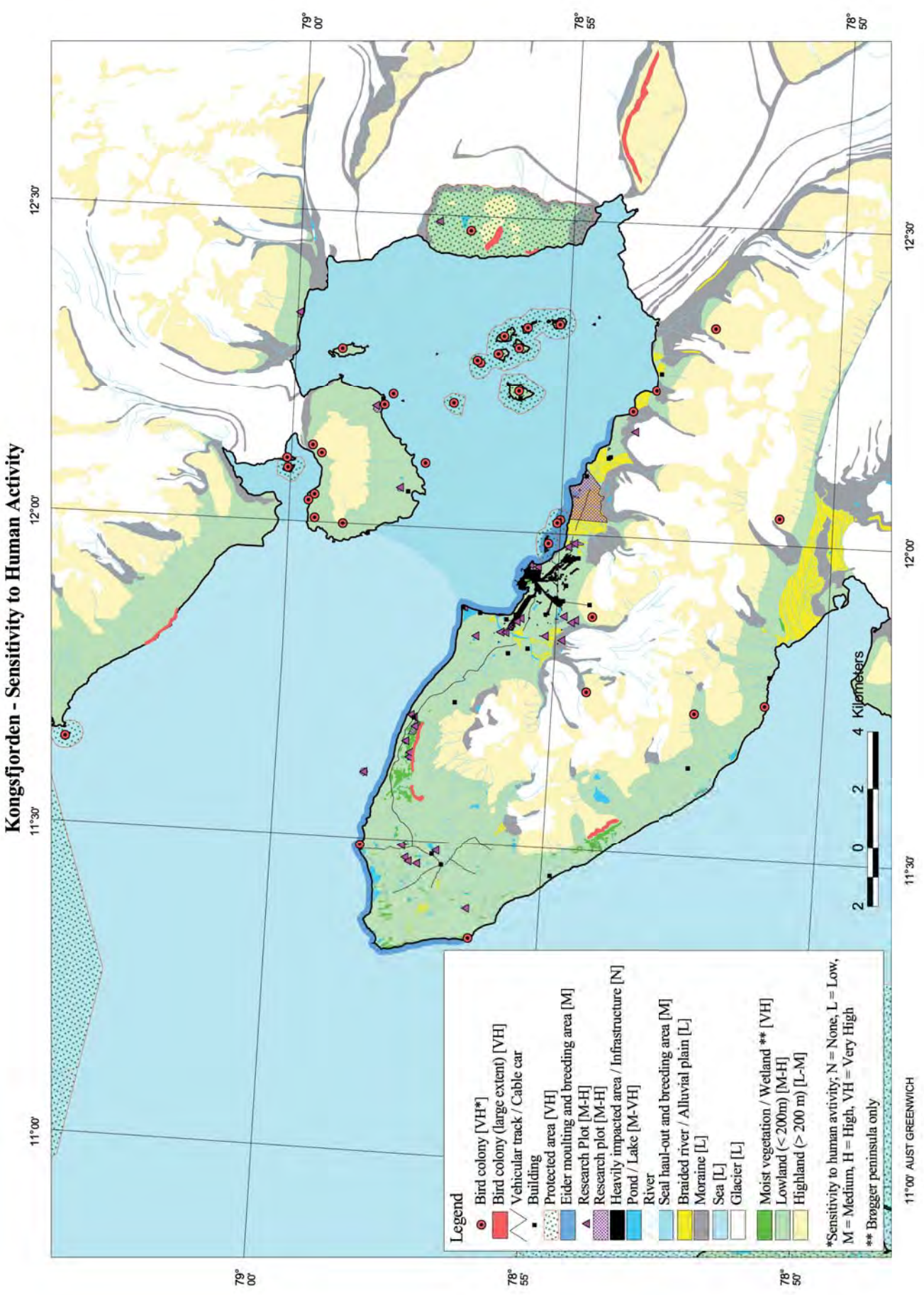


Figure 18. General environmental sensitivity of Kongsfjorden.

8. IDENTIFICATION AND PREDICTION OF ENVIRONMENTAL IMPACTS

This section of the EIA summarises the major impacts of human activities at Ny-Ålesund, which were identified by the technical studies (see Table 1). Impacts are then summarised and their significance evaluated in Section 10.1.

Heavy vehicles working on the expansion of the airstrip at Ny-Ålesund in 1997. Photo: B. Frantzen (NP)

8.1 Air

Local sources of air pollution

The major sources of air pollution at Ny-Ålesund are the power station, large construction projects, ships, aircraft and vehicles travelling in the local area (see Section 4.4). Currently, the emissions are low and appear not to have caused damage to vegetation or acidification of freshwater systems. For example, NO_x levels at Ny-Ålesund are about 3,000 times lower than in the city of Oslo, Norway (Beine, 1997). However, even these very low levels are large enough to cause significant contamination problems for atmospheric research and monitoring being carried out at the station (see Section 9.1).

In 1996, NILU made an estimate of the local emissions at Ny-Ålesund (Beine, pers. comm. 1996). This was difficult as some operations are poorly documented. For example, no records are kept of the use of cars, vans or snowmobiles. Table 4 shows the estimates. Power generation dominates emissions of NO_x, SO_2 and CO_2, while snowmobiles are important sources of Volatile Organic Compounds (VOCs) and CO. Large cruise ships produce high emissions of most pollutants.

The combustion of diesel fuel at the power station is considered by NILU to be the major local source of polycyclic aromatic hydrocarbons (PAHs) and black carbon (soot). The consumption of gas oil for power generation is currently approximately 100 m^3 per month in winter, while 60 m^3 is used in summer. Fuel consumption has doubled since 1986 (Shears, 1996a).

Demand for power continues to increase and in 1996 consultant engineers to KBKC recommended that a new slow running diesel power generator rated at 1,200 kVA with an excess heat recovery system and exhaust cleaning should be purchased (Brevik and Pedersen, 1996). The recommendation was strongly disputed by consultants working for NP (KanEnergi, 1996). However, KBKC considered that there was no real practical alternative to a diesel power plant and this was built adjacent to the current power station during summer 1997.

The power station will have a cleaning module in order to reduce emissions, but this has not yet been installed. Table 5 shows the predicted emissions from the new power station compared to those from the old power station (Instanes, 1997). With a cleaning module installed, emissions of critical components such as NO_x and SO_2 will be reduced by an order of magnitude. Without a cleaning module, improvements will be moderate and emissions could even increase for some components, such as NO_x.

NILU, as well as estimating local emissions, have also attempted to quantify emissions from some sources through measurement programmes at the Zeppelin atmospheric monitoring station. In summer 1996, emissions produced by the expansion of the airstrip were examined (Beine, 1996). The expansion involved rock blasting and crushing, and the frequent movement of heavy vehicles. This caused considerable local atmospheric pollution, particularly of NO_x, dust particles and hydrocarbons (see Box 3). In 1997, the burning of fuel and tyres as part of the annual station fire exercise was studied (Beine, 1997). This produced large emissions of soot and tar particles, NO_x and CO_2 over a period lasting ten hours.

Table 4. Emissions (kg/hour) from different activities at Ny-Ålesund. Source: NILU (1996).

Activity	Component (kg/hour)					
	CO2	SO2-S	NOx	NMVOC	Soot	CO
Diesel generators	220	0.35	4	0.5	0.34	1
Central heating	150	0.23	0.2	-	-	-
Snowmobiles and small boats	8	0	0.005	1.7		3
Diesel cars and heavy equipment	40	0.06	0.64	0.1	0.07	0.2
Aircraft	70	-	0.08	0.87	-	1.46
Small ships	180	0.25	3	0.3	0.35	0.7
Cruise ships	9000	26	140	16	12	40
Expansion of airfield	48	0.13	0.68	0.1	0.1	0.2

Table 5. Predicted emissions (kg/hour) from the new power station at Ny-Ålesund at an average power output of 500 kW. Source: Instanes (1997).

Activity	Component (kg/hour)					
	CO2	SO2-S	NOx	TCH	Soot	CO
Old power station	370	0.58	4.2	0.5	0.34	1
New power station without cleaning module	252	<0.31	<5.0	<0.09	<0.7	<0.64
New power station with cleaning module (90% cleaning)	-	0.031	0.5	0.009	0.07	-

A further source of atmospheric emissions may be the landfill site at Ny-Ålesund. Since 1994, NILU have measured very high concentrations of polychlorinated biphenyls (PCBs) in air samples taken at the Zeppelin station (Stordal, pers. comm. 1996). These results suggest a local rather than a long distant source. Mining waste, such as old barrels containing PCB based hydraulic oil, buried at landfills around Ny-Ålesund could be a major local source.

8.2 Visible and other electromagnetic radiation

Visible (e.g. light from street lamps and buildings) and other electromagnetic radiation (e.g. VHF radio) do not appear to have caused any environmental impact. However, light pollution has caused problems for scientific research projects requiring undisturbed polar night conditions, and there are also concerns about the effects of increasing electromagnetic radiation from human activities conflicting with the operation of the space geodesy observatory (see Section 9.1).

8.3 Vegetation and soils

Physical damage by roads

Krzyszowska-Waitkus (1997) examined the extent of the physical damage caused by roads at Ny-Ålesund in 1996, and compared her results to the study she carried out in 1986 (Krzyszowska, 1989). She found that the total length of major roads had increased from 8.8 km in 1986 to 9.8 km in 1996.Over the same period the total length of minor roads with some vegetation (< 20% plant cover) had increased from 1.5 km to 3 km. The width of some major roads had increased significantly due to supply lines being buried alongside. For example, the road from Ny-Ålesund to the lake Tvillingvatnet was widened in summer 1996 so that a freshwater supply pipeline could be installed. This increased the road width from about 4 m to 7 m over a distance of about 1 km.

Vegetation changes

Major vegetation changes were observed by Krzyszowska-Waitkus (1997) at the track going from the settlement to the airship mooring mast. The track is now used intensively by tourists walking to see this Cultural Monument. Here plant cover had decreased from 40 - 60% in 1986 to 5% in 1996, the depth of the track had increased from 6 cm to 18 cm, and the permafrost thaw depth from 96 cm to 100 cm. There were also changes in plant composition. In 1986, the dominant plants on the track were the grasses *Deschampsia alpina* and *Poa arctica*. By 1996, *Deschampsia alpina* had disappeared, probably because of increased trampling by people and over-grazing by reindeer (see Section 5.7), and instead had been replaced by *Saxifraga oppositifolia* and *Saxifraga cespitosa*. No lichens were observed on the track in either 1986 or 1996.

Outside of Ny-Ålesund, several old vehicle tracks can be found on Brøggerhalvøya which have persisted for decades. This is because of compaction of the soil profile by heavy vehicles, which has resulted in slow revegetation, further thawing of exposed soil and erosion by running water. For example, in 1973-74, Norsk Polar Navigasjon drilled two small exploratory boreholes at Kvadehuksletta, on Brøggerhalvøya, whilst searching for oil and gas deposits. The drilling was unsuccessful, but the vehicle tracks linking the drilling camp to Ny-Ålesund still remain almost 25 years later.

Tundra degradation associated with the activities of field parties in Kongsfjorden has been investigated by West (1997). He surveyed the campsite at Ny-Ålesund, which is to the east of the Amundsen mooring mast, and compared it to an unaffected control plot nearby. The campsite was opened in 1987 and is frequently used by small parties of scientists, private expeditions and tour groups during the summer months. West (1997) found significant differences between the two sites. At the campsite, the mean soil compaction was 3 kg/cm^2, more than twice that found at the unaffected control, which was 1.3 kg/cm^2. The mean water infiltration rate was 83 mm/hr at the campsite, but at the control it was 1698 mm/hr. Plant cover at the campsite averaged 57%, but at the control it averaged 97%. Lichens were almost absent from the campsite, but were recorded at the control.

These studies of tundra degradation at Ny-Ålesund show that traffic, both of vehicles and pedestrians, causes increased compaction of surface soils, thereby significantly decreasing water infiltration rates. This can lead to increasing soil erosion by run-off and thawing of the soil profile. Trampling and compaction also causes reduction in plant cover, and a significant change in plant species composition with lichens disappearing very quickly.

Damage to tundra due to underground burial of pipelines and services. Photo: J. Shears (BAS).

Box 3

Emissions from the expansion of the airstrip at Ny-Ålesund in summer 1996

NILU examined the extent of the emissions generated by the expansion of the airstrip at Ny-Ålesund in summer 1996 (Beine, 1996). Figure 19 shows the levels of NO_x recorded at the Zeppelin atmospheric monitoring station between 9 July 1996 (Day Of Year - DOY 190) and 17 July 1996 (DOY 198). Table 6 shows the log kept by KBKC of rock blasting and construction activity at the airstrip over this eight day period. Construction work kept a regular routine, but the time series of the NO_x measurements does not have a similar pattern. There are large increases in NO_x on 9 July and 10 July (DOY 190 and 191), 12 July (DOY 193) and 15 and 16 July (DOY 196 and 197). These spikes in the time series were most probably caused by dynamite blasts.

Table 6. Log of rock blasting and construction activity during the expansion of the airfield at Ny-Ålesund in summer 1996. Source: Beine (1996).

Dates July 1996	DOY	Time of activity	Diesel use (l)	Time of dynamite blasts	Amount of dynamite used (Kg)
9	190	01:00 - 17:00 19:00 - 24:00	1500 550	10:15 16:35	305 406
10	191	01:00 - 17:00 19:00 - 24:00	1570 501	9:35 15:40 21:35	360 915 440
11	192	01:00 - 17:00 19:00 - 24:00	1630 508	8:45 13:45 22:30	180 550 455
12	193	01:00 - 17:00 19:00 - 24:00	1175 405	9:45 16:15 21:40	330 685 431
13	194	6:00 - 17:00	406		
14	195	20:00 - 23:00	80	22:30	530
15	196	01:00 - 17:00 19:00 - 24:00	1345 555	12:45 20:15	585 610
16	197	01:00 - 17:00 19:00 - 24:00	1020 780	11:45 18:00 22:10	485 935 205
17	198	01:00 - 17:00 19:00 - 24:00	1558 642	7:50 11:45 17:00 21:55	355 585 660 610

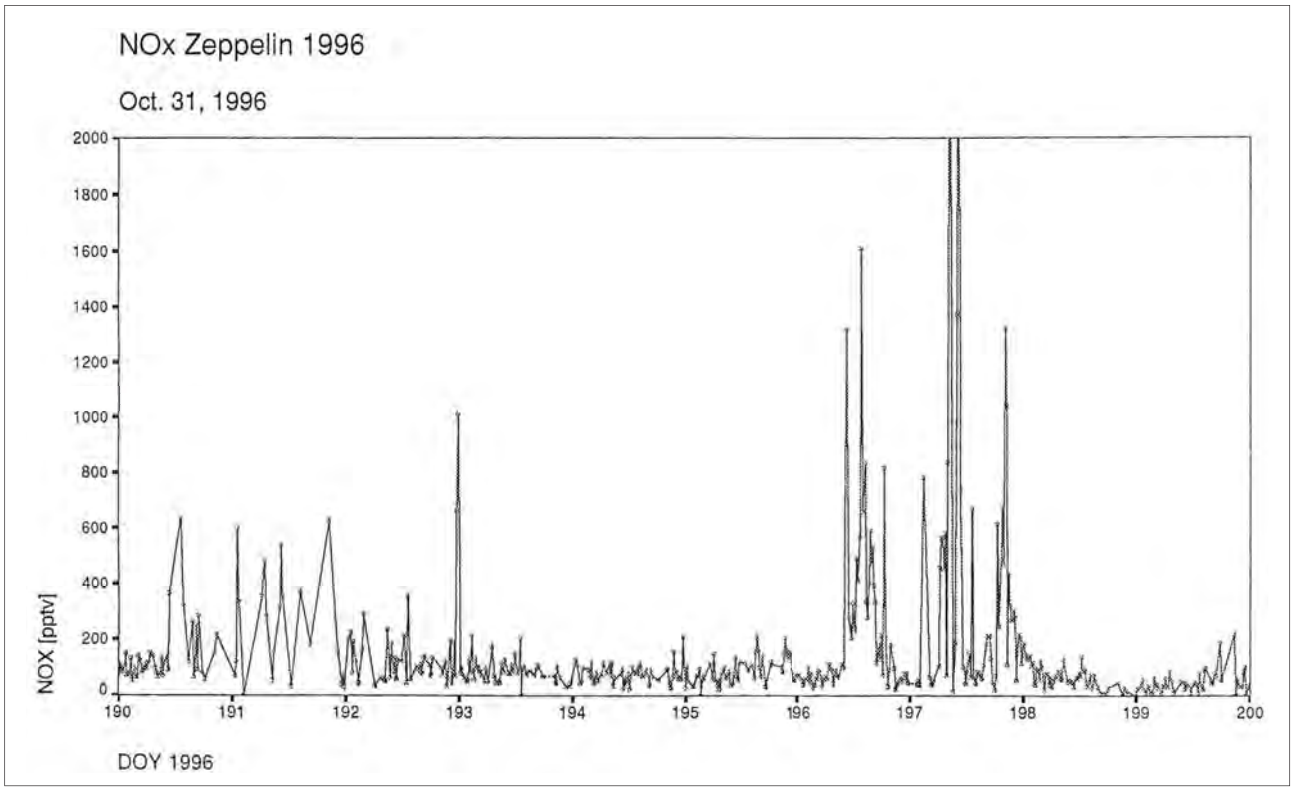


Figure 19. Variations in the levels of NO_x (pptv) recorded at the Zeppelin station between 9 July 1996 (DOY 190) and 17 July 1996 (DOY 198). Source: Beine (1996).

The track going from Ny-Ålesund to Kvadehuksletta. Photo: J. Shears (BAS)

Fuel spills and leaks

Several major fuel spills have occurred at Ny-Ålesund in the past. Krzyszowska (1989) documented three spills that occurred at the station between November 1985 and July 1986 together releasing about 110 m^3 of diesel fuel mostly onto the tundra, but also into the sea. A further spill of about 35 m^3 of diesel fuel occurred in 1990 (Theisen, pers. comm. 1996). Unfortunately, KBKC has kept no records of fuel spills and leaks so it is impossible to calculate the total amount of fuel that has been lost.

Since 1990, no major spills are thought to have occurred but small leaks of diesel, petrol and lubricating oil have continued. High petroleum hydrocarbon concentrations were found in surface soil samples taken in summer 1996 from the vicinity of the vehicle fuel dispensing pumps by the bulk fuel depot (75.6 g/kg), and at the drum depot (26.9 g/kg) (Krzyszowska-Waitkus, 1997). In the absence of any bunding around the bulk fuel tanks it seems likely that fuel spills have flowed downslope, particularly during snowmelt, and have then leached into the soil profile. Krzyszowska-Waitkus (1997) found soil samples highly contaminated by petroleum hydrocarbons at 18 cm depth to the east of the bulk fuel depot (30.8 g/kg), and at 5 cm depth near the old barn immediately below the old power station (58.5 g/kg).

Fuel management at Ny-Ålesund has improved since 1991. Between 1991 and 1993 the old bulk fuel pipeline was replaced, and new tanks for arctic diesel oil and petrol were installed by Esso Norge. A refuelling plan was prepared by Esso Norge in 1993 (Esso Norge, 1993). However, the bulk gas oil tanks are old by polar standards with one of the tanks dating back to 1958 and the other to 1965. The risk of a major fuel spill occurring remains high (Shears, 1996a).

Petroleum contamination from the spills that occurred in 1985 and 1986 persists. The worst pollution is found on the slope immediately to the north of the main bulk fuel tanks. Despite a clean-up operation in summer 1986, some of the fuel still remains. Much of it now appears to have accumulated in a layer between the present ground surface and the underlying permafrost. A small ditch dug across the bottom of the slope during the clean-up was found to contain very heavily polluted runoff and snow melt, and the water surface was covered by a heavy brown oily film during summer 1996. Not surprisingly, Krzyszowska-Waitkus (1997) found high concentrations of petroleum hydrocarbons in water samples taken from the pond in summer 1996 (maximum 26.7 g/l). Oily water from this ditch drains into a culvert under a road and enters the small lake Solvatnet.

The ecological effects of diesel fuel spills on vegetation in Ny-Ålesund have not been studied. However, the toxic, aromatic components of diesel fuel are likely to kill actively growing plant tissue, and therefore destroy plant cover. Hasty clean-up can cause further damage. For example, at Ny-Ålesund about 80 m^2 of moss-tundra and soil contaminated by diesel fuel were removed from the southern slopes below the bulk fuel tanks in summer 1986, and the area was then covered in gravel. Ten years later many plant species had not recolonised the site, and it now consists of strips of bare ground interspersed with tussocks of *Saxifraga cespitosa* (Krzyszowska-Waitkus, 1997).

Waste disposal

The landfill site at Ny-Ålesund is a major pollution source to the local terrestrial environment around the settlement (Shears, 1996b), and also to the marine environment of Kongsfjorden (Skei, 1994) (see Section 8.5).

KBKC is responsible for waste management and disposal at Ny-Ålesund (KBKC, 1995). Unfortunately, no accurate records of waste production and disposal have been kept. In 1995, KBKC estimated that the total amount of general non-hazardous waste (e.g. paper, plastics, glass) produced at the settlement was about 20.5 tonnes/year of which 6.5 tonnes/year were landfilled. The total amount of hazardous waste produced at the station was estimated to be 1 tonne/year (e.g. chemicals, batteries) all of which was removed for disposal elsewhere. KBKC adopted a waste management plan for Ny-Ålesund in 1995 (KBKC, 1995). Open burning of rubbish was stopped that year, and a recycling programme began in 1996. Paper/card, plastic, glass and drinks cans are separated and sent to Longyearbyen for recycling. Other non-hazardous wastes, such as metal, wood, packing materials and waste building materials are dumped in a pit at the landfill site at Thiisbukta. Here, wastes are periodically compacted by bulldozers. When the pit is full it is covered in earth and a new pit dug nearby. Hazardous wastes produced by KBKC and other Norwegian organisations are removed from Ny-Ålesund and sent to mainland Norway for proper disposal. The foreign research organisations

are expected to send their hazardous wastes back to their respective home countries.

Shears (1996b) found that as well as non-hazardous solid waste, waste food, cooking oil and some hazardous wastes (e.g. paints) were also being dumped at the landfill. He found that the site was being operated as an unsupervised dump. Loose rubbish was being blown away, and untreated leachate was draining into the bay at Thiisbukta.

Hazardous wastes produced by past mining operations, such as electrical equipment and drums of hydraulic oils containing PCBs, are probably buried at a number of old disposal sites around Ny-Ålesund. PCBs were widely used in transformers, capacitors and other electrical equipment up to the middle and late 1970s. No historical records exist of the dumping of these wastes. A preliminary investigation by Skei (1994) found high concentrations of PCBs, and elevated levels of PAHs, mercury and cadmium in soil samples taken from around Thiisbukta.

Fuel contaminated pond to the north and below the bulk fuel tanks at Ny-Ålesund. Photo: J. Shears (BAS).

Sewage

During the mining period, sewage was disposed of into earth closets beside the houses. There were also cattle, horses and pigs kept at the settlement. This has had the effect of fertilising the wetland moss-tundra around lake Solvatnet and the bay at Thiisbukta.

Sewage is still disposed of on the tundra at Ny-Ålesund. This causes local pollution as the soils are known to be nutrient deficient, particularly of nitrogen and phosphorus. The major land outfall for sewage is located at Kolhamna and drains sewage and grey water from the Japanese NIPR research station and the NMA space geodesy observatory. The outfall is on a low cliff and discharges directly onto the tundra below where an obnoxious deposit of new and old faecal material has formed.

A second, much smaller sewage outfall is located on the top of the cliff to the north east of the old power station. The effluent discharges directly onto the cliffside and the beach below.

The environmental effects of sewage disposal onto the tundra at Ny-Ålesund have not been studied.

8.4 Freshwater ecosystems

No studies have been carried out of the environmental impact of human activity on freshwater ecosystems at Ny-Ålesund. The most likely impact on freshwater ecosystems would be a diesel fuel spill entering the lake Solvatnet, as occurred in 1986 (see Section 8.3). There is also contamination of the stream draining into Thiisbukta from the landfill, as well as possible contamination of other streams draining from the abandoned mine workings.

The rubbish dump at Thiisbukta, Ny-Ålesund. Photo: J. Shears (BAS).

8.5 Marine ecosystems

Shrimp fishing

Fishing for deep-water shrimp is probably responsible for the most significant marine impact in Kongsfjorden.

Sonar imagery taken by NP has shown that shrimp trawls have disturbed large areas of soft sediments in the deeper outer parts of Kongsfjorden (Figure 20), mostly at depths below 120 m. The furrows made by the trawls are a dominant physical feature of the surface of the fjord floor. This is because the shrimp live in the deep waters just above sand, mud or flat rock beds, but fishermen prefer to trawl across the relatively flat, soft mud banks where their nets will not get caught. Trawling damages and kills many benthic fauna. In areas with frequent trawling, benthic communities may be very different from areas that are untouched. The overall effect is that communities in frequently trawled areas are kept to early successional stages with respect

to recolonisation and growth (Hop, pers. comm. 1997).

The deep-water shrimp is an important food source for polar cod and certain other fish, seabirds and marine mammals. However, it is not known what environmental effects the shrimp fishing is having on the marine ecosystem as this has not been studied.

The harvested shrimp population consists mainly of immature individuals. It is not clear whether the population is local and genetically distinct, or part of a larger population. If the biomass of the population is related to the fishing catches, biomass appears to fluctuate considerably with a cycle of about five years. To what extent the population is impacted as a result of harvesting is unknown, and it is not clear whether the present levels of harvesting are sustainable (Hop, pers. comm. 1997).

The effect of shrimp trawling on predators is also largely unknown. Shrimps are not the main prey for polar cod, and because the shrimps live in deep-water they are not thought to be an important food source for marine mammals and seabirds. A possible exception may be the bearded seal.

Waste disposal

Skei (1994) investigated marine pollution in Kongsfjorden in 1992. He found high levels of PAHs in marine sediments, and concluded that the landfill at Thiisbukta, rather than fuel spills or leaks from the station or shipping, was the most likely source. There may also have been marine sediment contamination in the past from coal particles blown off from the large open coal stocks stored at Ny-Ålesund prior to 1962. The pattern of PAH contamination in Kongsfjorden is dominated by volatile compounds like napthalenes and phenantrenes with few heavy aromatics. This is probably a result of low temperatures in the fjord and consequently long residence times for volatile compounds in the marine sediments. Organochlorine compounds, such as DDT and dioxins, were also detected in marine sediments by Skei (1994). They are

Shrimp fishing boat moored at Ny-Ålesund. Photo: J. Shears (BAS)

thought not to have come from the landfill or old dumps but to have been brought by long-range atmospheric and marine transport from sources far way from Svalbard. Skei (1994) found that heavy metal levels in sediments from Kongsfjorden were at background levels.

The landfill at Thiisbukta is a major local pollution source and discharges leachate into the nearby bay. Krzyszowska-Waitkus (1997) found that a water sample from the small stream running off from the landfill, taken in summer 1996, contained very high concentrations of oil and

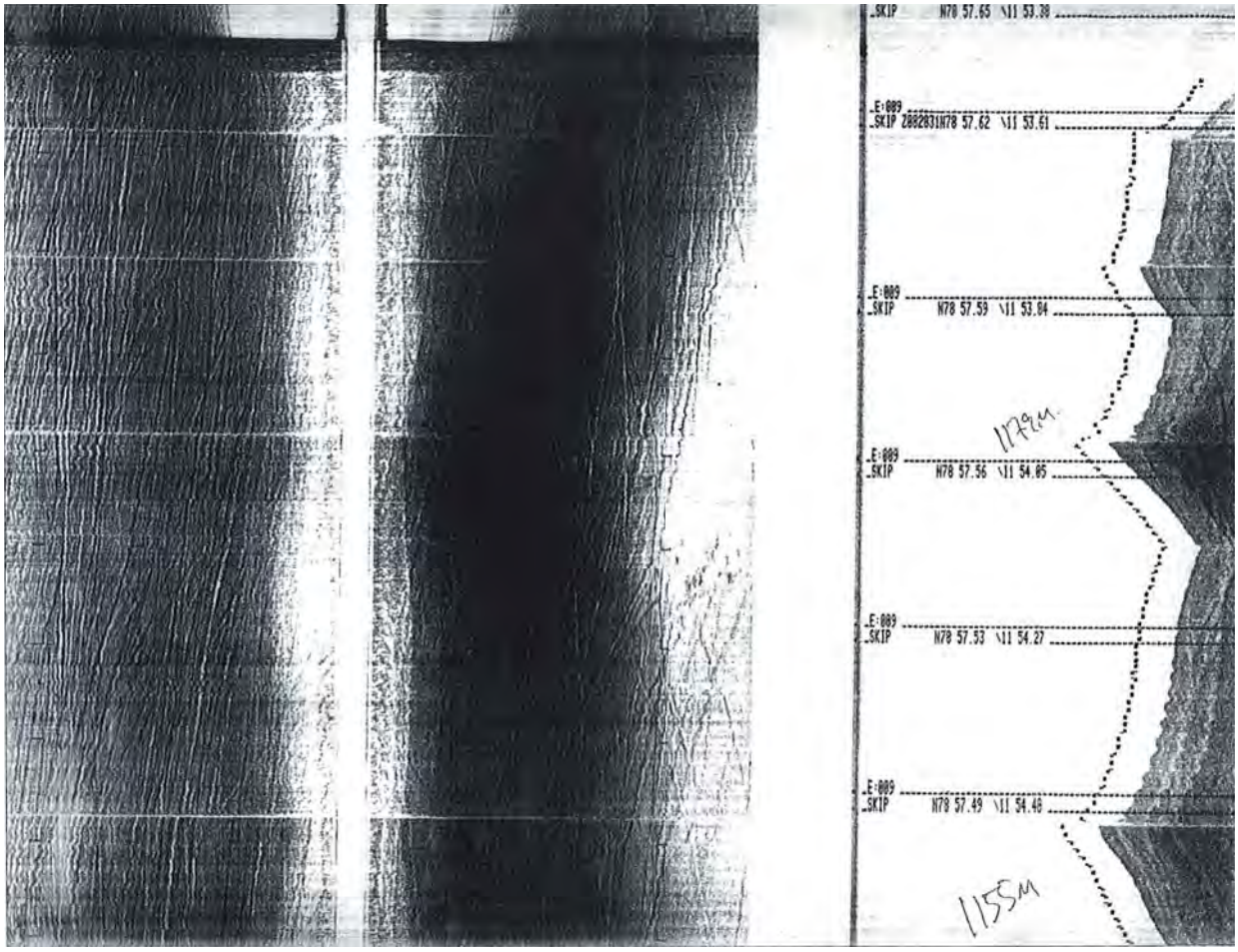


Figure 20. Sonar picture of the seafloor sediments in Kongsfjorden. Source: NP.

grease (31.8 g/l). Skei (1994) found extremely high levels of PAHs in a marine sediment sample (82,364 ng/g) taken from the bay at Thiisbukta, about 50 m away from the landfill.

The ecological effects of the elevated levels of PAHs in Kongsfjorden are unknown. Benthic fish such as sculpins can bioaccumulate PAHs directly from sediment. However, fish are able to break down PAHs, and these compounds do not seem to bioconcentrate or biomagnify up the arctic marine food chains (AMAP, 1997).

Sewage

The sewage effluent from the central settlement area in Ny-Ålesund is discharged via an underwater sea outfall located below the beach beside the old boathouse. The effluent is not treated and contains sewage, grey water from showers and sinks, detergents and cleaning agents from the kitchen and laundry, as well as small quantities of waste hazardous chemicals produced as a result of scientific experiments. Toilet wastes, including faeces, have been seen washed up on the beach (Cox, 1997).

Prior to summer 1995, sewage effluent from Ny-Ålesund was discharged to a beach to the east of the settlement via a surface utilidor. In summer 1986, Krzyszowska (1989) examined the effect of this discharge. She found that sewage polluted a surface seawater area of only 0.5 ha around the outfall, measured in terms of an increase in nutrient concentrations. Apart from this limited work, nothing else is known about the ecological effects of discharging untreated sewage into Kongsfjorden.

However, the effects of local marine pollution, including sewage disposal, on benthic macrofauna have been investigated in Adventfjord, Svalbard (Holte *et al*., 1996). This study showed that Adventfjord had a relatively high faunal abundance, and a macrofaunal community dominated by the opportunistic polychaetes *Capitella capitata* and *Chaetozone/ Tharyx* spp. Holte *et al.* (1996) suggested that this macrofaunal community indicated local organic enrichment of the fjord and was related to sewage disposal and/or drainage water from garbage dumps at Longyearbyen. The volume of sewage effluent at Longyearbyen is far greater than at Ny-Ålesund. Longyearbyen has a population of about 1100 compared to only about 150 maximum at Ny-Ålesund. Nevertheless, there has probably been some limited affect of sewage disposal immediately adjacent to the sea outfall at Ny-Ålesund.

Fuel spills and leaks

The large diesel fuel spills which occurred at Ny-Ålesund in 1985 and 1986 (see Section 8.3) are known to have contaminated the shoreline to the north of the station (Krzyszowska, 1989). It is not known what the toxic effects of the diesel fuel on the marine ecosystem of Kongsfjorden were. However, in 1978 a similar diesel fuel spill at Sveagruva, in van Mijenfjorden, Svalbard, resulted in the shore fauna in the immediate vicinity of the leak being killed, although the impact on the fjord ecosystem as a whole was considered to be negligible (Carstens and Sendstad, 1979).

Antifouling agents (tributyltin)

The ecological effects of the antifouling agent, tributyltin (TBT), in Kongsfjorden has been investigated. TBT compounds are used as biocides in antifouling paints on boat hulls and moorings, and leach into the water column and cause harmful effects to some marine organisms. A major effect on whelks is a condition known as imposex - the superimposition of male characters on the female's genitalia. Brick and Bolte (1994) and Nicholson and Evans (1997) have investigated the incidence of imposex in common whelks (*Buccinum undatum*) in Kongsfjorden. Both studies showed that whelks collected from Kongsfjorden had mild imposex, but TBT is unlikely to be the cause because it has not been detected in the water column (Brick and Bolte, 1994) or in sediment samples (Evans, pers. comm. 1997).

8.6 Birds

Habitat loss

Mehlum and Bangjord (1997) have shown that there has been a significant decline in the numbers and types of breeding wader species at

The sewage outfall at Rabben, Ny-Ålesund. Photo: J. Shears (BAS).

Ny-Ålesund since 1981 (see Section 5.6). They have suggested that the most important factor contributing to the decline is nest habitat loss due primarily to reindeer grazing, and the construction of roads, pipelines and buildings at the settlement. For example, an important breeding and feeding area for birds in the 1980s was the tundra between the old New-London houses and the old school. Since then two new buildings, the KBKC shop and the NERC research station, have been constructed on this area and the remaining vegetation has been almost completely destroyed by foot, bicycle and vehicular traffic.

Human disturbance

Eiders and barnacle geese may also be vulnerable to disturbance from people on foot straying into breeding territories or trampling nests. Ground-nesting birds, such as common eiders, are easily scared from the nest, which makes eggs or chicks easy prey for predators like the glaucous gull and Arctic fox. Mehlum (pers. comm., 1997) found in a study carried out in Kongsfjorden that glaucous gulls took eider eggs in 13% of the occasions when incubating females left their nests.

Research has also shown that feeding by barnacle geese in Ny-Ålesund can also be affected by human disturbance, and that the geese prefer to feed at night when most people are

asleep and activities have stopped for the day (Mehlum and Bangjord, 1997). Up to 1995, cruise ships were allowed to land tourists at Ny-Ålesund during the night and the large numbers of people wandering around the settlement at this time led to significant disruption to the local population of barnacle geese (Loonen, pers. comm. 1996).

The pair of red-throated divers which nest on the lake Solvatnet can also be easily frightened by people coming too close. They usually leave the nest and enter the lake when disturbed.

Noise

Some bird species which nest in Kongsfjorden, such as waders and eiders, are shy and vulnerable to noise disturbance. However, the effects of noise on different bird species have not been studied in detail. Helicopter noise may have had some impact on local bird populations, but this is not proven.

Mehlum and Bangjord (1997) have suggested that the increased number of helicopter landings and take-offs at Ny-Ålesund in recent years might have had an effect on the local wader populations. Up to 1996, helicopters often used the sports field in the centre of the settlement as a landing site. Grey phalaropes nested in the moss-tundra near the sports field in the early 1980s, but have now abandoned the area.

In 1987, Fjeld *et al.* (1988) carried out a study on the effects of helicopter noise on a small colony of Brünnich's guillemots (1,300 individuals) in Kongsfjorden, approximately 10 km away from Ny-Ålesund. The results from this study showed that non-breeding birds left the colony when the total noise level exceeded 70 - 75 dB. All helicopter flights within 2 km of the colony seemed to cause disturbance to non-breeders. However, breeding birds did not leave their breeding ledges, and no loss of eggs or chicks was recorded as a result of the helicopter flights. One possible reason for the lack of reaction by the birds may be that they were habituated to helicopter noise because of the frequent flights, often several times a week during summer, going to and from Ny-Ålesund.

Hunting

Hunting is minimal and is only carried out by four or five people at Ny-Ålesund, mostly for ptarmigan. The impact on the local population of ptarmigan is considered to be minor.

8.7 Terrestrial mammals

Human disturbance of reindeer

Human activities at Ny-Ålesund have had only a minor effect on the population of reindeer on Brøggerhalvøya.

After the 15 reindeer were first introduced to Brøggerhalvøya in 1978, one of the females was found dead and its remains indicated that it had been killed illegally by poachers. No further illegal killing has been detected. In 1996, a total of three reindeer were killed as a result of being hit accidentally by snowmobiles or by becoming entangled in fencing wire (Thon, pers. comm. 1996). However, human activity does not seem to be a major factor controlling the overall reindeer population on Brøggerhalvøya. The most important cause of death is starvation resulting from severe winters.

The Svalbard reindeer has a highly sedentary lifestyle in order to reduce energy expenditure. Disturbance from snowmobiles and other traffic can frighten reindeer and cause them to run. However, a study by Tyler (1991) has shown that direct provocation by snowmobiles only causes an increase in a reindeer's daily energy expenditure of approximately 0.4%. Therefore, it seems highly unlikely that the current level of snowmobile or other vehicular traffic at Ny-Ålesund is directly affecting the physical condition of the local population of reindeer. Frequent observation of male reindeer grazing within the settlement itself suggests that they have become habituated to the traffic and disturbance.

Scavenging by the arctic fox

The arctic fox is a food opportunist and will scavenge waste food and other edible wastes produced as a result of human activity on Svalbard. Food wastes are particularly important as a food source in winter when other sources are scarce, and can determine the number of foxes that will survive and reproduce the next summer.

At Ny-Ålesund, arctic foxes have been observed scavenging faeces deposited on the tundra at the Rabben sewage outfall (Rekkedal, pers. comm. 1996). It would appear likely that this food has helped to sustain the arctic fox population in Kongsfjorden during winter, but does not appear to have led to a major increase in population size and thereby increased predation of seal pups in spring or of seabirds and wildfowl in summer.

Hazardous waste (paint) dumped at Thiisbukta. Photo: J. Shears (BAS)

8.8 Marine mammals

Human disturbance of seals

Human disturbance of seals in Kongsfjorden has not been studied. However, it is thought that the effects of human disturbance are likely to be very minor in comparison to natural factors, particularly the variability in sea ice conditions (Gjertz, pers. comm. 1998).

It is not known if shrimp fishing in Kongsfjorden is affecting seal populations. The bearded seal would be the seal species most likely to be impacted as it feeds predominately on benthic animals (fish, shell-fish, snails, crabs and deep-water shrimps).

Entanglement of seals in fishing debris has not been recorded in Kongsfjorden, but entangled harbour seals have been found at Forlandet. The scale of the problem is unknown, but entanglement is thought to be more of a problem for reindeer grazing on beaches littered with marine garbage (Gjertz, pers. comm. 1998).

Human disturbance from scientific research and tourism also has the potential to disturb walruses at their haul-out site at Sarstangen, to the south of Brøggerhalvøya.

The most significant human impact on seal populations in Kongsfjorden is probably hunting. Most hunting is carried out for scientific research, and it is estimated that several hundred seals have been shot for this purpose over the past two decades. Hunting at this low level is, however, not a threat to the large local seal populations (Gjertz, pers. comm 1998).

8.9 Protected areas and buildings

Damage to local bird protection areas

Both the local bird protection areas at Ny-Ålesund have been damaged by human activities, despite entry to these areas being forbidden during the summer except for scientific research purposes. In the past, tourists and other visitors to the station have been observed entering the area protecting Solvatnet to watch birds or take photographs. Efforts have been made by NP to reduce the disturbance by tourists by sign posting and fencing off the most vulnerable areas using ropes, but this has been only partly effective (Mehlum and Bangjord, 1997).

Arctic fox. Photo: B. Frantzen (NP)

Of particular concern has been the construction of pipelines through the local bird protection areas in recent years. In summer 1996, KBKC installed an underground sewage pipeline across the western boundary of the lake Solvatnet area, and in summer 1997 the company installed an underground service pipeline across the southern edge of the Thiisbukta area.

8.10 Cumulative impacts

Habitat loss

There has been a major cumulative loss of tundra at Ny-Ålesund because of the development of infrastructure at the station. Mining activities, such as coal storage, railway construction and, later, road construction caused the initial destruction. Wind blown coal dust also covered areas of vegetation near to the mines and coal storage areas. Further destruction occurred in 1974 when the airstrip was constructed. More recently, the construction of a new wharf and research stations, redevelopment of the airstrip, gravel and rock extraction, burial of pipelines, and widening and lengthening of roads have all resulted in further losses of tundra.

As a result of these past and present activities a total of 116 ha of tundra has been destroyed or severely damaged around Ny-Ålesund since 1917 (Theisen *et al*., 1997). The total area degraded has increased by almost 50% in the last decade, from 78 ha in 1986 (Krzyszowska, 1989) to 116 ha in 1997 (Theisen *et al*., 1997). The rate of degradation has increased significantly since 1990 when the station was opened up to foreign research institutions.

The piecemeal loss of tundra when added all together has resulted in the widespread degradation of the local environment at Ny-Ålesund, resulting in the most conspicuous and significant environmental impact identified by the EIA.

As well as the direct loss of land, station activities themselves are now causing significant encroachment on the local environment. Effects include vehicles driving over, and people trampling, vegetation adjacent to buildings, fragmentation of natural habitats by roads and pipelines, and disturbance to wildlife from noise and frequent activity around the station. For example, there are some sites in Ny-Ålesund which have not been physically disturbed but are no longer used by ground-nesting birds (e.g. in front of Trønderheimen) (Cox, pers. comm., 1998). The cumulative increase in people, noise and traffic has probably scared these birds away.

9. IDENTIFICATION AND PREDICTION OF CONFLICTS BETWEEN ACTIVITIES

Conflicts between activities at Ny-Ålesund were identified and discussed by Shears (1997) as part of the EIA. He undertook a questionnaire survey of the key "stakeholders" at Ny-Ålesund in summer 1996. This section of the EIA identifies the major results of this survey. The conflicts are summarised and their significance evaluated in Section 10.2.

The NMA VLBI antenna at Rabben, Ny-Ålesund. Photo: J. Shears (BAS)

9.1 Conflicts between scientific research and other activities

Logistical operations

Land, sea and air operations at Ny-Ålesund are the largest local sources of atmospheric pollution. Although the pollution is low-level, it is sufficient to have a significant impact on atmospheric research being carried out at the station, particularly the global atmospheric monitoring carried out at the Zeppelin station.

Table 7 shows the background concentrations of several atmospheric components (species) measured at the Zeppelin station and the influence on these concentrations from local sources (Beine, pers. comm. 1996). Current emission levels of NO_x, SO_2, VOCs and black carbon are all of particular concern because their estimated influence is greater than one order of magnitude below the significant natural variation. There are also concerns about emissions of heavy metals and some VOCs, in particular persistent organic pollutants (e.g. PCBs and PAHs), from local sources.

Beine (1996) concluded that around 5% of the atmospheric data collected at the Zeppelin station were definitely influenced by local sources. However, it is impossible to identify all the episodes of local pollution from the atmospheric records alone and this therefore casts doubt on around 20% of the data. Local pollution usually occurs during periods of surface inversions when there is low atmospheric stability and wind speeds (Beine *et al.*, 1996).

Figure 21 shows how difficult it can be to separate local pollution sources from long-range transport events.

There is therefore great concern amongst atmospheric scientists that slowly increasing activity at Ny-Ålesund will create virtual trends in the time series of atmospheric measurements (Beine, pers. comm. 1997).

There is no doubt that local pollution sources are having a significant effect on atmospheric research and monitoring programmes at Ny-Ålesund and the problem has created the most serious conflict of activities at the station (Shears, 1997). Already, considerable time has to be put aside by the atmospheric scientists to check their data for local pollution events. If local air pollution continues to increase then NILU consider that measurements of background atmospheric concentrations at the Zeppelin station will become unreliable and this unique site will then become unusable for global reference monitoring (Beine, pers. comm. 1996).

Street and building lights have caused problems for research which requires undisturbed polar night conditions. Stray light has interfered with winter auroral observations carried out by NP using a 180° all-sky camera, and with measurements of the spectral optical depth of the atmosphere carried out by AWI using a star photometer (Shears, 1997).

There is also a potential problem of electromagnetic radiation interference with some of the scientific instruments operated at Ny-Ålesund. Scientific research based on weak

Table 7. Concentrations of a range of atmospheric components (species) (μgm^{-3}) at the Zeppelin station, and the range of possible influence on these measurements from local activities. Emissions are calculated from 1995 data. Source: Beine (pers. comm. 1996).

	CO2	SO2-S	NOx	CO	VOC	Black carbon (soot)
Mean background concentration	700000	0.2	< 0.1	100	5	0.01
Annual variation	± 30000	0 - 0.5	0.002 - 0.2	± 30	2 - 10	0.001 - 0.1
Significant variation	± 2000	± 0.02	± 0.002	± 10	± 0.1*	± 0.01
Influence from 'normal' activity‡	9	0.01	0.1	0.01	0.05	0.01
Influence from Cruise ships	200	0.5	3	0.1		0.24

‡ 'Normal' activity includes powerplant, cars, snowmachines, etc.
* For the sum of all VOCs. Individual hydrocarbons have both lower concentrations and only a fraction of the shown significant variability.

natural electromagnetic signals is increasingly difficult to carry out as anthropogenic radiation from the station intensifies. In particular, the Very Long Baseline Interferometry (VLBI) carried out by the NMA at Ny-Ålesund requires the study of the undisturbed natural radio environment over a large frequency band. New sources of electromagnetic radiation, such as radio transmitters and active scientific radars, would lead to a further deterioration of the conditions required for passive observations. Therefore, Ny-Ålesund is designated a radio-quiet area by the Norwegian Ministry of the Environment. Specifically, the frequency window used by the NMA space geodetic observatory (1 – 10 GHz) must be protected from interference (Petterson, pers. comm. 1996).

There has been a significant loss of tundra around Ny-Ålesund because of station logistical operations (see Section 8.10). The decline in the local breeding populations of some bird species, such as waders, has limited the range of ornithological studies that can be undertaken around the station. Within Kongsfjorden, alternative research areas where these birds are found are very few and much further away from Ny-Ålesund, which limits access to the technical facilities and laboratories available at the station. Apart from this, the large loss of tundra appears to have had little impact on botanical, geomorphological or other scientific research projects. Research requiring pristine tundra is carried out to the west and east of the settlement where large areas of undamaged terrain remain.

There is no evidence that freshwater research in Kongsfjorden has been affected by logistical operations, or other human activities, undertaken in Ny-Ålesund.

Commercial fishing

Commercial fishing causes significant conflicts with marine scientific research and reduces the value of Kongsfjorden as a research and monitoring site.

The damage done by trawling to benthic communities and the stratigraphy of marine sediments from bottom trawling means that affected areas cannot be used as undisturbed reference sites for scientific studies. Sonar imagery taken by NP (Figure 20) shows that trawls have disturbed large areas of the seabed, particularly in the outer fjord at depths below 120 m.

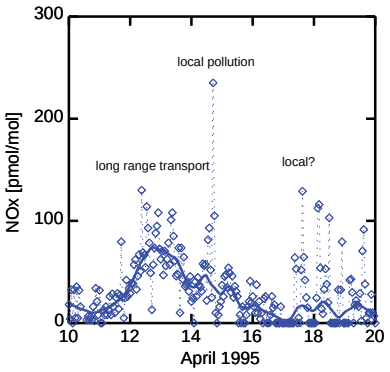


Figure 21. Variations in NO_x (pmol/mol) levels at the Zeppelin station during a 10 day period in 1995. Source: Beine (1996).

Trawling also prevents researchers from deploying instruments in Kongsfjorden because of the risk of equipment loss (Forsberg, pers. comm. 1996). However, marine research undertaken in shallow parts of the fjord or within the sea ice is unlikely to be affected as trawling is carried out in the deeper areas.

The use of Kongsfjorden by fishing boats also conflicts with the global atmospheric monitoring carried out at the Zeppelin station. Although the boats are small (< 20 m length), they often work in Kongsfjorden for long periods when the shrimp fishery is open. Their engine emissions are a significant local source of air pollution.

Tourism

There is evidence that cruise ships operating in Kongsfjorden, and the large numbers of tourists walking around Ny-Ålesund during the summer months, have both affected scientific research.

NILU consider that the use of Kongsfjorden by cruise ships is an important source of local pollution. Emissions from individual tour ships can significantly influence atmospheric measurements of SO_2, NO_x, VOCs and black carbon. The large pollution episodes generated by cruise ships can normally be deleted from the atmospheric monitoring records. However, Kongsfjorden is often visited by two or three cruise ships per day at the height of the summer season and in certain weather conditions this can cause a substantial loss of data at the Zeppelin station.

Shears (1997) found that tourists entered research stations without permission. He also saw tourists walking into the roped-off meteorological station in the centre of Ny-Ålesund where they were seen touching, leaning against or sitting on the steps to the instruments.

As well as direct conflicts, tourism is also responsible for indirect conflicts. Shears (1997) found that a German research project investigating the breeding ecology of the grey phalarope at Ny-Ålesund was severely affected after two of the phalarope chicks being studied were attacked and killed by arctic terns. The terns had become extremely agitated after being repeatedly disturbed by tourists walking through, or very close to, their nests.

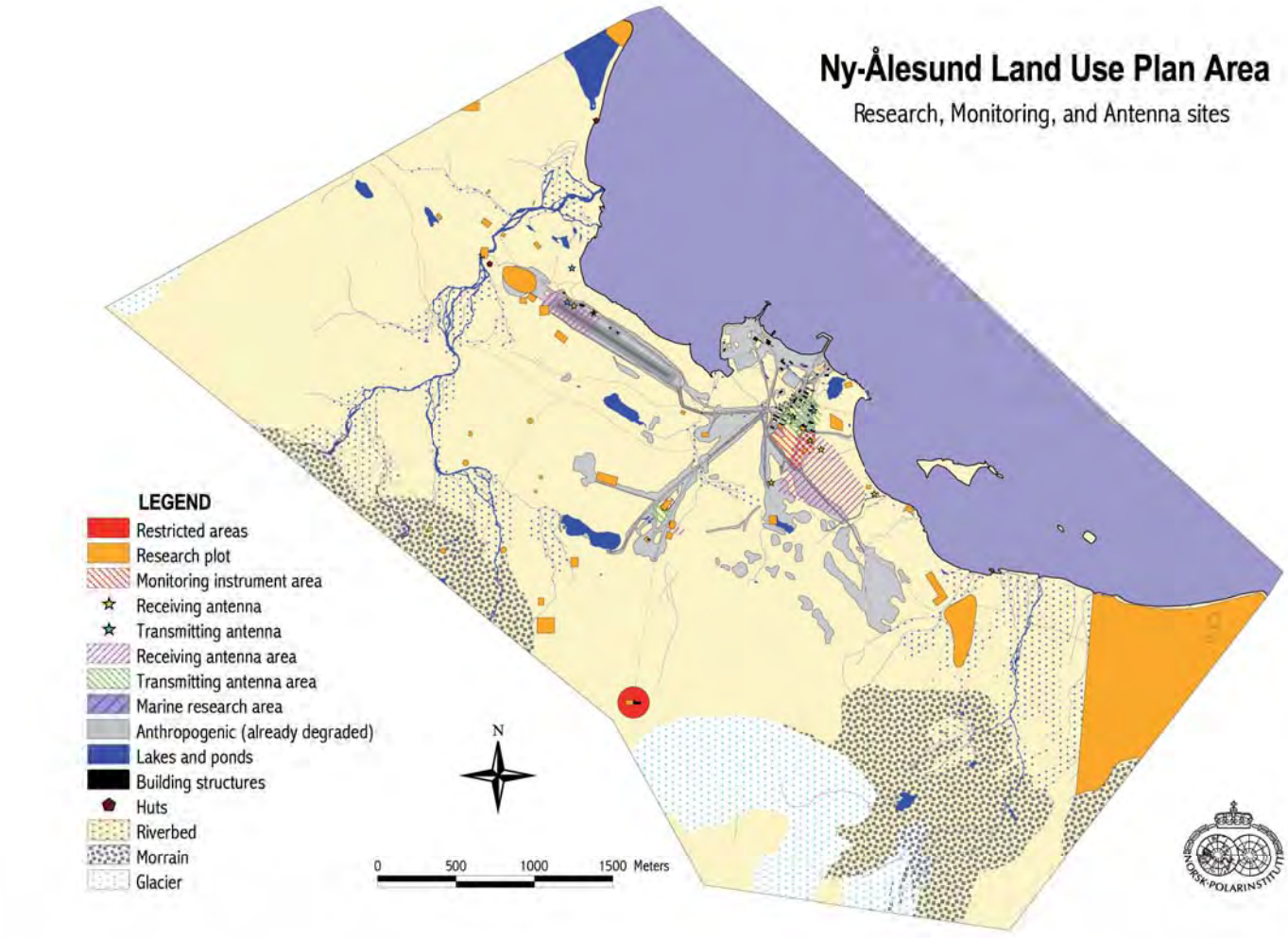
9.2 Conflicts between different scientific research activities

Introduction of reindeer

The introduction of the reindeer in 1978 as part of the NP reindeer research programme has affected both botanical and ornithological research on Brøggerhalvøya. Heavy grazing has caused significant changes in the plant communities, with some plants such as *Deschampsi alpina* disappearing almost completely. The change in vegetation has made the area less suitable for nesting waders, particularly phalaropes.

Unauthorised entry to local protected areas and research sites

Shears (1997) found that there had been unauthorised access by researchers to local protected areas, particularly the area around the lake Solvatnet, and to research sites around Ny-Ålesund. However, Shears (1997) concluded that this conflict had diminished considerably since NySMAC, through NP, had established a database of all the past and present research plots located in and around the station. The database



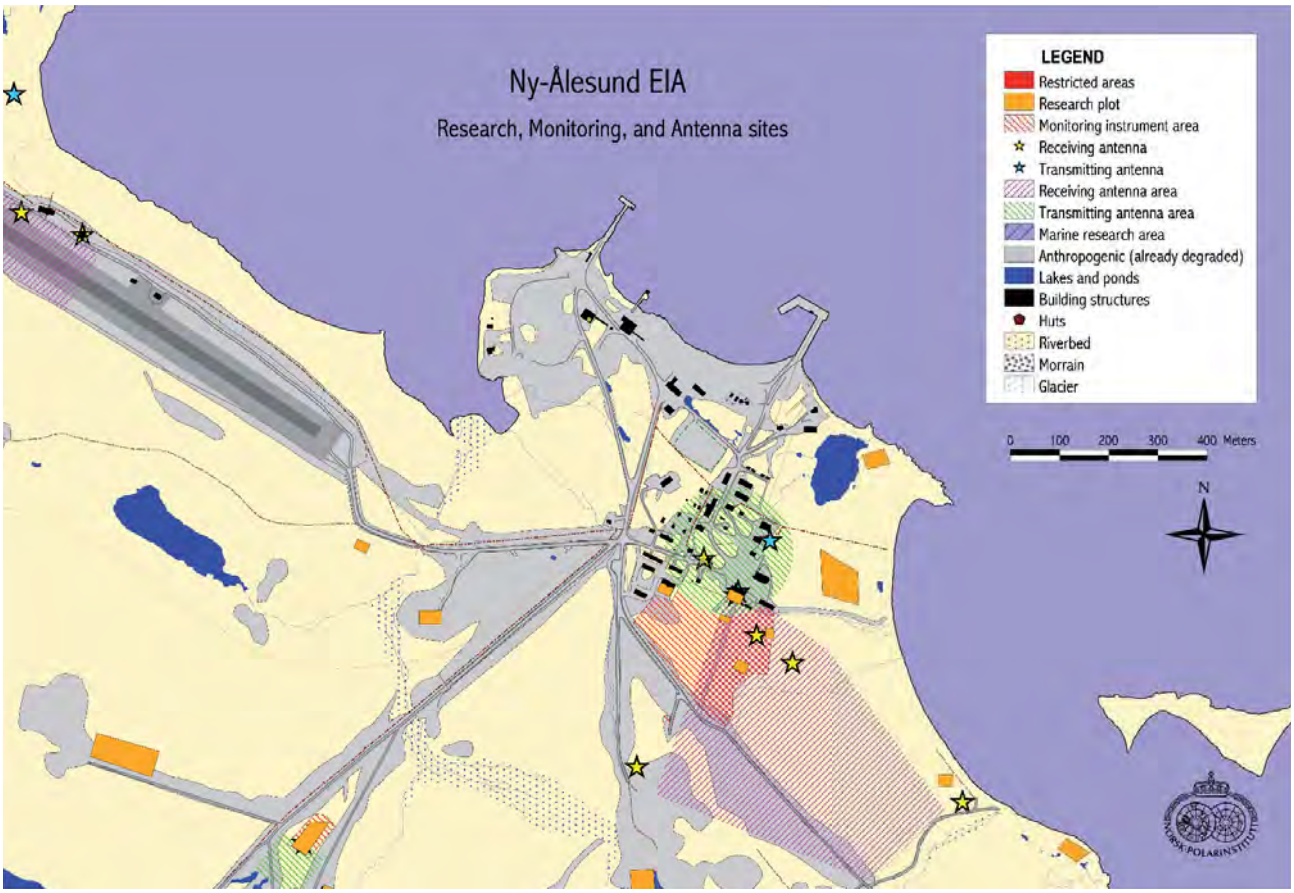


Figure 22 a and b. Scientific research plots and antenna sites around Ny-Ålesund in 1997.

Tourists from a cruise ship visiting Ny-Ålesund. Photo: J. Shears (BAS)

has been linked to a GIS to produce regular updated digital maps of all the research sites in the local area (Figure 22).

Warning signpost at lake Solvatnet. Photo: J. Shears (BAS)

9.3 Cumulative conflicts

Loss of global atmospheric monitoring data due to local emissions

The most serious and significant conflict at Ny-Ålesund is between the global atmospheric monitoring being carried out at the Zeppelin station and logistical operations being carried out at the scientific station and in Kongsfjorden. Here the conflict is widespread in that it involves any activity in the local area that generates atmospheric emissions, but it is also cumulative as activities in the local area increase in number and size.

There is also a cumulative conflict between ornithological research and station logistical activity. The cumulative impact of human activities have combined with overgrazing pressure from reindeer to produce a serious decline in the local breeding populations of waders. The reduction in the number of birds has resulted in the loss of local ornithological research opportunities.

10. SIGNIFICANCE OF IMPACTS AND CONFLICTS

This section examines the significance of the various environmental impacts and conflicts between activities, which have been identified in the EIA. Table 8 summarises these impacts and evaluates their significance in the context of the local environment. Table 9 summarises the conflicts and evaluates their significance in the context of Ny-Ålesund as an international scientific research and monitoring station.

10.1 Impacts of very high and high significance

Table 8 shows that there are impacts of activities of very high and high significance. These are:

Very high significance

i) damage and destruction of habitat (e.g. tundra) from station activities;

ii) cumulative effects of the increased human "footprint" at the station (e.g. fragmentation of habitats by roads and pipelines, disturbance to wildlife by noise, movement and oil pollution).

High significance

i) disturbance of marine soft sediments and to benthic communities by shrimp trawling;

ii) potential contamination of soils, streams and lakes, as well as the marine environment from major fuel spills and leaks at the station and from vessels;

iii) chronic contamination of the marine environment by pollution, particularly PAHs, leaching from dump sites.

10.2 Conflicts of very high and high significance

Table 9 shows that there are conflicts between activities of very high and high significance. These are:

Very high significance

i) loss of atmospheric monitoring data because of local air pollution from station operations and vessels.

High significance

i) partial loss of Kongsfjorden as a scientific research and monitoring site because of shrimp trawling;

ii) potential interference with scientific instruments (e.g. VLBI) by electromagnetic radiation produced by active sources operating in Ny-Ålesund (e.g. active radars, radio transmitters).

Table 8. Summary of impacts on the environment at Ny-Ålesund due to human activities.

Nature	Extent	Duration	Significance
Damage and destruction of habitat (e.g. tundra) from station activities	Ny-Ålesund and local vicinity	Permanent/Long-term (> 5 years)	Very High
Cumulative impacts of increased human "footprint" at the station (e.g. fragmentation of habitats)	Ny-Ålesund and Kongsfjorden	Permanent/Long-term (> 5 years)	Very High
Disturbance of marine soft sediments and to benthic communities by shrimp trawling	Deep water (> 120 m) in Kongsfjorden	Long-term (> 5 years)	High
Pollution of soils, streams and lakes, and the marine environment from fuel spills and leaks at the station and from vessels	Land: around fuel tanks at Ny-Ålesund Sea: much of Kongsfjorden if a major spill from a vessel	Depends on fuel. Maybe long-term if fuel leaches into soil (> 5 years)	High
Pollution (e.g. PAHs) from the dumping of wastes at the station	Land: around Thiisbukta landfill and old dumpsites Sea: much of Kongsfjorden	Long-term (> 5 years)	High
Damage to local bird protection areas by station activities	Ny-Ålesund	Long-term (> 5 years)	Medium
Pollution from the disposal of sewage into the sea near the station	Wharf area at Ny-Ålesund	Medium-term (< 5 years)	Medium
Human disturbance (e.g. noise) of breeding birds	Ny-Ålesund	Long-term (> 5 years)	Medium
Effects of air pollution from local sources on local environment	Ny-Ålesund and Kongsfjorden	Short-term (< 1 week) during periods of low atmospheric stability and wind speeds	Low
Hunting of birds and seals	Brøggerhalvøya and Kongsfjorden	Short-term (< 1 week)	Low
Visual/aesthetic deterioration	Ny-Ålesund	Permanent/Long-term (> 5 years)	Low
Human disturbance (e.g. noise) of reindeer	Brøggerhalvøya	Very short-term (< 1 day)	Low
Scavenging of sewage and/or waste food by Arctic fox	Ny-Ålesund	Very short-term (< 1 day)	Very low

Table 9. Summary of conflicts between activities at Ny-Ålesund.

Nature	Extent	Duration	Significance
Loss of atmospheric monitoring data because of local air pollution from station operations and vessels	Ny-Ålesund and Kongsfjorden	Short-term (< 1 week) during periods of low atmospheric stability and wind speeds	Very High
Partial loss of use of Kongsfjorden as a scientific research and monitoring site because of shrimp trawling	Deep water (> 120 m) in Kongsfjorden	Long-term (> 5 years)	High
Interference with scientific instruments (e.g. VLBI) by electromagnetic radiation from other scientific experiments (e.g. active radars) or station operations	Ny-Ålesund and vicinity	Depends on length of time of operation of active sources	High
Cumulative conflicts due to increased and more numerous human activities at the station	Brøggerhalvøya, Ny-Ålesund and Kongsfjorden	Permanent/Long-term (> 5 years)	Medium
Partial loss of use of Brøggerhalvøya as a botanical and ornithological research area due to over grazing by reindeer	Brøggerhalvøya	Long-term (> 5 years)	Medium
Disruption of scientific research by tourists visiting the station	Ny-Ålesund	Summer only	Low
Interference with scientific instruments from stray light from street lamps and buildings	Ny-Ålesund	Winter only	Low
Unauthorised entry to local protected areas and research sites	Ny-Ålesund	Short-term (< 1 day)	Very low

Box 4

Mission Statement for Ny-Ålesund

Background

The Norwegian Government has formulated as a goal that Ny-Ålesund is to be developed into a leading international Arctic environmental research and monitoring station.

The Norwegian Ministry of Environment White Paper No. 42 "Norwegian Polar Research", 1992-93, states that:

- A prerequisite for Ny-Ålesund continuing to attract Norwegian as well as foreign scientific activities is that the local human impacts on the environment are kept at a very low level.
- Other activities in the area must adapt to the conditions set by scientific research and monitoring.

The following Mission Statement was adopted by the Ny-Ålesund Science Managers Advisory Committee at the 7th NySMAC Meeting on 24 August 1997:

The mission of Ny-Ålesund, Svalbard is to:

1. Serve as an international station for scientific research and monitoring;
2. Encourage international scientific co-operation;
3. Give priority to scientific research and monitoring that is dependent on the near pristine environment or unique qualities of the Ny-Ålesund area, in particular research related to long range pollution, climate change and polar ecology;
4. Preserve the near pristine environment of Brøggerhalvøya and the Kongsfjorden area, as well as the cultural heritage of Ny-Ålesund;
5. Keep local human environmental impacts at the lowest possible level so as not to jeopardise scientific research and monitoring;
6. Give scientific research and monitoring priority over other local human activities, such as tourism and commercial fishing;
7. Be a prime example of the sustainable operation and development of a research station in the polar regions.

The success of the station will be judged on its scientific merits and achievements.

11. MEASURES TO MINIMISE OR MITIGATE IMPACTS AND CONFLICTS

11.1 Environmental Action Plan

Section 10 has demonstrated that there are impacts and conflicts of very high and high significance at Ny-Ålesund. These impacts and conflicts need to be prevented, minimised or at least mitigated if their significance is to be reduced to an acceptable level. A twelve point Environmental Action Plan (EAP) for Ny-Ålesund is therefore recommended. This prioritises the actions that need to be taken and is outlined below.

"Mission statement"

The first priority of the EAP is to develop a "mission statement" for Ny-Ålesund. The aim of this is to set out a clear and agreed written statement as to the exact role of the station.

Recommendation 1

Prepare a "mission statement" for Ny-Ålesund.

A draft "mission statement" was examined and developed at the NySMAC EIA Workshop held at Ny-Ålesund on 23 August 1997. It was subsequently adopted at the 7th NySMAC Meeting on 24 August 1997. The agreed "mission statement" sets out seven guiding principles for the operation and development of the station so that international scientific research is given priority and human impacts are minimised. The full text of the mission statement is shown in Box 4.

Precautionary upper limit on total activity/people

The second priority is that a precautionary limit should be placed on the total activity/numbers of people at the station. This is necessary because the EIA has shown that there are already impacts and conflicts of very high significance. Further development, if it is not restrained, will inevitably increase human impacts and conflicts. It is recognised that this recommendation may be contentious as the Svalbard Treaty gives all signatories equal rights of access to the archipelago. The determination of how the upper limit of activity should be calculated and what it should be has not been undertaken by this EIA. This requires further work by NySMAC in co-operation with KBKC.

Recommendation 2

Set a precautionary upper limit on the total activity/numbers of people at the station.

Stabilisation and reduction of local emissions

The EIA has shown that the current level of local emissions poses a very serious threat to the global atmospheric monitoring being carried out at the Zeppelin station. If local emissions continue to increase then the level of contamination will be so high that the Zeppelin station will become unusable. Local emissions must therefore be stabilised and reduced.

Recommendation 3

Stabilise and reduce local emissions, and stop any open burning.

Protect flora and fauna and revegetate degraded tundra

The EIA has revealed that there has been significant destruction and disturbance of the tundra around Ny-Ålesund. Under the terms of the Svalbard Treaty of 1920, Norway is obliged to ensure the preservation and, if necessary, the reinstatement of the natural environment of the archipelago (see Box 1). At Ny-Ålesund there is an opportunity to put this legal requirement into action by revegetating tundra around the station, particularly in areas that have been abandoned (e.g. old coal mining areas, worked out gravel and rock pits). Experiments by Klokk and Rønning (1987) have shown that revegetation of native plants at Ny-Ålesund is possible and can be done in a simple way by applying commercial fertilisers. The fourth priority is therefore that measures need to be taken to protect flora and fauna, and damaged tundra should be restored.

Recommendation 4

Protect flora and fauna, and revegetate degraded tundra areas.

Increase and improve visitor information

Many of the people working or visiting Ny-Ålesund are unaware of how vulnerable some environmental resources in the Arctic are to human activity, or how easy it is to disturb important scientific research. At present, people visiting or staying at the station are given very little information on how they should minimise impacts or conflicts. The fifth priority of the EAP is therefore that better information should be provided and that this information should be made easily accessible.

Recommendation 5

Increase and improve the information provided to all visitors and residents of Ny-Ålesund giving them guidance as to how they can reduce human impacts on the environment and minimise conflicts at the station. There should also be better circulation of information on current and planned activities.

Incorporate the results of the EIA into the Land Use Plan

The preparation of a Land Use Plan for Ny-Ålesund began in 1997 (Ramberg, 1997). This will set out how the settlement should be developed in the future. The plan is the responsibility of KBKC as the land owner, but requires the approval of the Sysselmannen and the Norwegian Ministry of Environment before it can be adopted. It is important that the results of the EIA should be taken into account in the Land Use Plan so that both the environment and scientific research can be adequately protected.

Recommendation 6

Incorporate the key results of the EIA into the Land Use Plan for Ny-Ålesund.

Prevent fuel spills

Major diesel fuel spills occurred at Ny-Ålesund in 1986 and 1990. However, the EIA has shown that little has been done to prevent, prepare for and respond to similar spills in the future. It is of serious concern that the station does not have a written

spill contingency plan. The prevention of fuel spills is therefore the next priority.

Recommendation 7

Prevent fuel spills and establish a station fuel spill contingency and clean-up plan.

Improve waste management

The EIA has shown that current waste disposal practices at Ny-Ålesund impact the environment, although the situation has improved considerably since 1994. The current disposal of sewage onto the tundra at Raaben and the poor operating standards at the open landfill at Thiisbukta are unacceptable at a modern polar research station. The EIA has found that the current dump, as well as other old, local dumps, are probably major sources of pollution in Kongsfjorden, particularly of PAHs. Improving waste management and reducing contamination from the dumps is therefore a further priority.

Recommendation 8

Improve waste management by closing the rubbish dump at Thiisbukta, and reducing contamination from this dump and others in the Ny-Ålesund local area.

Reduce tourism

Approximately 10,000 tourists now visit Ny-Ålesund every year. The vast majority of tourists arrive by cruise ship. In Svalbard, only Magdalenefjord and Longyearbyen now receive more cruise ship passengers. The EIA has shown that cruise ships are a major source of local emissions, and that tourists have disturbed breeding birds around the station and conflicted with some scientific research. The next priority is to reduce the numbers of tourists visiting Ny-Ålesund to a level more appropriate for an international scientific research and monitoring station.

Recommendation 9

Reduce the number and size of tour ships calling at the station.

Protect the Kongsfjorden area as a combined terrestrial and marine "scientific research area"

The environmental impact of shrimp fishing on the marine food web in Kongsfjorden is unknown. However, trawls have ploughed large areas of the soft bottom sediments in the deeper waters (> 120 m) of Kongsfjorden. In areas where there is frequent fishing benthic communities are likely to be highly disturbed. The deeper waters of Kongsfjorden cannot therefore be used as an undisturbed scientific reference site for marine sedimentology or benthic ecology. Trawls have also damaged moored scientific instruments, and fishing now prevents further instruments from being deployed. Increased cruise ship and land-based tourism also has the potential to disturb scientific research and monitoring in Kongsfjorden. As the next priority, the Kongsfjorden area should be designated as a combined terrestrial and marine "scientific research area" with special regulations to ensure that other activities do not harm its value for scientific research and monitoring.

Recommendation 10

Establish the Kongsfjorden area, including Brøggerhalvøya, as a combined terrestrial and marine "scientific research area".

Employ a scientific/environmental manager at Ny-Ålesund

Currently at Ny-Ålesund nobody is employed on a day-to-day basis to liase between the different scientific organisations and KBKC to ensure that human impacts and conflicts are minimised. A further priority is that a senior scientific/environmental manager should be employed at the station.

Recommendation 11

Employ a senior scientific/environmental manager at the station.

Establish stricter control over activities

The EIA has shown that the station has grown rapidly over the past decade, particularly since 1990. Until the formation of NySMAC in 1994 the management of activities at Ny-Ålesund was somewhat loose and laissez-faire. The situation has improved, particularly through the use of the hearing procedure adopted by NySMAC for major projects. However, the pace and scale of change at the station remain rapid and as a final priority there needs to be stricter controls over activities if human impacts and conflicts are to be prevented.

Recommendation 12

Introduce stricter controls over activities.

Box 5 shows the detailed measures that are recommended to implement each of the twelve priorities suggested for the Environmental Action Plan.

Box 5.

Measures recommended to implement the twelve priorities of the Ny-Ålesund Environmental Action Plan

1. Prepare a "mission statement" for Ny-Ålesund

Task already accomplished.

2. Set a precautionary upper limit on the total activity/ number of people at the station.

Methods to determine an upper limit should be developed by NySMAC in co-operation with KBKC.

3. Stabilise and reduce local emissions, and stop any open burning

3.1 Reduction of emissions from power generation

Emissions should be minimised through the use of best available technology, energy recovery and cleaning of flue gases.

Emissions should have an estimated influence at the Zeppelin monitoring station smaller than one order of magnitude below the natural variation.

A 99% reduction in emissions of NO_x, soot, VOCs and SO_2 compared to 1996 levels.

Secondary emissions and waste from cleaning of flue gases must be taken into consideration to avoid new sources of local pollution.

3.2 Energy conservation

An energy conservation survey should be carried out, and cost-effective measures implemented.

3.3 Use of alternative energy sources

A preliminary assessment of the wind energy potential for power generation at the station should be undertaken.

A preliminary assessment of the solar energy potential for different purposes at the station should be undertaken.

3.4 Control and reduction of transport emissions

Restrictions on the number and use of vehicles and snowmobiles.

Incentives to increase the use of bicycles.

The idling of vehicles and snowmobiles to be banned.

Increased use of engine block heaters.

A common pool for vehicles and snowmobiles.

Control of emission levels from vehicles and snowmobiles.

Replacement of older vehicles with modern ones with the best available emission controls.

A daily log of all activities at the station could have a significant influence on atmospheric measurements (e.g. cars, snowmobiles, boats).

Snowmobiles and cars to be confined to clearly defined transport corridors up to 5 km away from the station.

3.5 Introduction of a "quiet" period

Local emissions reduced to the absolute minimum for establishment of baseline conditions regarding local emissions.

3.6 New international scientific programme

A research project should be established to monitor the state and stability of the atmosphere in Kongsfjorden to help interpret local pollution events.

4. Protect flora and fauna, and revegetate degraded tundra areas.

4.1 Habitat protection

Areas designated as local bird reserves, and all areas with relatively intact or lush vegetation within the station, should be protected.

Proper marking of protected areas and other "no go" areas.

Expansion of local bird protection areas.

4.2 Hunting

Ban hunting.

4.3 Restoration of habitats

Removal of redundant infrastructure to restore important habitat (e.g. closure of the western road to the old harbour).

New developments should include, as part of their planning, the restoration of the surrounding local tundra.

Revegetation of abandoned areas (e.g. old coal mining areas) with native plants.

5. Increase and improve visitor information

Provide adequate information and guidance to all residents and visitors (e.g. leaflets containing simple sensitivity maps, noticeboards showing the maps at key locations around the station).

6. Incorporate the key results of the EIA into the Land Use Plan for Ny-Ålesund

6.1 Location of new developments (e.g. buildings and infrastructure)

New developments should be restricted to already disturbed areas.

New developments should avoid disturbance, or loss of:

- local bird protection areas;
- other important nesting, feeding and resting sites for birds;

wetlands and areas with moist or otherwise vulnerable vegetation or ground surfaces; or,

other areas with undisturbed or lush vegetation.

Building sites should be assessed to determine if the ground is contaminated by fuel spills, PCBs or other pollutants, and if necessary cleaned-up, before construction work takes place.

6.2 Transport minimisation

New buildings should be located so that they minimise the need for motorised transport.

6.3 Avoid conflicts with research and monitoring activities

6.4 Protection of the cultural environment and historic sites

New buildings and infrastructure must be adapted to:

the cultural and architectural environment of Ny-Ålesund;

show regard for aesthetic values; and,

must not disturb historic sites.

6.5 Use of environmental sensitivity maps

Use the environmental sensitivity maps as a key information source in the preparation of the Land Use Plan.

7. Prevent fuel spills and establish a station fuel spill and clean-up contingency plan

7.1 Prevention of fuel spills

Strengthen management procedures for fuel spill response, including the production of a written station contingency plan.

Improve bulk fuel storage by constructing bunds around tanks.

Improve drum storage.

Spend capital on spill response equipment, materials and clothing.

Introduce a station fuel spill training programme.

Maintain records of fuel use and spills.

Minimise atmospheric emissions from storage and handling of fuels.

7.2 Clean-up of spills and contaminated ground

Prevent chronic pollution from present and past spills, including the installation of oil traps and barriers at polluted sites.

Develop a clean-up plan for areas contaminated by past fuel spills.

8. Improve waste management and reduce contamination from dumps

8.1 Improve waste management procedures

Strengthen waste disposal policy and management, including a commitment that all wastes should be removed from Ny-Ålesund, except for sewage and food wastes.

Close the dump at Thiisbukta, and ban dumping of wastes at the station.

Ban burning of wastes and fuel.

Dispose of all sewage to the sea via submerged, inshore outfalls.

Install secondary treatment plant for sewage disposal.

Remove all hazardous wastes (e.g. laboratory chemicals) from the station.

Improve current disposal and recycling procedures.

Monitor production and disposal of wastes.

Introduce a waste minimisation programme.

Carry out one-day station litter pick-up at mid-summer each year.

Extension of sewage pipeline to avoid littering of beach.

8.2 Identify contamination from dumps and implement remedial action

Identify dumps that are sources of contamination (e.g. PAHs, PCBs).

Develop a clean-up plan for old dumps, including clean-up of the dump at Thiisbukta.

9. Reduce the number and size of tourist ships calling at the station

Regulation of large vessels entering Kongsfjorden

10. Establish Kongsfjorden area, including Brøggerhalvøya, as a combined marine and terrestrial "scientific research area"

Stop the sale of fuel and provisions at Ny-Ålesund to ships**;**

Relocate trawling and other fishing activities that may reduce the value of Kongsfjorden as a site for scientific research and monitoring;

NySMAC to develop an outline proposal for the "scientific research area", and submit this to the Norwegian Ministry of Environment.

11. Employ a senior scientific/ environmental manager at Ny-Ålesund

The manager's role would be to develop and co-ordinate new major research programmes, resolve conflicts between activities and ensure impacts on the environment are minimised.

12. Introduce stricter controls over activities

12.1 Management procedures

Establish a Ny-Ålesund Planning Group that would meet once a month to evaluate new proposals, particularly construction projects and major research programmes.

Prepare written guidelines for

activities (e.g. construction work, transport) at the station, which would set out requirements for minimising interference.

12.2 Regulation of off-road driving

Protect areas of undisturbed or lush vegetation and vulnerable ground surfaces from off-road driving by:

- restricting off-road driving to either heavily disturbed areas or frozen and snow covered ground;
- ensuring that unnecessary disturbance of vegetation and animal habitats, in particular nesting, feeding and resting bird sites is avoided;
- preventing the establishment of new, or enlarged, roads or vehicular tracks.

12.3 Control of helicopter traffic

Landing of helicopters inside the settlement in the summer should be restricted to emergency purposes only.

12.4 Control over pedestrian traffic

Disturbance from pedestrian traffic should be kept to a minimum by providing adequate information and guidance to all residents and visitors (e.g. leaflets containing simple sensitivity maps, noticeboards showing the maps at key locations around the station).

Tourists should be restricted to existing roads and pathways.

Tundra revegetation experiment, Ny-Ålesund. Photo: J. Shears (BAS)

12. ENVIRONMENTAL MONITORING

12.1 Monitoring of key ecosystem indicators

At present there is no organised, long-term environmental monitoring carried out at Ny-Ålesund. If a carefully focused monitoring programme were introduced it could be used to assess and verify the actual environmental impact of human activities at the settlement for relatively little cost. Monitoring could also be used to check the predictions made in this EIA, as well as the effectiveness of the recommended mitigation measures. Here, environmental monitoring is defined as the repeated measurement of an environmental variable so that a trend is established which can be related to a desired goal or standard.

The key ecosystem indicators which should be monitored at Ny-Ålesund are shown in Table 10. It is recommended that NySMAC organises the monitoring programme, and requests its members to carry out the various studies. Data from the monitoring programme should be incorporated into the GIS which has been established for Ny-Ålesund by NP (Norris, 1995).

12.2 Monitoring of station environmental performance

In addition to key ecosystem indicators, human activities at Ny-Ålesund also need to be monitored. This is because data from the key ecosystem indicators may not be sufficient to determine the actual source of the impact. For example, analysis of atmospheric monitoring data for the EIA has shown it is very difficult to determine the input from different local sources from the atmospheric data alone (see Section 9.1).

Table 11 shows which indicators need to be monitored to determine the environmental performance of the station. These measurements concentrate on logistics and operations, and are best carried out by KBKC as they are responsible for maintaining and operating the settlement. It is recommended that KBKC should make this monitoring data freely available at least every week to other organisations working at Ny-Ålesund, and submit an annual summary and review of the environmental performance data to NySMAC. If accidental fires or fuel spills occur then interested parties should be notified immediately by KBKC.

Table 10. Recommended key ecosystem indicators for monitoring human impacts at Ny-Ålesund.

PHYSICAL INDICATORS	PARAMETERS
Emissions	Concentrations of atmospheric species (e.g. NOx, SO2, PCBs, black carbon, heavy metals).
	Levels of persistent organic pollutants (e.g. PCBs) and heavy metals in moss and lichens.
Discharges	Levels of petroleum hydrocarbons (e.g. PAHs), chlorinated hydrocarbons (e.g. PCBs) and heavy metals in sediments and selected biota (e.g. predatory benthic fish).
Fuel spills	Levels of petroleum hydrocarbons (e.g. PAHs) in soils, fresh water, sea water, marine sediments and selected biota (e.g. benthic dwelling fish).
BIOLOGICAL INDICATORS	
Habitat	Mapping of terrestrial vegetation.
	Mapping of kelp forests
Sedentary marine organisms	Biological effects on selected species (e.g. imposex in whelks).
	Composition of benthic macrofauna.
Birds	Breeding success/distribution of bird colonies (e.g. waders).

Table 11. Recommended indicators for determining the environmental performance of Ny-Ålesund.

PERSONNEL INDICATORS	PARAMETERS
Numbers of people	Number of overnight stays/week for people living at Ny-Ålesund, the campsite, and at huts/field camps around Kongsfjorden.
Tourists visiting the station	Number of tourists/week.
Other visitors (e.g. fishermen)	Number of other visitors/week.
ENERGY INDICATORS	
Fuel usage	Usage of gas oil, Arctic diesel oil and petrol (tonnes)/week.
Energy usage	Energy usage (GWh)/week.
ACTIVITY INDICATORS	
Vehicles	Daily log of all station vehicle traffic (e.g. cars, snowmobiles).
Aircraft	Daily (weekly in winter) log of all aircraft traffic in Kongsfjorden(e.g. fixed-wing aircraft, helicopters).
Vessels	Daily (weekly in winter) log of all vessels using Kongsfjorden (e.g. cruise ships, research vessels, fishing boats, yachts).
Construction projects	Daily log of major construction projects (e.g. major buildings or facilities).
WASTE INDICATORS	
Solid non-hazardous waste	Waste to station landfill (tonnes)/week. Waste recycled/removed to Longyearbyen (tonnes)/month.
Sewage	Sewage and grey water disposed of via outfalls (litres)/week.
Hazardous waste	Hazardous waste removed to Norway for safe disposal (tonnes)/year.
ENVIRONMENTAL INCIDENTS	
Fires	Details of incident (time, date, cause, materials burnt, emergency action taken).
Fuel and chemical spills	Details of incident (time, date, cause, type of fuel/chemical, quantity spilled in litres, emergency action taken).
Complaints	Details of complaint (time, date, cause of complaint, person making complaint, action taken).

13. CONCLUSION

This EIA has demonstrated that the current operation of Ny-Ålesund is having a significant impact on the local environment, and that there are serious conflicts between activities being carried out at the station.

Environmental impacts identified as having very high significance are the damage and degradation of habitat, particularly tundra, from station activities, and the cumulative effects of the increased "footprint" of the station which is causing fragmentation of habitats and disturbance to wildlife. The total area of tundra lost has increased by almost 50% in the last decade, from 78 ha in 1986 to 116 ha in 1997.

Other environmental impacts of concern are the widespread disturbance of marine soft sediments and benthic communities in the deeper waters of Kongsfjorden by shrimp trawling, and pollution of the fjord by PAHs leaching from the station rubbish dump and other old dump sites nearby. There has also been a significant decline in the species and numbers of waders breeding at Ny-Ålesund since 1981 due to habitat loss as a result of station activities and reindeer overgrazing. Major diesel spills occurred at the station in 1986 and in 1990, and contamination of soils from the 1986 spill persists. The risk of further fuel pollution remains high, as little has been done to prevent or prepare for possible future spills.

There are some significant conflicts between the various activities undertaken at Ny-Ålesund. The most serious is the major disturbance to global atmospheric monitoring carried out at the Zeppelin station due to local air pollution from station activities at Ny-Ålesund and from vessels in Kongsfjorden. If urgent steps are not taken to reduce local emissions then the measurements taken at the Zeppelin station will become unreliable and this unique site will no longer be useful for scientific research and monitoring.

Commercial shrimp trawling also causes conflicts with marine scientific research by preventing the deployment of moored instruments, and reduces the value of Kongsfjorden as a scientific research and monitoring site.

There is also a potential problem of electromagnetic radiation generated by active emitters (e.g. radars, radio transmitters) at the station interfering with scientific instruments that require a very quiet radio environment (e.g. the Very Long Baseline Interferometery antenna).

The policy of the Norwegian Government for Ny-Ålesund is that priority is to be given to scientific research over other human activities, and that local human environmental impacts at the settlement should be kept to the lowest possible level. This EIA has shown that in practice this policy has not been properly enforced or implemented.

Continuing the current pace and scale of development of Ny-Ålesund is not sustainable, and if left unchecked will lead to continued degradation of the local environment and disturbance to scientific research. This in turn will jeopardise the reputation of Ny-Ålesund as a leading Arctic scientific research and monitoring station, and may eventually result in scientific organisations relocating.

It is concluded that a "business-as-usual" approach to the management of Ny-Ålesund is no longer acceptable and comprehensive action needs to be taken to protect scientific research and monitoring and stop further degradation of the local environment.

This EIA has recommended an Environmental Action Plan (EAP) for the station, which prioritises the actions and mitigation measures that need to be taken. Parts of the EAP, most notably the "mission statement", have already been agreed and adopted by NySMAC. A wide-ranging environmental monitoring programme has also been recommended so that the effectiveness of the EAP can be judged. It is suggested that this programme should include not only the monitoring of key ecosystem indicators (e.g. breeding success of birds), but also monitoring of station environmental performance (e.g. waste production).

If the EAP and monitoring programme are implemented properly by NySMAC and KBKC, it is considered that human impacts and conflicts at Ny-Ålesund will be reduced to the minimum. The establishment of these environmental management procedures will help Ny-Ålesund to regain, and then greatly enhance, its reputation as a leading Arctic scientific research and monitoring station.

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LIST OF ACRONYMS

AMAP	Arctic Monitoring and Assessment Programme
AWI	Alfred Wegener Institute for Polar and Marine Research
BAS	British Antarctic Survey
CASP	Cambridge Arctic Shelf Programme
CNR	Consiglio Nazionalle delle Ricerche
EAP	Environmental Action Plan
EIA	Environmental Impact Assessment
ESRO	European Space Research Organisation
GIS	Geographic Information System
KBKC	Kings Bay Kull Company A/S and Kings Bay A/S
NERC	Natural Environment Research Council
NILU	Norwegian Institute for Air Research
NIPR	National Institute for Polar Research
NMA	Norwegian Mapping Authority
NP	Norwegian Polar Institute
NSC	Norwegian Space Centre
NySMAC	Ny-Ålesund Science Managers Advisory Committee
PAH	Polycyclic Aromatic Hydrocarbons
PCB	Polychlorinated Biphenyls
SFT	State Pollution Control Authority
TBT	Tributyltin
VHF	Very High Frequency
VLBI	Very Long Baseline Interferometry
VOC	Volatile Organic Compounds