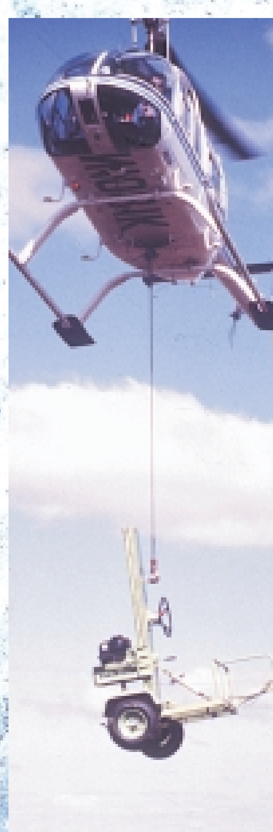
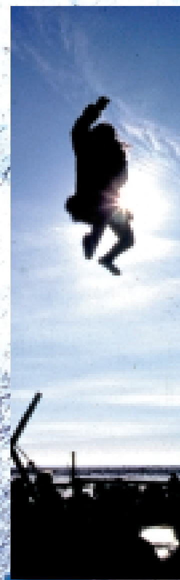
The Future of an Arctic Resource





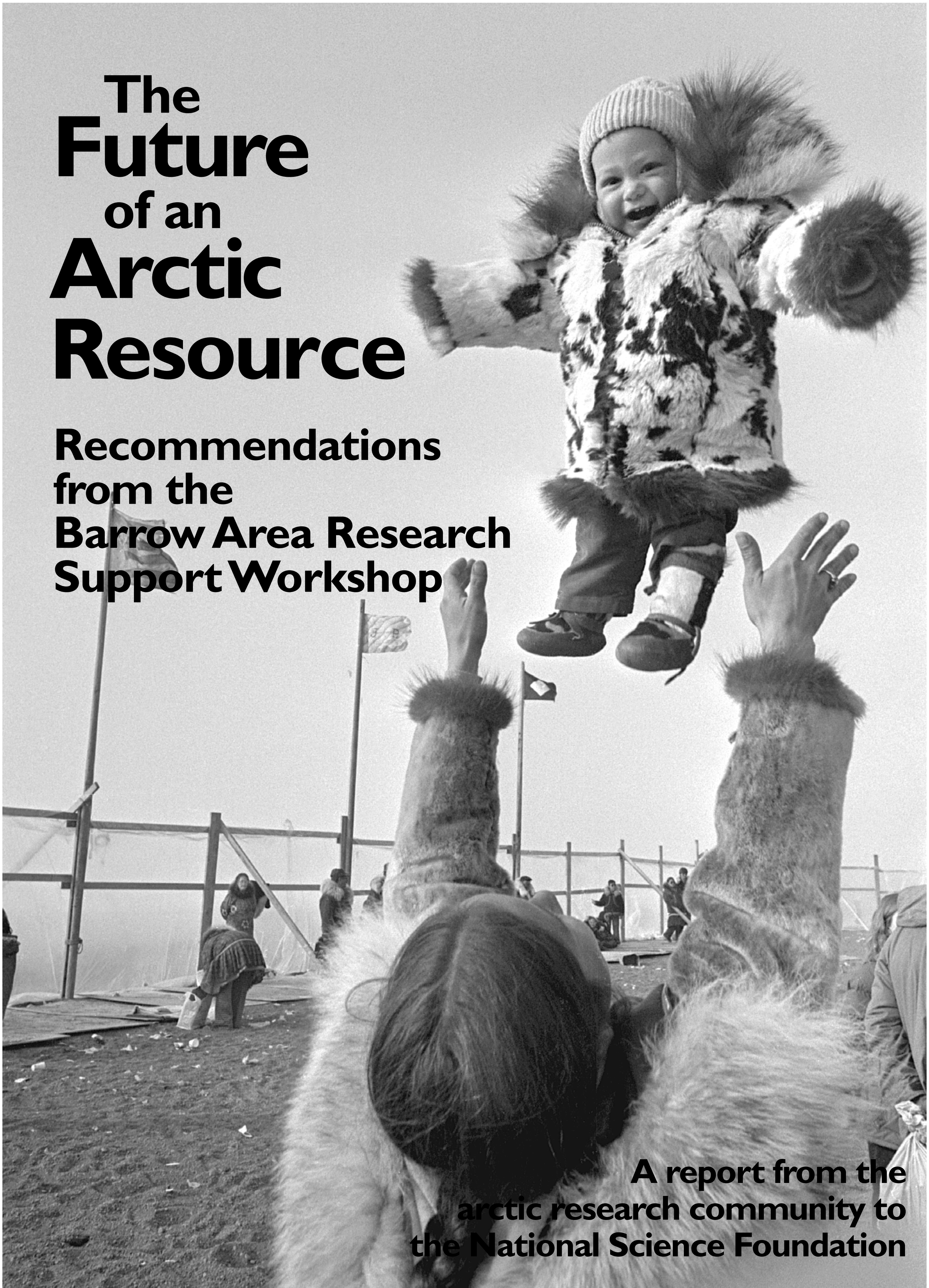
Recommendations from the Barrow Area Research Support Workshop

"It was late evening. The sun cruised low over the icy horizon to the northwest. Although we were still a few days from the last sunset of the season, we had entered the time of year when there is no darkness. Sunset would slowly give way to a couple of hours of pastel blue twilight, which would then yield to the glow of sunrise."

Bill Hess
in whaling camp in early May 1985
from *Gift of the Whale,* 1999

The Future of an Arctic Resource

Recommendations from the Barrow Area Research Support Workshop



A report from the arctic research community to the National Science Foundation

Cover (clockwise from bottom): ***An open boat (umiak) rests on the sled used to pull it to the edge of the ice to hunt bowhead whales near Barrow, Alaska. Photo © Dave Koester.*** ▼ *San Diego State University researcher Dmitri Karelin taking measurements at SDSU's tundra manipulations site located in Barrow. Manipulations of temperature and water table at this site demonstrate the response of CO_2 flux to elevated tundra temperatures and varying water table depths, as a means of predicting future changes and feedbacks in arctic ecosystems due to climate change. Photo by Rommel C. Zulueta.* ▼ *Denver Holt of the Owl Research Institute examining a nest of snowy owls. Holt has been investigating the owls' breeding biology in the Barrow area since 1991. Photo by Michele Hauschulz.* ▼ *Student Aaron Putnam (drilling) and teacher Tim Buckley of Barrow High School drill an ice core from the Arctic Ocean to study chemical and biological properties of ice and sediment during the Arctic West Section '98 cruise of the U.S. Coast Guard Cutter* Polar Sea. *Their participation in the cruise was supported by the NSF-funded Teachers Experiencing Antarctica and the Arctic. Photo by Terry Tucker.* ▼ *A portable drilling rig used in permafrost studies by Cold Regions Research and Engineering Laboratory researchers during the late 1970s and early 1980s. Photo by Jerry Brown.* ▼ *A blanket toss at the Nalukataq (celebration of spring whaling) in Barrow. Photo by Henry Huntington.* ▼ *Background satellite photos from the University of Alaska Fairbanks Geophysical Institute Geodata Center.*

Title page photo: Jana Harcharek gives her son Nagruk a preview of the blanket toss. Photo © Bill Hess, Running Dog Publications.

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Foreword

The range of research that has been and is being undertaken in the Barrow area, the opportunities that exist, and the commitment of the Barrow community to research make this part of the Arctic a remarkable place for research. Taking full advantage of this unique combination of factors requires many things. First, the commitment to the legacy of rigorous, innovative, and important research must continue and expand as larger and more complex questions are studied. Second, Barrow residents must continue to be involved in all aspects of research to enrich the research and maintain local interest. Third, the logistical and infrastructure needs of researchers must be provided so that research can be carried out efficiently, safely, and successfully.

The Barrow Area Research Support Workshop, the results of which are reported here, covered all three topics and produced a set of recommendations that address the third point, logistics and infrastructure. The number of participants, the diversity of fields represented, and the vigor of the discussions emphasized the importance of research in Barrow and the need to enhance the logistics provided to researchers. The questions that were raised do not all have simple answers, nor can the recommendations be followed simply and quickly. A great deal must be done over the next years and decades to maintain the facilities that exist and to add the capacity for more and different research. This report and its recommendations are a starting point and should help guide the efforts of researchers, funding agencies, and the Barrow community to provide research support that will not only accommodate researchers but encourage and stimulate them as well.

That the workshop succeeded in its goals is due in large part to the commitment of the participants as well as to the tireless efforts of many people to plan and conduct the sessions. Wendy Warnick of ARCUS guided the planning process. Alison York coordinated the report drafting process and provided crucial editorial expertise. Sue Mitchell contributed technical expertise for graphics and layout of the report. Diane Wallace, Dan LaSota, and other staff at ARCUS took care of logistics and made sure everything went smoothly during the workshop. On behalf of the arctic research community, I thank the National Science Foundation for the opportunity to participate in this planning process.

Henry P. Huntington

Henry P. Huntington, Ph.D.
Workshop Chair

Benjamin P. Nageak was mayor from 1996 to 1999 of the North Slope Borough, a county-like subdivision that provides regional governmental services for the North Slope of Alaska. As a young man, Ben Nageak worked with scientists at the former Naval Arctic Research Laboratory (NARL). Along with many of his friends and relatives, he grew up thinking that taking part in scientific research was a natural part of life. When the Navy left Barrow, everyone recognized it as a great loss. When Ben Nageak helped start the Barrow Arctic Science Consortium (BASC) in 1995, it was with the idea that it is truly important to bring together the local community and the scientific research community.

Richard Glenn is president of BASC, a non-profit organization dedicated to promoting research and local involvement in research in the Barrow area. Richard is a geologist with a graduate degree from the University of Alaska Fairbanks and has just been reappointed by President Clinton to membership on the U.S. Arctic Research Commission. Richard heeded the Barrow elders, who wanted the same opportunities for working with scientists extended to younger people that had once been available to them. Richard works tirelessly to help researchers and to help provide opportunities for exposure to scientific research for young people.

Photos © Bill Hess, Running Dog Publications.

The Barrow Community and Science

We welcome the thought and attention that the scientific community has directed to the issue of supporting scientific research in the Barrow region. As members of the Iñupiat Eskimo community living in Barrow, we are very aware of and gratified by the interactions that have historically taken place and continue between our groups.

As mayor of one-sixth of Alaska's landmass, and as president of a nonprofit organization dedicated to facilitating science in the Arctic, we commend to you, our colleagues, the work of the participants in the Barrow Area Research Support Workshop and the others in the arctic research community who have contributed to this planning effort. We think that you will find this report to be insightful and to the point. Scientists find that working in the Barrow area and with the people of the North Slope of Alaska is helpful to their research. They also find that, as America's northernmost community, Barrow is lacking in certain necessities and amenities that today's scientists require in order to make the most of their research opportunities. We know that some arctic localities outside the U.S. are well endowed with sufficient laboratory space, field equipment, and support personnel to really make research support "transparent" to the scientists. We know that the recommendations of this workshop are designed to give the U.S. the same resources in its own share of the Arctic. We hope that you will help to see these improvements come true.

We thank the National Science Foundation for sponsoring this planning effort and the many members of the research community and the community of Barrow who have participated. We also recognize the important role that ARCUS has played in gathering the research community together and channeling the efforts of a diverse group toward a common goal. We pledge that the people of Alaska's North Slope will continue to help in these endeavors!

Honorable Benjamin P. Nageak
Mayor, North Slope Borough
30 August 1999

Richard S. Glenn
President, Barrow Arctic Science Consortium (BASC)

Introduction

I

Scientific research has been conducted in the area around Barrow, Alaska, for more than a hundred years. Few places in the world, and fewer still in the Arctic, have witnessed a similar concentration of research over an extended period or such outstanding community support for both the research and the researchers (BASC, 1998). This unique legacy continues today and is expected to remain strong in the years and decades to come. This report describes the context of scientific research in Barrow and makes recommendations for providing common support for scientists and their research in the Barrow area in order to make the best use of the opportunities present in the area.

The recommendations were developed at a workshop held at the Marconi Conference Center in Marshall, California, December 2–4, 1998. The purpose of the workshop was to consider what is needed to support scientific research in the Barrow area and beyond and to make recommendations regarding:

- broad research questions that could be or are being addressed in the general area of Barrow, Alaska,

The community of Barrow, Alaska, seen from the air, 10 August 1989. The village of Barrow is in the foreground, the residential area of Browerville is located on the far side of the town reservoir, and UIC-NARL is in the background. Photo by Tom Albert.

Personnel and temporary employees of the North Slope Borough Department of Wildlife Management (DWM) conducting the bowhead whale census on an ice ridge near the seaward edge of the shorefast ice off Point Barrow. The census is conducted on a nearly annual basis, depending on need and available funds. Since 1981, acoustic surveys conducted simultaneously with visual counts have documented a healthy whale population. See page 23 for more details. Photo by Craig George.

- research that is important but cannot be currently undertaken because of the lack of research support or logistics infrastructure, and
- supportive infrastructure and additional facilities that must be developed to sustain such research.

This report is intended to give guidance and information to those who provide research support on the North Slope of Alaska and to those who conduct research in the area. The ultimate goal of the report is to provide the rationale and recommendations to increase the efficiency, effectiveness, and extent of research taking place in the Barrow area. The provision of common support facilities and services in Barrow will remove some of the difficulties associated with conducting research in this part of the Arctic and will be a significant step toward that goal.

For the purposes of the workshop and of this report, "the Barrow area" is defined as the area for which research is best supported from Barrow. The size and shape of this area will vary by discipline and by the nature of an individual project, will include terrestrial, offshore, and atmospheric research, and undoubtedly will be influenced by the development of additional support capability in the region. The report has five parts:

- a brief review of the history of scientific research in the Barrow area;
- an overview of current arctic research in a circumpolar context;
- an overview of current research and future opportunities in the area;
- a description of the support facilities and services available today in Barrow; and
- a description of research support and logistics needs, with recommendations for implementation.

The main body of the report is followed by appendices that include:

- detailed information on the current research facilities and support;
- options for implementation of technology and information investments;
- a bibliography of references cited in the report;
- an abridged bibliography of research in the Barrow area with sources of further information; and
- a listing of workshop participants and report contributors and reviewers.

2

History of Research Based in the Barrow Region

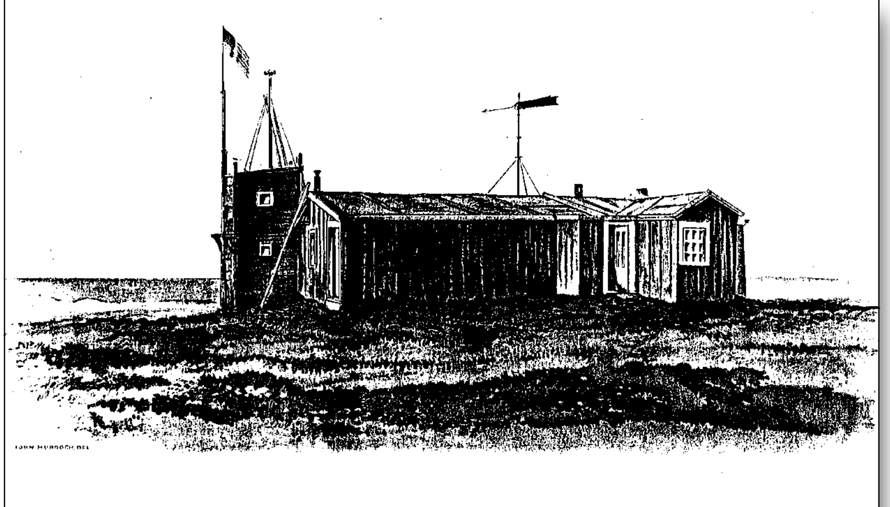
This chapter is summarized from several sources, including Reed and Ronhovde, 1971, Departments of the Interior, Defense, and Energy, 1982, and material prepared by Max Brewer, Arnold Brower, Sr., John Kelley, David Norton, Lori Quakenbush, John Schindler, and Glenn Sheehan for the commemoration of the Naval Arctic Research Laboratory's 50th anniversary in 1997 (BASC, 1997; Norton, in prep.).

Early Years

The U.S. Army Signal Corps, on one of 15 expeditions to the Arctic and Antarctic during the First International Polar Year in 1881, began the long research tradition at Barrow when they encamped at what is now the location of the Cape Smythe Whaling and Trading Company in Browerville. Led by Lt. P. H. Ray and documented extensively by Sgt. John Murdoch, the expedition spent two years investigating the northernmost point of U.S. territory. Ray led geographic explorations. Murdoch conducted ethnological studies, which resulted in a publication (Murdoch, 1892) that is still a standard reference guide. The enlisted men tried to dig a hole to find the bottom of the permafrost. This excavation continued until the Army decamped and resulted in one of the largest ice cellars in Barrow, which is still in use. Later investigators discovered that the permafrost is more than a thousand feet thick at Barrow (Lachenbruch and Marshall, 1969).

Several other independent investigators followed. In the 1890s, for example, J. A. McIllhenny collected thousands of specimens in Barrow for museums. The Academy of Natural Sciences in Philadelphia still has drawers filled with the lemming skins that he contributed. As a trading post site, a focus of

The site of the 1881 Signal Corps encampment, where one of the original buildings still stands, is now on the National Register of Historic Places.



FRONT VIEW OF MAIN BUILDING, UNITED STATES SIGNAL STATION,
POINT BARROW, ALASKA.

For the first half of this century, most of the arctic bird collections, birds' egg collections, and animal skins that were found in scientific museums in the South-48 were prepared by the Brower brothers at Barrow. . . . In those days, if a scientist wanted to research long-term animal cycles on the North Slope or the earlier snow geese populations in northern Alaska or on Banks Island, he consulted with Tom Brower. If the scientist was interested in fish populations and ranges, he consulted with Arnold Brower. If he wanted to develop natural dioramas for displaying bird and animal specimens, he consulted with Harry Brower.

Brewer and Schindler, 1997, in Norton, in prep.

The Naval Arctic Research Laboratory as it Appeared in 1961

early twentieth-century reindeer herding, and the location of a church and government school, Barrow was a natural jumping off point for regional expeditions.

Barrow residents assisted scientists from very early on. In 1905, Vilhjalmur Stefansson relied on Charles Brower and his family for local information and logistic support. For the next several decades the Browers and other local residents served as field technicians for a variety of research projects, including collecting birds' eggs for the Denver Museum of Natural History, obtaining polar bears for zoological gardens, and translating for visitors.

Native people also did research themselves. When the University of Pennsylvania Museum needed follow-up work to the 1919 archaeological work of teacher and missionary William Van Valin, they turned to Barrow resident Alfred Hopson, Sr., who conducted his first archaeological excavation in 1929. In 1930, Hopson traveled over 2,000 miles by dog team to take the first census in arctic Alaska. Native Greenlander Knud Rasmussen did some of his research in Barrow.

Establishment of the Arctic Research Laboratory

The development of a research laboratory in the Barrow area resulted from the coincidence of two actions by the U.S. Navy: first, to undertake a program of petroleum exploration based in Barrow and, second, to create the Office of Naval Research.

The first action came in 1944, when the Navy began a program of petroleum exploration in Naval Petroleum Reserve No. 4 (NPR-4, now the National Petroleum Reserve-Alaska or NPRA) in northwestern Alaska, which continued until 1953. The site selected for the NPR-4 base camp was a gravel beach ridge on the shore of the Chukchi Sea, about four miles northeast of the village of Barrow and about seven miles southwest of Point Barrow. The "temporary" camp, comprised largely of about 100 World War II Quonset and Jamesway huts, provided for the living, working, transportation, and communication needs of the approximately 1,000 personnel carrying out the exploration program.

The second action was the creation in 1946 of the Office of Naval Research (ONR). Congress charged ONR with two principal missions:

- the promotion, initiation, planning, and coordination of a program of naval research; and
- the conduct of a research program to augment those conducted by other elements of the Navy.

ONR responded by initiating a broad program of basic and applied research designed not only to meet the needs of the Navy but to encourage research having importance to other sectors of the economy as well. M. C. Shelesnyak of ONR led the development of the concept of an arctic research program supported by a laboratory located within the NPR-4 camp.

The Arctic Research Laboratory (ARL) began in two surplus NPR-4 Quonset huts in 1947 under the scientific direction of Laurence Irving. By

1948, nine projects were in progress, and, with ARL as a base, researchers ranged as far as Anaktuvuk Pass and Point Hope. By 1949, when George MacGinitie became technical director, ARL had already begun its tradition of providing support to research projects that were not part of its regular program, including investigations funded by the Public Health Service, the Hydrographic Office, the Corps of Engineers, and the Coast and Geodetic Survey (CGS). In that year, the CGS established the Barrow Magnetic Observatory, which has been in continuous operation for 50 years (now under the U.S. Geological Survey [USGS]), and in 1964 built an underground "seismic vault" and installed equipment for recording earthquakes. Year-round permafrost investigations started under Max Brewer and Robert Black of the U.S. Geological Survey in 1950, when Ira Wiggins became technical director. By 1951, ARL also was helping support research on the sea ice north of Barrow through Project Skijump, which used R4D aircraft for ice landings.

From the beginning, ARL was operated as a national facility with resources open to all federally funded scientists and engineers. There was no national guidance as to what research should be done and no overall coordination of research projects, however. The coordination that did occur was largely achieved by ONR planning, assisted by the Arctic Institute of North America (AINA) and the directors of ARL. Research projects proposed by academic scientists were primarily selected through this informal process. These pioneering projects, many of which

On the 6th of August 1947, a heavily laden G46 aircraft lumbered over the pierced-metal surface laid on the coarse beach sand and rolled to a stop. Out from the load of freight climbed seven men led by Professor Laurence Irving of Swarthmore College. The sun was still high . . . . The dull greenish brown tundra, relieved by its myriad lakes, large and small, stretched southward seemingly without limit. Thus the Arctic welcomed . . . the first group of scientists that formed the nucleus of what was to become the . . . ARL. . . . Not much attention was being paid to the small group of scientists for this was the main supply camp of the Navy's exploration for oil in NPR-4, an operation that . . . was in full swing. Caterpillar tractors churned the soft sand as they hauled equipment to storage areas. Weasels (MZ9C), those small tracked vehicles so useful in the Arctic, seemed to be scooting in all directions on a variety of missions. The landscape was dotted with 56-gallon fuel drums, that ubiquitous trademark of the American developer in out of the way places all over the world. At the beach lay power barges ready for their mission of lightering freight ashore.

Reed and Ronhovde, 1971

Outside and equipment foreman Kenneth Toovak with the hot water drill that he developed for use on ice. The drill was later used in an attempt to drill through the ice island at T-3. Toovak's prowess at accomplishing the seemingly impossible was legendary. Toovak is now on the BASC Board of Directors and was recently elected to honorary membership in the American Polar Society for his "notable contribution to exploration and scientific research in the polar regions." Photo courtesy of Office of Naval Research.

Staff members of NARL developed by experience into a cadre of Arctic experts, and then trained thousands in the successful ways of living and working in the Arctic. . . . This centralized living and working community of scientists was especially important to the younger graduate students who found NARL a rich intellectual stimulus . . . and returned to take up Arctic research careers. . . . The laboratory offered the opportunity to discuss common research interests, the availability of museum collections, an excellent Arctic library, and formal seminars of interdisciplinary educational value. . . . The Laboratory provided long continuity of research, some projects extending almost through its total history. An enormous baseline of environmental data on natural, physical, and biological systems was compiled. Long-term study permitted interpretation of what natural Arctic systems are, how they are organized, how they function, how man disrupts them, and the measures needed to avoid or ameliorate such disruption. To facilitate the long-term studies, NARL provided protection for several terrestrial areas . . . important to future research.

Departments of Interior, Defense, and Energy, 1982

developed into long-term programs, were for the most part broadly environmental in nature, at first terrestrial and atmospheric with some near-shore marine projects. Later emphasis shifted to the sea as aircraft availability permitted the establishment of research stations on drifting ice. (Details on these research programs can be found in Departments of Interior, Defense, and Energy, 1982; Reed and Ronhovde, 1971; Norton, in prep.)

The development and operations of the ARL were strongly affected by its status as, essentially, a guest facility dependent on a military installation. The years immediately following the establishment of the ARL were marked by rapid changes at all levels of operation as the Navy closed the NPR-4 camp in 1953, and the ONR's role in the lab was reorganized. During this transition, the ARL had three short-term technical directors: Ted Mathews, Dallas Hanna, and Ira Wiggins, while the operating contract moved from Swarthmore College to Johns Hopkins University.

DEW Line Construction

When oil exploration in NPR-4 ended in September 1953, the Navy camp went into caretaker status with the exception of the core group of ARL buildings needed in support of a reduced research program. In 1954, the Navy camp was turned over to ONR. Almost immediately the U.S. Air Force requested use of nearly all the Navy facilities, excluding the ARL buildings, to support the construction of the Distant Early Warning (DEW) Line of radar stations. In exchange for agreed support of ARL, use of the base camp was given by permit to the Air Force in December 1954.

Information from diverse arctic research projects, principally at ARL, was essential to the Air Force in the DEW Line construction project. After completion of this huge enterprise, a Canadian government official with long arctic experience observed that the assistance the DEW Line received from ARL saved the Air Force more money than had been spent on ARL and its research programs up to that time.

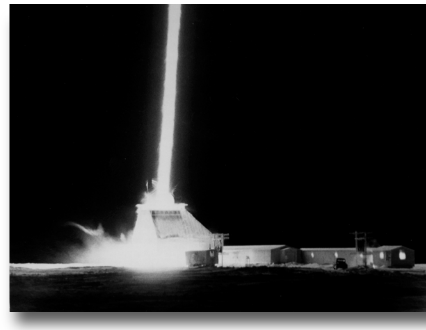
A new period of stability and growth began for ARL after the 1954 Navy-Air Force agreement. The Air Force operated the camp for 17 years through a series of civilian contractors and provided all basic community services, which greatly decreased operations and maintenance costs to ARL. The lab maintained its own carpentry, vehicle maintenance, and machine shops, housekeeping, and other services. The lab also maintained a network of satellite field stations at locations across the North Slope. These simple buildings provided basic living support for small field teams.

During this period, the ARL, which became known as the Naval Arctic Research Laboratory (NARL) in the mid-1960s, also benefited from consistent leadership. Maxwell E. Britton, an ARL researcher since 1952, was scientific officer for the Arctic Program at ONR from 1955–70. Max Brewer served as the ARL technical director from 1956–71. John Schindler served as technical director at NARL from 1971–73, Warren Denner from 1973–76, and John Kelley from 1976–80. The University of Alaska contracted for the support functions of the lab continuously starting in 1954.

A major research emphasis at ARL in the 1950s and 60s was the physiology and ecology of arctic animals (Pitelka and Batzli, 1993; Folk, 1969; Irving, 1969). Much of this research was possible only because of excellent captive animal facilities, which housed at various points weasels, lemmings, seals, wolverines, wolves, caribou, ravens, and polar bears. The contributions of local animal experts were also crucial to the success of these studies. In particular, Pete Sovalik, who acted as head animal caretaker for many years, had invaluable traditional knowledge of animals.

A significant expansion of arctic research infrastructure came with the lab's air fleet, with its own staff pilots, mechanics, and, most important, operational control. An oceanographic program in 1958 used chartered light aircraft to make landings on the ice pack. Later that year, the lab acquired two Cessna 180 aircraft. The fleet rapidly grew to five single-engine and two twin-engine R4D planes. By 1977, NARL was operating a total of eight aircraft. The multiengine fleet provided capability from the Bering Sea to the Greenland Sea and routinely furnished logistics and research service throughout the Arctic Basin, especially in support of drifting ice station research. Over the years, thousands of research flights were made for geophysical and oceanographic purposes.

When the Air Force began ice island research in the early 1950s, ARL support was critical to the effort. Several drifting stations were operated in association with the International Geophysical Year (IGY, 1957–58). Following IGY, new ice station support came directly from ARL, starting with ARLIS-I (Arctic Research Laboratory Ice Station-1), which operated for six months in 1960 and was followed by five more ice stations, the last of which was abandoned in 1970.



Prudhoe Bay Development

The discovery in 1968 of major oil and gas reserves at Prudhoe Bay, 200 miles east of Barrow, led to major changes to the North Slope of Alaska and to its people. Because of the severe environment, the oil industry faced massive engineering problems, for which there was little U.S. experience. Moreover, in 1969, Congress passed the National Environmental Policy Act (NEPA), and construction of the Trans-Alaska Pipeline became the first major engineering project required to prepare an environmental impact statement and to meet federal and state stipulations for environmental acceptability.

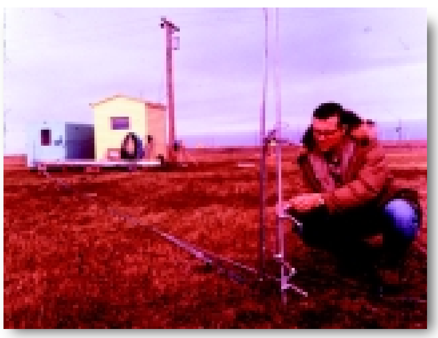
Above: Second Nike-Cajun launch from the NARL launch facility, February 1965. Photo by Don C. Knudsen, courtesy of John Schindler. Second: Max Brewer and Pete Sovalik in the ARL wolf pens. Third: April 1968. An overland caterpillar tractor train hauling buildings and supplies to a remote camp. A snow plow is attached to the lead cat for the deep drifts that are encountered. Photo by Kenneth Toovak, courtesy of John Schindler. Below: On Fletcher's Ice Island (T3) May 1962. Front (L to R): Bud Kanayurak, Simon Akpik, Jimmie Ningeok. Back (L to R): Wyman Panigeo, Kenneth Toovak, Harry Brower, Frank Akpik. Photo courtesy John Schindler.

Many government and company representatives, consultants, and contractors urgently sought information on the Arctic. As in the construction of the DEW Line, the NARL staff provided design expertise for roads and airstrips and on living and working facilities. The accumulated information at NARL, including the extensive holdings in the library, were critical to a fast start-up and continuing engineering effort by the industry, as well as for preparation of the environmental impact statement. Information on permafrost alone saved the oil industry years of delay and large expenditures of money.

In 1971, the National Science Foundation (NSF) was designated the lead agency for arctic research, and emphasis was placed on the funding of large, integrated studies. This change reflected efforts by government agencies to make more efficient use of resources and the recognition by scientists that integrated team efforts were essential to attack many research problems. Investigators began to take a regional and ecosystem, rather than disciplinary, approach to environmental research issues. Recent reviews place investigations in Barrow in scientific context with the development of other research programs in the Arctic (Hobbie, 1997; Shaver, 1996). The complex arctic research programs of the 1970s were only possible because of NARL's extensive logistics capabilities:

The Tundra Biome Program (1970–74). The successes of the International Geophysical Year (IGY, 1957–58) stimulated thinking in other fields of science in the direction of large coordinated programs. Following the IGY, both private institutions and government agencies began planning for an International Biological Programme (IBP). In cooperation with the Department of Energy, the U.S. Army, and industry, NSF funded a large integrated program of arctic ecological studies of terrestrial and freshwater systems as part of the IBP. Most of the terrestrial research and all of the aquatic work was conducted in the Barrow area. The program led to publication of the first syntheses of tundra environmental knowledge on an ecosystem basis (Brown et al., 1980; Hobbie, 1980; Tieszen, 1978).

Exploration of the National Petroleum Reserve in Alaska (1974–82). In the Naval Petroleum Reserve Production Act of 1976, Congress transferred responsibility for the newly designated NPRA to the Department of the Interior, which in turn assigned the exploration program and related activities to the USGS in 1977. In addition to the exploration program, studies were conducted on physical and thermal aspects of permafrost, vegetation, soils, pollution control, and innovative engineering properties



Above: An open lead at AIDJEX mess hall, summer 1975. Photo by Brian Shoemaker. Second: Lowell Thomas and Kenneth Toovak at the Teshekpuk Lake field camp, May 1963. Photo courtesy John Schindler. Third: Pat Coyne measuring CO_2 at the North Meadow Lake IBP/CRREL site as part of the U.S. Tundra Biome Program in 1972. This site is now within the BEO and offers the opportunities to study gas fluxes, the year-round thermal regime of a shallow tundra lake, and other atmosphere-tundra-lake interactions. Photo by Jerry Brown. Below: The oilfields of the Prudhoe Bay facility are distributed on the fragile tundra of the North Slope. Photo by Anna Klene.

of snow, ice, and construction techniques. An operational base was established at Lonely to the east of Barrow, but Barrow and NARL remained the center for many aspects of the program (Gryc, 1988).

Research on Arctic Tundra Environments (RATE 1975–77). NSF also funded the RATE Program, which built on the results of the Tundra Biome Program and involved some of the same investigators. The terrestrial component was conducted on a 2,300-acre NARL study area on the Meade River near Atqasuk about 65 miles south of Barrow, while the aquatic component was conducted at Toolik Lake adjacent to the Trans-Alaska Pipeline.

Arctic Ice Dynamics Joint Experiment (AIDJEX 1975–76). Funded by NSF, the U.S. Navy, and NASA, this large project was designed to relate the drift and deformation of pack ice to the physical properties of sea ice and to the driving forces of winds, currents, Coriolis force, and gravity. An array of manned and instrumented drifting ice stations was operated in the Beaufort Sea.

Outer Continental Shelf Environmental Assessment Program (OCSEAP 1975–82). Funded by the Bureau of Land Management (BLM) and coordinated by National Oceanic and Atmospheric Administration (NOAA), OCSEAP assessed the Outer Continental Shelf as a prerequisite to the BLM lease program for oil and gas exploration. The program included major studies in the Beaufort Basin, Chukchi Basin, and the Bering Sea.

NARL was . . . an excellent laboratory providing a maximum of service to workers in a wide variety of fields . . . including marvelous communications systems, base camps, transportation facilities, equipment, cuisine, laboratory space, accommodations, machine shop, and . . . general base of operations . . . . NARL did the difficult immediately and the impossible on many occasions.

Reed and Ronhovde, 1971

NARL's Transition to the Local Community

By the 1970s, the NARL facility encompassed almost 5,000 acres. Most of its 135 buildings were Quonset huts, though several relatively modern buildings, including a 45,000-square-foot main building (Building 360), had been added. The complex also included full utilities, a runway, and a hangar. The original cost of the facility was about $11 million. In 1981, the replacement cost for NARL's real property was estimated at $50 million.

In the early 1970s, the Navy's arctic interests began to shift to the developing importance of the Kola Peninsula and the White Seas as the homeport of the world's largest fleet and the site of a principal Soviet industrial complex. This new emphasis on the eastern

A portable drilling rig used in permafrost studies by Cold Regions Research and Engineering Laboratory researchers at Fish Creek and Oumalik sites in NPRA during the late 1970s and early 1980s. Photo by Jerry Brown.

UIC-NARL in August 1989. The Chukchi Sea is on the left. The H-shaped building (Building 360) in the right foreground was used in the NARL era for laboratories, accommodations, offices, and library. The small Quonset huts in the center foreground were used primarily as staff housing. Building 360 now houses the offices of the Barrow Arctic Science Consortium (BASC), the North Slope Borough Department of Wildlife Management, the Real Estate Division of Ukpeagvik Iñupiat Corporation (UIC), and Iḷisaġvik College, as well as a dining facility. Photo by Tom Albert.

Arctic decreased the Navy's need for NARL. In 1971, custody of the camp was returned from the Air Force to the Navy, but NARL had diversified to supporting such a spectrum of other agencies, both national and international, that the Navy found it difficult to justify sole fiscal responsibility for the lab. Despite the institution of a policy of reimbursement for all users of NARL, the fortunes of the lab declined. From 1975–79, overall usage declined 67% and Navy usage by 91%, while costs increased 67% and were offset by only a 39% increase in funding, causing the Navy to consider closing the lab. On 30 September 1980, the University of Alaska contract was terminated, and all support of research ceased. The Naval Facility was decommissioned in June 1981, and NARL was placed in caretaker status in September of that year.

During the same period, residents of Alaska's North Slope experienced important social and political changes. Congressional passage of the Alaska Native Claims Settlement Act (ANCSA) in late 1971 had resolved longstanding issues of property ownership and control over resources with the Native people of Alaska. ANCSA provided for the establishment of Native-owned regional corporations and associated village corporations. Ukpeagvik Iñupiat Corporation (UIC, the Barrow village corporation) became the local corporate entity closest to, and most interested in, the fate of NARL's infrastructure. The Barrow community, meanwhile, experienced rapid development and expansion in the 1970s and 1980s, increasing needs for both land and housing. Many of the people in decision-making positions in the North Slope Borough (NSB) government and UIC had worked at NARL or in the field with NARL scientists. Their involvement with NARL helped create a generally positive outlook toward research and the value of science to Native people (Albert, 1988). The UIC began inquiring into the transfer of NARL to them in 1978.

The Navy and the BLM rejected the initial UIC proposal in 1983. In 1985, a caretaker agreement for the NARL facility was negotiated but by then deterioration of many parts of the facility threatened to make it a costly arrangement. Alaska Senator Ted Stevens helped negotiate a transfer agreement in 1986. An amended agreement was completed in 1988, which protected UIC from accepting an unknown but potentially huge burden of liability due to preexisting environmental problems. UIC signed the final transfer of NARL on 14 June 1989.

After the Navy left, the UIC Real Estate Department became the landlord of the NARL camp, which became a multiple-use facility known as UIC-NARL, dedicated to using its assets for community benefit. UIC-NARL now concentrates on the support of four types of use: government, education, industrial and commercial activities, and arctic research.

Governmental Uses. Four science-related governmental functions operate at UIC-NARL: environmental protection, wildlife management, veterinary services, and energy management.

When NARL went into caretaker status, the North Slope Borough had already established a Conservation and Environmental Protection Office (CEPO), which had hired some of the laboratory staff. By 1984, the work of the CEPO had expanded to the point that pollution monitoring matters were transferred to the Planning Department.

The North Slope Borough's own research programs have been executed primarily through its Department of Wildlife Management (DWM), successor to the CEPO and headed for a number of years by Benjamin Nageak, a former member of the NARL staff and mayor of the NSB from 1996–99. Dr. Thomas Albert, who had been a visiting scientist at NARL in the 1970s, became the DWM senior scientist. In addition to the NSB research programs, DWM scientific staff have collaborated with researchers from a variety of agencies, universities, and private firms. For example, the DWM has collaborated since 1991 with investigators from the U.S. Fish and Wildlife Service on studies of the endangered Steller's eider; the long-term population data available from the Barrow area indicates a general decline in king and common eider populations as well. More details on the DWM research program can be found in Chapter 4.

The DWM leases a row of laboratories in the Science Wing of Building 360—which it uses as offices for department biologists and staff—and the former Animal Research Facility (ARF) at Building 350. Building 350 has been converted to modest laboratories and living quarters for visiting technical personnel and renamed the Arctic Research Facility. After the closure of NARL, researchers visiting Barrow with externally funded research projects but without a designated center for local assistance often had little alternative but to seek help from DWM staff. Despite limited resources, the NSB and the DWM have extended support, including accommodations at the ARF, to visiting scientists and graduate students in recent years. The ARF remains the only science facility at UIC-NARL available to support short-term visitors.

Veterinary services for local animals and the rabies control program, which is important because of endemic rabies in arctic fox in the region, are maintained by the NSB Health Department.

By the mid-1990s, the North Slope Borough Department of

These cooperative efforts allowed research to be conducted on a much larger scale and on a greater diversity of topics than the budget of either the U.S. Fish and Wildlife Service or the borough would have allowed independently. By leasing the ARF, the Borough has kept the spirit of NARL and its contribution to arctic science going beyond the well-funded Navy days by providing a place for scientists.

Quakenbush, 1999, in Norton, in prep.

The Arctic Research Facility (ARF). The skull in front and the shoulder blades on the wall are from a bowhead whale. Photo by Dave Ramey.

Energy Management had been established and located at the UIC-NARL complex. Borough oversight of the Barrow Gas Field was facilitated by convenient access to the contracted operators of the field and to the field itself.

Postsecondary Education. The North Slope Borough has developed its own higher education system. Its North Slope Higher Education Center was founded in 1988 and, in 1990, renamed the Arctic Sivunmun Iḷisaġvik College (now named Iḷisaġvik College). With the goal of developing a residential campus for vocational education, the college became the major tenant at the NARL facility. A laboratory for teaching natural sciences took shape adjacent to the Department of Wildlife Management offices in Building 360 in 1990. In 1994, the college moved its administrative offices to Building 360, turned the Personnel Wing into student dormitory rooms, expanded its vocational training shops by renovating several Quonset huts, and created a new athletic facility out of the former shop and window fabrication plant. The NARL Hotel was moved from the Personnel Wing of Building 360 to ATCO units behind the building.

Commercial and Industrial Activities. Private enterprise at the UIC-NARL facility includes a commercial outlet for construction supplies and several joint ventures with UIC or its subsidiaries.

Research and Research Support. Both short-term and ongoing research continue to be based out of UIC-NARL. Research support has developed around community initiatives, chiefly the establishment of the Barrow Environmental Observatory (BEO) and the recent nonprofit incorporation of the Barrow Arctic Science Consortium (BASC). Scientific activity increased in the 1990s after the transfer of the NARL facility to UIC. In 1992, UIC, seeking to encourage long-term research into phenomena such as global change, took the unprecedented step of setting aside the 7,466-acre reserve known as the Barrow Environmental Observatory (BEO). The BEO land adjoins the NOAA-Climate Monitoring and Diagnostics Laboratory site (details below), extends eastward to the shore of Elson Lagoon, and encompasses the "Old Beach Ridge," Central Marsh, and East and West Twin Lakes. The BEO is a unique testament to the commitment of North Slope residents to the advancement of science and to collaboration among local people and scientists.

The U.S. Department of Energy Atmospheric Radiation Monitoring (ARM) site in the Barrow Environmental Observatory began operations in 1997. The Barrow site is one of three ARM sites worldwide; the other two are in Oklahoma and Papua, New Guinea. Photo by Bernard Zak.

Adjacent to the BEO, the NOAA Climate Monitoring and Diagnostics Laboratory (CMDL), established in 1972, monitors atmospheric parameters and is involved in many cooperative programs with other agencies. In 1991, NSF funded installation of instruments to monitor ultraviolet (UV) bands of the spectrum of incident energy at Building 360. This UV sampling, part of a UV monitoring network for polar regions, complements stratospheric ozone monitoring by CMDL. In 1992–93, the U.S. Department of Energy (DOE) began to undertake, with community partnership, the 10-year intensive Atmospheric Radiation Monitoring (ARM) program. Details of the instrumentation at these facilities can be found on pages 62 and 63.

Other ongoing projects working on or adjacent to the BEO include the International Tundra Experiment (ITEX) funded by NSF, the long-term interagency Terrestrial Ecology and Global Change (TECO) program, the annual BEO Snow Survey, and Electromagnetic Properties of Sea Ice (EMPOSI, 1993–98). Numerous other single-season scientific projects take place throughout the year, including institutional activities from the U.S. and from abroad, such as Japan's Earth Science and Technology Organization and China's Institute of Geography of the Chinese Academy of Sciences. On lands and waters adjacent to the BEO, significant ongoing research activities are funded by organizations such as NSF, the North Slope Borough Department of Wildlife Management, the Alaska Department of Fish and Game, the U.S. Bureau of Land Management, and the U.S. Fish and Wildlife Service. The Office of Naval Research is in the preliminary stages of the Arctic Climate Observations using Underwater Sound (ACOUS) project. Details of most of these programs can be found in Chapter 4.

This map indicates the locations of Barrow, Browerville, UIC-NARL, various research facilities, and important geographic features in the immediate area. Illustration by Sue Mitchell. Satellite photos from University of Alaska Fairbanks Geophysical Institute Geodata Center.

A critical mass of scientists and technicians resident in Barrow gradually developed by the mid 1990s. This group included the biologists with the DWM, veterinarians with the Borough Health Department, the CMDL scientists, the Iḷisaġvik College science instructor, and the staff of the growing ARM project. In recognition of the disproportionate contribution by the DWM to the support and logistics needs of visiting investigators and of expanding demands for research support, UIC and the resident scientists in Barrow founded the Barrow Arctic Science Consortium (BASC), a nonprofit membership organization, in 1995. The charges to BASC were to manage the BEO and attract and support researchers. Recently, the NSF Office of Polar Programs has signed a Cooperative Agreement with BASC to support management of the BEO. The North Slope Borough also supports the BEO. To facilitate BEO research efforts, BASC is undertaking a variety of projects: construction of an all-weather access road to the BEO, "recapturing" and making available scientific data generated by previous researchers, and providing electronic access to Geographic Information System-linked mapping and overlay data for the BEO region. BASC also facilitates logistics for research teams and provides information to researchers writing proposals.

Community Involvement

Barrow residents have worked diligently to ensure that research efforts would benefit the local community as well as scientific understanding of

Harry Brower, Sr., next to the bowhead whale he captured May 27, 1980. Mr. Brower was a respected hunter and worked most of his life as a carpenter at the Naval Arctic Research Lab. He had an amazing knowledge of ice, weather, and animals. He worked patiently with researchers, and he identified the major aspects of Eskimo traditional knowledge that formed the basis of the North Slope Borough's long-term bowhead whale research program. Photo by Tom Albert.

the Arctic in general. Residents of the North Slope have contributed to many research projects, including the valuable information given by senior Eskimo hunters to the design of the North Slope Borough's long-term bowhead whale research program, donation by many successful hunters of specimen materials from subsistence harvested animals for studies of contaminants, reproduction, etc., and routine assistance by Eskimo hunters to investigators working on sea ice. When a 1994 storm eroded a bluff in Barrow, revealing an ancient frozen body, elders collaborated with archaeologists to develop a research protocol to recover the little girl; the community participated in the excavation and in her reburial. In response to increasing petroleum exploration and development and to international constraints on subsistence harvest of the bowhead whale, the NSB and the Alaska Eskimo Whaling Commission (AEWC) recognized a need for impartial oversight on proposed research, as well as analyses of government and industrial plans. To meet these needs, the AEWC established a Science Advisory Committee (SAC) in 1980, chaired by John Kelley at the University of Alaska Fairbanks. Advisory services requested of the SAC rapidly broadened to such a degree that in 1982, it became the North Slope Borough Science Advisory Committee (Kelley, 1985). An indication of the unusual value the borough places on impartial scientific review, the SAC prepares an average of three to four reports per year in response to scientific and engineering needs of the NSB. Recent projects include reviews of the redesign of the borough's water, waste handling, and sewage systems; assessment of contamination at the Project Chariot site; advice and peer review services for the British Petroleum Alaska-North Slope Borough Endicott Fish Monitoring program; and development of options for mitigation of coastal erosion by beach nourishment.

Community involvement in research is an important matter for Barrow residents and one to which they have committed themselves. BASC itself is one example of community commitment to the research process and to a substantive and productive role for the community. These developments would not have occurred in the absence of the experiences, both for individuals and for the community as a whole, provided by the presence of NARL and its researchers for such a long period. NARL thus provided more than the foundation of a research tradition—it nurtured a new relationship between community members and researchers, to the lasting benefit of both.

3

Arctic Research in a Circumpolar Context

Research in the Arctic ranges from small-scale local projects to integrated, interdisciplinary programs across landscapes, the circumpolar region, and, in some cases, the globe. Several current initiatives examine large-scale processes such as climate change and long-range environmental pollution through a network of field stations and study sites. Barrow is one of a handful of places in the Arctic where such research has been and can be based. As such, it plays a critical role internationally in arctic research. For these and other reasons, Barrow is today, and is expected to continue to be, a center for arctic research in and across many scientific disciplines. Its location allows access to the marine, coastal, terrestrial, freshwater, and atmospheric environments, and the community of Barrow provides an opportunity for adding human dimensions to research in these areas and for other social and cultural research.

Thaw lakes are major features in the landscape of the Barrow area. Britton's (1957) work on the dynamics of these shallow lakes, in terms of the interactions among plants, soils, frozen ground, and erosional processes of the coastal plain, was an early contribution to interdisciplinary arctic research. Photo by Anna Klene.

Current Arctic Research

The Arctic includes some of the most extreme environments on the planet. Radical changes in temperature and the amount of daylight alternately constrain and stimulate arctic terrestrial and marine ecosystems. People around the circumpolar North have coped successfully over millenia with this environment, accumulating an extensive body of environmental knowledge as well as keen awareness of ecosystem changes. The Arctic's physical and biological systems are regulated by processes that offer numerous opportunities for advancing basic knowledge. Many of these processes have been or are being investigated in the Barrow area.

The Arctic and its residents appear to be particularly vulnerable to environmental, social, and economic changes. For example, climate model studies suggest that the arctic environment will react particularly sensitively to global climate change (Manabe and Stouffer, 1994). Research results show that arctic climate and ecosystems are indeed changing substantially and that these changes are having impacts on people living in and outside the Arctic. Some changes appear to have begun as early as the 1970s, but many have only become significant in the 1990s; many of these changes are documented by data collected in the Barrow area (Maslanik et al., 1996). The observed changes and the processes that cause them appear to be linked to changes in the whole Northern Hemisphere, involving physical characteristics in the atmosphere, ocean, and on land. Early indications suggest that the physical changes also are causing changes in the arctic biosphere. Because many of the Arctic's human populations are tied to the natural environment, they are sensitive to changing conditions. Many arctic residents, including some in Barrow, already are reporting ecosystem changes (Gibson and Shullinger, 1998).

Elise Poole and Brandon Baker, undergraduates at Michigan State University, working on the ongoing ITEX (International Tundra Experiment) research project in the Barrow Environmental Observatory. Their participation in the ITEX program is funded through the NSF Research Experience for Undergraduates program. The open-top chambers seen here increase plant canopy temperatures and are used to forecast vegetation responses to climate change. Similar sites are being monitored throughout the Arctic, the Antarctic, and the alpine regions of the world. Photo by Robert Hollister.

Rapid changes also are taking place in arctic societies, especially in political and economic systems. From relative self-sufficiency in the recent past, arctic peoples now are incorporated into national states and the global economy. In many places, arctic peoples are gaining political and economic power (Korsmo, 1999). In other places, such as Russia, arctic residents are struggling to cope with massive political and economic changes (Fondahl, 1998). Throughout the world, changes in markets for oil, minerals, forest products, and marine resources are having far-reaching consequences for subsistence and commercial activities (Chance and Andréeva, 1995).

Current research in the Arctic increasingly takes an integrated, interdisciplinary approach to such regional and global problems. Major arctic research efforts are directed at investigating the Arctic as part of the global system, including:

- Documenting major changes apparent in the arctic atmosphere, sea ice, and ocean,
- Estimating arctic freshwater flux and its effects on productivity and circulation of the Arctic Ocean and the global ocean system,
- Understanding ecosystem dynamics on many scales, including the harvestable fisheries and wildlife resources so important to the people of the Arctic,
- Quantifying snow/ice albedo effects on energy budgets,

- Determining whether arctic ecosystems are sources or sinks for carbon and quantifying the resulting trace gas dynamics, and
- Understanding the human populations in the North, particularly through the prehistory of the Arctic, the lifeways of indigenous peoples, and their responses to social and economic change.

These investigations require geographic as well as disciplinary integration as researchers elucidate process dynamics at local and regional scales and compare results from different locations around the Arctic. Scientific projects increasingly encompass the circumarctic region as a whole, requiring better year-round access to the Arctic and stimulating international collaborations. Expansion of current U.S. research efforts (which are small in comparison to the region's size and global importance) would allow documentation and understanding of the changes that are already taking place, how they are impacting the human population, and how people living in the Arctic can adapt to these changes. Logistical support for this circumpolar approach to arctic research, however, continues to lag behind U.S. researchers' needs (Schlosser et al., 1997).

Even the simplest needs can be difficult to provide in field sites in the Arctic. A surplus Bureau of Mines filtration system and a brackish pond provide drinking water for the archaeology crew working at Point Franklin after the advance of summer forces them to abandon the use of meltwater from the top of the Chukchi Sea shorefast ice. Photo by Glenn W. Sheehan.

U.S. Arctic Research Policy

Recommendations for an organized logistical system for U.S. arctic research have been discussed and developed for more than two decades by a variety of governmental and nongovernmental scientific organizations. The Arctic Research and Policy Act (ARPA) of 1984 recognized the inefficiencies in existing federal arctic research and the consequent need for improved logistical coordination and support. The U.S. Arctic Research Commission (USARC) and the Interagency Arctic Research Policy Committee (IARPC), both established by ARPA, are directed to evaluate the existing federal efforts and to create a program that, in cooperation with state and local governments, would become a meaningful national arctic research program. The National Science Foundation (NSF) is designated by ARPA as the lead federal agency for the development and support of arctic research policy.

Following the establishment of IARPC, the committee began consultations with residents of the U.S. Arctic regarding a national arctic research policy and its implementation. A formal aspect of this consultation was an NSF-sponsored workshop held in Barrow in October 1986 (Albert, 1989). At that workshop, residents from across the U.S. Arctic called for local involvement in arctic research initiatives and for establishment of one or more arctic research centers for:

- the conduct of arctic science,
- the logistical support of research, and
- the involvement of arctic residents in the flow of information to and from the scientific community (Albert, 1989).

The Social Science Task Force of IARPC developed the *Principles for the Conduct of Research in the Arctic* (IARPC, 1990). The *Principles,* which were approved by IARPC in 1990, are to be observed when carrying out or sponsoring research in arctic and northern regions and when applying the results of this research.

The NSF Office of Polar Programs supports the management of arctic data and information, including the Arctic Environmental Data Directory (AEDD). The AEDD contains information on several hundred arctic data sets and seeks to make arctic data and information more readily available to researchers (http://www-ak.wr.usgs.gov/aedd/history.html).

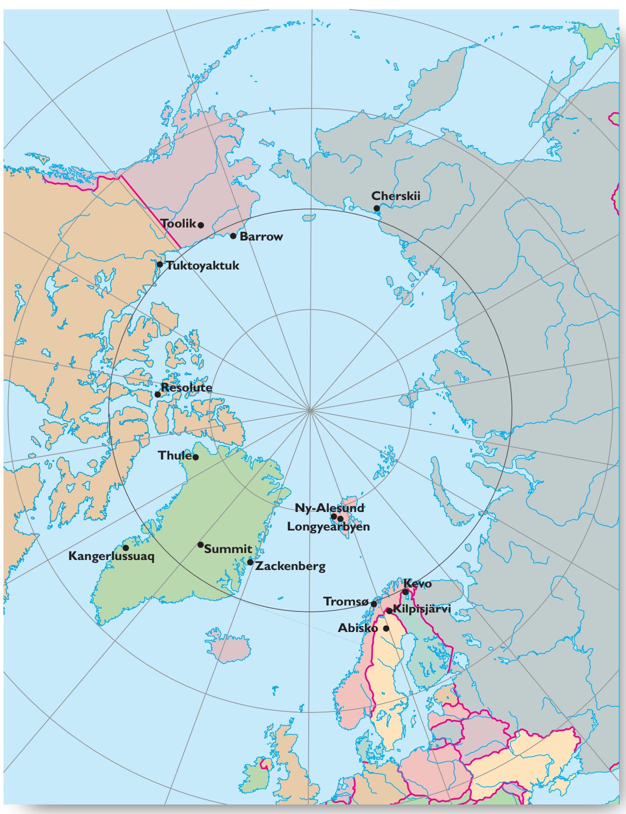
Circumpolar Research Infrastructure

The infrastructure supporting research in the circumpolar Arctic, summarized below, is extremely variable in quality, quantity, capability, and availability to U.S. investigators. Facilities differ in many factors that determine their appropriateness for a particular research use, including:

- location and types of environments available to researchers,
- condition of the environment, for example the extent of human disturbance,
- history of the area,
- costs and accessibility,
- capacity and equipment,
- utility as a logistics hub for the surrounding area,
- suitability for year-round use, and
- proximity to human communities.

More detailed information on international arctic research facilities and the arguments for an improved U.S. arctic research support capability can be found in *Logistics Recommendations for an Improved Arctic Research Capability* (Schlosser et al., 1997), which specifically recommends reestablishment of a year-round laboratory at Barrow. As described in that report, significant progress in U.S. arctic research support is needed in the near future because of:

- the increasing evidence of the importance of the Arctic in processes of global change,
- the rapid decline in scientific facilities in the Russian Arctic, and
- the corresponding need for U.S. scientists to have access to arctic research facilities in Canada and Europe, which requires reciprocal access to adequate U.S. facilities.



The major facilities supporting research in the Arctic are identified below by region.

Canada. The Polar Continental Shelf Project (PCSP) maintains two base camps in the Canadian Arctic, **Resolute** and **Tuktoyaktuk**. PCSP supports approximately 200 scientific projects each year through these camps, including accommodations, equipment loans, establishment of remote field camps, air transport through long-term chartering, and a radio communications system that maintains contact with remote field camps and aircraft. U.S. scientists can use PCSP facilities and services on a space-available basis for nominal fees.

Greenland. The U.S. currently supports, or U.S. researchers can access, logistical capabilities for research at **Thule, Kangerlussuaq, Summit,** and **Zackenberg**. The U.S. presence in Greenland is supported through an international agreement with Denmark. The logistical support system is based on open access to and use of a combination of Danish government-sponsored research programs, Danish and Greenlandic governmental and civilian transportation system infrastructure, the U.S. Department of Defense presence at Thule Air Base, the U.S. Air National Guard LC-130 air support capability, and U.S. federal agencies' investments in research facilities and support services at coastal and ice sheet locations.

Fennoscandia. The research stations in the Fennoscandian countries are supported directly by their governments and are of high quality and capability. Excellent research facilities exist on Svalbard near **Longyearbyen** and at **Ny-Ålesund**, a year-round international arctic environmental research and monitoring station in a more remote area (at 79°N) that can accommodate up to 150 persons. On the Norwegian mainland, the University of **Tromsø** has extensive research facilities and a medical school. The NSF OPP has recently signed a Statement of Cooperation with the Norsk Polarinstitutt to promote increased interactions among U.S. and Norwegian scientists in arctic and antarctic research efforts. In arctic Sweden, **Abisko** Scientific Research Station is a year-round research facility that can house up to 80 workers. **Kevo** Subarctic Research Institute and **Kilpisjärvi** Biological Station in arctic Finland are both year-round facilities, and each can accommodate around 40 researchers.

Russia. Much of the vast Russian Arctic is inhabited, and large parts of the region potentially can be reached by commercial air and rail systems. In addition, several research stations and sites with a rich heritage of environmental research and observations exist in the Russian tundra regions. For example, the year-round Northeast Science Station at **Cherskii** in Sakha can accommodate 15 to 20 people and affords access to an experimental wildlife preserve. Due to the recent transitions in Russia, accurate information on the status of and access to other research facilities can be difficult to obtain. In response to these and other practical obstacles, NSF has recently announced establishment of a science liaison office in Moscow to assist U.S. arctic researchers interested in conducting field work in the Russian Arctic.

U.S. The U.S. Arctic (northern Alaska) has two research facilities that include laboratory space and tracts of land reserved for research use and that act as logistics hubs for adjacent areas: **Barrow** on the Arctic Coast

An aerial view of the UIC-NARL complex. The Chukchi Sea is at the top of the photo. Building 360 is the large H-shaped structure. The long white lines are the elevated utilidors, which supply utilities to most of the complex. Photo courtesy of the North Slope Borough.

and **Toolik Field Station** (TFS) in the northern foothills of the Brooks Range. Details on facilities available at and planned for Barrow can be found elsewhere in this report. The TFS, established in 1975, is accessible from the Dalton Highway and has had a steadily growing user base. TFS currently supports over 3,000 user days each year. While facilities at TFS are still marginally adequate for current use, facilities upgrades funded by NSF since 1994 have improved laboratory facilities and now allow winter use of the station. Further upgrades are planned to improve other facilities at the station (for more details, see ARCUS, 1996). Operation of TFS is funded directly from daily charges to users ($163 per day in 1999). In other areas of the U.S. Arctic, individual investigators are responsible for making their own logistical arrangements using commercial transportation and facilities, which are sparse and expensive.

Barrow's Value and Potential

In this circumpolar context, Barrow's value as a resource for arctic research and its potential for further development include several distinctive advantages that make it suitable for a wide variety of research uses:

- its western location adjacent to the Arctic Ocean and the Arctic Coastal Plain, which includes access to diverse marine and terrestrial environments, an uncontaminated atmospheric sector, and healthy marine mammal and wildlife populations,
- the opportunity to build on existing scientific infrastructure and expertise, particularly the resources of UIC-NARL,
- the long history of diverse research in the area, and
- the year-round infrastructure and sustained support of an active human community.

Several long-term databases exist for the area, including complementary multidisciplinary ones, such as the bowhead whale census data, National Weather Service information, and magnetic and seismic observations; there is the opportunity for land-water interaction studies; and traditional knowledge of the area is extant and can be applied to research for which it is relevant. Logistically, there is access to the whole North Slope and areas off-shore, year-round infrastructure and organizational support are available, and there is strong local support for science.

4

Current Research and Future Opportunities in the Barrow Area

The following sections describe the areas of scientific inquiry that are, will be, or could be done best from Barrow. They are not intended as prescriptive science plans nor as exhaustive lists of potential research. Rather, they provide examples of possible research topics and projects in various fields and environments, which are the basis for the recommendations made in Chapters 6 and 7. Several of the major ongoing research programs based in Barrow also are discussed in these sections. A comprehensive inventory of recent research in the area is precluded by the lack of a dedicated research support entity prior to the establishment of BASC in 1995.

While the following sections are organized by marine and coastal research, terrestrial and freshwater research, atmospheric research, and social science research, the links and overlaps among these areas should be kept in mind. These interdisciplinary connections are among the most significant research opportunities in the Barrow area. Researchers examining different aspects of a topic, such as climate change, can work together to learn more about the relationships among, for example, fluxes of solar radiation, vegetation cover, sea ice thickness, subsistence hunting, bird nesting, seal distribution, and the impacts on human communities.

Logistical support from Barrow was important to the success of the 1998 Surface Heat Budget of the Arctic Ocean (SHEBA) project, funded by NSF, in which an icebreaker was moored into the pack ice for a year to help understand the thermodynamic coupling between the atmosphere, ice, and ocean. Photo © James H. Barker.

Marine and Coastal Research

The Barrow area presents an unparalleled opportunity for marine and coastal research for several reasons. Geographically, the two distinct water masses of the Chukchi and Beaufort seas converge at Point Barrow; there are estuarine, shelf, and deep-water areas nearby; continuous land and subsea permafrost exist in the area; and it is close to diverse sea ice environments.

Recent studies of the electromagnetic properties of sea ice to improve remote sensing determination of sea ice types and thicknesses exemplify marine research opportunities in the Barrow area. Sponsored by the Office of Naval Research, the Electromagnetic Properties of Sea Ice program (EMPOSI, 1993–98) included over thirty projects and a major research effort on the land-fast ice off Barrow in 1994, as well as smaller field programs in 1993 and 1995. The variety of ice types and conditions found in the Barrow area, in addition to the extensive local logistical support, enabled EMPOSI researchers to test new theories and methods prior to their use in programs, such as SHEBA, located in more remote areas.

In the arctic marine and coastal environments, the relationship among regional and local processes must be better understood, particularly for predicting specific local effects of changes that are typically modeled at larger scales. For instance, recent observations of significant changes in the Arctic Ocean and its ice cover point out research opportunities such as relationships between the Beaufort Gyre and coastal systems and the impact of large-scale atmosphere and ocean features on local ice-ocean dynamics (Cavalieri et al., 1997). Long-term research opportunities in the coastal and ocean environments include processes such as deep-water formation on the coastal shelves; halocline formation and maintenance; the significance of changes to the thermohaline structure of the Atlantic layer and upper mixed layer of the Arctic Ocean; shelf/coastal ice dynamics; fresh water inflow; heat, mass, and energy exchange among the land, ice, ocean, and atmosphere; and sediment transport and coastal erosion (Aagaard et al., 1999).

These physical processes in turn can be examined in terms of their relationships with biological production, distribution and abundance of marine flora and fauna, impacts on human activities such as subsistence hunting and ocean transportation, uptake of contaminants within food webs, and so on. For local effects such as coastal erosion, engineering solutions can be developed to protect valuable areas such as villages and archaeological sites.

Marine biological processes can be studied broadly and in detail. Long-term continuous observations of physical and biogeochemical processes will help our understanding of coastal and shelf fluxes and transformations. Studies to monitor populations of key species such as bowhead whales can also examine the impacts of human activity on the migration and behavior of these and other marine species. Ecological relationships, such as those between polar bears and ice seals, can be investigated in detail. For single species and for ecosystems, the potential impacts of global change can be studied for better predictive modeling and verification as well as for determining possible mitigative measures for human communities dependent upon marine resources.

In the Barrow area, a prominent example of the single species approach to marine biological studies is the long-term research program on the bowhead whale. When the traditional subsistence Iñupiat whale hunt was threatened with closure by the International Whaling Commission (IWC), Barrow hunters helped establish the North Slope Borough Department of Wildlife Management research program on the health of the bowhead whale population, based on community members' traditional knowledge. Since 1981, census efforts by the DWM have shown a growing and viable bowhead whale population, now estimated to be 8,200 and growing at 3% a year (Raftery and Zeh, 1998).

Recently, the DWM has collected evidence that bowhead whales may not all follow a single migration route. People on St. Lawrence Island, drawing on their own traditional knowledge, have long said that not all bowheads go up the Alaska coast, which is where they are counted for the census, but that some move north along the coast of Chukotka (Russia). When DWM investigators were able to work in Chukotka with the assistance of Native workers and some Russian scientists, this traditional knowledge was confirmed (Ainana et al., 1999). Genetic studies on these animals are currently under way. The DWM's other long-term bowhead whale research project involves examinations of harvested whales as assessments of the status and health of the population and for basic studies (morphology, serology, microbiology). In collaboration with researchers at several other institutions, these ongoing basic studies were started in 1978 and, among other uses, allow investigators to better predict the potential impact of a future oil spill (Albert, 1988).

Potential marine and coastal research questions:

What is the relationship between sea ice extent and primary production, and how might changes such as those predicted under global warming scenarios affect marine animals and subsistence hunting?

How do large-scale atmosphere and ocean dynamics, the formation of arctic deep water, and shelf water mass modes and circulation interact?

How can the long-term databases of the marine and coastal systems in the Barrow area assist us in predicting future changes? How broadly can we generalize findings based in Barrow to other parts of the Arctic?

What are the time scales of Arctic Ocean thermohaline and circulation variability, and how does this variability affect arctic and global climate?

How can coastal erosion be mitigated to prevent destruction of villages and archaeological sites?

What are the linkages and syntheses of biological and physical systems impacting food webs and humans, for example in relation to the transportation and uptake of contaminants?

Terrestrial and Freshwater Research

In the terrestrial and freshwater environments, the arctic coastal plain is a critical system that is not well understood, particularly in terms of its impacts from and influences on global change (ARCUS, 1998; LAII Science Steering Committee, 1997). Disturbances from human activities such as oil and gas development are also an important area of research, and, in the Barrow area, baseline studies can be undertaken as development occurs. Furthermore, studies in winter are essential for understanding the year-round dynamics of the arctic environment. Barrow provides the necessary base for all-season research on the tundra and freshwater systems (LAII investigators, 1998).

The Barrow Environmental Observatory (BEO) provides a unique opportunity to build on the history of research in the area. The 7,446-acre parcel, set aside by the Ukpeagvik Iñupiat Corporation, as described in Chapter 2, is also an impressive example of the commitment of the Barrow community to scientific research in their area. A number of intensive, long-term studies are possible on the BEO, looking, for example, at changes in vegetation structure from natural and anthropogenic impacts, surface-atmosphere heat and gas and vapor exchanges (or micrometeorology), and the implications of changes in snow cover and permafrost on gas exchange and tundra vegetation and hydrology. Existing databases from pre-1970 studies and the International Biological Programme (IBP), augmented by extensive traditional knowledge, provide baselines that do not exist for other arctic terrestrial systems. Furthermore, access to data from atmospheric observations at the Climate Monitoring and Diagnostic Laboratory (NOAA) and the Atmospheric Radiation Measurement (Department of Energy) sites bordering the BEO allow for integrative studies of the causes and effects of global change, strengthening our understanding of significant relationships at the local levels.

The San Diego State University (SDSU), in collaboration with the National Oceanic and Atmospheric Administration Atmospheric Turbulence and Diffusion Division and the Iniziative Industriali Italiane, have developed the Sky Arrow Environmental Research Aircraft for use in climate and atmospheric measurements. In conjunction with eddy covariance towers and satellite remote sensing, the landscape, regional, and ultimately circumpolar CO_2, energy, and additional trace gas fluxes can be obtained. The first mission of the Sky Arrow ERA will begin in the summer of 1999 as part of the Arctic Transitions in the Land-Atmosphere System (ATLAS) project's Western Transect between Barrow and Atqasuk. Photo by Joseph G. Verfaillie, Jr.

Expanding this type of research to the landscape and regional level can be done through use of transect studies such as that on the Arctic Transitions in the Land-Atmosphere System (ATLAS) project's Western Transect between Barrow and Atqasuk. Research in the Barrow area contributes to several larger research networks, offering tremendous opportunities to examine related questions across several geographic and temporal scales as well as to make comparative analyses across different biogeographic and climatic zones. These international networks include a hemispheric (AmeriFlux) and global (FLUXNET) network of continuously running eddy covariance sites measuring trace gas fluxes in many different ecosystems. NSF funds the U.S. portion of the International Tundra Experiment (ITEX), which conducts annual research on vegetation plots within the Barrow Environmental Observatory (BEO) as part of an international network. Comparable data are collected at other participating sites around the Arctic in order to assess and predict the response of the tundra vegetation to climate changes. The NSF-funded Circumpolar Active Layer Monitoring (CALM)

Potential terrestrial and freshwater research questions:

What physical and biotic cycles govern production and decomposition of tundra and in thaw lakes?

How do microbial processes and plant dynamics affect trace gas and carbon dioxide fluxes across the tundra-air boundary?

How do the dynamics and degradation of permafrost affect plant communities, surface and subsurface soil stability, and trace gas balance?

How can traditional knowledge help identify key aspects of environmental change?

What are the linkages between climate and vegetation? How might changes in vegetation affect other aspects of the tundra system?

How are interannual differences in the distributions of species across the landscape related to population levels, trophic interactions, and abiotic factors?

program takes a similar approach in mapping the depth of the annual thaw layer at 69 sites around the Arctic. This network will improve models of carbon flux from arctic ecosystems under climate change scenarios.

Studies of invertebrates, fish, and wildlife, which were major subjects of early NARL research, remain important. Wildlife population dynamics, particularly cyclic microtine populations and the interactions among predators and prey, are topics of continuing interest to managers and academics. Continued population monitoring can help us understand natural cycles as well as the relationship of wildlife populations to subsistence hunting and impacts of industrial development. There are great opportunities for research on physiological and behavioral adaptations to factors such as extreme cold, variations in daylight, and extensive ice cover of lakes and rivers. The migratory pathways of many species of birds converge in the Barrow area. These species are studied for their behavior, for the ecology of the tundra and nearby marine environments, for the health of their entire migratory ranges, and for their significance to the subsistence economy. Here, as elsewhere, integrative studies that look at the complex webs of food, physical environment, and behavior in which these species live are crucial opportunities to understand how the arctic system functions as a whole. Several relevant terrestrial biological studies have been carried out recently by the DWM, often in partnership with agencies and nongovernmental organizations, including telemetric monitoring of caribou populations, fish surveys, and work on the breeding biology of Steller's eiders and snowy owls.

Geological and geophysical research can help us understand past climate and tectonic origin of the area. Studies of lake sediments can provide high-resolution details about recent past climate. Sediment and fossil archives preserved in coastal and river bluffs can provide longer records of past climate, though at lower resolution. Detailed studies of the paleogeography of arctic Alaska, the evolution of the Brooks Range, and the tectonic evolution of the Arctic Basin can be undertaken. The thermal, chemical, and physical properties of permafrost and its development require additional investigation.

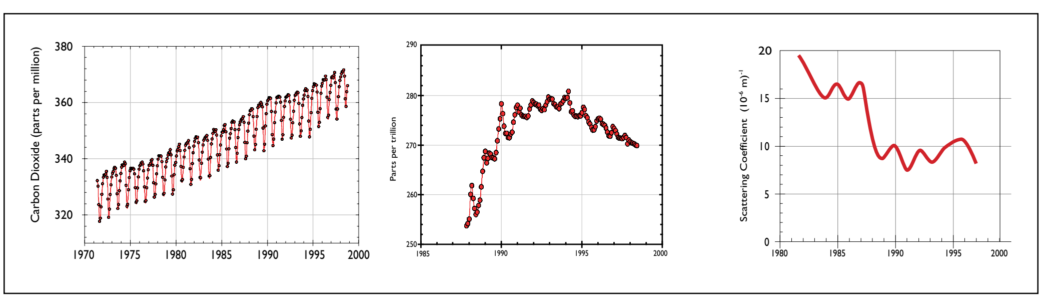
Atmospheric Research

The Barrow area offers opportunities for research on many atmospheric phenomena and processes. The principal research efforts currently underway focus on global climate change. In 1972, the NOAA Climate Monitoring and Diagnostics Laboratory (CMDL) established one of four manned global atmospheric monitoring facilities between the town of Barrow and Pt. Barrow, on land bordering the BEO to the north. The NOAA/CMDL Barrow Observatory measurements include the longest continuous records of atmospheric CO_2 and fluorocarbon trace gas concentrations, aerosols, surface and total column ozone, and solar radiation anywhere in the Arctic. In addition to its own programs, the NOAA/CMDL facility currently hosts 19 cooperative research projects with universities and other government agencies covering topics such as trace gas measurements, magnetic fields, earthquake detection, aerosols, and solar radiation.

Immediately adjacent to the NOAA/CMDL Barrow Station and on NOAA land, the U.S. Department of Energy (DOE) has established its North Slope of Alaska and Adjacent Arctic Ocean (NSA/AAO) Cloud and Radiation Testbed (CART) Barrow facility, which is part of the DOE Atmospheric Radiation Measurement (ARM) program. Adjacent to the NOAA/CMDL and ARM sites is an area that is part of the U.S. AmeriFlux network and is one of several circumpolar eddy covariance towers running year-round in the worldwide flux network called FluxNet. Since 1991, NSF has operated a spectroradiometer at UIC-NARL that is part of a polar network for monitoring ground-level UV irradiance with complementary stations in Antarctica. The National Weather Service collects meteorological data at its station in Barrow. Through these facilities, the atmosphere above Barrow is characterized more fully than at any other site in the Arctic. The data generated are available for a wide variety of purposes and applications, creating opportunities for additional atmospheric, terrestrial, and oceanographic research.

Research on global climate processes can look at radiative transfers through the atmosphere and to the surface. The influence of clouds on such transfers is poorly understood, and the formation and evolution of clouds and their radiative properties can be investigated further. The optical properties of the surface, and the variation in those properties through the annual cycles of freezing and thawing, are also important factors in climate modeling. How precipitation influences and is influenced by climatic factors is another critical aspect of climate models that requires further development and validation. All of these factors can be examined not only in the coastal environment, but also inland and extending to the pack ice.

Continuous records of CO_2 (left), the ozone depleting gas CFC-11 (center), and the annual March index of air pollution from Eurasia commonly known as arctic haze (right), from the NOAA/CMDL Point Barrow Baseline Climate Observatory. The magnitude of the annual CO_2 cycle measured at Barrow is the largest measured at any of the four NOAA/CMDL baseline stations (Barrow, Hawaii, Samoa, and South Pole). The concentrations of CFC-11 measured at Barrow have decreased since the reduction of CFC production in the early 1990s. Arctic haze air pollution measured in the month of March has reduced an incredible 50% between 1982 and 1997. This is thought to be the result of both a reduction in the sources in Russia and to a fundamental shift in the air flow patterns in the Arctic over the same period (Stone, 1997) and possibly an early signal of climate change in the Arctic. Figures courtesy of Russ Schnell.



Atmospheric composition monitoring and modeling is another key area for research. Such monitoring can examine gases and aerosols that influence climate change and a broad range of contaminants. The fluxes of these substances across the surface-atmosphere boundary and their impacts on radiant energy flow and the biotic environment are important components of such research. Ozone destruction in the upper atmosphere and related changes in ultraviolet radiation can also be studied. All of these areas are critical for integrative studies that can examine the effects of such changes on the flora, fauna, and human residents of the area.

Meteorological monitoring is important for trend analysis and for providing accurate baseline data for use by other researchers in a variety of disciplines. For this and other monitoring efforts, it is essential to maintain the integrity of the long-term effort. The clean air sector upwind of the measurement and sampling facilities on the BEO must be maintained.

Remote sensing of several important factors in climate modeling requires validation by surface measurements. These factors include temperature, humidity, aerosols, snow and ice thickness and characteristics, vegetation cover, and many others. The Barrow area provides an excellent place for much of this validation work, since it can combine long-term atmospheric observations with terrestrial and marine observations to validate or correct remote sensing data. Additional work can help develop correction algorithms for the effects of atmospheric factors such as humidity and composition on remote sensing of surface characteristics.

Potential atmospheric research questions:

How do concentrations of greenhouse and ozone-depleting gases behave at high latitudes relative to mid and low latitudes?

How do changes in arctic temperatures and atmospheric conditions affect properties of the tundra such as soil moisture and whether it is a source or sink for carbon dioxide and methane?

How should the radiative and other climate feedbacks related to snow and ice melt be represented in climate models? Are currently used representations adequate?

How should the formation, evolution, evaporation, and radiative effects of ice and mixed phase clouds be modeled in global climate models?

How can the Barrow site be used to improve the algorithms used to interpret satellite-based remote sensing measurements for regions where snow and ice occur?

Social Science Research

Research opportunities in the social sciences in the Barrow area range from the likely impacts of global change on arctic communities to the ways in which traditional knowledge is transmitted today, and from the factors that shape changes in subsistence practices to identifying opportunities for science education in local schools (ARCUS, 1997, 1999). The possibilities for research in archaeology, anthropology, and other fields are greatly enhanced with the recent creation of the Iñupiat Heritage Center in Barrow. As with other fields of research in the Barrow area, research in various aspects of the social sciences has taken place over the course of several decades and longer, providing an extended baseline against which modern changes can be identified and analyzed.

Traditional knowledge—the system of experiential knowledge gained by continual observation and transmitted among members of a community—is gaining acceptance and becoming more integrated with Western science. The Barrow area offers many opportunities for documentation and application of such knowledge in collaborative projects. The use of traditional knowledge within the Barrow community is an area ripe for research, especially amid concerns about impacts from rapid cultural change. Developing appropriate ways for traditional knowledge experts to work with scientists is of particular importance in the continuing development of the community-science partnership.

Subsistence hunting, fishing, and gathering are of vital importance to the people of Barrow and to the Iñupiat culture. Subsistence practices have changed during this century as a result of many factors, including the introduction of a cash economy, new technology such as snow machines and outboard motors, and increased exposure to the Western way of life. These changes have in turn had significant implications for local society, from the assertion of Native rights with regard to hunting and management of marine mammals, to the erosion of some cultural values and the associated increase in social pathologies such as domestic violence and substance abuse. In addition, these changes in technology and other factors may also affect the impacts of humans on wildlife populations.

Global change is also likely to have a significant impact on arctic communities such as Barrow, but attempts to predict and quantify these impacts have just begun. Sea

Potential social sciences research questions:

How can traditional knowledge be better used in the formation of research questions?

What changes have occurred in subsistence and land-use patterns and practices recently and over longer periods, and what factors have driven these changes?

How has community participation in research affected both local residents and visiting researchers, and what lessons can be learned from this experience?

What does the archaeological record tell us about past adaptations to environmental change?

What factors can be used as indicators of community health, both for maintaining traditional practices and for adapting to modern circumstances?

level rise, changes in the extent and duration of sea ice cover, and the increase in contaminant burdens in subsistence foods threaten infrastructure, hunting traditions, and human health. Identifying such impacts and potential mitigative measures is a significant challenge for the long-term viability of arctic communities and cultures.

Barrow residents preparing seal skins for a skin boat in the traditional work room at the Iñupiat Heritage Center, which opened in 1999. Richard Glenn, president of BASC, is in the foreground. The new center's superb facilities provide many opportunities for sharing traditional knowledge. Photo by Bernard Zak.

Education Opportunities

Addressing these concerns requires education, not only of Barrow residents but also of those outside the region who affect, or are affected by, the community and the region's environment. Science training opportunities should be expanded for Barrow schoolchildren, especially through participation in research projects in the area. Researchers coming to Barrow should learn about the community and its history, as well as about survival and safety in the Arctic. Public education materials can help generate better understanding of the global importance of the Arctic, of its communities and cultures, and of the significance of scientific research.

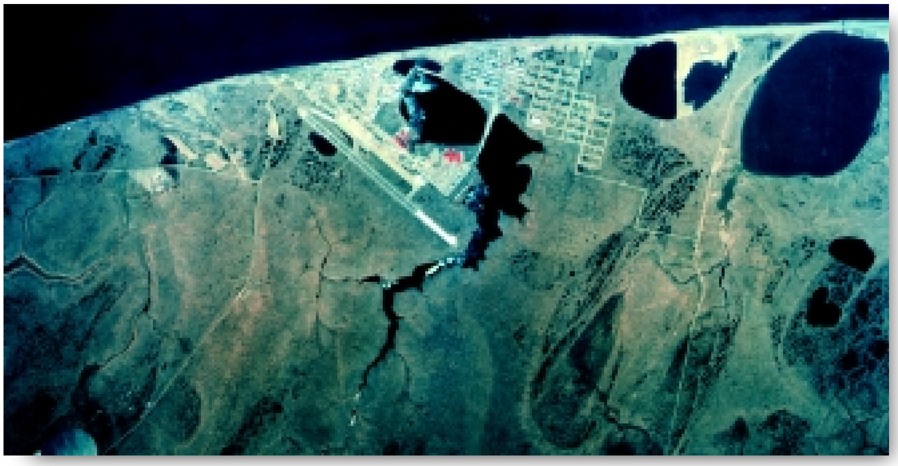
Research-education partnerships are a long tradition in Barrow, linking scientists with students and other members of arctic communities. Working in and communicating with local communities offers educational opportunities that can be deeply meaningful to researchers and arctic residents, particularly when local students and community members become involved with the research process (ARCUS, 1997; Seyfrit and Hamilton, 1997). Archaeologists bringing groups of elementary students into an excavation site or to a museum exhibit, for example, can turn science into an exciting venture for children. As a result, students will gain a more complex understanding of the issues facing people in the North and will use this knowledge in a variety of ways as they grow to adulthood. Such educational efforts also promote a better understanding of publicly funded research and improve popular awareness of the Arctic as a critical component of the global environment.

Researchers also need to explain to communities in other parts of the U.S. and the world the relevance of arctic research and the significance or usefulness of their results for the general public. Reaching the largest possible audience via regional and national television, Internet, traveling exhibits, popular publications, and, where possible, including local residents in the dissemination of the results will yield important results in terms of public support and community partnerships. Increasing use and development of communications and educational infrastructures (e.g., community-based electronic networks, Web sites, compressed video, etc.) will help investigators reach these important audiences.

Facilities and Support Available Today

When the Naval Arctic Research Laboratory (NARL) was closed in 1980, the Navy planned to demolish this unique arctic facility. The Barrow community acted to protect the infrastructure at the complex. The local Native corporation, Ukpeagvik Iñupiat Corporation (UIC), working with the Office of Naval Research, gained title to and preserved what is now known as UIC-NARL. Some buildings were beyond salvage and a few are still repairable but not currently in use; others have been upgraded over the years. While the UIC-NARL complex today gives a geographic focus to Barrow's diverse science support infrastructure, the majority of UIC-NARL facilities are now used for other community purposes.

The limited facilities at UIC-NARL that are available to support research are marginally adequate to meet current demand and are clearly inadequate for predicted future needs. Current demand on the research support resources of the Barrow area is difficult to estimate because of the diverse and decentralized activities of many investigators and because of the limited personnel resources of the research support organizations. Research use of the area is likely to be underestimated by available data since many investigators make completely independent arrangements and do not report their activities to a Barrow organization.



In this aerial view of Barrow, the village of Barrow can be seen to the left of the reservoir (the central body of water near the airstrip), while Browerville (the newer residential area) is to the right. The UIC-NARL complex is partially visible on the far right. Photo courtesy of the North Slope Borough.

Baseline information available for quantifying research use of the area includes the following:

- the DWM provided 970 man days of logistical support at no cost to 50 visiting researchers in 1998, primarily through accommodation at the ARF;
- in 1994–96, the NSF-funded Point Franklin archaeological project hosted up to 26 investigators for three months each year;
- the ARM program has about 800 visiting researcher days per year.

The demand for research support in the Barrow area is disproportionately concentrated in the summer, when other activities (construction, subsistence harvests, tourism) compete for infrastructure and personnel.

The needed infrastructure improvements and better logistics coordination that are described elsewhere in this document will build upon the solid base of Barrow's pro-science community residents, facilities such as UIC-NARL and the Barrow Environmental Observatory (BEO), and other active Barrow organizations and facilities. Appendix A provides details on organizations and facilities currently in Barrow that can be useful to scientific research projects. This chapter gives an overview of the research support available in Barrow today.

Planning and Logistics Assistance

The nonprofit Barrow Arctic Science Consortium (BASC) is home base for many support activities. The National Science Foundation Office of Polar Programs has a multiyear cooperative agreement with BASC to facilitate research in the Barrow area. Researchers can call upon BASC staff, including a full time, year-round logistics coordinator, for assistance. BASC also serves as the point of contact for projects that need to lease land, buildings, or equipment.

BASC represents the local landholder, UIC, as manager of the BEO and as the point of contact for providing UIC land-use permits for researchers who cross or work upon UIC land. Although the Bureau of Land Management is the largest landholder on the North Slope, UIC owns most of the land within several miles of Barrow. The North Slope Borough has designated BASC as the point of contact for researchers requiring borough permits for various land uses or near shore activities. Similarly, BASC can assist researchers who need local permits from any of the eight North Slope villages.

Building 360 at UIC-NARL contains the North Slope Borough Department of Wildlife Management offices, UIC's Real Estate Division office, BASC offices and labs, Iḷisaġvik College offices, conference room, cafeteria, and student housing. Photo by Dave Ramey.

Living and Working space

The main building on the UIC-NARL facility is the 45,000 square foot Building 360, which contains general office and lab space. Most of the former laboratories have been converted to use by Iḷisaġvik College. The Real Estate Division of UIC, BASC, and the North Slope Borough Department of Wildlife Management (DWM) also have some office space. BASC rents two wet laboratories in Building 360 for use by visiting researchers; these labs, which total 860 square feet, are filled to capacity by current users. Two smaller labs have been available on an ad hoc basis to visiting investigators, but are not leased to BASC and could be lost to competing uses.

The DWM also maintains the small Arctic Research Facility (ARF), a bunkhouse with modest laboratory and workshop space, which was formerly the NARL animal research facility. The DWM maintains the ARF primarily to support its own considerable research efforts (see Chapter 4), but it also is able to provide some support on a space-available basis to visiting scientists. Since the closure of NARL, the ARF has been the only multipurpose facility available to assist individual investigators, and its capacity of 20 persons is often exceeded during the summer field season. The high seasonal use of the ARF coupled with its limited funding have resulted in deteriorating facilities that are not adequate for research support in the long term.

Researchers also can be accommodated at the hotel at the UIC-NARL facility, at one of several hotels in Barrow itself, or, in some cases, with a local family. Relying on commercial facilities can be problematic, since the summer field season coincides with the construction season as well as the peak of the increasing tourist traffic to the region.

The DWM employs a full-time, year-round logistics coordinator based at the ARF. Through support for the ARF from NSF's cooperative agreement with BASC, the ARF facilities are available on a space-available basis for researchers, including access to snowmachines, 4-wheelers, and boats, as well as some arctic clothing and field equipment. BASC also maintains a heated, secure warehouse with additional arctic gear, including cold weather tents and various small tools, plus storage space. Additional work and storage space is available in a second heated building at UIC-NARL.

Federal Research Facilities

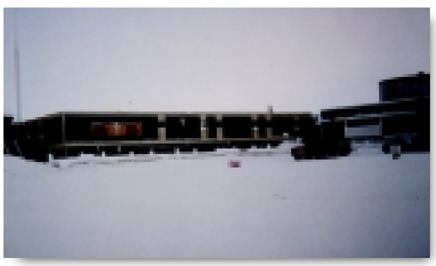
The federal government is active in several areas of research and data collection in the Barrow area. On the northern boundary of the BEO, the National Oceanographic and Atmospheric Administration has the Climate Monitoring and Diagnostics Laboratory (CMDL), a permanent facility that supports several dozen instrumented research projects. Adjacent to CMDL, the Department of Energy maintains the Atmospheric Radiation Measurement (ARM) field facility, which supports numerous long-term and seasonal research projects. ARM has support and operations contracts with UIC and rents its base facilities (a renovated duplex with living quarters, laboratory, and computer workshop space) through BASC at UIC-NARL. The National Weather Service has an installation in Barrow and a long series of recorded observations. With logistic and scientific observation support from NOAA/CMDL, the U.S. Geological

Above: BASC lab facilities in Building 360. Second: Warehouse and shop at BASC. Third: Specimen storage space at the ARF. Photos by Dave Ramey. Below: Outhouse at a whale census camp, carved from a piece of multiyear sea ice. Photo by Craig George.

Survey, Geomagnetism Branch operates the Barrow Magnetic Observatory on federal land adjacent to the NOAA/CMDL facility. Details on the ARM and CMDL instrumentation can be found in Appendix A.

Other Research and Support Organizations

Several North Slope Borough agencies support research, including the Department of Wildlife Management; the Commission on Iñupiat History, Language and Culture; the Planning Department and its GIS Division; and, for safety matters, the Department of Search and Rescue. The Barrow Volunteer Search and Rescue lends personal locator beacons at no charge to researchers who are working outdoors. The Alaska Department of Fish and Game (ADFG) maintains a Barrow office. The nationally and internationally recognized Alaska Eskimo Whaling Commission is headquartered in Barrow and provides researchers with a link to the subsistence user community. Iḷisaġvik College maintains facilities at UIC-NARL and operates the Iñupiat Heritage Center in Barrow. Students, faculty, and staff can be consulted or employed in research projects as they are available.



The new Iñupiat Heritage Center has outstanding exhibits on Iñupiat culture, regional natural history, and cultural and scientific research. As a community forum and a platform for historical and modern sociocultural research, the Heritage Center includes classroom space and traditional workrooms. Climate-controlled storage space houses artifacts and items of archaeological importance.

Human Resources

The expertise of Barrow's resident scientists is a crucial resource for visiting investigators. As the UIC-NARL example shows, the residents of Barrow have demonstrated a wholehearted willingness to help scientific research and are a reservoir of scientific and technical information. Local people work on research projects as investigators, technicians, guides, bear lookouts, drivers, and in other capacities. At public meetings and science lectures, elders and other residents share their knowledge and experiences with research teams.

Above: The Alaska Commercial store, a food and department store, is also called "Stuaqpak," which means "big store" in Iñupiaq.

Second: One of several barges that bring cargo to Barrow late each summer.

Third: Samuel Simmons Memorial Hospital.

Fourth: The Barrow tank farm stores gasoline, diesel, propane, aviation fuel, and jet fuel.

Below: An Alaska Airlines 737 being loaded at the Barrow airport.

Information and Technology

The North Slope Borough has spent over a decade and millions of dollars creating an electronic database. Portions of this database are now available to researchers through a digital data sharing agreement signed by the borough and BASC. The two largest components of the database are a geographic information system (GIS) with basic geographic features from most of the North Slope and a traditional knowledge (i.e., audio and video tapes, etc.) component. Within the restrictions applied to confidential and proprietary data, researchers can make use of this information as long as they share their own data with BASC and the borough. Technical assistance with these databases is not currently available to researchers.

The transportation infrastructure of Barrow enabled this Convair-580 to make 23 flights over the Arctic Ocean to measure trace gases, atmospheric aerosols, and clouds as part of the SHEBA project in 1998. The plane is owned by the Cloud and Aerosol Research Group at the University of Washington Department of Atmospheric Sciences. The in situ measurements obtained from the Convair-580 are now being compared to remote sensing measurements from the ship, satellites, and the NASA ER-2 high-flying aircraft. Extensive measurements were also obtained from the Convair-580 on aerosols and cloud structures in the Arctic and the reflectivity properties of various ice surfaces. These data are being used to increase understanding of aerosol-cloud-climate interactions in the Arctic. Photo by Bernard Zak.

The NARL science library and other materials are archived at the Rasmuson Library at the University of Alaska Fairbanks, complicating access to this material from Barrow. At UIC-NARL, BASC has been building the Bill Brower Memorial Science Library, a resource library for researchers. In Barrow proper, the Tuzzy Consortium Library is housed in the new Iñupiat Heritage Center. This library has a large collection that is regionally oriented as well as computers for on-line literature searches. BASC maintains some networked computers at UIC-NARL that researchers can use on a space- and time-available basis. These computers may be used to create small vector GIS overlays using ArcView and the BASC color map plotter.

Transportation

Barrow's modern airport has regularly scheduled jet service to Anchorage and Fairbanks by Alaska Airlines. Several air freight companies serve Barrow as well. For travel on the North Slope, local air carriers provide scheduled and charter services to North Slope villages and charter services to remote sites throughout the region.

For ground transportation, UIC has a small car and truck rental facility at the airport. Heavy equipment with operators is available for rental through several sources. As noted above, snowmachines, boats, and all-terrain vehicles are available on a limited basis through BASC at the ARF and also can be rented in Barrow.

Other Services

The Science Division of UIC undertakes contracts for long-term support of research efforts not funded by NSF. The Science Division also undertakes contracts to provide cultural resources clearances for construction projects. Both UIC and the Native regional corporation, Arctic Slope Regional Corporation (ASRC), have subsidiary companies that do architectural work, engineering, and surveying. Various construction companies are located in Barrow, and bulk construction materials and other supplies that are not flown to Barrow can be brought in via the annual barge service.

The Barrow area is served by a hospital administered by the Arctic Slope Native Association. Equipment at the hospital may be available for use by researchers. The North Slope Borough Health Department, including the Veterinary Clinic, is also engaged in research and can act as a resource for researchers.

Barrow's public (and only) radio station, KBRW, broadcasts throughout the North Slope with AM and FM programming. KBRW frequently interviews researchers and publicizes the work they are doing. KBRW will air public service announcements about particular research activities of which the public should be aware. The regional newspaper is the *Arctic Sounder.* The *Sounder* has a reporter in Barrow and frequently covers science activities. BASC maintains a community outreach program and makes arrangements for researchers to give public lectures and to contact specific members and groups of the Barrow community such as resident researchers, students, hunters, and others.

Barrow has several hotels and restaurants. A supermarket, computer store, hardware store, automotive store, and repair shops are included in the amenities available in Barrow, whose year-round residents number about 4,500.

Above: Sharing is a fundamental tradition of Iñupiat culture. At one of the celebrations in 1999 associated with spring whaling (Nalukataq), residents share the bounty provided by the bowhead whale harvest. The celebrations also include blanket tosses and dancing. The subsistence whale harvest also provides valuable tissue samples for investigations of bowhead whale biology. Photo by Michele Hauschulz.

Below: Kisik (George Woods), a resident of Nuiqsut, wins a round of the stick pull against Arnold Brower, Jr., from Barrow, at a celebration of Kivgiq. Photo © Bill Hess, Running Dog Publications.

Recreation

The Barrow High School offers public swimming during the school year. Other indoor recreation is available at the high school, at a City of Barrow facility, and at UIC-NARL through Iḷisaġvik College. Summer leagues for softball and other sports extend their hours late into the night to take advantage of Barrow's three months of continuous sunlight. Organized group tours are available in the village by bus or van, and outside of the village by off-road vehicle or on foot. Barrow has a public bus service and several taxi companies.

As the largest of the eight North Slope Borough villages, Barrow is the center of many regional gatherings. The people of the North Slope are legendary for their friendliness and hospitality, and visitors are welcome to join traditional celebrations such as Kivgiq, the messenger feast, and Nalukataq, the celebration of a successful whaling season.

Detailed listings of the organizations, activities, and services currently available to researchers who base their field activities in Barrow can be found in Appendix A.

Facilities and Support Recommendations

6

Most researchers and research projects share some or all of a general set of support needs. For each individual to locate and arrange support separately is neither effective nor efficient when it is possible to provide support from a single source. From the closing of NARL in 1980 to the present, the North Slope Borough has provided a limited amount of basic support to visiting researchers, but many services have had to be arranged separately by each project team. Today, interest in research in the Barrow area is increasing, due in large part to the importance of the Arctic in processes of global change. At the same time, the North Slope Borough's ability to support research is decreasing with its overall budget, and existing research support facilities in Barrow are beyond capacity and deteriorating. To take advantage of the tremendous research opportunities in the Barrow area, a system of coordinated support through a central organization for the benefit of all researchers in the area is essential.

The needs of the DWM's bowhead census field camps are typical of many arctic field researchers' requirements. Photo by Craig George.

This chapter first describes the general kinds of support necessary for researchers to carry out the full range of scientific inquiry that will, can, and should be done in the Barrow area. These descriptions are followed by

Cooperative research projects involving U.S. and Russian investigators on several topics, including global change and bowhead whales, take place in Barrow. A collaboration between San Diego State University and Moscow State University brought Dmitri Karelin to Barrow in 1999 to learn the complexities of the eddy covariance technique and to bring the technology and expertise to Russia's research efforts. Photo by Michele Hauschulz.

specific recommendations to the National Science Foundation and other relevant organizations. For clarity of presentation, support recommendations are listed in four categories: buildings, sites, and facilities; field equipment and transportation; technology and information; and human resources. When addressing the recommendations, however, the support needs in all categories should be considered together. Several overarching recommendations apply to all aspects of improving research infrastructure.

Providing such support will require the cooperation of the various federal, state, local, and other agencies and organizations involved in research in the Barrow area. Memoranda of agreement are one way to coordinate the activities of potential partners. Such memoranda can address not only cost-sharing for and access to common facilities and equipment and the exchange of other services, but also permitting requirements for federal, state, and private lands, routes of access, sharing of data and results, and other aspects of support, land use, and scientific research. Recommendations regarding interagency coordination are included in summary form in Chapter 7.

The workshop participants recommend that research support be available to all investigators active in the Barrow area. An important question for common support is that of funding, including the costs to be borne by those using such facilities and services. While researchers should be expected to budget for some of the costs associated with supporting their research, the full costs may be prohibitive for many researchers. Financial support should be available to allow undergraduate, graduate, and post-doctoral researchers to serve as interns on existing projects or to carry out their own research in the Barrow area. Funding mechanisms in use elsewhere in the U.S. Arctic and at international arctic research facilities should be examined for their applicability to Barrow.

Many types of support might best be provided at least in part through the private sector in the community of Barrow. For example, air charters and vehicle rentals may be preferable to the purchase of a dedicated airplane and several pickup trucks. The recommendations in this chapter concern what should be available and what would best be made accessible through a central support provider. Who actually provides the services and equipment is a detail to be worked out in further planning and through discussions with potential suppliers.

The specific recommendations, presented in summary form in the following chapter, are identified as short-term needs (for implementation within two years) or mid-term needs (implementation in two to five years). Some of the facilities and other infrastructure will have a far longer life span, and the scientific activities and associated support needs in the Barrow area may change rapidly with changes in technology, global climate, community needs, and other factors. Thus, an important part of providing support for research in the Barrow area will be a continued assessment of needs and evaluation of progress on implementation and the effectiveness of current support.

Buildings, Sites, and Facilities

The North Slope Borough Department of Wildlife Management (DWM) has for many years provided visiting investigators modest amounts of space at its Arctic Research Facility (ARF) for lodging, staging, equipment storage and maintenance, and limited laboratory work, in addition to using the ARF for its own research programs. Without this facility, much of the research that has taken place in the Barrow area since the NARL closure would not have been possible. The ARF, however, is barely adequate for many of the purposes for which it is currently used and clearly inadequate for the long term. Requests for lodging at the ARF each summer exceed capacity. In 1998, the DWM provided 970 man days of logistical support at no cost to 50 visiting individual researchers, primarily through accommodation at the ARF. Laboratory space, including that in the nearby main UIC-NARL building, is filled to capacity during the summer, and a full range of wet, dry, and cold laboratories is unavailable.

While maintaining the availability of space in the main UIC-NARL building and the ARF are essential in the near term, a modern, general-purpose research facility is needed as soon as possible. The new facility should be planned so that it can be built in stages and so that additions are possible in the future as needs and opportunities change. The requirements outlined below are the starting point for planning, and should be refined as necessary by those responsible for the funding, construction, and maintenance of the facility.

A new facility, built to accommodate up to 50 researchers, should include an appropriately equipped cooking and eating area, rooms for gatherings, and some recreational opportunities. The Iḷisaġvik College cafeteria, which is open to the public, will be a cost effective way for many researchers to eat, but a kitchen should be available for those whose research demands unusual hours. While many researchers are in the area for a short time and can use bunk rooms, some researchers stay for months or longer, at times with families, and so a limited number of more private rooms also will be required. Common gathering rooms, including the kitchen and dining areas, will help stimulate interaction among resident researchers. Such interaction often is difficult today, with research teams staying in different hotels or facilities.

Wet, dry, and cold laboratories are needed to process samples and conduct analyses. Necropsy facilities, tanks for storing live specimens, and housing for animals should be included, as well as connected research areas for physiological and other investigations. The facility's animal research components must comply with the Animal Welfare Act, Public Health Service Policy on Humane Care and Use of Laboratory Animals, and all applicable field research guidelines governing research on live vertebrates, plus current recommendations for biosafety in microbiological and biomedical laboratories. Researchers require office space, including access to computers, telephone, fax, and the Internet. Conference rooms of various sizes should be available, including at least one that can serve for presentations. Storage facilities are necessary for samples, including warm, cold, and ambient areas of various sizes.

In 1998, the NSB Department of Wildlife Management provided logistical assistance to researchers from the following institutions:

- Association of Village Council Presidents
- Chinese Academy of Sciences
- Environment Canada
- Eskimo Society of Chukotka, Russia
- Naukan Production Cooperative, Native Company, Russia
- Harvard University
- Louisiana State University
- National Aeronautics and Space Administration
- National Marine Fisheries Service
- Norwegian College of Veterinary Medicine
- Owl Research Institute
- Provideniya Museum, Russia
- Russian Academy of Sciences
- Scott Polar Research Institute, U.K.
- Scripps Institution of Oceanography
- State Seismological Bureau, China
- Universidad Autónoma de San Luis Potosí, Mexico
- University of Alaska Fairbanks
- University of California, Davis
- University of Washington
- U.S. Fish and Wildlife Service
- U.S. Geological Survey
- Virginia-Maryland Regional College of Veterinary Medicine
- Woods Hole Oceanographic Institution

Department of Wildlife Management Memorandum, 18 November 1998

One of the five bunk rooms in the Arctic Research Facility. Photo by Dave Ramey.

Staging areas and equipment storage also are essential for effective conduct of research. Sufficient warm and ambient storage space is needed for cold weather clothing, field equipment, vehicles (snowmachines, boats, ATVs, and sleds), food, and so on. Though Barrow has a large airport with sufficient aircraft support, no additional airplane hangar space is available for use by researchers with aircraft-based research laboratories. The need for parking and hangar space for aircraft also should be reviewed and, if necessary, such facilities should be developed. A workshop for maintenance and repair, as well as construction of field and other gear, also is necessary. The facility should have areas for organizing, packing, and unpacking field and other gear. Laundry equipment (or access to commercial services in Barrow) is necessary for proper maintenance of clothing and other gear.

Research facilities now available in Barrow in addition to UIC-NARL and ARF include the Barrow Environmental Observatory (BEO), Climate Monitoring and Diagnostic Laboratory (CMDL), the Atmospheric Radiation Measurement (ARM) site, and the USGS Barrow Observatory. Maintenance and in some cases expansion of these facilities is essential to support the long-term observations currently underway as well as specific research in the shorter term. For the other existing sites and facilities, utilities and road access should be developed, maintained, and improved as necessary.

For the BEO, a master plan is urgently needed to address permitting issues, scientific research needs and requirements, additional road access and power supply, coordination of research to avoid research or site incompatibilities, and other aspects of the BEO. The completion of the BEO master plan is expected to include the drafting of a North Slope Borough ordinance creating special scientific research districts to provide the BEO and other appropriate areas (e.g., Toolik Field Station, Atqasuk) with additional environmental protection and to allow blanket permits to be issued to BASC, reducing permitting processes and expenses for individual projects.

New research facilities also are needed in the Barrow area. These include specific stations on the BEO, such as micrometeorology monitors and transportable facilities (e.g., buildings on skids or sleds). Because of Barrow's high geomagnetic and geographic latitude, additional facilities to support radio propagation studies in the auroral and polar ionosphere would be valuable. Barrow provides a unique capability to support a long-term Arctic Ocean Observatory that could provide an urgently needed window into the Arctic Ocean. The Arctic Ocean is undergoing unprecedented changes in the thermohaline structure of the Atlantic Layer and in the upper mixed layer, which may or may not be manifestations of previously unrecognized cyclical phenomena of decadal scale (Aagaard et al., 1999). Long-term stable observations of these changes can be made with the installation of a fiber-optic subsea marine cable that would connect Arctic Ocean moorings, instrumented with a variety of in-situ physical oceanographic, biological, and acoustic sensors (for both in-situ and remote sensing using acoustic tomography and thermometry), with a shore facility in Barrow. This ocean observatory would provide year-round, long-term data in real time about Arctic Ocean physical oceanographic and marine biological processes, including observations of the bowhead whale important for subsistence hunting.

Planning and permitting requirements for research on much of the land in the Barrow area are crucial considerations. A common permitting process is necessary to streamline the work required of individual researchers and to identify the precise requirements applicable to a given project. Such a process would apply both to the construction or designation of research facilities and sites and to the conduct of research on federal and private lands. A common permitting process also would help prevent conflicts between research projects operating in the same area or in other ways incompatible with one another, such as vehicular activity in the clean air sector of the CMDL.

Between December 1998 and March 1999, BASC provided logistical support, equipment, information, or transportation assistance to 22 projects from 20 organizations, including:

- Cold Regions Research and Engineering Laboratory
- National Oceanic and Atmospheric Administration
- Oxford University, U.K.
- San Diego State University
- Science Applications International Corporation
- University of Alaska Fairbanks
- University of Cincinnati
- University of Colorado
- U.S. Army
- U.S. Department of Agriculture
- U.S. Department of Energy

BASC Logistics Coordinator's Report, May 1999

Field Equipment and Transportation

Researchers are active in the Barrow area throughout the year. In a typical non-summer month, the BASC logistics coordinator arranges for the loan or rental of equipment and helps with transportation for about 20 different projects. In the summer, the demand is much higher. Common equipment and transportation needs include the means for getting to and working at local and remote sites in the Barrow area, establishing movable and fixed camps to be occupied for periods ranging from one night to several months, and carrying out basic tasks related to field research such as preparing research sites and setting up field stations. Researchers need to be able to handle fuel and other hazardous materials appropriately, both in the field and in transit. Safety and survival measures are fundamental, including well-maintained facilities and field equipment, requisite safety equipment, and safety training.

Field camps require equipment for camping, safety, and research. Camps may be in a fixed location for several months or may need to be moved often, and the types of tents and other gear required will vary accordingly. Portable rigid shelters, wall tents, and lightweight tents

Ernie Rabellis maintains one of the few tracklaying personnel carriers remaining on the UIC-NARL facility. These vehicles are very useful for some projects that cannot be done by snowmachine or truck. Photo by Bernard Zak.

[BASC] was . . . asked to provide logistical assistance with a pre-fab 300 foot boardwalk being installed for the San Diego State University group . . . to receive the materials when they arrived, and to provide temporary labor . . . for the installation. . . . The four visiting scientists from Japan . . . are working out at the end of the boardwalk on foot. . . . [BASC] recommended . . . that they be provided with a shotgun for bear protection. . . . [BASC] held a gun training and safety class for the visiting scientists and provided a shotgun.

BASC Logistics Coordinator's Report, May 1999

should be available, with materials for flooring as appropriate. While personal camping gear should be the responsibility of individual researchers, common equipment such as cooking gear, heaters, and water treatment and sanitation facilities should be available. Research teams need cold weather clothing and raingear, depending on the season, as well as immersion suits and related gear for travel and research in or on the water. Nearly all field camps require power generation, whether mechanical, solar, or wind-powered, to run radios, computers, and a variety of tools for research and construction. Tools, such as saws, drills, and so on, also are essential.

Safety equipment and training are crucial for all field camps. This equipment includes first aid kits and training for immediate response in the field. It also includes a variety of means for communicating with the outside world. VHF and CB radios and cell and satellite phones provide two-way communication. Personal locator beacons (PLBs) and emergency locator transmitters (ELTs) are important safety equipment that send signals in an emergency to summon a rapid response. Global positioning system (GPS) units aid navigation and search. Bear deterrents will be needed for most research sites. For all of this equipment, maintenance and training will be required to ensure proper and timely use to prevent and respond to emergencies. The training must also include basic survival skills for remote arctic areas.

Some equipment will be required for the actual research activities. While specific equipment for a particular project will remain the responsibility of the principal investigator, a number of multipurpose research tools should be available in Barrow. These tools include equipment for surveying (e.g., theodolites, survey-quality differential global positioning systems, transits, and distance-measuring devices), basic laboratory work (e.g., microscopes, scales, centrifuges, soil ovens, and dry ice and other specimen preservation and transport materials), and drilling and excavation (e.g., portable equipment such as post-hole diggers, ice augers, coring barrels, and water jet drills, and heavy equipment such as backhoes and tractor-mounted augers). Researchers also will need the materials and equipment to build such things as boardwalks to protect sensitive tundra in heavily used pathways, for example, between a camp and a research site.

The tundra at the ITEX Atqasuk site is protected from trampling by temporary boardwalks. Even this simple infrastructure is relatively expensive in the Barrow area because of the high cost of lumber. The village of Atqasuk can be seen on the horizon. Photo by Anna Klene.

Provisions for handling hazardous materials, such as fuel and chemicals, are mandatory. These protocols are required for permits in most areas, and are necessary to the safety of the research team and the health of the local environment. Training and equipment should be provided to researchers for common materials such as fuel, and instructions should be available for less commonly used materials such as formalin.

Of equal importance to field gear is the transportation needed to reach the research site. As noted in the previous section, parking, storage, and repair space and equipment are needed for all forms of transportation. In Barrow itself, road vehicles such as pickup trucks are needed, especially for transporting gear and people to and from the airport.

For local use on land and sea ice, low-impact vehicles such as snowmachines with cargo sleds and all-terrain vehicles (ATVs) are needed. Larger vehicles such as Rolligons and snow cats also should be available. For local travel by water, several types of boats are required, from a boat with a cabin for ocean use to two or more inflatable rafts for river or near-shore use, all powered by outboard motors. As noted above, immersion suits, life vests, and other safety and survival gear must be provided with the boats. Access to a larger research vessel also may be desirable, although the lack of a harbor in Barrow may prevent stationing such a vessel there permanently.

In the ARF kitchen, Tim Obritschkewitsch and Kara Weller, researchers with the U.S. Fish and Wildlife Service (USFWS), piece together aerial maps to plan surveys for nesting Steller's eiders. The endangered eiders, which are known to breed in the U.S. only in the Barrow area, are the subject of a cooperative research project between USFWS and the DWM to monitor the population and learn more about the ducks' habitat use and breeding biology. Photo by Michele Hauschulz.

Air support—fixed wing and helicopter—is needed for more distant sites and to supplement ground transportation. In addition, most researchers and research equipment arrive in Barrow by air. Air support is currently available both through local air charter companies and through some government agencies such as the Bureau of Land Management that provide for air support during certain seasons. Schedules and requirements for getting to Barrow and out into the field should be coordinated centrally to avoid delays and misdirected gear.

Technology and Information

The current technology and information infrastructure in Barrow is inadequate for modern research practices. Existing data links to Barrow, while sufficient for basic e-mail and Internet functions, cannot support transmission of large volumes of data. A range of technology and information investments will need to be made to allow research in the Barrow area to be as efficient and productive as possible. These improvements include rapid transmission of data and information between Barrow and the outside world, complete digital automation of base maps, protocols for handling metadata concerning research in the Barrow area, advanced technological equipment to support research, and appropriate mechanisms for documenting, storing, and accessing traditional knowledge. Details on the possible options for technology and information improvements can be found in Appendix B.

Access to a high-speed, high-capacity data link to the contiguous United States is essential to allow researchers to efficiently use resources in Barrow and at diverse locations. A data link would be valuable to essentially every investigator in the Barrow area immediately and is likely to have additional uses in the future as the technology of wireless field communications systems develops. A computer system capable of spatial and attribute data analysis, modeling, map creation, and other high-capacity and high-performance tasks also will be needed and should include a network of work stations available to researchers.

Between April and June 1999, the Barrow Arctic Science Consortium (BASC) provided logistical support, equipment, information, or transportation assistance to 36 projects from 33 organizations, including:

- Cold Regions Research and Engineering Laboratory
- METOCEAN Data Systems Limited, Canada
- Michigan State University
- National Oceanic and Atmospheric Administration
- Polar Ice Coring Office
- San Diego State University
- Science Applications International Corporation
- University of Alaska Fairbanks
- University of Cincinnati
- University of Hawaii
- University of Pennsylvania
- University of Wyoming
- U.S. Army
- U.S. Department of Agriculture
- U.S. Department of Energy

BASC Logistics Coordinator's Report, May 1999

A web site dedicated to facilitating research in Barrow would be extremely useful. In the short term, the site should provide access to basic information about logistical support in the area. In the longer term, an interactive web site would enable logistics providers to update their information as well as allow researchers to browse information, ask questions, analyze data, enter data when appropriate, and download data. The web site should include logistical information, a Barrow Yellow Pages, bibliographic information (see page 73), information on current research projects, and a digital GIS data catalog. Design of the web site should be coordinated with the development of the NSF Office of Polar Programs' Arctic Logistics Information Access Service (ALIAS) to avoid duplication of efforts. Details on each of these components of the web site can be found in Appendix B.

Installation of a Differential Global Positioning System (DGPS) in Barrow with a geographic range of up to 300 miles would allow highly accurate mapping and plotting of research sites, facilitate data entry, and enhance the safety of field teams. Autonomous GPS users are able to obtain accuracy of 100 meters; the Differential GPS system would allow accuracies in the meter-to-centimeter range, depending on the user's receiver.

A high-capacity fiber-optic cable should be installed across the sea/shore interface at Barrow to facilitate the development of an Arctic Ocean Observatory by allowing access to moored ocean observing systems providing year-round, real-time oceanographic data needed for a broad spectrum of studies, ranging from climate change to bowhead whale monitoring.

Research in the Barrow area relies on relevant base data, such as GIS coverages of base features of the area and meteorological and remote sensing data. While many of the available base data sets have been digitized into GIS base maps, more work is needed to complete many of the coverages. In addition, feature maps remain to be created for a substantial amount of available data on topography, hydrography, and bathymetry. Many of these data sets are out of date, and updated maps of the region (e.g., from aerial photography) should be considered. Providing access to meteorological and remote sensing data will require coordination among the agencies and individuals responsible for gathering them. Technical assistance will be needed to facilitate use of these databases by researchers.

A satellite downlink receiver (e.g., TeraScan) at Barrow would provide real-time satellite remote sensing data. At present, visual, infrared, and passive microwave (AVHRR, SSM/I) data are available via such a receiver. Imagery and digital data will be used to support current projects, to develop an archive of high-resolution satellite products for the Barrow region, and for mission planning to service field sites and for search and rescue operations.

Policies and procedures for sharing data are needed to make data accessible to other researchers and to support integrated projects and analyses; they are also a complex matter. Consistent formats for data storage may not be desirable, but common standards for metadata exist and should be agreed on and adopted by agencies and organizations funding research in the Barrow area. Access to data will require a balance between reasonable and timely access and the protection of proprietary interests in unpublished data. Many research projects gather and store digital data on the North Slope. Providing a common facility for storing, accessing, analyzing, and manipulating data requires the development of digital data standards. Standards also enable other investigators to access and use the data. The Federal Geographic Data Committee (FGDC) has developed standards for spatial data and for metadata, which could be evaluated as a possible base line. A formal data-sharing policy and data-sharing agreements should be established among agencies and organizations that gather and store data for the Barrow area. Research conducted in the Barrow area should conform to the *Principles for the Conduct of Research in the Arctic* (IARPC, 1990).

In addition to these types of technological support, elders in the Barrow community hold a wealth of expertise, commonly referred to as traditional knowledge, which can provide information and interpretation of environmental, ecological, social, and other phenomena with great temporal depth. The commitment of the community of Barrow to the support of research in the area is in part the cause and in part the result of careful use of such expertise in research on the bowhead whale and other species of concern to Barrow residents. Greater use can and should be made of this source, though the details of how best to do so remain to be worked out. Respecting the rights of the holders of such knowledge is essential, as is collaboration in its use. Appropriate mechanisms for sharing traditional knowledge should be developed cooperatively and be refined based on experience in actual projects. Work in this area is a high priority because much of this expertise is being lost with the passing of today's elders.

Dr. Ken Hinkel was in Barrow to conduct NSF-sponsored research on permafrost. The work involved taking about 30 core samples along 6 transects. . . . BASC provided . . . snowmachines and sleds, work space in the BASC warehouse, assistance with picking up freight at the airport, and with UIC and NSB permitting.

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Human Resources

Support for science in the Barrow area requires human resources. Support staff are needed to administer and maintain the research facilities, equipment, and technology. People must be available to provide relevant information to interested researchers, to be a contact point for permitting and for orientation, to train researchers in safety and survival, to serve as technicians, field assistants, and guides, and to act as local liaisons. The number of people required will depend on the type and volume of research being done and will vary by season and by year, but core staff requirements must be met if the support outlined in the previous three sections is to be provided.

UIC Science Division technician George Leavitt checks the status of DOE/ARM instrumentation. Photo by Dave Ramey.

Providing central, common support to researchers will require a

When Agnaiyaaq, a 6-year-old girl who died about 800 years ago, washed out of a bank near Barrow in 1994, the excavation provided opportunities for Barrow elementary students to learn more about archaeology and Iñupiat culture. Here, North Slope Borough employee Karen Brewster helps elementary students excavate for "artifacts" that they made. Photo © James H. Barker

central administration. The central office will be responsible for making available all relevant information about research support in the Barrow area (for example, through a listing posted on the Internet), will be a contact point for permitting, and will oversee the operations of providing support in the Barrow area.

Support staff will be needed to operate and maintain the buildings, sites, field equipment, and vehicles. Local expediting—taking people and gear to and from the airport, arranging local purchases and rentals, and so on—also will be needed. Technological expertise will be needed to operate and maintain computers, the ocean-shore conduit, the GPS beacon, and other advanced equipment. Visiting researchers will need training in the use, care, and handling of equipment and facilities they use, as well as safety and survival training.

In addition to the nuts-and-bolts operations of research support, local contacts and liaison with the community are essential aspects of conducting research in the Barrow area. The strong support given to research and researchers by the Barrow community has developed from good relationships with researchers. Maintaining that level of local commitment depends on continued communication and collaboration. Potential interactions with community members range from public presentations about one's research to interviews with local experts to fully collaborative research. Learning about the community, how to conduct such interactive research, and what resources—intellectual and otherwise—are available in the community often requires a local contact person to make introductions and provide orientation. Support staff should include a person or persons with such expertise to help researchers before, during, and after their time in Barrow.

Many research projects require local guides, field assistants, laboratory technicians, and other seasonal workers. Finding capable and interested persons is often challenging, especially when planning research from a distance. The support office in Barrow should identify and train a pool of potential workers and help researchers select seasonal personnel. The use of local residents as research assistants also can provide training to students and may stimulate their interest in the sciences. Indeed, such experiences are one of the main reasons today's leaders on the North Slope are such strong advocates of research in their region.

In the long term, providing the necessary research support outlined above will depend on the ability of the Barrow community to provide capable people as staff. Training opportunities for local residents, including those that lead toward higher education in science and technology, should be promoted as one means of building local capacity for research.

Summary of Recommendations

7

The recommendations detailed in the previous section and summarized here reflect the research opportunities and needs for the Barrow area. They are directed to the National Science Foundation and other potential funding agencies and to those who will carry out the recommended actions. Improvements to the research support currently available in the Barrow area should be well-coordinated and should use existing resources whenever possible. Both the needs for support and the effectiveness of providing that support should be evaluated on a regular basis.

Because some recommendations could be implemented in the next few years, while others will depend on completion of requisite improvements or additional planning, the recommendations have been identified as short term or mid term. Many of the mid-term recommendations follow up on planning or infrastructure recommended in the short term. Six recommendations have been identified (with ★★) as highest priority either because of urgent needs or because other recommendations cannot be implemented until these items are completed. In addition, five overarching recommendations on improving coordination and communication are relevant to all major research areas and to improvements in research support. A table on the following pages summarizes and provides estimated costs for many of these recommendations.

Overarching Recommendations: Applicable to all Aspects of Improving Research Infrastructure

A major problem identified by workshop participants was the lack of coordination among research programs in the Barrow area. Better communication among researchers and community members would improve

Recommendations

(★★ indicates highest priority recommendations)

Overarching Priorities Supporting All Research

★★ Fund an organization to provide research support. ▼ Evaluate needs for and utility of current support regularly. ▼ Seek and promote opportunities for integrating research and results. ▼ Promote interactions between arctic communities and researchers. ▼ Provide educational opportunities for young researchers and local residents.

	Buildings, Sites, and Facilities	Est. Cost	Field Equipment and Transportation	Est. Cost	Technology and Information	Est. Cost	Human Resources	Est. Cost	Interagency Coordination	Est. Cost
Implement within 2 years	★★ Maintain the Arctic Research Facility ★★ Plan a new general-purpose facility including design fees and personnel support ★★ Develop a Master Plan for the Barrow Environmental Observatory	$200K/yr $ 200K $75K	▼ Assess needs, identify suppliers, and develop procurement agreements for field equipment ▼ Assess needs, identify suppliers, and develop agreements for providing research transportation, including mechanisms for improved air support		★★ Establish high-capacity, high-speed data link ▼ Install differential GPS system ▼ Install fiber-optic cable across shore-ocean boundary ▼ Develop a web site with basic logistical information ▼ Complete GIS coverages for base features of the area ▼ Develop approaches for using traditional knowledge ▼ Identify and adopt metadata standards	$220K $400K $1M $50–100K $100K $50–100K $120K	▼ Develop a plan and budget for centralized support ▼ Establish a local liaison position ▼ Develop training materials and classes for specialized needs	 $36K $51K	▼ Develop MOAs among agencies and organiza-tions to centralize permitting and coordinate agency research and support efforts	$67K
Implement within 5 years	★★ Build a new research support facility ▼ Develop, maintain, and improve utilities and road access	$10–20M	▼ Develop MOAs with local suppliers for a variety of goods and services ▼ Build a sufficient inventory of goods and a repertoire of services not available else-where so a reliable supply is available		▼ Develop and maintain a more complex interactive web site with logistics and resource information for researchers ▼ Install satellite downlink for real time retrieval of satellite remote sensing data		▼ Fully implement centralized support structure ▼ Implement ongoing liaison activities ▼ Offer ongoing training, as needed		▼ Expand and refine MOA among agencies and organiza-tions as coordinated logistics and science implementa-tion advance	

efficiency and increase educational opportunities. A great deal of the necessary communication and coordination can be done most efficiently by appropriate uses of technology (see Technology and Information, next page), but the level of coordination envisioned by workshop participants will require a dedicated science support organization. The overarching recommendations to improve communication and coordination are:

★★ **Identify and fund an organization and personnel based in Barrow to provide research support, infrastructure development, and coordination** by carrying out the activities recommended below or by coordinating and overseeing their implementation.

▾ **Regularly evaluate the needs for support and adequacy of available facilities and resources** to ensure that facilities and other research support evolve adequately, and that research support investments are effectively shared among appropriate agencies.

▾ **Promote the coordination of research programs and sharing and coordination of data** so that our understanding of the arctic system is enhanced through integrated multi-disciplinary and interdisciplinary studies.

▾ **Promote interactions between the community and researchers** to disseminate research plans and results, incorporate community participation, promote the use of traditional knowledge, and develop collaborative projects.

▾ **Provide educational opportunities for young researchers and local residents** through internships and fellowships to encourage local involvement as well as the development of local scientific capabilities and a strong cohort of arctic researchers in the future.

Short-term Recommendations: Appropriate for Implementation within Two Years

Some of the short-term recommendations are for planning and development, in cases where there are technical or other obstacles to immediate implementation. Others are for specific improvements that can and should be completed within two years.

Buildings, Sites, and Facilities

The space that is available to researchers in the Barrow area is at capacity in the busy summer season. The physical facilities of the ARF were not designed for many research uses and are degrading with time and heavy use. Currently, the North Slope Borough Department of Wildlife Management pays for the ARF and makes it available to visiting researchers. This arrangement will end soon due to budget cuts within the North Slope Borough, and outside support will be necessary to keep the ARF operating, even at its current level of use. To provide adequate living and work space in the short term:

★★ **Contribute to the maintenance of the Arctic Research Facility (ARF)** so that it can continue to provide modest living and working space for visiting researchers as well as a workshop and storage space for basic field clothing and equipment.

★★ Identify and fund an organization and personnel based in Barrow to provide research support, infrastructure development, and coordination by carrying out the recommended activities or by coordinating and overseeing their implementation.

★★ Contribute to the maintenance of the Arctic Research Facility so that it can continue to provide modest living and working space for visiting researchers as well as a workshop and storage space for basic field clothing and equipment.

★★ **Plan a new general-purpose research facility** with expanded capability to provide adequate living and working space for visiting researchers. The planning process should address not only the physical structure but the ways in which it will be funded, including core funding and fees collected from visiting researchers.

★★ **Develop a master plan for the Barrow Environmental Observatory (BEO)** to address land-use and planning requirements related to access, permits, utilities, structures, coordination of various activities undertaken on the BEO, road maintenance, and other aspects of managing the land through the cooperation of the North Slope Borough and the Ukpeagvik Iñupiat Corporation.

Field Equipment and Transportation

Researchers' equipment and transportation needs vary with the type of project and time of year. Safe access to field sites is a critical component of research support. To improve field equipment and transportation in the short term:

▾ **Assess field equipment needs, identify suppliers, and develop requisite agreements for procurement,** as part of planning for, providing, and maintaining the necessary equipment, including safety equipment, to researchers.

▾ **Assess transportation needs, identify suppliers, and develop necessary agreements for services,** to provide transportation services to researchers. This action includes exploring mechanisms for improved air support, such as sharing helicopter time.

Technology and Information

Barrow lacks a modern data link essential to high-capacity, high-speed computing and data transfer; further improvements depend on the installation of an appropriate link. Several other technology investments are needed to increase efficiency and comprehensiveness of data acquisition. To improve technology and information in the short term:

★★ **Establish a high-capacity, high-speed data link to the lower 48 states** to allow access to databases located throughout the U.S. and the world so that needed data can be accessed from Barrow. The link also would allow the transfer of data from Barrow to high-speed computing facilities elsewhere, making modeling and analysis possible during, as well as after, the field season.

▾ **Build a differential global positioning system (GPS) station** in Barrow to allow highly accurate mapping and plotting of research sites, to facilitate data entry during field work, and to enhance the safety of field teams.

▾ **Install a fiber-optic cable across the shore-ocean boundary** to allow access to moored ocean observing systems providing year-round, real-time oceanographic data needed for a broad spectrum of studies ranging from climate change to acoustic monitoring of bowhead whales.

- **Develop a preliminary web site with logistical support information** for the Barrow area to help researchers plan their activities and find the goods and services they require.
- **Develop a GIS data catalog** and complete GIS coverages for base features, for the BEO in large geographic scale and the North Slope in small geographic scale, so that researchers will have access to common base features, allowing better integration of data sets and more accurate recording of spatial data.
- **Develop approaches for using traditional knowledge** in research contexts to encourage greater use of this extensive source of observations and understanding.
- **Identify and adopt appropriate metadata standards** so that data sets can be integrated for analysis and interpretation within and across disciplines.

★★ Plan a new general-purpose research facility with expanded capability to provide adequate living and working space for visiting researchers. The planning process should address not only the physical structure but the ways in which it will be funded, including core funding and fees collected from visiting researchers.

Human Resources

The personnel currently dedicated to science support in the Barrow area are not sufficient to meet demands. To fill the gap, researchers frequently require help from others, such as the staff of the DWM, placing a large burden on those not specifically employed to provide their time and expertise for logistical support. Improvements in research support will require the assistance of additional personnel. To improve human resources available for research support in the short term:

- **Prepare a detailed plan for centralized support, including personnel needs,** so that the agencies and organizations supporting research in the Barrow area can plan their activities and budgets to meet the common needs of researchers.
- **Establish a local liaison position** to help community members and researchers interact smoothly and effectively, as described in the overarching recommendations.
- **Develop training materials and classes** to cover safety in field research, survival in arctic conditions, handling of hazardous material in the field, and other aspects of field research.

Interagency Coordination

Much of what is needed to support research in the Barrow area is already present, but spread among several federal, state, and local agencies. Effective interagency coordination will do much to address the logistical needs of researchers and facilitate collaborations. For example, obtaining the necessary permits to do research in the Barrow area is confusing and can be difficult because of the many overlapping agency jurisdictions. To improve interagency coordination in the short term:

- **Develop a centralized permitting process** so that researchers can submit the required information and obtain the necessary permits efficiently, with input from appropriate land managers.
- **Coordinate the support efforts of the agencies involved in research in the Barrow area** through Memoranda of Understanding (MOU) or Memoranda of Agreement (MOA). The NSF Office of Polar Programs should take the lead in developing and coordinating such agreements.

★★ Develop a master plan for the Barrow Environmental Observatory to address land-use and planning requirements related to access, permits, utilities, structures, coordination of various activities, road maintenance, and other aspects of managing the land through the cooperation of the North Slope Borough and the Ukpeagvik Iñupiat Corporation.

Mid-term Recommendations: Appropriate for Implementation in Two to Five Years

Mid-term recommendations include the implementation of tasks that require further planning or development in the short term, as well as the continuation and expansion of activities initiated in the first few years.

Buildings, Sites, and Facilities

Implementing the recommended major improvements to the research facilities in the Barrow area will require time for careful planning. During the planning for a new facility, short-term support of the ARF (recommended on page 49) will be necessary to provide temporary living and work space. In the longer term, the following improvements to research infrastructure should be completed:

- ★★ **Build a new research support facility**, with the capacity for expansion and including the work and storage spaces needed for the variety of field projects and disciplines based in the region.
- ▾ **Develop, maintain, and improve utilities and road access** to research sites and facilities as necessary and in accordance with the BEO master plan.

Field Equipment and Transportation

Assessment of researchers' equipment and transportation needs in the short term should be followed by coordinated provision for those needs:

- ▾ **Develop Memoranda of Understanding (MOU) and Memoranda of Agreement (MOA) with local suppliers for a variety of goods and services,** in order to promote efficiency and reduce the burden on the central facility, where appropriate. Longer-term agreements with suppliers will help to achieve more reliable and less cumbersome support for research projects.
- ▾ **Build a sufficient inventory of goods and a repertoire of services** for which there will be a significant demand and that are not available elsewhere so that a reliable supply is available when needed.

Technology and Information

Implementing the recommended short-term investments in technology and information should enable increasing efficiencies in data acquisition and research support. Continued development of these capabilities in the mid term should include:

- ▾ **Install a satellite downlink receiver** to make real-time remote sensing data available to support current research projects and mission planning.
- ▾ **Expand the web site** to include additional relevant information as well as an interactive capability for researchers and logistics providers to access and update their information.

Human Resources

Implementation of the short-term human resources planning and budgeting recommendations should ensure that additional research support personnel will be in place to meet researchers' needs in the mid term. Continued and expanded activities in the mid term should include:

- **Fully implement centralized and coordinated support** so that the agencies and organizations supporting research in the Barrow area can meet the common needs of researchers.
- **Continue local liaison activities to facilitate communication** among research projects and communities and to disseminate information about such topics as funding opportunities.
- **Continue to offer training materials and classes** as needed to cover safety in field research, survival in arctic conditions, handling of hazardous material in the field, and other aspects of field research.

Interagency Coordination

Cooperative efforts among agencies will require ongoing modification and expansion, therefore:

- **Further develop Memoranda of Agreement and Memoranda of Understanding** between funding agencies and organizations capable of providing research support as coordination of activities and research needs develop.

★★ Build a new research support facility, with the capacity for expansion and including the work and storage spaces needed for the variety of field projects and disciplines based in the region.

Particulars of Current Research Facilities and Support

compiled by the Barrow Arctic Science Consortium (BASC)

One important reason Barrow is an attractive location for staging and conducting arctic research is the existence of a diverse support infrastructure upon which to build. Although limited in number and capacity, there also are dedicated but modest science support facilities that are operational throughout the entire year.

Support Currently Available

Currently in Barrow, there are several organizations and individuals providing limited support for arctic research on a year-round basis. This support comes in the form of government, nonprofit, and commercial organizations as well as from local Iñupiat people who are rich with traditional knowledge and arctic experience. Visiting researchers also will find that Barrow has a significant and accessible pool of knowledge from resident scientists, veterinarians, educators, and other professionals. Support also is readily available from a wide variety of highly skilled tradespeople who are essential to the success of many research projects. Other areas of support include most of the basic amenities one would expect to find in a modern but remote rural community.

Barrow Organizations

The following is a list of relevant Barrow organizations, along with the type of support each is capable of providing.

Alaska Department of Fish and Game (ADF&G), Barrow Office

- Resident ADF&G area biologist is a valuable source of information for visiting scientists

Alaska Eskimo Whaling Commission (AEWC)

- A link to subsistence-user community for consent and research opportunities

Arctic Slope Regional Corporation (ASRC)

- Access to Native-owned lands, including surface and subsurface
- Architectural, engineering, and project management services
- Construction, fabrication, and repair services
- Retail supplier of fuel and auto parts
- Retail supplier for snowmachine, ATV, and marine products: sales, service, and parts
- Hotel and tour company operator

Barrow Arctic Science Consortium (BASC)

- Science expedition support
- Logistics coordination
- Community outreach
- Temporary skilled/unskilled labor (Guides, Ice Safety and Bear Protection Specialists, Field Assistants, Heavy Equipment Operator, etc.)
- Laboratory/office space
- Heated/unheated storage space
- Computer access
- Grant administration and proposal preparation
- Small science library
- Data sharing agreement with North Slope Borough/GIS

Iḷisaġvik College

- Iñupiat Heritage Center operations and management
- Library, with Internet access
- Labs (on space-available basis)
- Existing agreements with CRREL and BLM for internship opportunities
- Faculty/staff expertise
- Student interns
- Conference hall
- UIC-NARL cafeteria, serving breakfast, lunch, and dinner (7 days per week)

National Oceanic and Atmospheric Administration, Climate Monitoring and Diagnostics Laboratory (NOAA/CMDL)

- Frequent support of other climate/atmospheric researchers by allowing use of facilities and land and providing expertise

National Weather Service

- Access to regional weather data and ice conditions

North Slope Borough

- *Department of Wildlife Management*: Conducts research relevant to fish and game management. Operator of the North Slope Borough Arctic Research Facility (ARF), which provides modest research support for disciplines deemed critical to the NSB. Permanent staff includes: senior scientist, wildlife biologists, toxicologist/research biologist, subsistence research specialists, and logistics coordinator
- *Iñupiat History, Language and Culture Commission* (IHLC): Point of contact for Elders, cultural resources, and potential partners for research
- *Search and Rescue Department*: Helicopters and fixed-wing aircraft, including medevac jet

The Iḷisaġvik College cafeteria in Building 360 is open to the public and is commonly used by researchers. Photo by Dave Ramey.

- *Public Safety, Fire and Emergency Medical Services*: Fire Department includes ice/open water dive team
- *Veterinary clinic*
- *Permitting, Planning,* and *GIS departments*

Ukpeagvik Iñupiat Corporation (UIC)

- Owner of the UIC-NARL complex
- Owner of the Barrow Environmental Observatory (a 7,466-acre preserve dedicated to arctic research)
- Access to Native-owned lands (surface) near Barrow
- *Science Division*: Provides cultural resource management and logistical support
- Other UIC divisions provide architectural/engineering services, project management, surveying, real estate, and building contractor services
- Sea-going barge transportation, and Rolligon all-terrain vehicle transportation
- Construction, fabrication, and repair services (welding/carpentry/mechanical)
- Automotive repair; car, truck, and heavy equipment rental (with or without operator)
- Housing rental and hotel rooms
- Distilled water plant
- Heated and unheated storage space
- Walk-in freezers
- Video production services

U.S. Department of Energy, Atmospheric Radiation Measurement (DOE/ARM)

- Year-round experience conducting research in Barrow make DOE/ARM personnel a valuable source of information and expertise for visiting scientists

United States Geological Survey (USGS)

- *USGS Geomagnetism Branch:* Allows researchers the use of USGS land and portion of road across USGS property (provided there is not incompatibility with USGS magnetic observatory projects) and access to long-term magnetic observatory data
- *USGS Water Resources Division:* Maintains stream gauging station on Nunavak Creek

Volunteer Search and Rescue

- Ground and ocean/ice searchers in the eight North Slope villages.
- Search efforts coordinated with NSB Search and Rescue (airborne)
- Marine VHF communication link
- Personal Locator Beacons (PLB) available for temporary use

The new North Slope Borough Public Health Office and Veterinary Clinic. Personnel provide assistance in evaluation of animals for evidence of disease and conduct a vigorous rabies control program in all borough villages. Rabies is endemic in the arctic fox population. Photo by Dave Ramey.

Retail and Commercial Enterprises

The following goods and services are available in Barrow through local businesses:

- Two grocery/department stores
- Eight restaurants
- Building materials and hardware store
- Auto, boat, all-terrain vehicle, and snowmachine sales, service, and parts
- Computer and software sales and service
- Internet service provider
- Printing store
- Hotels
- Truck, van, and car rentals
- Heavy equipment rentals
- Taxi service
- Public transportation (scheduled bus service)
- Laundry and dry cleaning
- Travel agencies
- Construction contractors (building, fabrication, and repair (welding/mechanical/carpentry)
- Motor vehicle filling stations (one for diesel and unleaded gasoline, and one for compressed natural gas)

The North Slope Borough's Search and Rescue Hangar. Photo by Dave Ramey.

Air Support and Services

The following air support and services are currently available in Barrow:

- 6,500’ x 150’ paved airstrip with ILS approach at 060 degrees
- Numerous remote-site air strips throughout the North Slope
- Barrow FAA Station
- Three flights per day via major airline (Alaska Airlines) using Boeing 737 jet aircraft
- Three commercial cargo carriers using 737, 727, C-130, and smaller aircraft (multiple daily flights)
- Three regional air-taxi companies, and charters from Canada to Nome
- NSB Search and Rescue (two Bell 214ST helicopters, one Bell Long Ranger helicopter, one Caravan fixed-wing aircraft, and one Lear jet for medevac to Anchorage or Fairbanks)
- NSB Search and Rescue is a responding site for PLB alerts

Infrastructure

Existing infrastructure in Barrow includes:

- Natural gas for heating, power generation, and motor vehicle fuel
- Fuel tank farm with approximately 2.5 million gallon capacity (diesel, jet fuel, aviation gasoline, unleaded gasoline, kerosene, propane)
- Water and wastewater utilities
- Solid waste disposal
- Electric power covering most roads
- Road system (maintained year-round)
- U.S. Public Health Service hospital (12 beds), dental and eye clinics

North Slope Borough search and rescue helicopter providing assistance after the crash of a supply plane at the NSF-funded Point Franklin Archaeology Project. There were no injuries. Photo courtesy of Point Franklin Archaeology Project.

Dedicated Science Support Facilities

Currently in Barrow, two organizations operate facilities dedicated to the support of arctic research that also are capable of providing some support to other research projects. These organizations are the North Slope Borough Department of Wildlife Management and the Barrow Arctic Science Consortium (BASC). All facilities are located on the site of the former Naval Arctic Research Laboratory (NARL) camp, which is now owned by the Ukpeagvik Iñupiat Corporation (UIC).

NSB Arctic Research Facility (ARF)

The NSB Department of Wildlife Management operates the Arctic Research Facility (ARF) in support of its own research efforts, as well as to provide minimal support for numerous selected research projects conducted by visiting scientists. A full-time, year-round logistics coordinator is employed to support research efforts, and seasonal or temporary technicians are hired as needed.

The ARF provides approximately 5,000 square feet of heated indoor space, and approximately 2,500 square feet of unheated indoor storage space. There are living quarters for up to 20 visiting scientists (bunkhouse style), a modern kitchen/dining room, laundry facilities, men's and women's showers and toilets, and a small recreation room. The spartan work space and heated storage areas include: an office/communications room, two wet labs and one dry lab, a specimen storage room, a cold-weather clothing and equipment storage room, and a well-equipped workshop.

In addition to living quarters and work space, the ARF has a significant amount of research support equipment, including:

- 20 snowmachines
- 20 snowmachine-towed, wooden freight sleds with rigid tow bars
- 5 all-terrain vehicles (4 x 4)
- 2 three-wheelers
- 1 crew-cab, 1-ton 4 x 4 pickup truck, operated by the logistics coordinator
- 4 rigid hull and 2 inflatable power power boats (rigid hulls are 18 to 24 feet in length)
- 15 hand-held, two-way radios and 3 base station radios
- 15 12-gauge shotguns for bear protection and a trip-wire activated bear alarm system
- an extensive supply of cold-weather clothing and camping gear
- a wide range of specimen collection, processing, and preservation materials

BASC Facilities

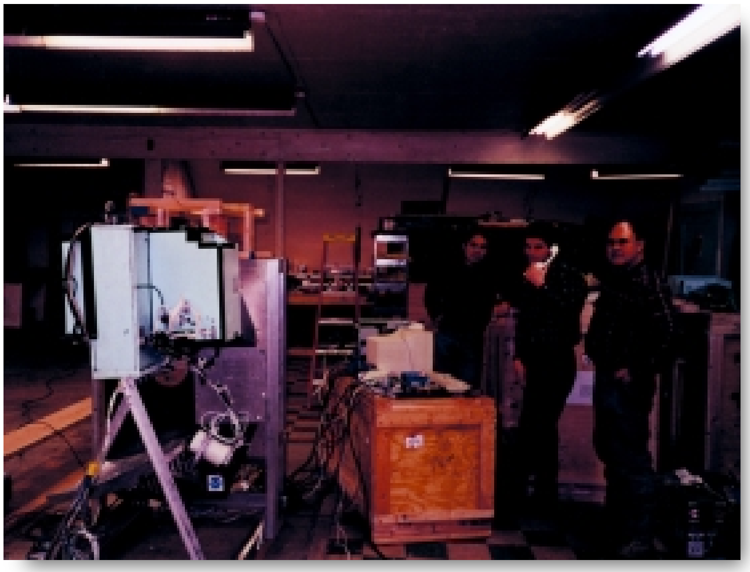
The Barrow Arctic Science Consortium currently is the only scientific research support organization operating in Barrow that provides modest logistical support and dedicated facilities to researchers on a nonselective basis. BASC employs a full-time, year-round logistics coordinator to provide for the needs of visiting researchers.

The BASC science support facilities, which are rented from the UIC Real Estate Division, include a 2,500-square-foot heated warehouse/ workshop, two 400-square-foot wet labs (currently leased to the Polar Ice Coring Office operated by the University of Nebraska and used by NSF-funded researchers), and two 200-square-foot wet labs available for transient scientists. Currently under lease to the DOE/ARM project is a 2,465-square-foot science support facility capable of housing up to 10 people. This facility (building 354A & B) includes 500 square feet of lab space, 500 square feet of office space, and 1,465 square feet of living space. Living quarters include five bedrooms, two kitchens, two bathrooms with showers, and laundry facilities. The facility is connected to a T-1 data transmission line. Under terms of the lease, DOE/ARM has control over who may use the facility.

BASC provides research support equipment from its own inventory, as well as from outside sources when necessary. Some of the current inventory of BASC research support equipment includes:

- 1 4 x 4 crew-cab, 1-ton pick-up truck
- 1 4 x 4 all-terrain vehicle (four-wheeler)
- 1 6 x 6 all-terrain vehicle (six-wheeler)
- 1 all-terrain trailer (pulled by four-wheeler or six-wheeler)
- 3 snowmachines
- 6 wooden freight sleds
- 1 small power boat and 1 inflatable boat
- 1 25-hp and 1 40-hp outboard motors
- 4 insulated, rigid-wall tents with heat, lights, and wooden floors
- 2 uninsulated, rigid-wall tents
- several electric generators up to 8 kW
- miscellaneous cold-weather clothing and camping gear
- assorted hand and power tools

In the BASC warehouse, three investigators from the Cooperative Institute for Research in Environmental Sciences at the University of Colorado prepare for their NOAA-sponsored remote sensing project. Photo by Bernard Zak.



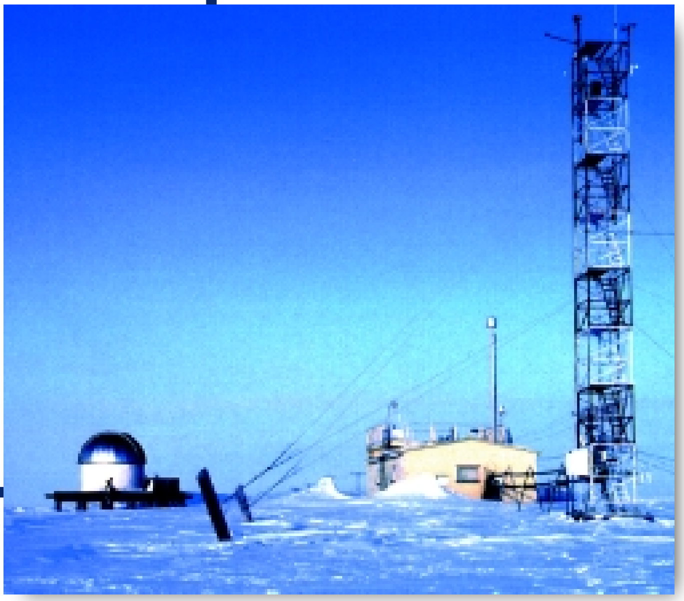
Current Atmospheric Instrumentation

Surface Meteorological Sensors	Location
Wind Speed, Wind Direction, Temperature, Humidity	CMDL, NWS, & SDSU
Same as Above, but at 2 m, 10 m, 20 m, 40 m	ARM
Dew Point/Frost Point Hygrometer (1 level fixed)	CMDL
Same as Above, but Elevation Scannable Over Tower Height	ARM, soon
Optical Precipitation Gauge	ARM
Standard Precipitation Gauges	CMDL, NWS, & SDSU
Precipitation (4 systems)	CMDL & NWS
Surface pressure	CMDL & NWS
Atmospheric pressure (4 systems)	NWS
3-D Wind Speed and Direction (eddy covariance)	SDSU
Wind, Temperature and Humidity Sounding Systems	
Microwave Radiometer (column liquid water & water vapor)	ARM
915 MHz Wind Profiler w/RASS (WS, WD, T profile)	ARM
Radiosondes	NWS & ARM
Cloud Observation Instrumentation	
Millimeter Cloud Radar	ARM
Micropulse Lidar	ARM
Ceilometer	NWS & ARM
Whole Sky Imager	ARM
Downwelling Radiation	
Extended Range Atmospheric Emitted Radiance Interferometer (FTIR, 4-26 microns)	ARM
UV Spectroradiometer	NSF
Infrared Thermometer	ARM
Cimel Sunphotometer (8 wavelengths)	NASA/ARM
Multi-Filter Rotating Shadowband Radiometer	ARM
Normal Incidence Multi-Filter Radiometer	CMDL & ARM
Precision Solar Pyranometer, Unshaded and Shaded	ARM
Normal Incidence Pyranometer (pyrheliometer)	CMDL & ARM
Precision Infrared Radiometer, Unshaded and Shaded	CMDL & ARM
Ultraviolet B Radiometer (UVB)	CMDL & ARM
RG8 Pyranometer	CMDL
Co-located PSPs and PIRs, NIP	CMDL
BSI Filter UVB Radiometer	CMDL
Filter Pyrheliometer	CMDL

Upwelling Radiation	
Infrared Thermometer	ARM
Precision Solar Pyranometer (1.5, soon 10 m)	ARM
Precision Infrared Radiometer (1.5, soon 10 m)	ARM
Multi-Filter Radiometer	ARM
Downward-Pointing Video Camera (snow cover)	ARM, soon
Co-located PSPs and PIRs at 1.5 and 10 m	CMDL
Photosynthetically Active Radiation (PAR)	SDSU
Aerosol Instrumentation	
Multi-Wavelength Integrating Nephelometer	CMDL
Condensation Nuclei Counter	CMDL
Filter Samplers (5 programs)	CMDL
Micropulse Lidar	ARM
Continuous Aerosol Black Carbon	CMDL
Gas Instrumentation	
Flask Samplers (55 trace gas species, isotopes of C and O)	CMDL
Gas Chromatography for Greenhouse & Ozone-Destroying Gases (12 trace gases, continuous)	CMDL
Gas Chromatography for CO and CH_4	CMDL
Continuous Measurements of CO_2	CMDL
Surface Ozone Monitor	CMDL
Total Column Ozone Monitor	CMDL
Open Path Infrared CO_2/H_2O Gas Analyzer	SDSU

The information on atmospheric instrumentation in the Barrow area was compiled by Bernard Zak (Department of Energy Atmospheric Radiation Monitoring Program [DOE/ARM]), Daniel Endres and Russ Schnell (National Oceanic and Atmospheric Administration Climate Monitoring and Diagnostics Laboratory [NOAA/CMDL]), Germar Bernhard (Biospherical Instruments, Inc.), and Rommel Zulueta (San Diego State University [SDSU]). CMDL and ARM sensors are co-located on NOAA land northeast of Barrow; the National Science Foundation (NSF) instrument at UIC-NARL is 2 km to the west; the National Weather Service (NWS) sensors and Upper Air Sounding Station are 6 km to the southwest near the Barrow airport; SDSU sensors are attached to the San Diego State University eddy covariance tower located adjacent to the CMDL and ARM sensors.

The National Oceanic and Atmospheric Administration Climate Monitoring and Diagnostics Lab facility near the Barrow Environmental Observatory. Photo courtesy of Russ Schnell.



Technology and Information Options Identified by BASC

The Barrow Arctic Science Consortium (BASC) has investigated the possible options for effective investments in upgrading the technology and information infrastructure supporting research in the Barrow area. This appendix presents the BASC recommendations for specific technology and information improvements.

Short-term Requirements

Telecommunications. A high-speed, high-capacity data link to the contiguous United States will be required to allow access to national and international databases, transfer of data from Barrow to high-speed computing facilities for analysis and modeling, and access to logistical information about working in Barrow. Two options have been considered for implementing a high-speed data link to Barrow. One option is leasing a satellite-based data link from Barrow to Seattle. Current satellite technology in the Barrow area will provide for one or more T-1 links, providing a data transfer rate of 1.544 megabits per second over a dedicated service. This means that the service is not shared and the transfer rate is guaranteed. This option has three parts: (1) leasing a T-1 line from the BASC facility to the ATT/Alascom Earth Station in Barrow through GTE; (2) leasing a satellite connection from the Barrow Earth Station to the Seattle Washington Earth Station; (3) leasing a connection from the Seattle Earth Station to a local Internet service provider in order to connect to the Internet. The best option would be to connect into the National Science Foundation backbone in Seattle. ATT/Alascom plans to have a new satellite in service in 2001 that will provide T-3 service. It is recommended that if a T-1 connection is leased, all hardware purchased at termination points have the capacity for both T-1 and T-3. This option could be implemented within a month. If a single T-1 connection becomes overloaded then additional connections could be leased.

The second option is connecting to the fiber-optic cable being built from Prudhoe Bay to the Pacific Northwest via the Alaska Pipeline corridor. Compared to satellite links, a fiber-optic cable alternative has three attractive aspects: much higher bandwidth, much lower operating cost, and freedom from ionospheric noise contamination. The design life of a seafloor cable is typically 25 years. It is recommended that a study be done to estimate the Barrow bandwidth requirements over the next 25 years, given the projected scientific, community infrastructure, and global outreach plans, including detailed 25-year cost estimates trade off of satellite vs. fiber-optic cable systems. For example, the cost to purchase a 550-km long section of 12-fiber cable is approximately $4M. Considerable cost savings can be achieved by combining the design, survey, and installation tasks of this communication route with the corresponding tasks for the proposed oceanographic observatory. In addition to financial considerations, it is recommended to undertake a feasibility study to determine the possibility of completing the fiber-optic cable route, covering protection from natural and man-made hazards, protection of the environment, and permitting issues. As a part of the cable route feasibility study, it is recommended that delivery of digital versions of the available bathymetric and geological information be provided that can be used as a foundation for many further GIS activities in Barrow.

Computing Facilities. A new server will be needed for spatial, attribute, and image databases. This server will store all of the data for research in the Barrow area and on the North Slope. It will enable integrated spatial/attribute analysis. This server needs to be capable of serving multiple concurrent users at the BASC facility, other agencies in Barrow, and researchers in the lower 48 states. The recommended operating system for this server is UNIX. This server will run a high-end relational database management system.

A new GIS modeling and analysis server is needed to run the web applications such as the yellow pages, the GIS data catalog, contact information, and logistical support (see below). In order to run the high-end GIS modeling software it should be a Windows NT Server.

Five new computer workstations, high-resolution plotter and printer, and LCD panel should be networked to the database server and the GIS application server and be available for BASC staff, staff from other agencies in the Barrow area, and for researchers. These workstations will have the necessary software for researchers to do most common work.

Software for the interactive web server, database server and clients, workstations, spatial database server and clients, work stations, spatial database engine server, GIS analysis and modeling, image processing and classification will require installation and configuration. The hardware will need to be network-configured. Off-site system software and networking administration will require additional personnel support.

Real-Time, Differential Global Positioning System. The recommended system is a differential global positioning system/MSK marine radiobeacon system. This system uses the 300 kHz marine radiobeacon band, which has proven to be the most reliable and economical means of augmenting the global positioning system for use in applications requiring greater accuracy than the 100 meters that autonomous GPS users obtain. Navigation service providers worldwide, including the U.S. Coast Guard, have adopted this system based on international standards. This system will provide the largest geographic range possible for highly accurate differential GPS in the Barrow area.

This DGPS system will provide differential correction data in the standard Radio Technical Commission for Maritime Services (RTCM) and International Association of Lighthouse Authorities (IALA) format. This internationally recognized standard format is used by the U.S. Coast Guard and other service providers worldwide, enabling users of the GPS to obtain the real-time accuracy needed in the areas of safety, survey, mapping, resource management, navigation, location, and positioning. This system is based on standard commercial equipment. The possibility of using the existing KBRW radio tower in Barrow for the antenna for the DGPS system is being explored before the erection of a new tower.

BASC Web Site Components

A web site should be established as soon as possible to facilitate research in the Barrow area. In the longer term, the web site should be interactive, allowing researchers and cooperating agencies to access and update databases, reports, contact information, etc.

Logistical Information. An on-line database will enable researchers to access information on the logistical support services in the Barrow area, including service providers, types of logistical support available, quantities of services and items, and contact information. Compiling this data and keeping it current may be most efficient if logistical support providers are able to enter their information directly into the database via a web browser.

Yellow Pages. The yellow pages should contain general information about the Barrow area, such as weather during different seasons, travel information, and types of infrastructure available in the Barrow area. Contact information on federal, state, and local government agencies working in Barrow would be helpful, including information on permitting requirements.

Bibliographic Information. This database would link a map of the Barrow area indicating the locations of previous research projects with the bibliographic information for each project, enabling researchers to access previous work on the geographic area they are interested in. Because of the long history of research in the area, this is an ambitious project that will begin with a subset of the available information.

Current Research Projects. Similar to the bibliographic project described above, this database would cover current research projects. BASC will need to work with researchers to determine the level of detail provided on each project as well as the level of access to the research data.

Digital Geographic Information System Data Catalog. Many spatial databases for the North Slope and the Barrow area are being developed by a variety of organizations, agencies, research projects, and individuals. These databases should be compiled into a geographic information system data catalog to allow these spatial data to be used in mapping and spatial analysis. This catalog should provide a list of the databases, the geographic extent of the data, and metadata for each of the databases. The data catalog should include a number of base maps and provide researchers with the ability to visualize the spatial databases, overlay multiple databases, perform basic queries and analysis, and to download data required for their research projects. BASC will need to work with researchers, government agencies, and private institutions in order to determine exactly what should be included in the digital geographic information system data catalog.

End of season scientist feedback form would be a formal process to get information from all personnel who were in the field about what equipment, facilities, and services they used. This information would be used, for example, to evaluate the technology and equipment researchers are using or need so that advances in safety equipment and computing power are incorporated as needed.

Data Automation and Acquisition

A data catalog should be developed that will enable users to search for available data, view data in map and report format, access metadata, and download data.

Acquiring the relevant base data is a matter of completing GIS base feature coverage at several scales, from 1:5,000 for the BEO to 1:250,000 for the entire North Slope, and arranging for other data to be accessible via the data link described above. BASC, the North Slope Borough Planning Department GIS Division, and others have started some of the GIS work. This effort should be continued. Further work will be needed to keep the GIS data up-to-date, since many are based on aerial photography and cartography done in the 1950s and 1960s.

Complete CRREL 1:5,000 data. The 26 Cold Regions Research and Engineering Laboratory (CRREL) 1:5,000 topographic maps of the Barrow area (see CRREL Special Report 101) provide the most detailed vector-based base map available for the geographic area. The CRREL sheets contain the following information: benchmarks, buildings, bridges, coast, contours, fences, horizontal control points, lakes, pipelines, rivers, roads, spot elevation, tanks, trails, and wells. Nine CRREL sheets covering the BEO have been converted to digital format and are available for use but have not been through quality assessment and control procedures. The remaining 17 sheets should also be digitized. All 26 sheets will then require quality control, coordinate conversion, sheet unions, and the development of some basic map products.

United States Geological Survey 1:250,000 Hydrography. The hydrography data is necessary for creating base maps to be used by researchers, planning, and permitting. The North Slope Borough has automated 16 of the 24 quads that are within or intersect the boundary of the North Slope Borough. The remaining eight 1:250,000 base hydrography quadrangles need to be automated: DeLong Mountains, Misheguk Mountain, Howard Pass, Killik River, Mt. Michelson, Arctic, Table Mountain, and Demarcation Point. Each quadrangle consists of rivers, lakes, ponds, and coastline. The automation process should use the attribute coding scheme that has been defined by the North Slope Borough Planning Department Division of GIS for all hydrography data to ensure consistency in all of the hydrography data for the North Slope.

United States Geological Survey 1:250,000 Topography. Topography is a fundamental data layer required for producing base maps. A variety of agencies and organizations have automated portions of this data set for use in specific research projects. A complete set of the data for the North Slope needs to be compiled and made available in several formats. These formats are each required for specific types of base mapping and analysis.

The Digital Elevation Models (DEMS) are available from the USGS web page, but the data requires a significant amount of processing in order to be used, including:

- Creating a vector contour data layer for the North Slope to enable researchers to place contour lines on base maps to be overlaid with research data.
- Creating a terrain model that will provide researchers with a surface base map that visually shows changes in elevation.

Bathymetry. This data set is used for research, planning, and permitting that involves near-coastal waters in the Arctic Ocean. The primary source of bathymetry is the NOAA nautical charts. While these have been automated for most of North America, the charts are in proprietary format and are not usable with standard GIS software packages. The existing digital NOAA charts were automated as images. They do not have separate bathymetric data layers that can be used independently of the image. It would be very helpful to researchers to have the bathymetric data as a vector data set that could be used to create maps. The NOAA charts in digital formats also could prove to be useful if they have a word file associated with them to enable use in standard GIS software packages. BASC is currently automating NOAA chart number 16082 (6th edition, 28 July 1990), which includes the Barrow triangle. This chart has been automated as an image data set. A substantial amount of digital bathymetric data are available from NOAA and from other sources. It will be important to maintain contact with the working group that is creating the International Bathymetric Chart of the Arctic Ocean (IBCAO), as reviewed at http://www.ngdc.noaa.gov/mgg/bathymetry/arctic/arctic.html. Data from a variety of sources will need to be collected, de-conflicted, and gridded into a database.

Current Aerial Photography. High-resolution aerial photography is required at periodic intervals (at least every 10 years) to assess cultural and natural changes to the landscape and to provide verification for satellite imagery (SAR, Landsat, SPOT, AVHRR, etc.). Complete stereo coverage of the Barrow land area has not been acquired since high-altitude coverage in 1979. Occasional strip photography has been done since but lacks complete coverage of inland areas. Most coverage is limited to towns or strips along roads. Conventional stereo photography should be acquired in color and be available both as photographic and digital products at a scale usable for detailed mapping of vegetation, soils, and erosion (approximately 1:10,000). A complete set of photos converted to digital files and georeferenced could be used as the base layers for all geographic data for terrestrial research. They could also be used for cover mapping, which is essential for habitat-related studies and impact studies.

Data Management

Policies and procedures for sharing data are complex matters. Consistent formats for data storage may not be desirable, but common standards for metadata exist and should be agreed on and adopted by agencies and organizations funding research in the Barrow area. Access to data will require a balance between reasonable and timely access on the one hand

and the protection of proprietary interests in unpublished data on the other. Many research projects gather and store digital data on the North Slope. Providing a common facility at BASC for storing, accessing, analyzing, and manipulating data requires the development of digital data standards. Standards also enable other investigators to access and use the data. Investigators in the Barrow area should be aware of the data sharing and repository requirements recently released by the Office of Polar Programs at NSF <http://www.nsf.gov/pubs/1999/opp991/opp991.txt> and of the *Principles for the Conduct of Research in the Arctic* (IARPC, 1990). The Federal Geographic Data Committee (FGDC) has developed standards for spatial data and for metadata, which BASC could adopt as a base line. BASC may need to add some additional elements to these standards to meet the requirements of specific research data. BASC should also develop procedures and standards for how data is stored, named, and organized to make the data easy to access and use.

Several major spatial data formats are used by software vendors who provide geographic information system software to researchers. It is recommended that BASC identify the formats being used by researchers in the Barrow area and determine which formats are required for spatial data stored on its GIS data server to allow researchers to access data in a format they can incorporate into their projects.

Data Sharing Policies. BASC currently has a formal data sharing agreement with the North Slope Borough Planning Department, which has enabled sharing of some of the digital base data for the Barrow area. BASC should develop a formal data sharing policy and explore data sharing agreements with other agencies and organizations that gather and store data for the Barrow area. These agreements help researchers by providing them with easy access to data while in the Barrow area and may result in BASC storing a copy of the other agencies' data on the BASC GIS server. In some cases BASC may provide links or Internet access to data stored at other locations.

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An Abridged Bibliography of Research in the Barrow Area

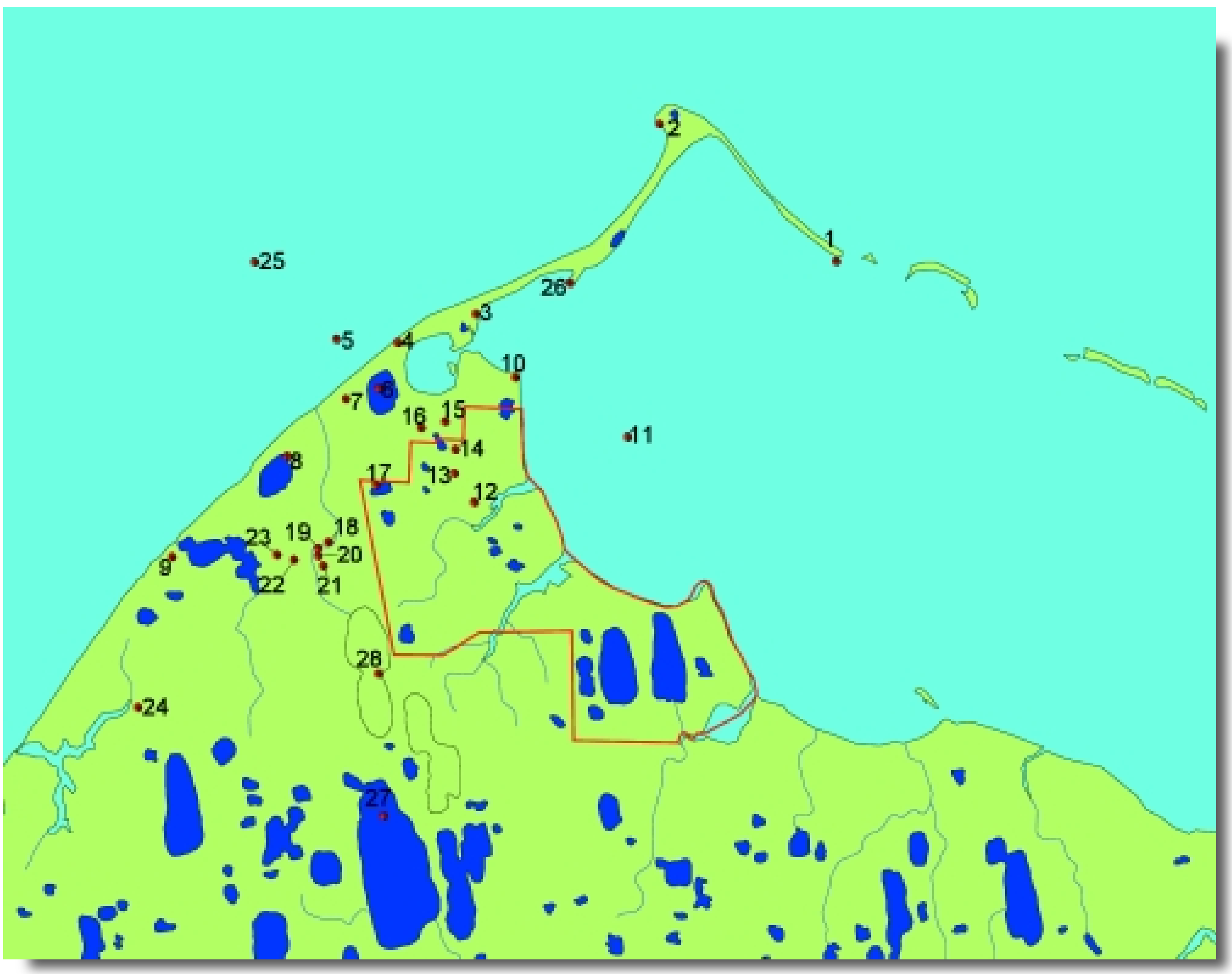
compiled by Jerry Brown

Research in the Barrow, Alaska, area since the 1940s has resulted in thousands of open-literature publications. This abridged compilation highlights significant and historic publications and indicates locations of many field studies on an index map (following page). The present compilation is based on Gunn's bibliography of the Naval Arctic Research Laboratory, prepared in conjunction with the 25th anniversary of NARL (Gunn, 1973), with additions from the Tundra Biome list of publications, the bowhead whale and Climate Monitoring and Diagnostics Lab (CMDL) compilations, and on-line bibliographic searches by Martha Andrews (Institute for Arctic and Alpine Research), Nancy Liston (Cold Regions Research and Engineering Laboratory), and Julia Triplehorn (University of Alaska Fairbanks). Due to space limitations, several selection criteria were used in editing this abridged bibliography: included were books and chapters in books about Barrow, at least one Barrow-related reference for each author who had worked at Barrow, and selective multiple listings for an author if the subject matter differs substantially. The author's most recent publication was usually cited in the case of a series of papers. Abstracts, dissertations, and the extensive gray literature, including contract reports, are not included. Many of these reports and other publications predating the early 1970s can be found in the NARL archive at the Rasmuson Library, University of Alaska Fairbanks.

Several large lists of publications were reduced for this compilation. The Tundra Biome site bibliography contains over 200 publications and 35 dissertations that are specific to Barrow. The present list of Biome citations is limited to the contents of books and single entries for individual authors. The complete Tundra Biome publication list as of 1983 is available in digital form (scanned and edited by Donna Valliere, Cold Regions Research and Engineering Lab) and based on Brown et al. (1983). Additional references provided by Tom Albert of the North Slope Borough Department of Wildlife Management and Dan Endres of CMDL are available on the ARCUS web site (www.arcus.org). The compiler of this abridged bibliography, Jerry Brown, takes full responsibility for omissions or inappropriate selection of references. This compilation could be used as the basis for a comprehensive electronically searchable bibliography of the Barrow area, which would be a valuable resource on the recommended web site (see pages 51 and 67).

The GIS indexing has been prepared by Christopher Kroot, TREESystems, with support from the Barrow Arctic Science Consortium. Ultimately, references, field sites, and accessible data will be incorporated into a GIS database. The following sites are indicated by number or letter [ ] at the end of each citation.

Barrow town sites (NWS) [9]
Beach Ridge: Trenches [14]; Arctic Brown [16];
Bowhead whale studies and related studies [25]*
Brant Point [10]
Britton Manor [8]
CMDL/GMCC/ARM [15]
Coastal studies [4]*
CRREL ice mine [23]
CRREL transect [12]*
Elson Lagoon [11]*
Footprint Drainage: Creek [18]; Lake [28]
Imikpuk Lake [6]
Ikroavik Lake [27]
ITEX sites [13]
NARL [7]
North Meadow Lake [17]
Nunavak Creek [24]
Point Barrow (Nuvuk) [2]
Sea ice, Subsea permafrost [5]*
Spit (site specific): Birnirk [3]; Eluitkak Pass [1]; Niksiuraq [26]; Nuvuk [2]
Tundra Biome: Site 1 [19]; Site 2 [20]; Site 4 [21]; Site 7 [22]
Non-site-specific citations for Barrow and adjacent region or location unassigned [G]
* indicates type location for broader geographic area



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At the workshop, Jack Townshend gave a stirring performance of his own lyrics to a well-known song. He was given a standing ovation, not least for expressing the connections to Barrow felt by many who have lived or worked there.

I Left My Heart in Barrow, Alaska

by Jack Townshend

The loveliness of Paris seems so sadly gay,
The glory that was Rome is of another day,
I was terribly alone and forgotten in Manhattan,
I'm going home to my city for today.
I left my heart in Barrow, Alaska,
High in the North, it calls to me,
To be where graceful northern lights
Will brighten up the nights.
The cold ice-fog will chill the air, but I don't care.
My love waits there in Barrow, Alaska,
Where golden hearts like you love me,
When I come home to you, Barrow, Alaska,
Your midnight sun will shine for me.

(based on I Left My Heart in San Francisco, words and music by Douglass Cross and George Cory)

This report from the arctic research community to the National Science Foundation was drafted at a workshop convened by the Arctic Research Consortium of the United States (ARCUS). The many review comments from members of the research community and from Barrow residents improved successive drafts of these recommendations. The workshop was chaired by Dr. Henry Huntington, who also guided the development of the report.

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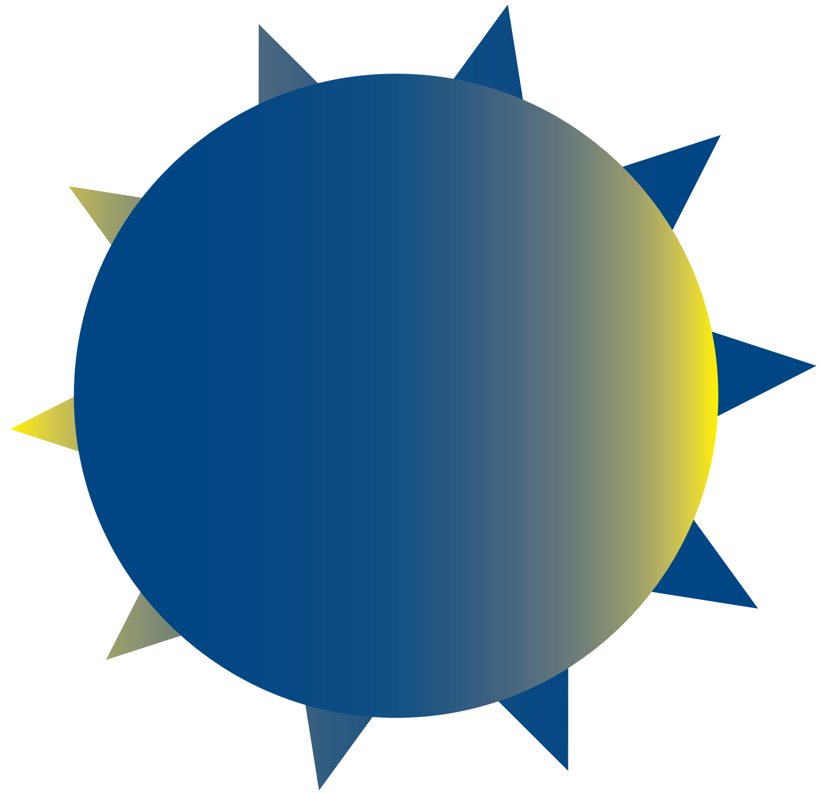

"There is appreciably less light every day; soon there will be none; but the good spirits do not wane with the light."

Fridtjof Nansen
journal entry for October 4, 1894
aboard the *Fram*

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