# NORTHERN ALASKA RESEARCH STUDIES



# Long-Term Habitat and Biological Changes on Disturbances at Oil and Gas Exploration and Development Sites in Arctic Alaska:

## Report on Field Studies, 1984–91, the National Petroleum Reserve in Alaska, Sagavanirktok River Valley, and Prudhoe Bay Oil Field

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Prepared for
**BP Exploration (Alaska) Inc.**

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# LONG-TERM HABITAT AND BIOLOGICAL CHANGES ON DISTURBANCES AT OIL AND GAS EXPLORATION AND DEVELOPMENT SITES IN ARCTIC ALASKA:

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# Executive Summary

This report is an attempt to compile, in a single document, some of the physical and biological information that has been acquired on the long-term changes in soil (gravel) and vegetation at sites in the Alaska Arctic for which historical data are available. It partially fulfills one of three phases of research on vegetating gravel pads in the Alaska Arctic being undertaken by BP Exploration (Alaska) Inc. and the University of Alaska, Fairbanks (McKendrick et al. 1993). It is designed to support a larger effort at the BP Put River No. 1 gravel pad in the Prudhoe Bay region, where methods of vegetating abandoned gravel fill are being examined. The purpose of the project is to increase the information that can be used by industry and land management agencies to establish attainable site rehabilitation standards that lead to identifiable goals. Not knowing which options are available is partially the reason for an absence of direction in tundra rehabilitation and land use guidelines for the Alaska Arctic.

This study involved examining 11 exploratory and development sites where gravel fill had been used to cover tundra vegetation. Four locations were selected in the National Petroleum Reserve in Alaska (NPRA), two were in the Prudhoe Bay Oil Field, and five were along the Trans-Alaska Pipeline in the Sagavanirktok River valley. The use of gravel fill has come under criticism because it alters wildlife habitat. Project investigation focused on the soil-plant relationships on gravel fill. General conditions for soil, water, plants, and animals were examined at the sites. These included: (1) profile description, gravel percentages, moisture content, and bulk density of soils; (2) electrical conductivity, pH, and temperature of water; (3) plant species lists, composition, and cover; and (4) evidence of human and wildlife presence and use at each site. Photoplots were established and aspect changes over time recorded for revisited sites. Studying the NPRA exploratory sites has the advantage of capturing time-dependent information from historical data.

Measurements of soil moisture and bulk density of gravel pads compared to those in the surrounding tundra soil revealed contrasting conditions sufficient to restrain any illusion of vegetating gravel pads to immediately imitate the surrounding moist or wet tundra plant communities. Only through improving the gravel environment for vascular plant growth will it become feasible to support a vegetation cover similar to that of the adjacent tundra communities. Even when overburden has been added to such sites to improve soil conditions, the natural qualities of the overburden and the conditions of its placement can restrict the plant growth. This was most evident at the East Dock site, a reserve pit rehabilitation project near Prudhoe Bay where naturally occurring salts in the subsurface layers of certain soils on the coastal plain were found to inhibit the establishment of grass seedlings. Compacting the backfill to support trucks and equipment used in the rehabilitation project intensified the negative influence of saline soil conditions by either delaying or preventing entirely the establishment of seedlings on portions of the site.

Between 1984 and 1991, there was a net decrease in the salinity levels of reserve pit water at Tunalik in NPRA (503 vs. 1,560 µmhos/cm). This was probably partially responsible for the concurrent increase in vegetation cover, through natural plant colonization, on the formerly bare area where reserve pit fluid leakage occurred. At Inigok in NPRA, the reserve pit salinity was higher than in 1984 (3,860 vs. 2,900 µmhos/cm) but had dropped from nearly 1,000 to about 300 µmhos/cm where reserve pit fluids were draining into the adjacent lake. The background level of dissolved salts in the lake system as a whole was unchanged since 1984 and was probably comparable to conditions before the site was constructed. In other words, the lake system was not noticeably altered, even though salty fluids from the drilling operation had drained into it. At Lisburne, salinity of the reserve pit water had declined slightly since 1984 (454 vs. 505 µmhos/cm), and there was no evidence that salts from this drilling operation were altering the natural water in downstream locations.

The salinity of water in the Tunalik and Lisburne reserve pits was higher than that of natural water immediately adjacent to those sites, but the level was within the regional background electrical conductivities (E.C.) for natural water bodies. The level of salinity in the Inigok reserve pit (3,860 µmhos/cm) was above that for tundra ponds and lakes (484 µmhos/cm) and similar to Beaufort Sea salinities. It was evident in both floral and faunal data and observations that the undesirable effects from reserve pit leaks at these locations were dissipating over time.

Among ten locations examined across the Arctic Slope between the Sagavanirktok River valley and the western edge of NPRA, 125 species of vascular plants were found colonizing gravel fill. This is an impressive number, considering the natural limits for plant species in the Arctic and the relatively poor environments for supporting plant growth on gravel pads. The largest number of vascular plant species (58) was found in 1991 at the Lisburne site in the Ivotuk Hills. The lowest number (four) was found on the Inigok test drilling pad in 1984. It was interesting to note that there was not a single species common to all ten locations.

This number of natural colonizers among the indigenous vascular plant species of the region indicated a significant potential for directing plant recolonization to achieve specific land management goals. There is sufficient variation in plant colonization rates among gravel fill habitats to justify searching for ways of improving conditions on gravel fill for the benefit of plants, short of totally removing the gravel. Increases in vascular plant species' numbers at sites between 1984 and 1991 — ranging from 13 to 27 species per site — showed a positive trend in colonization by indigenous vascular plants on gravel fill. There is also evidence of animal use on these sites, indicating that the sites are contributing habitat to the wildlife of the region.

In this study, three different habitats were identified and sampled for botanical species composition and cover on gravel pads at exploratory sites in the NPRA: insulated and non-insulated portions of the pad surface, and slopes at the margins of the pads. Seeded grasses dominated species composition on the insulated pads and slopes at all three sites, plus the non-insulated surface at Inigok. The only habitat in which native colonizers dominated over seeded grasses was on the non-insulated pad at Tunalik. Of the seeded grasses, *Poa glauca* was the dominant species on insulated pads at all three sites. On non-insulated pads, *Poa glauca* was the dominant seeded grass at Tunalik, while *Festuca rubra* dominated at Inigok. On the pad slopes, *Arctagrostis latifolia* and/or *Festuca rubra* were the dominant species.

Total biological canopy and basal cover (live plants, dead plants, feces) was lowest on the insulated pads (20% to 67%) and highest on the slopes at all three sites (47% to 114%). Live plant basal cover and canopy cover on the pad surfaces at Tunalik and Inigok were dominated by mosses, as was the basal cover at Lisburne. Vascular plants dominated the canopy cover on the pad surface at Lisburne, and both the canopy cover and basal cover of the slopes at all three sites. Live moss basal cover and canopy cover were lowest on the slopes (none to 6%) and highest on the non-insulated pads (49% to 68%) at each site. Moss cover was lower on the pad slopes because the taller-growing vascular plants grew more vigorously there and developed canopies and litter that obstructed mosses. Moss is not currently included in evaluating revegetation success in Alaska. That is an oversight, especially in Arctic and permafrost regions, because much of the climax communities in undisturbed tundra and other permafrost areas of Alaska owe their character to an abundant moss component (Steere 1978).

Vascular plant canopy cover was lowest on the insulated pad surfaces (7% to 16%) and highest on the slopes (30% to 46%) at each site. Plants on the slopes developed denser and taller canopies than stands on the pad surface. The lack of heavy compaction and perhaps protection by snow drifts during winter are probably important contributors favoring canopy development on the slopes. Vascular plant basal cover was also highest on the slopes (6% to 14%) for all three sites, but there was no consistency among sites for the insulated and non-insulated portions of the pads.

Observations of animal uses at the three abandoned drilling sites in NPRA in 1991 revealed a remarkable incongruity. More wildlife species (23) were recorded at Inigok, the location with the lowest diversity of colonizing plant species (23). Indeed, the highest use in terms of animal densities at Inigok was by geese and caribou on barren sand beaches of the reserve pit berm. At that location, the pressure from grazing geese had nearly eliminated all seeded grasses and prevented natural colonization on the berm. Conversely, the lowest animal diversity and evidence of use by animal species was found at Lisburne, the gravel pad with the greatest diversity of vascular plant colonizers (58). Although it may be aesthetically desirable and prudent management to increase the diversity of plant species during site rehabilitation, it may not always result in similar response in either wildlife diversity or population size. Animals may not be attracted to given sites simply on the basis of available forage and vascular plant cover and species diversity. Habitat features other than forage can be more powerful attractants for animals at some sites.

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## INTRODUCTION

Gravel fill is used for pads and roads on the coastal plain of Alaska's North Slope during exploration and production for oil and gas in order to insulate the underlying permafrost and provide a stable working surface. Concern for losses of tundra habitat buried by gravel fill have been raised (Walker et al. 1987a). Loss of forage plants and useful habitat for animals is the primary foundation for those concerns. Such losses could be mitigated by establishing useful, functioning tundra-plant communities on these fills after they are no longer needed for oil and gas production.

The term "vegetate" rather than "revegetate" is expressly used to distinguish this process from traditional rangeland revegetation. Establishing plant communities on gravel fill is a process of *primary* plant succession; i.e., plant communities and soil formation occur together. In contrast, revegetation involves replacing plant cover on soil that formerly supported vegetation. In other words, revegetation is a *secondary* plant succession process. Gravel fill is not soil, and gravel fills have not previously supported tundra vegetation. Vegetating gravel fill will require improving the environment for plant roots and obtaining seeds of suitable plant species. Revegetation projects are often focused mainly on selecting and seeding suitable plant species and are less directed toward improving soil conditions.

Land management standards for abandoned gravel roads and pads in the Alaska Arctic have not been established. There is uncertainty over what can and cannot be achieved when rehabilitating gravel fill for plants and animals. Permits usually state that upon abandonment, the site will be rehabilitated to the acceptance of the permitting agency. This research was designed to help clarify some of that uncertainty for both government agencies and industry. Specific information is needed to: (1) set realistic standards for vegetating gravel fill, (2) identify the most useful manipulations of gravel fill to improve it for supporting vascular plant communities, and (3) identify the species of vascular plants that are adapted to the gravel substrate and useful for wildlife habitat.

As the development of oil production proceeded in Arctic Alaska during the 1970s, the question of how to evaluate revegetation success along the Trans-Alaska Pipeline was debated. The U.S. Department of Interior Alaska Pipeline Office personnel needed a standard that could be used to judge how well industry met their compliance standards. A large group of advisors was called upon for suggestions, and from those suggestions the procedures for rating revegetation success along the pipeline corridor were written. The Alaska Pipeline Office sought a method that could be used by engineers who had little botanical or rangeland expertise, but who could be trained to apply a standard to gauge success of seeded areas. Vascular plant cover was selected as the basic indicator for this evaluation. Ever since, that standard has been generally used by government agencies and industry. However, the method has some limitations because in the case of tundra and permafrost regions, vascular plant cover does not take into account the significant contributions by lichens and mosses. Also, the method fails to account for species diversity, which has gained importance for rating revegetated communities for wildlife values. Personnel untrained in plant sciences can usually distinguish mosses from all other plants and barren soil, but identifying plants by species requires specific training and experience.

Another important consideration is when to pronounce success or failure of a rehabilitation project. It is advantageous to industry and government agencies to progress as quickly as possible in order to avoid undue delays and increased project costs. However, plant cover often develops very slowly in the Arctic, due to environmental limitations. An early indicator of either success or failure is needed. Ultimately, information for determining the condition and trend of plant communities developing on gravel fill in the Arctic would be quite valuable. With such information, it would be possible to approve a rehabilitation project as soon as there is certainty of a continuing positive trend and a minimum threshold of community condition has been established.

Because plant communities and soils form slowly in the Arctic, time is a critical factor that must be accounted for, not only with research but also by land management agencies and industry. One phase of this ongoing research project involves periodically examining abandoned gravel pads to gain contemporary and time-dependent information from those sites. This will generate a record of plant succession that can be used to compare current conditions for sites undergoing abandonment with those that are much older.

In the project files are historical data in the form of notes and photographs for several exploratory and development site locations on the Alaska North Slope. There is additional information available in the reports of activities in the National Petroleum Reserve in Alaska (NPRA). Some of the sites were active during the 1950s, and the most recent were active during the late 1970s and early 1980s. The oldest sites were explored at a time when there was relatively little environmental concern, and rehabilitation after abandonment was practically nil. Recent sites have been rehabilitated using the best available technology for vegetating gravel at the time. Thus, we have in NPRA examples of no rehabilitation and rehabilitation, as well as the lapse of time.

There are also historical sites in the vicinity of the Prudhoe Bay Oil Field. Some abandoned gravel fills in the Prudhoe Bay vicinity date to the late 1960s and early 1970s. In most cases, these were not rehabilitated, except to remove debris. The Trans-Alaska Pipeline route also has some gravel pads and roads which were rehabilitated using the best available technology of the 1970s.

## METHODS

Eleven study sites were selected from personal knowledge of the region (Fig. 1). Table 1 contains pertinent information and location data for these sites. To be useful for this project, a site must have been constructed from gravel fill and have historical documentation of when it was used and what kinds of rehabilitation occurred. Project personnel had visited several NPRA sites during the second exploration of that reserve (1970s and 1980s) and supplied information for vegetating the disturbances following abandonment. With respect to the concerns at Prudhoe Bay, only a few of the NPRA pads and roads were constructed with gravel, owing to the scarcity of that material in the region. Based on personal experience in the NPRA, four sites with gravel fill were selected for study: Tunalik Test Wellsite No. 1, Inigok Test Wellsite No. 1, Lisburne Test Wellsite No. 1, and Seabee Test Wellsite No. 1 (Table 1). Plant species at these sites were inventoried in 1984 (McKendrick 1986), and the chemical properties of reserve pit fluids were evaluated (Pollen 1986). Due to scheduling constraints, only the first three of these were reexamined during July of 1991. The Seabee site, which is near Umiat, was selected for study at a later date, because it is accessible from Umiat, while the other three locations are more remote and require special logistical support.

The Franklin Bluffs camp pad, several sections of the Trans-Alaska Pipeline south of Deadhorse, and a segment of an abandoned road in the Sagavanirktok River delta were examined for plant colonization during 1987–88. Aerial photographic records were used to estimate when the gravel road was constructed in the Sagavanirktok River delta. Two reserve pits that were capped with gravel and soil in 1988 at East Dock in the Prudhoe Bay Oil Field were examined in 1989.

This study involved obtaining specific information on dates when sites were used and rehabilitated and then examining them. Among those studied, the most detailed examinations occurred at the three NPRA locations. At those sites, the gravel was sampled for soil fines, bulk density (to measure relative compaction) was determined, and gravel profiles were described using standard soil science procedures. The plant communities were inventoried to include listing all vascular plant species occurring on the gravel fill and

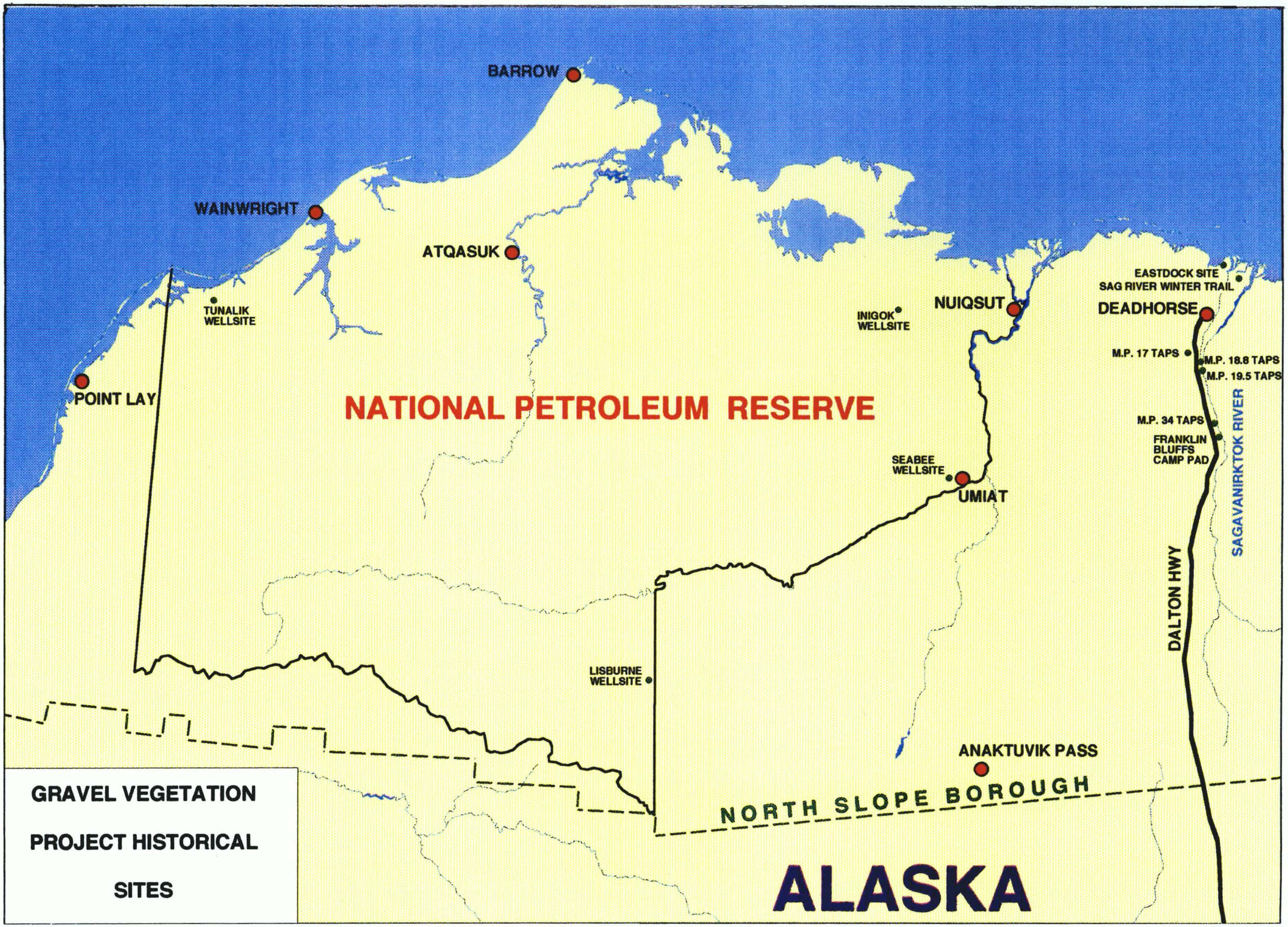


*Figure 1. Map showing gravel vegetation historical sites on the Alaska North Slope*

*Table 1. Listing of site information for 11 locations examined for plant colonization on gravel fill on the Alaska North Slope.*

| Site Name | Year(s) Disturbed | Year(s) Seeded | Elevation (meters) | Location Latitude | Location Longitude | Date(s) Examined |
|---|---|---|---|---|---|---|
| Tunalik Test Wellsite No. 1 | 1978, '80 | 1980, '82 | 43 | 70°12' | 161°04' | 15 Jul 1984<br>25–27 Jul 1991 |
| Inigok Test Wellsite No. 1 | 1978–79 | 1980, '82 | 41 | 70°00' | 153°06' | 10–11,19 Jul 1984<br>19-21 Jul 1991 |
| Lisburne Test Wellsite No. 1 | 1979–80 | 1981, '82 | 559 | 68°29' | 155°42' | 17 Jul 1984<br>21–23 Jul 1991 |
| Seabee Test Wellsite No. 1 | 1979–80 | 1981, '82 | 88 | 69°23' | 152°11' | 16 Jul 1984 |
| TAP[1] M.P. 17 | 1976–87(?) | 1977–(87)? | 46 | 70°00' | 148°40' | 5 Aug 1988 |
| TAP M.P. 18.6 | 1976 | 1977 | 52 | 69°59' | 148°41' | 5 Aug 1988 |
| TAP M.P. 19.5 | 1976 | 1977 | 54 | 69°58' | 148°42' | 5 Aug 1988 |
| TAP M.P. 34 | 1976 | 1977 | 92 | 69°48' | 148°43' | 30 Jul 1987<br>5 Aug 1988 |
| East Dock | 1970 (?) | 1988 | 4 | 70°18' | 148°18' | 8 Sep 1989 |
| Franklin Bluffs Camp Pad | 1970–84 (?) | 1984 | 108 | 69°43' | 148°42' | 30 Jul 1987 |
| Road (trail) Sagavanirktok River Delta | Pre-1970 | Not seeded | 12 | 70°12' | 148°17' | 13 Sep 1987 |

[1] TAP = Trans-Alaska Pipeline

surrounding tundra. Botanical species composition and cover were also determined. Photopoints were established to record changes at these sites over time. The pad areas were surveyed to map locations of photopoints and other pertinent features, in order to aid monitoring these sites in the future. The reserve pit fluids were tested for electrical conductivity and pH to document those water quality parameters. Water quality data at the NPRA locations, prior to 1991, are available from the U.S. Geological Survey (USGS) and Pollen (1986). All sightings of wildlife and signs of animal and human activities on these pads were noted.

## Site Descriptions

### *Tunalik Test Wellsite No. 1*

Tunalik Test Well No. 1 was drilled during the second exploration of the NPRA. It was an all-season drilling operation that produced the deepest well in Alaska to date (6,202 m). The site is approximately 157 km southwest of Barrow and about 11 km from the seacoast. It is located in the coastal plain of the Arctic Slope. The wellsite occupies approximately 5 hectares and is located on generally unbroken, easterly sloping terrain characterized by polygonal ground. Most of the polygons are relatively flat and low-centered, but a few high-centered polygons occur west and north of the drilling pad (Fig. 2). That microrelief and its associated drainage provide a mosaic habitat of alternating wet sedge meadow, moist meadow, and heath plant communities (ONPRA 1978).

Fill for the pad came from the reserve pit and from two well-drained ridges located approximately 8 km west of the wellsite (Hewitt and Brockway 1983). The gravel was quite sandy, with small, highly polished stones 1 cm or smaller in size, suggesting the source was probably an ancient beach ridge. This material was also used to construct a road about 2 km in length to an aircraft parking apron that was connected to the airstrip. The airstrip, taxiway, apron, road, and part of the drilling pad were insulated before the gravel fill was added (Fig. 2). Construction occurred from 4 February until 2 May 1978 (Mitchell 1983). Drilling began 10 November 1978 and was interrupted twice by severe pressures encountered downhole. The entire drilling period lasted 424 days, the longest for any of the wells drilled during the second exploration of the reserve (Hewitt and Brockway 1983).

After the drilling ended, the site was cleaned of debris during July 1980. The storage pad, road and drilling pad were seeded in 1980 and again in 1982. *Arctagrostis latifolia, Poa glauca, Poa pratensis,* and

*Festuca rubra* were the species planted, and fertilizer was applied in 1980, 1981 and 1982. No seeding occurred on the airstrip, and the only fertilizer added to the airstrip was that which spilled while loading the fix-wing aircraft used to apply fertilizer to the road, drilling pad, and parking apron. Total fertilizer equivalents added to the seeded areas were 202–225, 180–191, and 169–180 kg/ha of N, $P2O_5$, and $K_2O$, respectively (Schindler and Smith 1983). The site was examined for plant colonization in July 1984, when the seeded grasses were in their fourth full growing season, and again in July 1991, when seeded grasses were in their eleventh growing season.

#### *Inigok Test Wellsite No. 1*

Inigok Test Well No. 1 was an all-season operation drilled during the second exploration of the NPRA. It is the second deepest well drilled in Alaska to date (6,131 m). This site is located approximately 72 km inland from the seacoast and near the contact zone between the Foothills and the Coastal Plain provinces of the Arctic Slope. The generally flat topography is broken by dunes, sandy bluffs, and ridges, most of which are stabilized by varying amounts of plant cover. The wellsite is surrounded on three sides by interconnected thaw and oxbow lakes (ONPRA 1978a). High-centered polygons lie among a network of swampy troughs where the drilling pad was constructed (Fig. 3). The material excavated from the reserve pit was used for part of the drilling pad, and well-drained gravel and sand were hauled to the location by truck 61 km over an ice road from a material site.

The site includes a drilling pad, reserve pit, a camp pad, airstrip, aircraft parking apron, and a road connecting the drilling pad with the airstrip and camp pads. Insulation was used under part of the drilling pad and the other fill sites to reduce the need for fill and to maintain stability of the structures (Mitchell 1983a). The wellsite and associate facilities were surveyed during 1977. Construction commenced 24 January 1978 and was finished 1 June 1978.

Drilling started 7 June 1978. Hydrogen sulfide under high pressure was encountered 26 December 1978 at a depth of 5,359 m, creating problems which prevented progress for the next 79 days (until 16 March 1979). Elemental sulphur crystals were precipitated in sufficient quantity to eventually clog the drill pipe. In 1991, elemental sulfur was still evident on the surface of the drilling mud deposited at the margins of the reserve pit. Zinc carbonate, iron oxide, caustic and other treatments were used to overcome the sulfur gas problem during drilling. The elemental sulfur and various countermeasure chemicals eventually were exhausted into the reserve pit as part of the drilling process, producing undesirable habitat for organisms. The sulfur content of the reserve pit acidified the water, which was treated with sodium hydroxide to neutralize the acidity. The well was completed 22 May 1979 (Hewitt 1982).

An accidental fire early in the 1978 growing season burned tussock tundra along the road that connects the drilling pad and the airstrip apron. The burned vegetation appeared to recover well during the 1978–84 period, and the effects of the fire were not readily visible when the site was examined in July 1991.

The road, apron, and pads were seeded in 1980 and 1982 with *Poa glauca, Festuca rubra,* and *Arctagrostis latifolia.* Fertilizer was added in 1980, 1981, and 1982 in the equivalent amounts of 202–219, 177–219, and 168–219 kg/ha of N, $P_2O_5$, and $K_2O$, respectively (Schindler and Smith 1983). The site was evaluated for plant colonization in July 1984 and again in July 1991. At the time of the 1984 survey, the oldest seeded grasses would have been in their fourth full growing season since the year of establishment. In 1991, they were in their eleventh year.

#### *Lisburne Test Wellsite No. 1*

During the second exploration of the NPRA, the Lisburne Test Well No. 1 was drilled to explore formations at the southernmost point in NPRA. At this location, a gravel pad was constructed on a 6–7 percent north-facing slope above a small stream in the Ivotuk Hills (Fig. 4). The area was surveyed during the summer of 1978 (ONPRA 1978b). That winter, staging began in December at Lake Betty, 32 km to the west. On February 21, 1979, workers began construction at the Lisburne location. Material for pad, road, and airstrip construction came from the Otuk Creek floodplain, about 915 m west of the drilling pad (Brooks and Mitchell 1983). Gravel used for the site construction was more coarse and angular than any other found on sites examined in our study in the NPRA. Gravel removal occurred during the winter of 1978–79, and the disturbed material site areas were seeded and fertilized during the summer of 1979. When examined in 1984, the material site seedings were in their fifth growing season. In 1991, they were in their twelfth growing season.

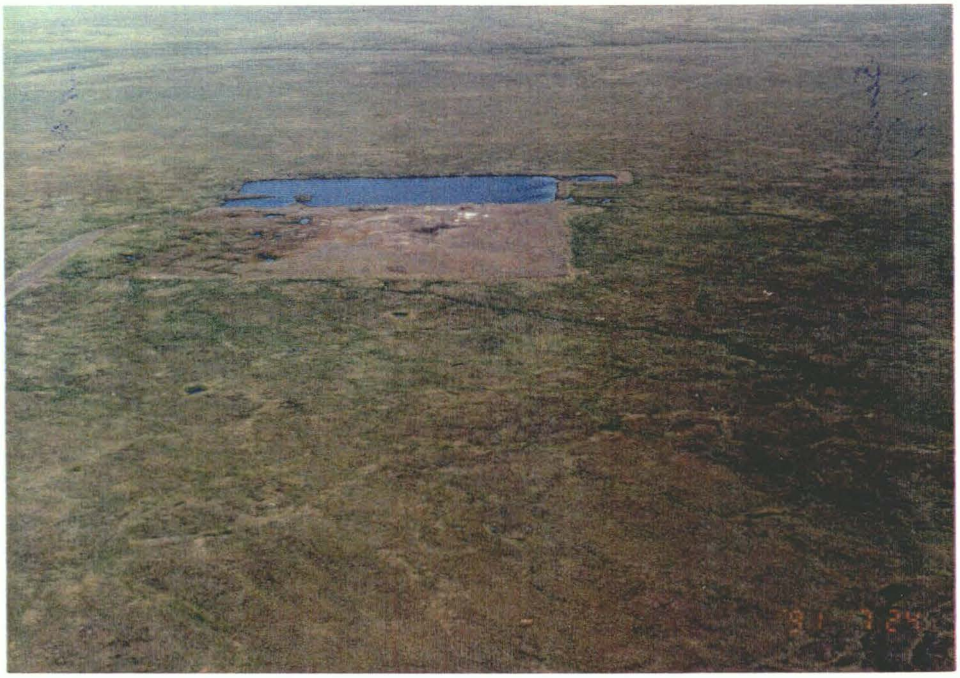

*Figure 2. Aerial oblique view from south of the Tunalik drilling pad (upper) and aerial oblique view from north of parking apron showing taxiway, and portions of the airstrip and road (lower) (24 July 1991).*

*Figure 3. Aerial oblique of Inigok drilling site from southwest, showing the pad surrounded by lakes on three sides and the channel cut through the former flare pit (17 July 1991).*

*Figure 4. Aerial oblique of the Lisburne drilling site, which is situated on a north facing slope among the Ivotuk Hills (22 July 1991).*

The well was spudded 11 June 1979, and drilling was interrupted by a labor dispute 23 August to 23 October 1979. During that suspension period, the upper 306 m of hole was filled with JP-5, which was flared upon reentry on 24 October 1979. After drilling was completed 2 June 1980 (Hewitt and Brockway 1983a), the equipment was removed, and the pad was fertilized and seeded with grasses, primarily *Festuca rubra*, *Arctagrostis latifolia*, and *Poa glauca* (Schindler and Smith 1983). We were unsuccessful in identifying seeding and fertilizing applications. During the summers of 1980 and 1981, labor crews cleaned up the area. In 1984, the seeding on this pad was in its fourth full growing season, and by 1991, it was in its eleventh season.

According to the environmental impact analysis, the area is not waterfowl habitat and appeared to be used occasionally by caribou and moose. Predators, including mammals (bear, fox and wolf) and avian species, are common (ONPRA 1978b).

The only event reported during drilling that might have had an impact on vegetation was the flaring of JP-5 during reentry on 24 October 1979 (Hewitt and Brockway 1983a). No other unusual conditions were noted in historical accounts at this wellsite.

### *East Dock, Prudhoe Bay*

Reserve pits two and three of the SOHIO drilling pad at East Dock were closed out at this location in 1988. The pits were covered with clean gravel to cap the contents, and then soil was placed on the new gravel layer to provide a medium for tundra plant establishment. The soil was overburden stripped from the Duck Island gravel site, which was used to construct the Endicott facilities. This overburden consisted of surface and subsurface soil and included a large component of gravel. Thus, the backfilling material has a gravelly, loamy sand texture.

The area was seeded in 1988 with *Arctagrostis latifolia*, *Festuca rubra*, and *Poa glauca*. Fertilizer was added in the hydroseeding mixture and included nitrogen, phosphorus and potassium. At this writing, seeding and fertilizer application rates were unavailable. The seeded grass stand emerged very patchily, and bare areas were obvious across the pad. Debate over reasons for the poor establishment of these grasses was divided. One theory was that the application of seed and fertilizer had been uneven, while the other side argued that poor-quality seed was used. On 8 September 1989, the gravelly soil was sampled. The sampling was allocated to span the array of plant establishment conditions, i.e., none (bare ground), sparse, medium, and dense. These samples were submitted to the University of Alaska Fairbanks (UAF) Palmer analytical laboratory for the following analyses: salinity (electrical conductivity of saturated paste), pH (1:1 soil/distilled water), available nitrogen (KCl extraction), potassium (normal ammonium acetate extraction), and phosphorus (sodium bicarbonate extraction).

### *Franklin Bluffs Camp Pad*

A construction camp used during the building of the Dalton Highway and Trans-Alaska Pipeline was located on this gravel pad near the Sagavanirktok River. Presumably, this gravel originated from various material sites along the nearby Sagavanirktok River. In 1984, after the camp was dismantled, the surface of the pad was ripped, fertilized and seeded. When the Franklin Bluffs Pad was seeded in 1984, the seeding mixture used by the Alyeska Pipeline Service Company had been revised (Table 2). Obtaining seed of *Arctagrostis latifolia*, *Deschampsia beringensis* and *Calamagrostis canadensis* was difficult at that time, and *Poa pratensis* was often used to compensate for deficient components in applications. Consequently, precise information of site-specific seeding mixture and application is unavailable, and the absence of one of those recommended grass species in resulting stands cannot be attributed to failure by that species, because it may have been missing from the planting mixture. *Poa glauca* appeared to be the main grass used at this location. Presumably, fertilizers were applied, because that is a standard practice, but information regarding the kind and amount was unavailable. Based on the amounts used normally in the region, 673 to 897 kg/ha of 10-20-10 (N-P-K) may have been applied. The site was examined for species colonizing on the gravel in July 1987, when the seeding would have been in its third full growing season.

### *Four Trans-Alaska Pipeline Sites*

Four locations along the Trans-Alaska Pipeline route south of Deadhorse were selected for study. These were near the following Trans-Alaska Pipeline mile posts: 17, 18.8, 19.5, and 34. In this region, the pipeline route passes through the valley of the Sagavanirktok River. At each of these locations, the pipeline was buried, and the covering over the pipe was material excavated from the site (often gravel). Because double trenching was not used during excavation, the topsoil was usually lost and could not be used as a surface covering of the backfill. Gravel fill from the Sagavanirktok River channel was used to construct the adjacent workpad, which was needed during construction and is still being used as an access road to the pipeline.

The M.P. 34 location is about 6 miles north of the Franklin Bluffs Camp site. The mound over the buried pipe was seeded in 1977 with a mixture of grasses. Walker et al. (1987) reported there were two different mixtures of seed used for the arctic portions of the pipeline route (Table 2). The 1975 and 1977 seed mixtures and application rates are calculated to provide 7,500 and 5,600 seeds/m$^2$, respectively. During short visits in the 1987 and 1988 growing seasons, sites were examined for vascular plant species, and gravel samples were collected.

### *Abandoned Winter Trail in Sagavanirktok River Delta*

During the late 1960s, petroleum exploration in the Prudhoe Bay area involved constructing winter trails. One such trail crosses the Sagavanirktok River delta and was built by laying a thin lift of gravel fill from the Sagavanirktok River over the tundra surface. The year when this road was last used was not available, but it appeared on air photos taken 27 June 1970, and the trail was probably constructed during 1968 or 1969. The 0.3–0.6 m of gravel fill buried the natural vegetation, leaving a barren strip across the landscape. No rehabilitation was attempted, and natural colonization is responsible for plants occurring there. This site was examined in September of 1987, when the disturbance was 19 or 20 years old. Lists of the species colonizing were generated, and botanical species composition was measured.

## Sampling Procedures

### *Mapping*

At each NPRA drilling location, Warren E. Fiscus, a licensed surveyor, used a transit to survey locations for all photopoints and locations of other features pertinent to the sites. Base maps provided by the USGS are being used with this survey data to generate maps of each site for future use in relocating photopoints and specific plots.

### *Soil and Gravel Profile Descriptions*

At the NPRA sites in 1991, soil and gravel profiles were described by Dr. Maynard A. Fosberg, Emeritus Professor of Soil Science, University of Idaho. Dr. Fosberg used standard soil science descriptive techniques, described by U.S. Soil Survey Staff (1975).

*Table 2. Three versions of seeding mixtures used by Alyeska Pipeline Service Company for revegetation of tundra sites north of the Brooks Range for years 1975, 1977, and 1984.*

| Genus species | Common Name | Variety | Year & Application Rate (kg/ha) | |
|---|---|---|---|---|
| Original (1975) and First Revision (1977) | | | 1975 | 1977 |
| *Festuca rubra* | Red fescue | Arctared | 17 | 12 |
| *Lolium multiflorum* | Annual ryegrass | Common | 17 | 15 |
| *Festuca rubra* | Red fescue | Boreal | 6 | 10 |
| *Poa pratensis* | Kentucky bluegrass | Nugget | 11 | 12 |
| *Agrostis alba* | Redtop | Common | 6 | 2 |
| *Arctagrostis latifolia* | Polargrass | Alyeska | 0 | 1 |
| Second Revision (1984) | | | | 1984 |
| *Festuca rubra* | Red fescue | Arctared | | 13 |
| *Poa glauca* | Glaucous bluegrass | Tundra | | 9 |
| *Lolium multiflorum* | Annual ryegrass | Common | | 5 |
| *Arctagrostis latifolia* | Polargrass | Alyeska | | 4 |
| *Deschampsia beringensis* | Bering hairgrass | Norcoast | | 3 |
| *Calmagrostis canadensis* | Bluejoint reedgrass | Sourdough | | 3 |

Profiles were described from pits excavated at three NPRA drilling sites: Tunalik, Inigok, and Lisburne. For gravel profiles, pits were located on the pad surface and were situated to represent a typical profile for the fill. At Tunalik and Inigok, portions of the pads were constructed without insulation, and at those sites gravel-fill profiles were described and sampled in both insulated and non-insulated areas. Natural soil profiles were also described in tundra areas at the three NPRA drilling sites. These "control" locations were selected to represent the typical soil, which was believed to have been buried beneath the gravel fill at these sites. At each site, there was usually a mosaic of natural soils. The predominant pattern varied between upland and lowland microsites. The upland soils represented the dry portion of the continuum within the mosaic, and the wet sedge meadows represented the moist extreme.

In order to measure effects on soils from leaking drilling fluids, it was necessary to sample a control soil genetically related to the one affected by the leakage, which generally occurred at the lowest point and impacted the wettest soils at these NPRA sites. Soils formed in wet sedge meadows differ strikingly from adjacent upland soils (U.S. Soil Survey Staff 1975 and Lucas 1982). If the effects from differences in soil genesis and those from reserve pit leakages are confounded, it becomes impossible to distinguish between impacts from drilling fluids and natural variations in soil properties resulting from genesis. This important point was not considered when soils at these NPRA sites were examined in 1984. Usually, control soils in the 1984 study were sampled from upland (relatively dry) sites, whose soils were inherently different from the wet-affected soils. Thus, the control soils in the 1984 investigation were often invalid comparisons with reserve pit fluid-affected soils, because they differed in soil genesis and their chemical and physical properties, i.e., bulk density, organic matter, and moisture content. Essentially, variations due to differences in genesis and reserve pit leakages were confounded for some sites in the 1984 investigation. An attempt to correct that error was made in 1991 by having a soil genesis expert select the soil sampling locations for affected and control soils.

Profiles at all three NPRA locations studied in 1991 were described in wet-sedge-meadow sites that had not been affected by washouts of reserve pit berms and reserve pit fluids. At Inigok and Tunalik, profiles were described and sampled in the washout areas where reserve pits had leaked. At both of those wellsites, fill that had eroded from the pit berm was deposited on the surface of the natural soil. At Lisburne, the reserve pit fluids had neither overflowed nor eroded the berm; therefore, a fluid-affected area was not identified for sampling. An upland moist meadow soil upslope from the reserve pit was described and sampled as a control site at the Lisburne location.

### *Soil Fines*

Typical gravel fill contains relatively little silt- and clay-sized particles. Hence, it has relatively low capacity for retaining moisture and nutrients to support plant growth. There is also considerable variation in the quality of fine fractions among different sources of gravel in the region. For instance, at some locations in the Kuparuk field, there appears to be more silt and organic matter than present in the gravels of the Prudhoe Bay locality. Therefore, gravel samples in this investigation were taken at each site, placed in 1-gallon Ziploc® bags, and taken to the laboratory in Palmer where they were air-dried and sieved. The portion retained on each sieve and that in the bottom pan (<2 mm size, or fine fraction) were weighed to the nearest 0.1 g. The <2-mm soil fraction was stored for further analysis, while the >2-mm fraction was discarded.

### *Soil Bulk Density*

Bulk density is the specific weight of soil, expressed as grams oven-dry weight per cubic centimeter. The lower the bulk density, the greater the volume of air and/or organic matter in the soil. Thus, for gravel fill, it is an index to the degree of compaction of the material and is related to the porosity and water infiltration capacity of the gravel. A bulk density of 1.2 to 1.3 $g/cm^3$ is considered normal for a typical mineral soil for cropland production. Highly organic soils will have bulk densities less than 1 $g/cm^3$, often in the 0.2 – 0.6 $g/cm^3$ range; i.e., they are lighter than water. For very stony soil, the bulk density will approach 2 $g/cm^3$ as the mass of rock becomes the dominating feature in the soil. The average specific weight for rock in the earth's mantle is about 2.6 $g/cm^3$.

Bulk densities were measured for insulated and non-insulated portions of the Tunalik and Inigok drilling pads. Because the entire pad at Lisburne was constructed with an insulation layer between the gravel fill and underlying tundra, only the insulated portions of the gravel fill could be sampled at that location. Bulk density was measured near the surface of the gravel pads at Tunalik and Lisburne. At Inigok, bulk density was measured in the surface of the pad and at various depths in the fill profile. Also at Inigok, the undisturbed upland tundra soil adjacent to the pad was sampled for bulk density. Bulk densities of the wetland tundra soils could not be measured because they consisted mainly of masses of *Carex* and *Eriophorum* roots, which rendered it impossible to determine the soil bulk density with the field method used.

Bulk density was measured with a VOLU-VESSEL, a device which consisted of a sealable graduated cylinder with a thin-walled bladder attached to the bottom and a hand aspirator affixed to the top (Fig. 5). The cylinder was secured over a 10-cm-diameter hole in a metal plate which was held in place at each sampling site by steel pins. After the graduated cylinder was first filled with water, it was pressurized by air pumped from the aspirator, thereby forcing water into the bladder, which occupied any void below the hole. Volumes were determined by aspirating until a stable water level was observed in the graduated cylinder. After the first reading was obtained, materials under the hole were carefully excavated and placed in a Ziploc bag; then a second reading was taken. Because the gravel surfaces were compacted, removing gravel samples required careful excavation. A cold chisel and hammer were used to loosen the gravel, which was then removed with a spoon and placed in doubled resealable (Ziploc) bags, and labeled with a moisture-resistant marking pen. Volume was determined by the difference in water level of the two readings. The gravel samples were taken to the laboratory and weighed fresh, then again after drying 48 hours at 105°C. Bulk density was calculated by dividing the laboratory-determined oven-dried weight (grams) by the field-measured volume (cubic centimeters) of excavated samples. Data were entered onto a computer spreadsheet and formulas created to calculate grams of material per cubic centimeter ($g/cm^3$).

### *Soil Moisture*

In the course of obtaining bulk density data, we also gravimetrically measured soil moisture for all soil and gravel samples. Samples which had been sealed in plastic bags at the time of collection were taken to the laboratory. Fresh weights were measured, then samples were oven-dried for 48 hours at 105°C. The weight loss between the fresh and the oven-dried weights represented moisture content in these samples. The moisture weight was divided by the oven-dried weight of soil to obtain percent soil moisture, i.e., (weight of water/weight of oven-dry soil) x 100.

It is important to point out that this is the standard method for measuring soil moisture. Often technical reports on studies from the Alaska Arctic and elsewhere by environmental scientists and technicians contain soil moisture data that have been incorrectly calculated, i.e., (weight of water/weight of soil+water) x 100. The magnitude of the error increases with increasing wetness of soil; thus, the seriousness of these errors becomes most pronounced for data from arctic wetland soils, where the water content often exceeds 100%. This is particularly true where organic matter is a major component and permafrost is present. If the *incorrect* formula is used to calculate soil moisture, the percentage never exceeds 100%.

### *Water Electrical Conductivities*

Electrical conductivity (E.C.) has proven to be a reliable field method to identify water affected by drilling wastes in this region. Natural water in arctic ponds and lakes, excluding that influenced by seawater and anthropogenic forces, generally has an electrical conductivity of about 90 to 600 µmhos/cm. If the E.C. of lakes, thermokarst pools and ponds is greater than 600 µmhos/cm, they may have been affected either by seawater or anthropocentric factors. If the E.C. exceeds 1,000 µmhos/cm, there is greater certainty of influence from either human activities or seawater. Therefore, the electrical conductivities of water bodies around the NPRA test wellsites were measured for evidence of reserve pit leakages.

In addition to E.C., water temperature and pH were measured with portable instruments. The temperature sensors were calibrated using ice water at the laboratory and mercury thermometers in the field. Water temperature data were needed to adjust the E.C. meter at each site. Standard solutions were used to calibrate the electrical conductivity and pH meters.

### *Areas Affected by Reserve Pit Leaks*

The reserve pits at three NPRA exploratory drilling sites in this survey are known to have leaked fluids and affected tundra soils and plant communities near the drilling pads. These three locations are the Tunalik, Inigok, and Seabee drilling sites. Examining these leak-affected areas was the main purpose of site evaluations in the 1984 survey (McKendrick 1986, Pollen 1986). In 1991, the objective was not restricted to leak-affected areas at these locations, although the plants

*Figure 5. The VOLU-VESSEL used to measure the volume of a bulk density sample from the surface of insulated portion of Inigok drilling pad (17 July 1991).*

and any surface water in leak-affected habitats were examined, and photoplots were established to monitor any aspect changes that might occur over time. At both Inigok and Tunalik, there were breaches in the reserve pit berms through which fluids flowed and eroded the berm. At the Lisburne drilling site, no breaching of the reserve pit berm was found, but the areas downslope from the reserve pit were examined for evidence of damages to vegetation from seepage through the gravel fill. The Seabee drilling site was evaluated in 1992, and the data reported in McKendrick et al. (1993).

#### *Plant Species Lists*

Lists of plant species were obtained by walking over the pad and recording each species recognized. Any plants unknown to the observer were collected and examined under a microscope and/or with a hand lens in order to identify the species with the use of plant keys. Hultén (1968) was used for the forbs and some shrubs, while Welsh (1974) was used for grasses, Argus (1973) for willows, and Viereck and Little (1972) for other woody plants. At most sites only the vascular plants were included in species lists. However, where lichens were abundant, the most common were listed by species. For the NPRA sites, separate listings were created for distinct habitats: (1) insulated pad surfaces, (2) non-insulated pad surfaces, (3) slopes of pads, (4) adjacent undisturbed upland tundra, (5) wetland areas affected by reserve pit leaks, and (6) undisturbed wetland areas. All six habitats were not always found at each of the NPRA locations. At the sites outside NPRA, species were listed for only gravel fill portions of the area and not for control habitats.

#### *Botanical Species Composition and Basal Cover*

Botanical species composition and basal cover were obtained from walking-point data (Owensby 1973) at three NPRA locations sampled in 1991 and on the gravel trail in the Sagavanirktok River delta in 1987. Areas of the NPRA drilling sites sampled were insulated and non-insulated pad surfaces and the pad slopes. Areas beyond the gravel fill were not sampled with the walking-point method. Observers walked transects across representative areas sampled. At every pace or every other pace, depending on the size of the area to be sampled, the legs of the pointer were positioned on the ground in front of the observer, without looking to anticipate the placement, and the pointer lowered to touch the surface of the ground (Fig. 6). If the pointer touched the base of a live plant, the species encountered was recorded and noted as a live basal hit. If no live plant was touched, the plant species nearest the pointer was recorded, and whatever was touched by the pointer (rock, feces, litter, bare soil, moss, etc.) was recorded for the basal hit. The record of these points was scored on tally sheets by another person. Botanical species composition was calculated by dividing the number of records in which a species was encountered (either as a direct hit with the pointer or as the nearest plant) by the total number of points recorded by habitat at the sites. This produced an array of decimal fractions that totaled one for each habitat. Percent composition was calculated by multiplying the decimal fractions by 100.

Basal cover was similarly calculated from the records of items encountered by the pointer. Decimal fractions of various categories were calculated by dividing the number of recorded basal hits by the number of points obtained by habitat at each location. These decimal fractions were converted to percentages by multiplying by 100. The categories included live vascular plants, moss, lichen/liverwort, litter (dead plant fragments), rock, bare ground (which was sand or silt as opposed to rock), and animal feces. The live vascular plant, moss, lichen/liverwort categories were combined into a designation termed "total living." The litter and feces categories were combined into a "total dead" category. The total living and dead categories were then combined to form a class of "total biological." Rock and bare (ground) were combined into a "total mineral" category.

A pointer was not available when the gravel trail in the Sagavanirktok River delta was sampled. Instead of a pointer, a notch in the toe of the observer's boot was used to define the point to obtain species composition on that gravel fill. The observer and recorder paced along the fill. The observer avoided looking at the ground by keeping eyes on the horizon between sampling points. After the foot was placed, the notch in the boot toe was examined. If there was a plant base within the notch, a record for that species was recorded. If there was no plant within the notch, the species nearest to the notch was noted. These records were used, as described previously, to calculate decimal fractions for all species encountered and converted to percentages by multiplying by 100. Basal cover was not calculated for this location, because the sampling was preliminary.

Botanical species composition and basal cover have not been measured at other locations in this study.

### *Canopy Cover*

Canopy cover provides an index to the dominance of various plant lifeforms; and as with botanical species composition, it indicates relative importance among categories of plants. We used it to compare among gravel-fill habitats within and among locations. Canopy cover was measured on gravel fill at the three NPRA wellsites examined during the 1991 field season. It was measured using a 20-by-50-cm rectangular plot frame (Fig. 7). This is commonly referred to as the Daubenmire method (Daubenmire, 1959). An observer placed the plot frame at random locations on the surfaces of various portions of the gravel pad, i.e., insulated and non-insulated pad surfaces and pad slopes. The area defined by the plot frame was examined. Graminoid, forb, shrub, moss, lichen, dead plants, feces, rock and bare ground were each given class ratings that corresponded with cover percentage ranges. These data were recorded on field sheets. In the laboratory, these data were entered into computer spreadsheets, and the corresponding cover percentages totalled for each cover class. This total was divided by the number of plots sampled at the site to obtain a final percentage for each cover class.

Because the environments differ greatly between gravel fill and adjacent wet or moist tundra, there was no point in comparing those vegetation features. Therefore, canopy cover was not measured in habitats adjacent to gravel fill at any of the sites in this study. Priority was focused on the gravel fill communities, which are undergoing changes as vegetation invades and occupies these habitats. The surrounding communities are assumed to be stable climax stands that probably change relatively little among years. If at a future date it becomes important to document the differences between the communities on gravel fill and those of adjacent tundra, it can be incorporated into the study.

### *Photoplots*

Long-term changes in plant communities and landscape features can be documented with photographic records. Photoplots and photopoints have been used successfully in the Alaska Arctic (McKendrick 1976, 1991) and elsewhere (Sharp et al. 1990). In 1991, photoplots were established at the three NPRA locations examined. Where possible, photographs obtained during previous visits to these sites were used to relocate positions from which those photos were taken. At each wellsite, at least ten photopoints were selected.

The photopoint (i.e., camera point) was marked by driving a 1.6-cm steel reinforcement rod into the soil. Information to identify the photopoint was stamped onto aluminum caps, which were fastened atop these reinforcement rods. Pertinent data on these caps include the project leader's name, date of establishment (when the first photo was taken at the point), and number of the photopoint. Numbers were assigned chronologically in order of selection.

Photos were taken using a 35-mm single-lens-reflex camera equipped with a 50-mm standard lens. Exceptions to this choice of lens were rare and varied only by using a 28-mm wide angle lens when needed to include certain features beyond the angle of view of the normal lens. The camera orientation was usually horizontal, although vertical positioning was used to include specific features that could not be photographed otherwise. Usually, some permanent, obvious landscape feature was used to center the camera view to assist in accurately rephotographing the scene. Lens and view deviations were noted in the photo records.

A record for each photo was kept in a field book. These records included the date, photopoint location (site name and photopoint number), the film type, roll, and frame number. Color transparency film was used. Film roll numbers were consecutive, beginning with calendar year; and frame numbers were those on the processed film after it was returned from the laboratory. Because frame numbers in field records may differ slightly from those on the finished film, it is necessary for the photographer to verify accuracy and labeling of all photo transparencies.

### *Wildlife Observations*

At each NPRA site, all wildlife sightings and evidence of use by wildlife were recorded. Birds were identified by two of the field crew (Peter C. Scorup and Dr. Maynard A. Fosberg), who were the most experienced bird observers in the group. Names of birds were from Johnson and Herter (1989), and the National Geographic Society's field guide (1983) was the most used reference. Signs of animal uses included grazing, feces, bedding, burrowing, hair, feathers, carcasses, etc. Observations from all individuals in the group were combined into a single listing for each location.

### *Evidences of Human Uses at Location*

At each NPRA location visited in 1991, signs of human activities since the area had been rehabilitated

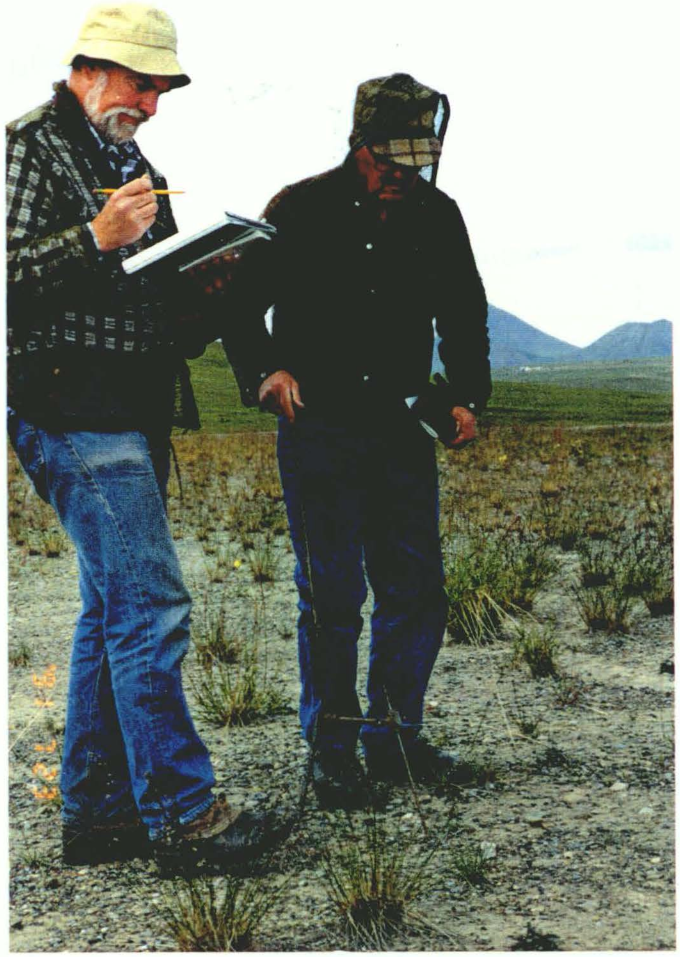

*Figure 6. Collecting walking point data on the insulated portion of Lisburne drilling pad, 23 July 1991.*

*Figure 7. Collecting Daubenmire plot cover data on the non-insulated portion of Inigok drilling pad (18 July 1991).*

were noted and recorded. Evidence included seeing people in the area; tracks of vehicles; debris from hunting, fishing, and/or camping; and any other sign of human presence.

## RESULTS

### Mapping

A map of each of the three NPRA sites examined in 1991 was produced showing the location of photopoints and gravel and water sampling sites, as well as delineating reserve pit leakage areas and other areas or points of impact or interest. Copies of maps may be found in the pocket inside the back cover of this report. These maps will help researchers relocate sampling sites and track changes in vegetation over time.

### Gravel Texture

The content of silts and clay particles in gravel affects its physical and chemical properties with respect to how well vascular plants can colonize and survive on such substrates. Fine fractions measured in gravel from preliminary samples collected at the Franklin Bluffs Camp pad and Trans-Alaska Pipeline mile posts 17, 17.8, 19.5, and 34 are given in Table 3. These samples were collected within four classes of plant cover: barren, sparse, medium, and dense (as judged on appearance in the field). The percentages of fine fractions (≤2 mm) ranged from 19% to 36% and did not appear to be consistently related to the vegetation cover, among locations sampled.

### Bulk Density

Bulk density data for all samples collected during the field survey of sites in NPRA are presented in Appendix A and summarized in Table 4. The surface of the insulated and non-insulated portions of the Tunalik pad averaged 1.93 and 1.83 g/cm$^3$, respectively. At Inigok, the insulated surface portions of the pad ranged from 1.80 to 2.10 g/cm$^3$, and the one sample from the non-insulated pad surface was 2.20 g/cm$^3$. Surface bulk densities for insulated pad surfaces at Lisburne averaged 2.00 g/cm$^3$ for the upper pad and 2.23 g/cm$^3$ for the lower pad.

The bulk densities of insulated fill at three depth ranges (0–15, 25–38, and 46–58 cm) in the fill for the Inigok pad were 1.80, 1.70, and 1.60 g/cm$^3$, respectively. The bulk densities for three layers (0–12, 25–38 and 51–64 cm) of the non-insulated fill at Inigok were 2.20, 1.80, and 1.80 g/cm$^3$, respectively. Bulk densities for a natural upland soil at Inigok were 0.60, 0.50, and 0.60 g/cm$^3$, respectively. The bulk density for the Inigok leak area, which consisted of gravel and sands washed from the berm of the flare and reserve pits, was 1.70 g/cm$^3$.

### Soil Moisture Percentages

Soil moisture percentages in the gravel fill at NPRA drilling sites examined in the 1991 survey are presented in Appendix A and summarized in Table 4. The insulated and non-insulated pad surfaces at Tunalik averaged 3.30% and 8.80%, respectively. At the Inigok pad, the insulated-fill surface samples ranged from 1.70% to 5.30% moisture, with an overall

*Table 3. Listing of fine fraction percentages in 1988 collections of surface gravel from four locations along the Trans-Alaska Pipeline route and the Franklin Bluffs Camp Pad.*

| Location | Plant Cover Rating | Percent Fines (≤2mm) |
|---|---|---|
| Trans-Alaska Pipeline M.P. 17 | Sparse (n = 1) | 19 |
| | Medium (n = 1) | 33 |
| Trans-Alaska Pipeline M.P. 17.8 | Medium (n = 1) | 22 |
| Trans-Alaska Pipeline M.P. 19.5 | Barren (n = 1) | 21 |
| | Medium (n = 3) | 29 |
| Trans-Alaska Pipeline M.P. 34 | Barren (n = 1) | 31 |
| | Medium (n = 1) | 36 |
| | Dense (n = 1) | 31 |
| Franklin Bluffs Camp Pad | Sparse (n = 1) | 29 |
| | Medium (n = 2) | 22 |

*Table 4. Summary of bulk densities and soil moisture percentages for samples collected from three NPRA exploratory drilling wellsites during the 1991 field season.*

| Number of Samples | Location | Habitat | Sample depth (cm) | Bulk Density ($g/cm^3$) | Moisture (%) |
|---|---|---|---|---|---|
| 3 | Tunalik | Insulated Pad | 0–10 | 1.93 | 3.30 |
| 3 | Tunalik | Non-Insulated Pad | 0–10 | 1.83 | 8.80 |
| 1 | Inigok | Upland Tundra | 0–10 | 0.60 | 62.00 |
| 1 | Inigok | Upland Tundra | 10–18 | 0.50 | 81.80 |
| 1 | Inigok | Upland Tundra | 18–25 | 0.60 | 73.80 |
| 3 | Inigok | Insulated Pad (Site 1) | 0–18 | 2.10 | 2.03 |
| 1 | Inigok | Insulated Pad (West) | 0–12 | 2.10 | 1.70 |
| 1 | Inigok | Insulated Pad (East) | 0–15 | 1.90 | 5.30 |
| 1 | Inigok | Insulated Pad (Site 3) | 0–15 | 1.80 | 4.80 |
| 1 | Inigok | Insulated Pad (Site 3) | 25–38 | 1.70 | 4.00 |
| 1 | Inigok | Insulated Pad (Site 3) | 46–58 | 1.60 | 8.20 |
| 1 | Inigok | Non–Insulated Pad | 0–12 | 2.20 | 6.00 |
| 1 | Inigok | Non–Insulated Pad | 25–38 | 1.80 | 11.80 |
| 1 | Inigok | Non-Insulated Pad | 51–64 | 1.80 | 15.70 |
| 1 | Inigok | Pit Leak Area | 0–12 | 1.70 | 21.80 |
| 3 | Lisburne | Insulated Upper Pad | 0–18 | 2.00 | 4.50 |
| 3 | Lisburne | Insulated Lower Pad | 0–18 | 2.23 | 5.06 |

average of 3.46%. The one surface sample from the non-insulated portion of the pad at Inigok had a soil moisture of 6.00%. At Lisburne, the insulated upper pad averaged 4.50% moisture, while the insulated lower pad had an average moisture of 5.06%.

In the natural soil at Inigok, soil moisture ranged between 62.0% and 81.8%, averaging 72.5%. The soil moisture ranged between 4.0% and 8.2% in the profile of the insulated gravel fill at Inigok, and was 6.0% to 15.7% for the non-insulated gravel-fill profile at Inigok. The soil moisture content of the gravel fill washed from the berms into the leak area at Inigok was 21.8%.

## Gravel Characteristics and Vegetation at East Dock Reserve Pit

Table 5 contains data by plant cover classes for salinity (E.C.), nitrogen, phosphorous, potassium, and pH from the fine fractions of surface gravels at the East Dock site. These data show a significant negative relationship between soil salinity and plant cover. Conversely, there was a significant positive relationship between soil available nitrogen and plant cover. Potassium availability and soil pH were not related to plant cover in the samples; they showed only trends and were not statistically significant.

## Water Electrical Conductivities

Water E.C. data were collected at Tunalik, Inigok, and Lisburne test wellsites in the NPRA during the 1991 field season. There were few water bodies to sample, other than the reserve pit, near the Tunalik drilling pad. At Lisburne, an intermittent stream that flowed past the lower end of the drilling site was sampled in addition to Otuk Creek, the eventual drain for the entire area of the drilling site. Most of the water sampling occurred in the many water bodies around Inigok, from small thermokarst pools to variously sized ponds. Water E.C. data from around these locations are listed in Appendix A and summarized in Table 6.

Among the three reserve pits tested, Inigok contained the highest concentration of dissolved salts (3,860 µmhos/cm), followed by Tunalik (503 µmhos/cm) then Lisburne (454 µmhos/cm). Compared to similar data taken by Pollen (1986) in the 1984 study at

*Table 5. Means (n = 4) and F-test probabilities for soil E.C.; available N, P, and K; and pH in gravel fines (<2 mm) from surface gravel sampled by vegetation cover class at East Dock Reserve Pit pad, sampled 8 September 1989.*

| Plant Cover Classes | E.C. (mmhos/cm) | Nitrogen (mg/kg) | Phosphorus (mg/kg) | Potassium (mg/kg) | pH |
|---|---|---|---|---|---|
| Bare | 13.0 | 4.3 | 15 | 58 | 7.68 |
| Sparse | 4.7 | 6.3 | 24 | 46 | 7.69 |
| Medium | 3.9 | 2.3 | 25 | 36 | 7.74 |
| Dense | 1.1 | 14.8 | 38 | 62 | 7.84 |
| F-Test Probability | 0.005* | 0.002* | 0.203 | 0.297 | 0.095 |

*Significant at the 95% level

*Table 6. Listing of average electrical conductivity (E.C.), standard error of the mean (S.E.M.), and number of samples tested (n) data for water at Tunalik, Inigok, and Lisburne test wellsites (July 1991).*

| Specific Location | E.C. µmhos/cm | S.E.M. | n |
|---|---|---|---|
| **Tunalik Test Wellsite No. 1** | | | |
| Pool Upslope of Site | 105 | n/a | 1 |
| Reserve Pit | 503 | n/a | 1 |
| Fuel Pit | 513 | n/a | 1 |
| Leak-Affected Area | 587 | n/a | 1 |
| Soil Pit (leak-affected area) | 1,100 | n/a | 1 |
| **Inigok Test Wellsite No. 1** | | | |
| Lake on West | 95 | n/a | 1 |
| Lake on East | 135 | n/a | 1 |
| Lake on North | 136 | n/a | 1 |
| Fuel Pit (not mixed with reserve pit) | 263 | n/a | 1 |
| Inlet to Lake (leak-affected) | 323 | n/a | 1 |
| Pools Around Pad | 484 | 297 | 24 |
| *Arctophila fulva* Pools on West | 1,159 | 704 | 3 |
| Reserve Pit | 3,860 | n/a | 2 |
| Soil Pit Leak Area | 6,120 | n/a | 1 |
| Flare Pit Leak Area | 7,870 | 4,213 | 3 |
| **Lisburne Test Wellsite No. 1** | | | |
| Tundra Pool Upslope Side of Pad | 186 | n/a | 1 |
| Otuk Creek at Bridge (upstream any leak from site) | 230 | n/a | 1 |
| Thermokarst Pool on Upper Pad Surface | 234 | n/a | 1 |
| Flare Pit East Edge of Pad (independent of reserve pit) | 278 | n/a | 1 |
| Stream Above Pad | 331 | n/a | 1 |
| Stream Below Pad | 364 | n/a | 1 |
| Reserve Pit | 454 | n/a | 1 |

these locations, the Tunalik fuel pit water was more saline in 1991 (513 vs. 115 µmhos/cm), and the reserve pit water was less saline (503 vs. 1,585 µmhos/cm). The reserve pit at Lisburne also had slightly lower dissolved salts in 1991 than in 1984 (454 vs. 505 µmhos/cm). In contrast, the reserve pit water at Inigok in 1991 averaged more saline than reported in 1984 (3,860 vs. 2,900 µmhos/cm).

Five water bodies at the Tunalik location were sampled on 25 July 1991. The lowest E.C. (105 µmhos/cm) was found in a tundra pool in the drainage above the site (Table 6). The surface water in the leak-affected area and the reserve and flare pits was about equivalent in salinity (503 to 587 µmhos/cm). Water beneath the surface of the leak-affected area had an E.C. of 1,100 µmhos/cm. Meltwater enters the reserve and fuel pits on the west and flows out of the reserve pit through a breach in the berm on the east side.

At the Inigok site, water electrical conductivities were measured on 17, 19, and 20 July 1991 at 38 locations (Appendix A). The lowest value (95 µmhos/cm) was recorded in the lake south and west of the reserve pit, and the highest value (13,790 µmhos/cm) was recorded for a stagnant pool in the flare pit leak area (Table 6). The highest average E.C. at Inigok (7,870 µmhos/cm) was calculated for stagnant pools in the flare pit leak area, which ranged from 4,330 to 13,790 µmhos/cm. The pad is surrounded on three sides by interconnected ponds and lakes, and three lake-water samples taken averaged 122 µmhos/cm. The E.C. for 24 pools around the drilling pad ranged from 117 to 1,035 µmhos/cm, with an average of 484 µmhos/cm. It appears that meltwater from snow accumulated in the reserve pit during winter breached the berm between the reserve and flare pit and then breached the berm on the outer edge of the flare pit. These fluids then flowed into a small inlet of the lake to the north of the drilling pad, which had an E.C. of 323 µmhos/cm.

At the Lisburne site, water electrical conductivities were measured at seven locations. The lowest reading (186 µmhos/cm) was found in a small tundra pool formed next to the upslope edge of the upper pad. The highest reading (454 µmhos/cm) was recorded in the surface waters of the reserve pit. Stream water downslope from the drilling pad had an E.C. only slightly higher (364 vs. 331 µmhos/cm) than that above the pad.

## Areas Affected by Reserve Pit Leaks

Leakage of fluids from reserve pits at Tunalik and Inigok was noted in the 1984 survey. There was no obvious breaching of the berm or leakage at the Lisburne drilling site either in 1984 or 1991. It is possible that water seeped downslope from the Lisburne pit, but the absence of vegetation damage was considered evidence that such a problem did not exist. Therefore, only leak-affected areas at the Tunalik and Inigok drilling sites were examined.

### *Tunalik Test Wellsite No. 1*

The Tunalik reserve pit leaked on the east side between the flare pit and the drilling pad. It was evident that breakup meltwater entered the reserve pit on the west side and overflowed the east berm. This process has eroded a portion of the east reserve-pit berm, carrying gravel fill onto the adjacent wet sedge meadow.

In 1984, the vegetation in this area downslope from the reserve pit was mostly dead. Evidence of oily residues and damage to vegetation extended for several hundred feet downslope from the pad, and there was no colonization by vascular plants in the gravel that had been washed onto the tundra near the reserve pit. *Carex aquatilis*, *Eriophorum angustifolium*, and *Salix planifolia* ssp. *pulchra* appeared to be the vascular plant species most tolerant to the reserve pit fluids. *Saxifraga cernua* appeared in some of the channels downslope from the gravel deposit on the tundra and may have either colonized after other plants were killed or may have resisted the effects from the fluids, according to the 1984 observations (McKendrick 1986).

At the Tunalik site in 1991, most of the area where vegetation had been killed from the leaking reserve pit prior to the survey in 1984 had recolonized with sedges, predominately *Carex aquatilis* and *Eriophorum vaginatum*, making photopoint relocation difficult. Outlines of what were previously areas of dead vegetation could be recognized because the new plants were greener and more robust than adjacent vegetation, and there was less standing dead in these new plant communities compared to the adjacent undamaged stands. *Arctophila fulva* and *Senecio congestus* were prominent colonizers on the wet gravel washed from the berm. Although not all of the gravel was covered with new vegetation, there was less bare area than observed in 1984. Other vascular plant species colonizing in the damaged area at Tunalik included: *Arctagrostis latifolia*, *Carex bigelowii*, *Eriophorum vaginatum*, *Eriophorum scheuchzeri*, *Festuca rubra*, *Phippsia algida*, and *Ranunculus gmelini*.

***Inigok Test Wellsite No. 1***

Inigok Test Wellsite No. 1 had the most serious environmental problems of all gravel-fill drilling sites explored during the second exploration of NPRA. There was an initial problem in the well with high sulfur and $H_2S$, which lead to acidity in the reserve pit. The acidity was neutralized with sodium hydroxide, which elevated the salinity level in the reserve pit fluids. The berm between the reserve and flare pits was breached by 1984, permitting reserve pit fluids to enter the flare pit (Fig. 8). By 1991, the flare pit outer berm was breached, allowing reserve pit fluids to flow through the flare pit and into the lake north of the pad via a small inlet (Fig. 3). The reserve pit seepage also occurred into a wetland on the southwest edge of the reserve pit and the lake system off the northwest edge of the pad. Consequently, by 1984, there were already known environmental problems at this site (Pollen 1986). Since the Bureau of Land Management (BLM) was assuming responsibility for the surface management of NPRA, and the USGS was responsible for the drilling operations, there was a potential for environmental controversy. Therefore, in 1991, the project investigation included a more thorough measurement of water salinities and impacts and considerations for reserve pit leakage at Inigok than given other drilling sites examined in 1991.

Comparing the E.C. readings of 1991 with those taken in 1984 indicated that during the six intervening growing seasons, some areas decreased in salinity and other areas increased (Fig. 9). A substantial decrease in salinity occurred in the wetland on the southwest side of the reserve pit. In 1984 these surface waters ranged between 1,200 and 6,000 µmhos/cm. In 1991, the readings ranged from 183 to 2,100 µmhos/cm. Tundra pools on the south side of the reserve pit may have increased slightly in salinity between 1984 and 1991. In 1984, water in tundra pools on the south of the reserve pit ranged between 210 and 265 µmhos/cm, compared to a range of 232 to 389 µmhos/cm in 1991.

Salinity within the fuel pit appeared to decline slightly between 1984 and 1991. Fuel pit E.C. in 1984 was 350 µmhos/cm, and in 1991 it ranged between 263 and 332 µmhos/cm (Fig. 9). In contrast, average salinities in the reserve pit were much greater in 1991 than in 1984 — 3,880 vs. 2,825 µmhos/cm. There also seemed to be a slight increase in variabilities in water salinities in the leak-affected area northwest of the flare and reserve pits. In 1984 these salinities ranged between 4,800 and 6,000 µmhos/cm. In 1991, salinities in these areas ranged between 4,330 and 6,120 µmhos/cm. The highest salinity (13,790 µmhos/cm) was found in a small pool of surface water inside what had been the flare pit, before the berm eroded.

By 1984, there was irrefutable evidence that the reserve pit fluids had seeped through the southwest berm and into the wetland swale on the southwest and northwest sides (Pollen 1986). Wind-driven foam and spray were also responsible for carrying fluids from the reserve pit, as noted on the diagram by Pollen (1986). Figure 9 shows water electrical conductivities measured by Pollen (1986) on 10 July 1984 and on 17, 19, and 20 July 1991 in surface (0–15 cm) waters in the lake and various water bodies around the Inigok drilling pad. The surface water of the inlet became less saline between 1984 and 1991 — 450 and 328 µmhos/cm compared to 323 and 324 µmhos/cm. Conversely, between 1984 and 1991, the water in the lake on the northwest and north sides of the drilling pad became slightly more saline, with readings increasing from 90–96 to 136 µmhos/cm on the northwest and from 85–88 to 135 µmhos/cm on the north. It should be noted that the E.C. levels recorded in 1984 and 1991 in the lake complex at Inigok are well within the normal ranges for surface waters of the region, even though saline reserve pit fluids had entered the system.

Responses to reserve pit fluids at Inigok differed among vascular plant species. Wetland vegetation appeared more tolerant of the fluids than upland species. *Arctophila fulva* and *Hippuris vulgaris* were the two main vascular plant species in the affected wetland on the southwest side of the reserve pit. These species were still present in 1984 — although appearing somewhat stressed — in the swale that was affected by reserve pit fluids. They were present in the E.C. range of 1,200 to 6,000 µmhos/cm (Fig. 9). Plant vigor in this area improved greatly between 1984 and 1991.

On the northwest side of the pad, wetland vegetation dominated the low microsites; and moist tundra dominated the upper microsites. It was evident that fluids had breached the berm between the flare pit and the reserve pit and were seeping through the berm toward the northwest (Pollen 1986), affecting this area of mixed vegetation types. E.C. readings in this area ranged between 4,800 and 6,000 µmhos/cm in 1984 (Fig. 9). Also, sand had washed from the berm, partially to completely burying vascular plants. The vegetation had been tussock tundra (*Eriophorum vaginatum*) in the elevated microsites and perhaps *Dupontia fisheri* in the low microsites. These plants

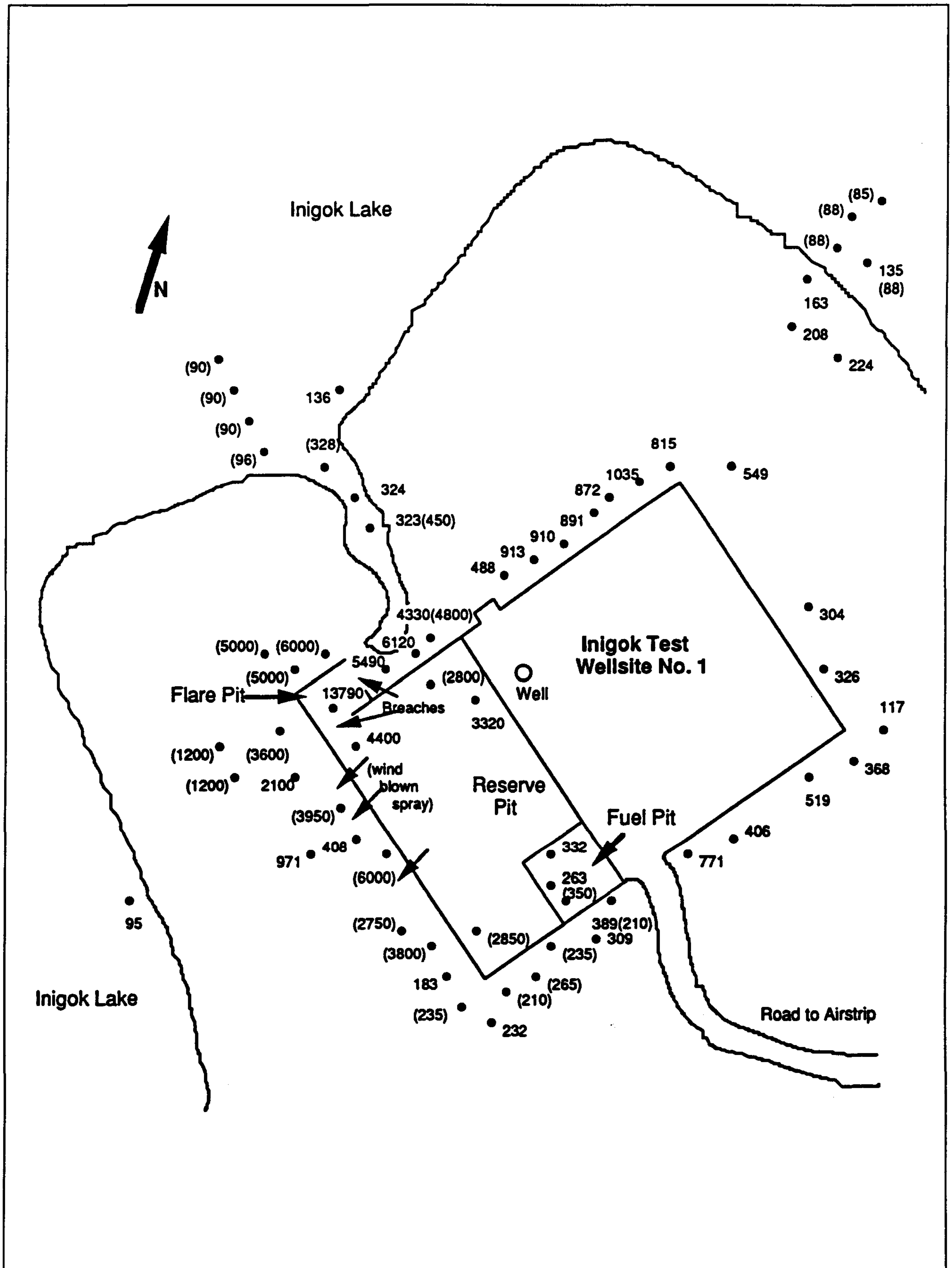


*Figure 9. Electrical conductivities measured in Inigok Lake and various water bodies around and on the Inigok drilling pad on 19 July 1984 (in parenthesis) and 17, 19, and 20 July 1991.*

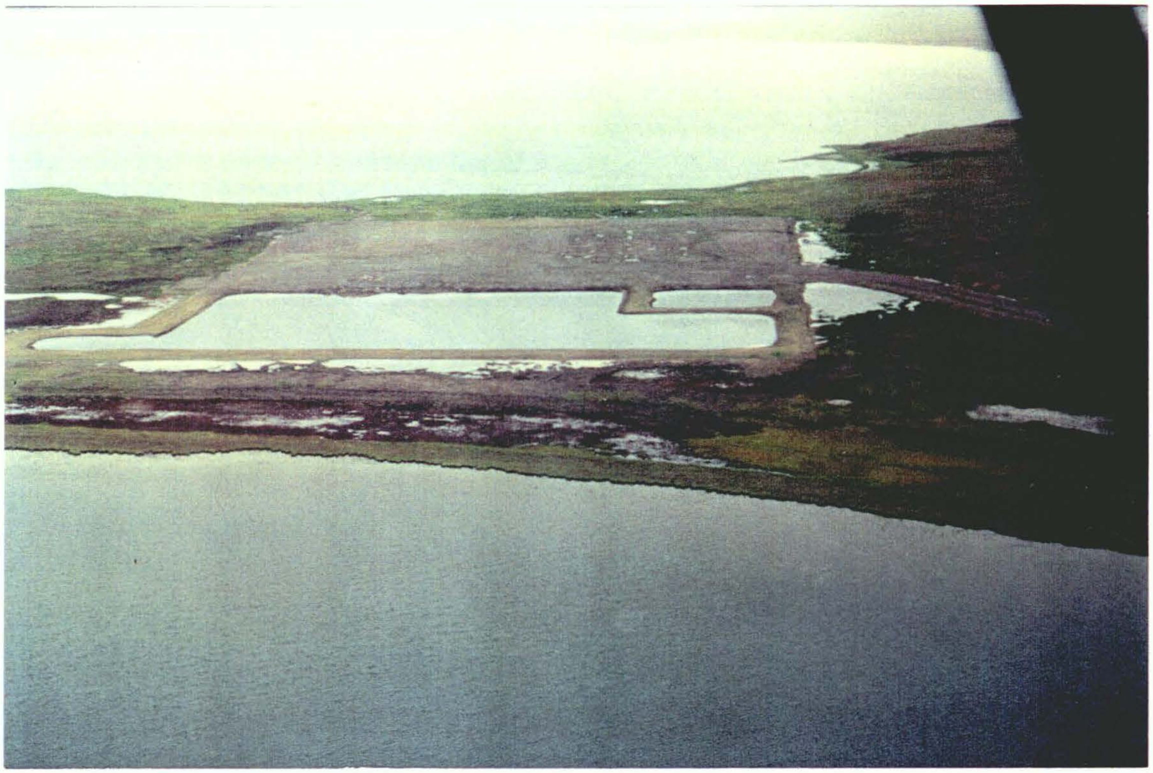

*Figure 8. Aerial oblique view of Inigok drilling site from the southwest, showing that the inner berm of the flare pit was eroded by 8 August 1980.*

were dead in 1984 where the leak occurred. By 1991, *Arctophila fulva* and *Dupontia fisheri* had reinvaded the wet areas of the damaged site and were growing relatively vigorously. However, the drier tussock tundra showed little colonization.

The fluid levels in the reserve pit declined substantially between 1984 and 1991. *Phippsia algida* was colonizing on portions of the dry, sandy habitat within and adjacent to the drained flare pit. In the drainage channel between these pits and the lake, there were depressions, some moist and some with shallow pools of water. *Arctophila fulva, Dupontia fisheri, Eriophorum angustifolium, Carex aquatilis, Hippuris vulgaris*, and *Ranunculus gmelini* were colonizing in these wet portions of the leak-affected area near the head of the inlet. In a shallow pool within the former flare pit, there was a colony of grass seedlings that had germinated since breakup in 1991. These were tentatively identified as *Puccinellia* spp.

## Vascular Plant Species Lists

One hundred twenty-five vascular plant species were found colonizing on gravel fill among ten sites examined during the 1984 through 1991 period. These species are listed in Appendix B, Table B-5, which is a general listing for plant species found at the ten sites. Detailed listings of plant species by habitats within sites are given in Appendix B, Tables B-1 through B-3, while summaries of number of species by habitat are listed in Appendix B, Table B-4. A summary of the families, genera, and species found at each location is given in Table 7. The largest number of species (58) on a single gravel fill was recorded at the Lisburne site in 1991, and the fewest was four species at the Inigok site in 1984.

Family, genera, and species diversity increased over time for the NPRA sites examined in 1984 and in 1991. The largest proportional change in number of vascular plant species on gravel fill occurred on the Inigok pad, which increased 575% (4 to 23 species). The Tunalik, Inigok, and Lisburne drilling pads gained 13, 19, and 27 vascular plant species, respectively, during the interval from 1984 to 1991 (Table 7).

The only other location examined more than once was at M.P. 34 on the Trans-Alaska Pipeline route, which was inventoried in 1987 and again in 1988. At this location, the number of vascular plant species declined by eight (Table 7).

## Botanical Species Composition

Appendix C contains listings of raw data and percentages for vascular botanical species composition from walking-point sampling at the three NPRA drilling pads. Usually the seeded grasses dominated the vascular plant stands on the three NPRA drilling pads. Species composition for grasses seeded at three drilling pads in NPRA are given in Figure 10. *Poa glauca* dominated the insulated pad surfaces. The pattern was less consistent for non-insulated surfaces among the three drilling pads. *Festuca rubra* was an important seeded grass on the non-insulated surface of the Inigok pad, whereas *Poa glauca* was of greater importance on the non-insulated portion of the Tunalik pad. *Festuca rubra* and *Arctagrostis latifolia* shared dominance on pad slopes; *Poa glauca* was not a major species on pad slopes, except at the Tunalik drilling pad.

Botanical species composition for vascular plants, obtained by the walking-point method, was summarized within the three habitat types sampled and by sites. Data sets are presented in Appendix C. Crypto-

*Table 7. Totals of family, genera, and species of plants recorded colonizing ten gravel fill sites in arctic tundra on Alaska's North Slope. Surveys occurred during the 1984–1991 period.*

| Colonizing Plant (Totals) | Tunalik Testwell No. 1 | | Inigok Testwell No. 1 | | Seabee Testwell No. 1 | Lisburne Testwell No. 1 | | Franklin Bluffs Camp | TAP M.P. 17 | TAP M.P. 18.6 | TAP M.P. 19.5 | TAP M.P. 34 | | Trail Sagavanirktok River Delta |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Years Observed | '84 | '91 | '84 | '91 | '84 | '84 | '91 | '87 | '88 | '86 | '88 | '87 | '88 | '87 |
| Families (25) | 6 | 10 | 2 | 12 | 9 | 16 | 20 | 5 | 13 | 5 | 8 | 10 | 9 | 10 |
| Genera (70) | 14 | 22 | 4 | 19 | 16 | 26 | 41 | 8 | 27 | 15 | 16 | 21 | 16 | 23 |
| Species (125) | 15 | 28 | 4 | 23 | 20 | 31 | 58 | 8 | 33 | 18 | 19 | 25 | 17 | 28 |

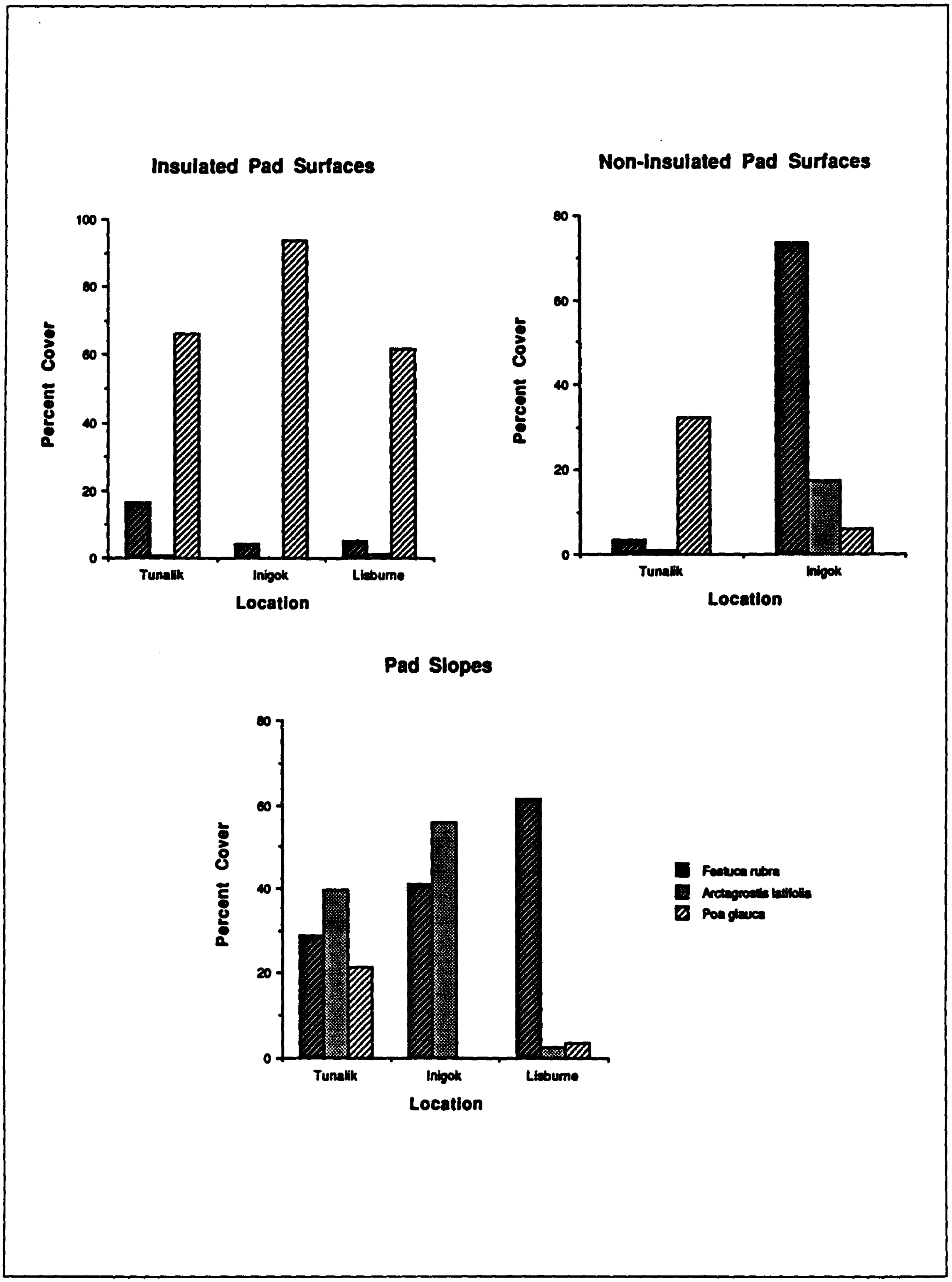


*Figure 10. Percent composition from walking-point data for seeded grasses by three habitats: (1) insulated pad surfaces, (2) non-insulated pad surfaces, and (3) pad slopes at Tunalik, Lisburne, and Inigok drilling pads sampled July, 1991.*

grams (moss, lichens, and liverworts) were not included in the botanical species composition data. Moss was too abundant to include with vascular plants in the walking-point data; in order to obtain a reasonable estimate of vascular botanical species composition, moss would have been over-sampled. Cryptograms were, however, incorporated with basal cover in the walking-point data. Other than the three surviving grasses seeded on the drilling pads (*Poa glauca*, *Festuca rubra*, and *Arctagrostis latifolia*), all other species encountered were natural colonizers.

### *Insulated Pads*

*Poa glauca* was the predominant vascular plant on the insulated portions of the three drilling pads sampled in NPRA during July 1991 (Table 8). *Festuca rubra* ranked second on the Tunalik and Inigok pads, and fourth on the Lisburne drilling pad. *Agropyron boreale* was the second most abundant vascular plant on the insulated Lisburne drilling pad, followed by a forb, *Astragalus alpinus* ssp. *alpinus*.

Six vascular plant species (four grasses and two forbs) were prominent in the walking-point data from the insulated drilling pad at Tunalik. Grasses included the three seeded species and a natural colonizer, *Phippsia algida*. The two dominant forbs were *Cochlearia officinalis* and *Draba macrocarpa* (Table 8). Only four vascular species (three grasses and one shrub) occurred abundantly enough to appear in the walking-point data of the insulated drilling-pad surface at Inigok. Grasses included two seeded species, *Poa glauca* and *Festuca rubra*, and a natural colonizer, *Puccinellia arctica*. *Salix glauca* was the shrub found (Table 8).

On the Lisburne insulated drilling pad, 16 vascular plant species were recorded in the walking-point data. Among these 16 were six grasses, one sedge, eight forbs, and one shrub (Table 8). The grasses were the three seeded species plus *Agropyron boreale*, *Trisetum spicatum*, and *Festuca baffinensis*. The sedge was *Carex aquatilis*, and *Salix alaxensis* was the shrub. Other than the three seeded species, none of the dominant species was prominent at more than one site.

*Table 8. Plant species composition on thick, insulated gravel pads at three NPRA exploratory drilling sites sampled during July, 1991, with the walking-point method.*

| Vascular Plant Species | Composition Percentage |
|---|---|
| **Tunalik Test Wellsite No. 1** | |
| *Poa glauca* | 66.4 |
| *Festuca rubra* | 16.8 |
| *Phippsia algida* | 14.4 |
| *Arctagrostis latifolia* | 0.8 |
| *Cochlearia officinalis* | 0.8 |
| *Draba macrocarpa* | 0.8 |
| **Inigok Test Wellsite No. 1** | |
| *Poa glauca* | 93.9 |
| *Festuca rubra* | 4.4 |
| *Puccinellia arctica* | 1.3 |
| *Salix glauca* | 0.4 |
| **Lisburne Test Wellsite No. 1** | |
| *Poa glauca* | 61.9 |
| *Agropyron boreale* | 12.9 |
| *Astragalus alpinus* ssp. *alpinus* | 6.1 |
| *Festuca rubra* | 5.4 |
| *Papaver macounii* | 2.7 |
| *Androsaceae septentrionalis* | 2.0 |
| *Arctagrostis latifolia* | 1.4 |
| *Epilobium latifolium* | 1.4 |
| *Trisetum spicatum* | 1.4 |
| *Artemisia tilesii* | 0.7 |
| *Carex aquatilis* | 0.7 |
| *Cerastium beeringianum* var. *beeringianum* | 0.7 |
| *Festuca baffinensis* | 0.7 |
| *Oxytropis deflexa* | 0.7 |
| *Papaver lapponicum* var. *porsildii* | 0.7 |
| *Salix alaxensis* | 0.7 |

### *Non-Insulated Pads*

Botanical species composition from walking-point data for vascular plants colonizing the non-insulated surfaces of gravel structures are presented in Table 9. Again, Inigok had the fewest species (four) recorded for the non-insulated portion of the drilling pad. Numbers of vascular plant species colonizing the non-insulated portion of the Tunalik drilling pad and the (unseeded) gravel trail in the Sagavanirktok River delta were 10 and 19, respectively. Unlike the insulated portions of the pads, there was no single dominating species on the non-insulated portions of the two NPRA pads.

The three seeded grass species and one sedge (*Carex aquatilis*) were the only vascular plants colonizing the non-insulated portion of the Inigok drilling pad in sufficient numbers to be detected in the measurements (Table 9). This was the same number of dominant species as measured for the insulated pad;

*Table 9. Plant species composition on non-insulated gravel fill at two wellsites in NPRA (July 1991) and an abandoned trail in the Sagavanirktok delta (September 1987) sampled with the walking-point method.*

| Vascular Plant Species | Composition Percentage |
|---|---|
| **Tunalik Test Wellsite No. 1** | |
| *Poa glauca* | 32.1 |
| *Arctophila fulva* | 25.9 |
| *Phippsia algida* | 17.9 |
| *Carex aquatilis* | 13.4 |
| *Festuca rubra* | 3.6 |
| *Ranunculus gmelini* | 3.6 |
| *Dupontia fisheri* | 0.9 |
| *Arctagrostis latifolia* | 0.9 |
| *Cochlearia officinalis* | 0.9 |
| *Tanacetum bipinnatum* | 0.9 |
| **Abandoned Trail Sagavanirktok River Delta** | |
| *Sagina intermedia/Minuartia rubella* | 31.5 |
| *Braya pilosa/Braya purpurascens* | 15.0 |
| *Puccinellia langeana* | 14.2 |
| *Salix ovalifolia* | 7.9 |
| *Deschampsia caespitosa* | 6.3 |
| *Alopecurus alpinus* | 4.7 |
| *Arctagrostis latifolia* | 3.9 |
| *"Festuca vivipara"* | 3.2 |
| *Festuca baffinensis* | 2.4 |
| *Carex maritima* | 2.4 |
| *Stellaria* spp. | 1.6 |
| *Equisetum scirpoides* | 1.6 |
| *Cochlearia officinalis* ssp. *arctica* | 1.6 |
| *Carex bigelowii* | 1.6 |
| *Salix polaris* (?) | 0.8 |
| *Dryas integrifolia* ssp. *integrifolia* | 0.8 |
| *Carex aquatilis* | 0.8 |
| **Inigok Test Wellsite No. 1** | |
| *Festuca rubra* | 73.7 |
| *Arctagrostis latifolia* | 17.6 |
| *Poa glauca* | 6.1 |
| *Carex aquatilis* | 2.7 |

but a seeded grass (*Arctagrostis latifolia*) replaced the naturally colonizing grass (*Puccinellia arctica*), and there was a sedge instead of a willow on the non-insulated pad surface.

Six grass species, one sedge, and three forbs were the vascular plants colonizing on the non-insulated portion of the Tunalik drilling pad. Grasses included the three seeded species plus *Arctophila fulva*, *Phippsia algida*, and *Dupontia fisheri*. *Carex aquatilis* was the sedge. The colonizing forbs were *Ranunculus gmelini*, *Cochlearia officinalis*, and *Tanacetum bipinnatum* (Table 9). There were five more naturally invading species on the non-insulated pad than the insulated pad at Tunalik.

There were eight forb, six grass, three sedge, and two shrub species prominent in the walking-point data for the gravel trail in the Sagavanirktok River delta (Table 9). These were all natural colonizers, since the trail was never seeded. Only four of the species recorded on the trail were also present on non-insulated portions of NPRA sites: two grasses (*Arctagrostis latifolia* and *Festuca baffinensis*), a sedge (*Carex aquatilis*), and a forb (*Cochlearia officinalis*). Only three of these species were prominent at Tunalik. *Festuca baffinensis* was not a major species on the non-insulated portion of the Tunalik pad. Lisburne and Inigok had only two species in common with the trail: *Carex aquatilis* and *Arctagrostis latifolia* at Inigok and *Carex aquatilis* and *Festuca baffinensis* at Lisburne.

### Pad Slopes

The botanical species composition for vascular plants colonizing the slopes of three drilling pads constructed from gravel fill in NPRA are given in Table 10. The fewest number of species (three) was recorded for the slopes of the Inigok drilling pad, whereas there were seven and nine species, respectively, for the slopes of the Tunalik and Lisburne drilling pads.

The three seeded grass species and a natural grass colonizer (*Phippsia algida*) were the most common species colonizing the slopes of the Tunalik drilling pad. Two sedges (*Carex aquatilis* and *Eriophorum scheuchzeri*) and a forb (*Stellaria humifusa*) were the other species found in sufficient numbers to appear in the data (Table 10). The number of naturally invading species (four) for the pad slopes was less than found on the non-insulated pad (seven), but greater than on the insulated pad surfaces (two) at Tunalik. Two seeded grasses (*Arctagrostis latifolia* and *Festuca rubra*) and *Equisetum arvense* were the dominant vascular plants colonizing on the slopes of the Inigok drilling pad.

Five forb and four grass species were the prominent colonizers on drilling pad slopes at the Lisburne exploration site. A seeded grass (*Festuca rubra*) was the dominant vascular species, followed by a forb colonizer (*Epilobium latifolium*). Other colonizing forbs included *Astragalus alpinus* ssp. *alpinus*, *Aster sibiricus*, *Oxytropis deflexa*, and *Epilobium*

*Table 10. Plant species composition on the slopes of gravel pads at three exploratory drilling sites in NPRA sampled in July 1991, with the walking-point method.*

| Vascular Plant Species | Composition Percentage |
|---|---|
| **Tunalik Test Wellsite No. 1** | |
| *Arctagrostis latifolia* | 39.6 |
| *Festuca rubra* | 28.8 |
| *Poa glauca* | 21.6 |
| *Phippsia algida* | 4.5 |
| *Carex aquatilis* | 3.6 |
| *Eriophorum scheuchzeri* | 0.9 |
| *Stellaria humifusa* | 0.9 |
| **Inigok Test Wellsite No. 1** | |
| *Arctagrostis latifolia* | 56.1 |
| *Festuca rubra* | 40.9 |
| *Equisetum arvense* | 3.0 |
| **Lisburne Test Wellsite No. 1** | |
| *Festuca rubra* | 61.5 |
| *Epilobium latifolium* | 15.6 |
| *Astragalus alpinus* ssp. *alpinus* | 9.2 |
| *Poa glauca* | 3.6 |
| *Agropyron boreale* | 2.8 |
| *Arctagrostis latifolia* | 2.8 |
| *Aster sibiricus* | 1.8 |
| *Oxytropis deflexa* | 1.8 |
| *Epilobium angustifolium* | 0.9 |

*angustifolium*. The grasses recorded on the slopes of the Lisburne drilling included the other two seeded species and a natural colonizer (*Agropyron boreale*) (Table 10). This was less than half the number of prominent species colonizing the insulated pad surface at Lisburne.

### *Fertilizer Influences on Botanical Composition*

A striking change in plant species composition was found on the Tunalik airstrip where fertilizer had been spilled in 1982. There were fertilizer pellets still present on the surface of the gravel in July 1991 where fixed-wing aircraft had been loaded with fertilizer. Dense stands of *Tanacetum bipinnatum* and *Descurainia sophioides* developed where fertilizer was spilled (Fig. 11). These two forbs out-competed *Sagina intermedia* and *Phippsia algida*, which otherwise dominated portions of the surface of the insulated airstrip that were neither seeded nor fertilized.

## Plant Cover

The basal and canopy cover data for three NPRA sites are listed in Appendix C. Table 11 contains a summary of the data by categories representing various biological and mineral types. These two cover types were acquired by separate methods (the basal, by point sampling and the canopy, by Daubenmire plot estimates), and they should not be considered equivalents. Because litter was estimated separate of plant canopy cover, total biological cover exceeded 100% in some instances. Canopy cover always exceeded basal cover for live vascular plants. Dominance varied among habitats and sites for other biological categories, but canopy cover always exceeded basal cover for all the biological categories combined ("total biological"). Mineral cover, which was listed under canopy cover for convenience of distinguishing between the two sampling methods, was measured to document the relative surface area of rocks versus that for bare soil.

Live vascular canopy cover ranged from 6.9% on the insulated pad at Inigok to 46.3% on the slopes at Lisburne. It was lowest for the insulated pads (6.9% to 16.4%) and highest for the slopes (30.3% to 46.3%) at each site. Total biological canopy cover ranged from 20.9% on the insulated pad at Lisburne to 114.3% on the slopes at Inigok. Values followed the same pattern as for live vascular canopy cover: the lowest were recorded for the insulated pads (20.9% to 67.2%), and the highest for the slopes (79.3% to 114.3%) at each site.

Live vascular basal cover ranged from 3.3% for the insulated pad at Lisburne to 13.8% for the slopes at Tunalik. As with canopy cover, it was highest (6.1% to 13.8%) for the slopes at each site. The lowest live vascular basal cover values at Lisburne and Tunalik were the same as for canopy cover of the insulated pad (3.4% to 5.7%); but at Inigok, the lowest value (3.4%) was on the non-insulated pad. Total biological basal cover ranged from 19.6% on the insulated pad at Lisburne to 97% on the slopes at Inigok. As with the canopy cover, total biological cover was lowest (19.6% to 64.8%) for the insulated pad at each site and highest for the slopes at Inigok (97%) and Lisburne (46.8%). At Tunalik, however, total biological cover was highest for the non-insulated pad (78.6%), rather than the slopes (73.4%).

Basal and canopy cover values for the moss, rock, and bare categories in Table 11 were obtained by two different sampling techniques, i.e., basal from the walking-point method and canopy from the Daubenmire method. Moss cover ranged from less than measurable on the pad slopes at Inigok to 68% on

*Table 11. Listing of basal and canopy cover data for three NPRA drilling pads sampled during July 1991. Basal cover was obtained from walking points, canopy cover from the Daubenmire frame. Figures in this table were summarized from Appendix B.*

| | Insulated Pad | | Non-Insulated Pad | | Pad Slopes | |
|---|---|---|---|---|---|---|
| **Cover Type** | **Basal** | **Canopy** | **Basal** | **Canopy** | **Basal** | **Canopy** |
| **Tunalik Test Well No. 1 Drilling Pad** | | | | | | |
| Live Vascular | 5.74 | 16.43 | 8.93 | 19.87 | 13.76 | 30.31 |
| Moss | 39.34 | 26.63 | 50.89 | 48.66 | 5.50 | 1.56 |
| Lichen | 7.38 | 3.33 | 0.00 | 0.22 | 0.00 | 0.00 |
| **Total Living** | **52.46** | **48.39** | **59.82** | **68.45** | **19.26** | **31.87** |
| Litter | 12.30 | 18.35 | 15.18 | 8.04 | 54.13 | 47.29 |
| Feces | 0.00 | 0.50 | 3.57 | 2.23 | 0.00 | 0.52 |
| **Total Dead** | **12.30** | **18.85** | **18.75** | **10.27** | **54.13** | **47.81** |
| **Total Biological** | **64.76** | **67.24** | **78.57** | **79.02** | **73.39** | **79.68** |
| Rock | 18.85 | 20.16 | 8.04 | 6.80 | 11.01 | 7.29 |
| Bare | 16.39 | 9.48 | 13.39 | 22.16 | 15.60 | 16.44 |
| **Total Mineral** | **35.24** | **29.64** | **21.43** | **28.96** | **26.61** | 23.73 |
| **Inigok Test Well No. 1 Drilling Pad** | | | | | | |
| Live Vascular | 4.33 | 6.88 | 3.40 | 13.82 | 6.06 | 35.36 |
| Moss | 43.29 | 40.21 | 68.03 | 63.76 | 0.00 | 4.11 |
| Lichen | 3.03 | 1.04 | 2.04 | 1.32 | 1.52 | 0.00 |
| **Total Living** | **50.65** | **48.13** | **73.47** | **78.90** | **7.58** | **39.47** |
| Litter | 8.23 | 16.25 | 19.73 | 24.84 | 89.39 | 74.62 |
| Feces | 0.43 | 0.21 | 0.68 | 1.32 | 0.00 | 0.18 |
| **Total Dead** | **8.66** | **16.46** | **20.41** | **26.16** | **89.39** | **74.80** |
| **Total Biological** | **59.32** | **64.59** | **93.88** | **105.06** | **96.97** | **114.27** |
| Rock | 32.03 | 40.00 | 4.76 | 16.12 | 1.52 | 3.75 |
| Bare | 8.23 | 21.25 | 1.36 | 0.16 | 1.52 | 3.84 |
| **Total Mineral** | **40.26** | **61.25** | **6.12** | **16.28** | **3.04** | **7.59** |
| **Lisburne Test Well No. 1 Drilling Pad** | | | | | | |
| Live Vascular | 3.38 | 11.75 | | | 8.26 | 46.25 |
| Moss | 12.84 | 3.13 | | | 6.42 | 2.62 |
| **Total Living** | **16.22** | **14.88** | | | **14.68** | **48.87** |
| Litter | 3.38 | 6.00 | | | 32.11 | 30.38 |
| **Total Biological** | **19.60** | **20.88** | | | **46.79** | **79.25** |
| Rock | 52.70 | 34.25 | | | 35.78 | 30.50 |
| Bare | 27.70 | 50.23 | | | 17.43 | 5.13 |
| **Total Mineral** | **80.40** | **84.48** | | | **53.21** | 35.63 |

the non-insulated pad surface, also at Inigok. It was lowest on the pad slopes (0% to 6.4%) at each site. Where there were non-insulated portions of pads, at Tunalik and Inigok, moss cover was highest (48.7% and 68%). Moss cover was intermediate (3.1% to 43.3%) on insulated portions of pads.

As it should be, total mineral canopy and basal cover was inversely related to total biological cover. It was always highest on the insulated portions of pads (29.6% to 84.5%) and except for Tunalik, lowest on the slopes (3% to 53.2%) at each site. At Tunalik, total mineral cover was lower on the non-insulated portions of the pad (21.4%) than the slopes (23.7%).

### Photoplots

Among the three NPRA drilling locations studied,

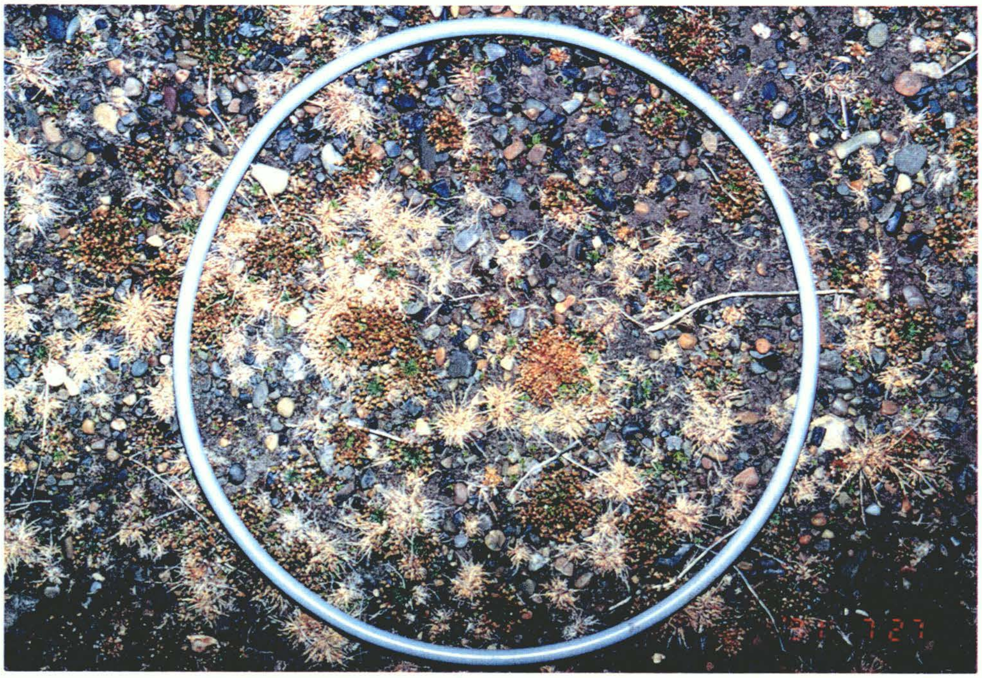

*Figure 11.* Phippsia algida *and* Sagina intermedia *colonizing most of the Tunalik airstrip (upper);* Tanacetum bipinnatum *and* Descurainia sophioides *on fertilized areas (lower) (27 July 1991).*

43 photopoints were established. Some of these were used for only one photo, while at others, several photos were taken of separate views from the same location. A total of 141 photo frames were used to record photoplot views for the three sites visited in 1991 (Table 12 and Appendix D).

At some locations, camera points of photos taken during previous years were relocated. Figures 12 through 14 are examples of current ground-level photos and those of a previous visit. Some oblique aerial views also provide useful information about changes that occurred at these sites over time. Figures 15 and 16 are examples of aerial oblique views that attempted to repeat the perspective of a previous photo.

Various kinds of information can be obtained from photopoints. Comparing the 1984 and 1991 views of the Inigok drilling site (Figs. 12 and 15) revealed that the water level in the reserve pit dropped and the vegetation aspect changed as the seeding on the pad aged. Figure 16 illustrates the Lisburne drilling site during drilling with the pad 12 years later. Photo records of recovery of vegetation on gravel source areas, such as the pad slopes in Figures 13 and 14, will possibly provide some of the most useful information on long-term aspect changes.

## Wildlife Observations

A number of wildlife species were either sighted or signs of their presence in the form of feces, feathers, hair, antlers, skeletons, grazing stubble, burrowing, etc. were recorded at the three NPRA drilling sites inventoried in 1991. Wildlife noted for these sites are listed in Table 13. The largest number of bird species (16) was recorded at the Inigok drilling pad, followed by Tunalik and Lisburne, with 14 and 10, respectively. Seven species of mammals were recorded during the survey (six at Inigok and Lisburne and four at Tunalik). Two species of fish were found, one each at Inigok and Lisburne.

### *Tunalik Wellsite*

It was stated that migratory waterfowl, shorebirds, and caribou frequent the Tunalik drilling site vicinity (ONPRA 1978). Evidence of caribou were observed during the 1984 visit, but no signs of waterfowl were seen at that time. In 1991, it was evident that geese had been at the location earlier in the growing season, and Pintail ducks were observed at the location. One female and ducklings were feeding in thermokarst pools on the surface of the drilling pad. These birds were sighted the evening before in another thermokarst pool at the east end of the airstrip. In a 24-hour period, they had apparently walked approximately 2 km across tussock tundra from the airstrip to the drilling pad.

Single caribou, as well as groups of 15 or more, moved through the area and across the pad during the site visit in 1991. The caribou made, and were observed using, a trail on the road (Fig. 17). Even though people were in sight, the caribou were often reluctant to leave the road or drilling pad. The reason for this could have been that those features were elevated and provided some insect relief for the animals (Curatola and Murphy 1983, Johnson and Lawhead 1989). Due to warm weather, insect populations were quite high during the 1991 visit.

Evidence of grazing at Tunalik included small-mammal use of *Carex aquatilis* and caribou and geese feeding on *Arctophila fulva, Arctagrostis latifolia, Carex aquatilis, Carex bigelowii, Eriophorum angustifolium, Eriophorum scheuchzeri*, and *Festuca rubra*.

### *Inigok Wellsite*

At Inigok, *Arctophila fulva* and *Carex aquatilis* leaf tips had been eaten by geese during early spring, mostly in the vicinity of the reserve and flare pits, and in thermokarst pools near the southwestern edge of the drilling pad. *Poa glauca* leaves were heavily grazed by caribou and geese on the sandy berms of the reserve

*Table 12. A listing, by site, of photopoints established and photos taken at three NPRA drilling pads during the 1991 field season.*

| Drilling Site in NPRA | Photopoints Staked | Number of Photos |
|---|---|---|
| Inigok Testwell No. 1 | 13 | 33 |
| Lisburne Testwell No. 1 | 16 | 59 |
| Tunalik Testwell No. 1 | 14 | 49 |
| Totals | 43 | 141 |

*Table 13. Listing of bird and mammal sightings (A) and signs (S) observed at three NPRA drilling sites during July 1991 field surveys.*

| Wildlife Species Common Name | Location: Tunalik Test Wellsite No. 1 | Location: Inigok Test Wellsite No. 1 | Location: Lisburne Test Wellsite No. 1 |
|---|---|---|---|
| **Birds** | | | |
| Long-billed Dowitcher | | A | |
| Greater Scaup | | A | |
| Oldsquaw | A | A | A |
| Northern Pintail | A | | |
| Steller's Eider | | A | |
| Unidentified Geese | S | S | |
| Pacific Loon | | A | |
| Glaucous Gull | A | A | |
| Long-tailed Jaeger | A | A | |
| Parasitic Jaeger | A | | |
| Lapland Longspur | A | A | A |
| Short-eared Owl | A | | |
| Snowy Owl | A | | |
| Red-necked Phalarope | | A | A |
| Lesser Golden-Plover | A | A | |
| Semipalmated Plover | | | A |
| Say's Phoebe | | | A |
| Willow Ptarmigan | | S | S |
| Common Raven | A | | |
| Semipalmated Sandpiper | A | A | A |
| Common Snipe | | A | |
| Swamp Sparrow [1] | | | A |
| Surfbird | A | | |
| Arctic Tern | A | A | |
| Northern Wheateater | | | A |
| Small brown bird (unidentified) | | A | A |
| Total Birds (24) | 14 | 16 | 10 |
| **Mammals** | | | |
| Caribou | A | S | A |
| Lemming | S | S | A |
| Fox | | S | |
| Wolf | | S | S |
| Moose | | | A |
| Grizzly Bear | S | S | A |
| Ground Squirrel | S | S | A |
| Total Mammals (7) | 4 | 6 | 6 |
| **Fish** | | | |
| Lake trout | | S | |
| Grayling | | | A |
| Total Fish (2) | | 1 | 1 |

[1] This bird was identified by Dr. M.A. Fosberg, who studied it for a considerable time and realized that this species was out of its natural range. He hesitated making the call and knew at first glance young Lapland Longspurs resemble the Swamp Sparrow, but this bird lacked the white tail markings for the longspur. We are supporting Dr. Fosberg's decision and including it in this listing.

*Figure 12. Photopoint #8 at Inigok: 10 July 1984 (upper) and 17 July 1991 (lower)*

*Figure 13. The Lisburne drilling site from Photopoint #2, located at edge of road connecting airstrip and the drilling pad. The upper photo was taken 8 August 1979, and the lower photo was taken 22 July 1991.*

*Figure 14. A material site along a creek near the Lisburne drilling site. The upper photo shows the area on 8 August 1979; the lower on 22 July 1991.*

*Figure 15. Aerial oblique of Inigok drilling site from the northeast side. The upper photo was taken on 4 August 1982, while the lower was taken on 17 July 1991.*

*Figure 16. Aerial oblique of the Lisburne drilling site. The upper photo was taken on 8 August 1979; the lower on 22 July 1991.*

pit. Lemmings had heavily grazed leaves of *Carex aquatilis*, *Dupontia fisheri*, and *Festuca rubra* during winter in the thermokarst areas of the non-insulated portions of the drilling pad. Lemming feces covered the surface in these depressions. Ptarmigan had fed on florets of *Festuca rubra* during the winter. Feces from these birds were concentrated mostly on the non-insulated pad opposite the wellsite, but were also observed over the entire drilling site.

Ground squirrels had burrowed extensively in the vicinity of the wellhead, and there were signs that bear had attempted digging ground squirrels from their burrows. Evidently the bear did not get all of the squirrels, because several of the burrows had been repaired. Some large animal, possibly a bear, had been rubbing on the surface of the reserve pit muds. It may have been the presence of the ground squirrels that attracted the bear to this location.

Loons and ducks, including ducklings, were swimming in the reserve pit when the project team first arrived. The loons seemed more wary of human presence and moved to the lake, but the ducks remained in the reserve pit pond. Two pair of Arctic Terns were obviously nesting in the vicinity of the wellhead; one was usually perched on the wellhead and seemed to be on the lookout for intruders. Whether or not the loons were nesting in the vicinity was not determined.

#### *Lisburne Wellsite*

Evidence of wildlife foraging at Lisburne included stripping of willow leaves (*Salix alaxensis* and *Salix planifolia* ssp. *pulchra*) which formed stands along the margins of the wet sedge meadow, downslope from the drilling pad. This willow browsing may have been by moose and/or caribou. Grazing had also removed portions of *Carex aquatilis* and other graminoids in the wet sedge meadow. Near the upslope edge of the pad, a bear had fed on the leaves of grasses and sedges. Where ground squirrels inhabited the drilling pad, they had grazed the leaves of the seeded grasses.

At the Lisburne location, a group of about 25 caribou moved across the hillside above the drilling pad on 21 July 1991, and a geological crew camped at the airstrip informed us that approximately 200 head were grazing around the drilling pad on either 19 or 20 July 1991. On 21 July 1991, a grizzly bear traveled across the hillside above the Lisburne drilling pad, and on 22 July a bull moose was observed in the willow stands downslope from the drilling pad.

### Evidences of Human Uses at Locations

The majority of project observations of human uses were from NPRA sites during the 1991 survey. When the sites in the Sagavanirktok River valley were examined, recording evidences of human uses was not a priority.

The greatest use of sites along the Trans-Alaska Pipeline route was by maintenance personnel tending to operational activities of the pipeline itself. There was evidence of excavation, backfilling, and subsequent seeding and fertilizing of the area near M.P. 17.8. There may have been excavation work at M.P. 19 also. It was difficult to explain why there was vegetation only around the inspection tubes and route markers at that location, unless the intervening areas had been disturbed in the recent past. However, it may have been a vegetation response strictly associated with seed and snow accumulations around the markers and tubes. A large amount of equipment was stored at the Franklin Bluffs Camp Pad for seismic work. A generator was running, and there was evidence that caretakers were in the vicinity to maintain equipment and guard against vandalism of the camp and equipment. There is a pullout on the Dalton Highway at the Franklin Bluffs site, and vehicles frequently can be observed stopping there. Traffic in the area usually consisted of heavy and light trucks supporting the coastal oil production facilities and the pipeline. A few private vehicles have been observed on the Dalton Highway, and the number seems to be increasing each year. In recent years, tour buses from Fairbanks and Anchorage travel the route, but they did not appear to be stopping at the Franklin Bluffs location. There is a litter barrel at that location, and it is sometimes overflowing with garbage.

Another human use that seems to be growing sharply in this vicinity of the Dalton Highway is hunting. Even though there are restrictions on hunting near the road, evidence of violations are clear. During seed-collecting near the road in 1989, three hunting arrows that had been shot and lost by hunters were found. Vehicles were often pulled off at the gravel sites along this route, and camping is commonplace, particularly during the bow-hunting season. These people leave debris in the form of food and packaging, drink containers, and related objects.

#### *Tunalik Wellsite*

At the Tunalik location there was no evidence of aircraft use on the airstrip during the 1991 growing season. The only signs of human activity occurring since the site was abandoned was a shovel presumably left by the USGS field party that surveyed the site in 1989 and 1990. Ground-control markers remained from the aerial photographing activities.

#### *Inigok Wellsite*

While sampling was ongoing at the Inigok drilling site in 1991, a hunting guide was forced to land one night due to poor weather conditions. The guide slept on the abandoned camp pad and departed in the morning when the weather improved. There is a cabin, constructed from materials that appeared to have come from the former Husky NPR-A Operations, Inc. camp, and an aluminum boat near the lake. These are reputed to be owned by a Barrow resident, who claims traditional hunting and fishing rights to the area. There were three-wheeler vehicle tracks, which had been made during the 1991 growing season, on the road and drilling pad. Spent shotgun and rifle casings were also found in the vicinity, indicating either target practice or actual hunting of waterfowl and wildlife that periodically occupy the locale. Stakes on the pad were assumed to mark sampling locations used by the USGS crews in 1989 and 1990, and ground-control markers for aerial photography were found.

#### *Lisburne Wellsite*

At Lisburne, a summer camp for a geological party working in the region in 1991 was located on the airstrip apron. A tent camp, which was secured against bear by a fence, was set up. On at least two occasions, while they were in camp due to inclement flying weather, individuals from the camp either hiked or rode four-wheelers from the camp to the Lisburne pad to investigate our presence. There was no other evidence of human use on the pad.

## DISCUSSION

### Gravel Conditions

Gravel types vary visibly across the Alaska North Slope. Those near the foothills contain large, angular stones; the Lisburne pad is a good example of this gravel type (Fig. 18). The fines among these stones are often less sandy than fines in gravel nearer the seacoast and distant from the mountains. Stones in gravel near the seacoast are smaller and more rounded that those in the foothills, and are decidedly more polished, such as those on the Tunalik drilling pad (Fig. 18). Gravel along streams varies in fine contents depending on location in the stream bed. In some places accumulations of fines are large, while in others, the fines have been removed by either water or wind. These variations affect the capacity of the gravel to hold water and nutrients for root uptake.

The failure to verify a relationship between vegetation productivity and the percentages of fines in gravel samples from the Trans-Alaska Pipeline corridor and Franklin Bluffs Camp pad was probably caused by confounding effects from compaction and texture of fines. At M.P. 34, the area with relatively high plant populations had the same fine content (31%) in gravel compared to the area where little plant growth was occurring. However, the unproductive gravel was compacted, and the productive was not. In addition to compaction, there were variations in the texture of the fine materials. Fines consisting mostly of sands will not be as effective in holding water and nutrients as those with higher proportions of silt, clay, and organic matter (Knabe 1965). In the more productive areas at M.P. 34, silt and organic matter contents appeared to be greater in the gravel fine fraction than in the less productive portions of the gravel. Other physical and chemical factors in these gravels may also be contributing to the conditions limiting plant colonization on these gravel sites. Time since disturbance should also not be overlooked as a contributing factor. Recent traffic may have deprived plants from portions of the site.

Soil salt concentration can also affect productive capacity. Salinity, through osmotic potential, amplifies xeric conditions by decreasing the availability of water for uptake by plant roots. The positive relationship between soil salinity and plant cover at East Dock illustrated this factor (Fig. 19). Soil salinity was initially not a suspected problem at the East Dock rehabilitation site, but salts eventually proved an inherent part of the overburden that was used to cover this reserve pit. It is not unusual for subsurface soil in this region to contain salts. Many of these soils formed from alluvium affected by seawater in the geological development of the landscape. After the sea receded, salts were leached downward in the profile and accumulated in subsurface deposits. Consequently, when the saline layers were deposited to the surface of the East Dock site, they furnished an undesirable rooting medium for vascular plants. Presumably, these salts will eventually either leach from the root zone or dissipate laterally at the East Dock rehabilitation site, and the conditions for plant growth will improve.

*Figure 17. Caribou using the trail on the road between the Tunalik airstrip and drilling pad (25 July 1991).*

*Figure 18. Coarse, angular gravel on the surface of the Lisburne drilling pad (upper) compared to polished, fine gravel fill used for construction at the Tunalik drilling pad (lower).*

*Figure 19. Grass stand unevenness on East Dock fill, from variations in soil salinity (upper) and microrelief (lower) (8 September 1989).*

The positive relationship between soil nitrogen and plant cover supports the theory that fertilizer was not uniform at East Dock. However, the nonsignificant relationship in available soil phosphorus does not support this theory. Typically, alkaline soils at Prudhoe Bay that test greater than 4 or 5 mg/kg available phosphorus have been affected by artificial applications of that element. Thus, the 15 mg/kg value for the bare sites indicates fertilizer had been applied to those areas.

There is evidence at East Dock that seed and fertilizer may have been redistributed after application. Most of the bare areas appeared to be on the upper portions of the microtopography at this pad (Fig. 19). Often those areas were very hardened and resistant to the sampling corer. These elevated areas appeared dry on the surface and undoubtedly shed water to the lower-lying microsites. Because nitrogen moves easily with water, it may have been redistributed in that manner. Phosphorus is less mobile than nitrogen in soils (Tisdale and Nelson 1956) and may be redistributed with water less easily than the nitrogen fertilizer.

Another aspect to the East Dock gravel fill likely influenced vegetation growth. It was learned from a security guard that the contractor hired to backfill the pits had difficulty with trucks becoming mired in the loose gravel and overburden. To overcome that problem, the fill was compacted to support truck and equipment traffic, a process that would negatively affect plants seeded on the site.

Insulation used between the gravel fill and underlying tundra to help maintain thermal stability and physical strength of some pads markedly affected the kinds of plant communities forming after the NPRA sites were abandoned. The non-insulated portions of pads developed thermokarst depressions which were subsequently invaded by moss and indigenous vascular plants. This is illustrated in Figure 20, which shows the insulated and non-insulated portions of the Tunalik pad. These thermokarst depressions were also attractive to lemmings, which developed colonies during the winter and fed on the seeded and volunteer vegetation. These plants produced shoots that probably were more succulent than those produced on the drier, insulated portions of the pads. Higher moss cover was also found on the non-insulated portions of the NPRA pads than the insulated portions.

## Bulk Density

Compaction of gravel fill used for roads and pads reduces the pore space in gravel. For some soils, moderate compaction improves conditions for plant growth because it reduces the size of voids among the particles and increases the retention of water. However, too much compaction reduces the total volume of air spaces in the fill to the point that movement of water and air in and out of the gravel is highly restricted. Conditions for plant roots deteriorate when that occurs.

The soil moisture and bulk density data from these sites could be used to explain some of the differences among habitats within the gravel fill and between gravel fill and adjacent tundra. A bulk density of 1.2 $g/cm^3$ is typical for mineral cropland soils, and organic soils will be less than half that. A bulk density of 1.2 $g/cm^3$ provides a pore space about equal to 50% of the soil volume, as a rule (Lucas 1982). When compaction is greater than that, moisture and air movement in and out of soil is restricted, and plants can become stressed. Some of our gravel bulk densities were greater than 2.0 $g/cm^3$. However, these data were not corrected for large amounts of gravel, which should have a mean bulk density of 2.6 $g/cm^3$; without such corrections, bulk density would be biased upward.

The bulk density of upland tundra soil at Inigok was 0.5 and 0.6 $g/cm^3$, indicating a very porous material relatively rich in organic matter. The high moisture levels found in these soils supported that conclusion. Where soils contain large amounts of organic matter, greater pore space and usually better nutrient holding capacities exist. As a consequence of these differences in substrate, it is unreasonable to expect gravel fill to support the level of biomass produced on adjacent tundra soils. Sparse stands of plants adapted to xeric substrates are probably all that can be expected until something is done to improve the root zone environment of the gravel. Limited soil moisture content alone is sufficient to deter plant production on gravel fill. Applications of fertilizer can elevate the nutrient conditions of gravel fill, but they cannot compensate for lack of available soil moisture and poor aeration.

## Water Electrical Conductivities

The electrical conductivity of water was a reliable indicator of possible contamination from drilling wastes because it measured the dissolved salts, which were the most mobile component in wastes from drilling (except for volatile substances that escaped into the atmosphere). Most of the dissolved salt was probably sodium chloride, which was used to condition the mud during the drilling operation. The sodium ions dispersed clays that constitute the matrix of the drilling mud. When the drilling wastes were exhausted into the reserve pit, this sodium chloride additive and other sodium-bearing substances accompanied those wastes. If the fluids subsequently escaped the reserve pit, the salts were the first potentially damaging elements to move, because they were in solution.

Measurement of water E.C. is a method for assessing where fluids from the drilling operation may have affected the surrounding environment at these locations. An indication of how site conditions are changing over time is presented by comparing the 1991 data with that reported by Pollen (1986) for the same locations during the 1984 site evaluation in NPRA. If the fluids are draining from the reserve pits and continuing to move salts away from the site, there should be a decline in the concentration of salts in reserve pits. At some distance beyond the reserve pit there would be a moving front of salts that is diminishing in concentration through dispersion.

The data indicated a general improvement (i.e., decline in salinity of water in the Tunalik reserve pit) which suggested annual flushing that occurs when meltwater flows through the pit and onto the adjacent tundra. That process is what killed the wet meadow tundra vegetation reported in the 1984 survey (McKendrick 1986). There was a marked increase in the salinity of water in the fuel pit at Tunalik, a direct result of the mixing of reserve pit fluids with meltwater accumulations in the fuel pit since 1984. The berm between the two pits was breached during the intervening period.

At the Inigok location, the reserve pit E.C. readings averaged higher in 1991 than in 1984 (3,860 vs. 2,900 µmhos/cm). This increase may be related to the marked drop in water level, which would reflect a loss of water and cause salt concentrations to increase, assuming there was a constant supply of salt dissolving from the drilling wastes. The salt:water ratio had to have been shifted in favor of the salt through some process that reduced only the water component (i.e., evaporation). The fuel pit water had a few more dissolved salts than in 1984, but it was still within the range of conductivities found in natural waters of the region. The berm between the reserve and fuel pits was intact in 1991, and it appeared to have prevented the saline water of the reserve pit from substantially altering the electrical conductivity of the water in the fuel pit. There was no change in the lake to the west of the site, and salinity for the inlet into the lake on the north declined (323 vs. 450 µmhos/cm). These waters were contaminated by reserve pit fluids, but the effects on lake water were not apparent in the E.C. data.

Elevated readings in water E.C. were noted in ponds near the reserve pit at the Inigok drilling pad in 1991. There was, however, no apparent flow of reserve pit fluids to these locations. It is most likely that these elevated readings were from fertilizer applied to the tundra next to the pad.

Water E.C. at the Lisburne site showed little change from 1984. The reserve pit water declined slightly, a relatively small change compared to that observed at the Tunalik location. It may indicate a very slow net movement of salts from the pit into the berm and then as seepage from the site into the intermittent stream below the pit. Conversations with USGS personnel after the 1991 field season indicate that such seepage is probably occurring, according to their data. In that case, the rate of salt movement is currently controlled sufficiently that the water conductivity downslope is similar to the background (364 vs. 331 µmhos/cm). The background level of dissolved salts in the intermittent stream at Lisburne was slightly higher than the background for Otuk Creek (331 vs. 230 µmhos/cm). These kinds of differences among water bodies in the region can also reflect varying natural conditions in the minerals of the watershed. Actually, the surface water in the Lisburne reserve pit is within the range of natural waters in this part of Alaska, although it is slightly higher than that of the two streams nearby.

### Areas Affected by Reserve Pit Leaks

There was general improvement between 1984 and 1991 in the vegetation cover at Tunalik and Inigok in the areas affected by reserve pit leaks. At Tunalik, *Senecio congestus* had colonized on the barren gravel washed from the berm.

Damaging properties of the fluid in the Inigok reserve pit must have diminished also during that period, because grass seedlings were emerging in the southwest margin of the pit. These may have been either *Arctophila fulva* or *Arctagrostis latifolia*, but they were too small for positive identification. Colonization by vascular plants was also occurring outside the reserve pit, where fluids had drained and killed the wet-sedge-meadow vegetation. Graminoids were the predominant colonizing species, and *Arctophila fulva* was the major contributor in the wettest microsites. Other wet-sedge-meadow species (*Eriophorum*


*Figure 20. Aerial oblique view of non-insulated (upper) and insulated (lower) portions of the Tunalik drilling pad on 24 July 1991.*

*vaginatum*, *Carex aquatilis*, and *Dupontia fisheri*) were also contributing to the recovery. *Hippuris vulgaris* was the prominent forb in the wettest portions. In some wet microsites, *Ranunculus gmelini* was usually noted with *Arctophila fulva* and *Hippuris vulgaris*, but this species was not generating biomass and cover comparable to the grass and *Hippuris*.

The water in small ponds in the leak-affected areas containing small fish, invertebrates, and *Arctophila fulva* at Inigok had a pH of 7.7 and an E.C. of 4,330 µmhos/cm. This indicates speculations in 1984 that salinity was a major cause of dead plants in these leak-affected areas were probably accurate. Salinity was still a problem, especially at the Inigok location, but dissipation over time by the salts was sufficient for plant species to recolonize portions of the area and for fish to survive in the lake water. This indicates that, should accidental leakages occur, the effects are naturally ameliorated in the long term.

At both Tunalik and Inigok, *Phippsia algida* was colonizing in some portions of the leak-affected areas. Since this grass species is often found in saline sands along the seacoast in this region of Alaska, finding it colonizing sandy soils affected by reserve pit fluids was not unexpected. The species was recorded in this habitat at Inigok in 1984 (McKendrick 1986) and again in 1991. Grass seedlings had also germinated in the highly saline water in the Inigok flare pit. These grass seedlings appeared to be *Puccinellia* spp., and they were living in water with E.C. of 13,790 µmhos/cm and a pH of 8.6. This level of salinity is comparable to that found in saline desert soils and is not typical for the Alaska North Slope, except possibly where seawater has flooded soils. The seedlings may have been *Puccinellia arctica*, which was recorded on the pad. These seedlings in the overflow area were not likely to survive as long as the pit continued to overflow and erode the channel in which they were germinating.

## Plant Species Composition

Finding 125 vascular plant species colonizing among the ten gravel pads examined was impressive. In addition to the seeded grasses, a few naturally invading species were widely distributed, but most "volunteers" occurred in relatively restricted patterns. *Epilobium latifolium* was one natural colonizer that occurred over a wide range of sites. Attached trichomes make seeds of this species easily wind-borne, which was probably partially the reason for its distribution. However, other vascular plants producing wind-borne seeds were among the colonizers, and they did not occur as widely as did *Epilobium latifolium*. Therefore, it must be concluded that habitat restrictions and adaptations were additional factors influencing the geographic distribution of these plants.

*Arctagrostis latifolia* was recorded on nine of the ten locations, *Festuca rubra* at eight, and *Poa glauca* at seven locations. All three of these grasses were included in seed mixtures planted at the sites, which had been rehabilitated. Records were difficult to verify for actual seeding amounts for each site in the NPRA, because mixtures were adjusted according the availabilities of seed at the time the rehabilitation was underway. It was believed that *Poa pratensis*, variety Nugget, was also usually included in some of these seed mixtures.

*Arctagrostis latifolia*, which is a common native grass in the tundra regions, often occurs on sites that are somewhat drier than the norm. It also responds to disturbances and can be found increasing in vehicle trails (McKendrick et al. 1978). However, among the seeded grasses, neither *Arctagrostis latifolia* nor *Festuca rubra* had the drought tolerance of *Poa glauca*. This was evidenced by the survival pattern among these three grasses at the NPRA sites. *Poa glauca* persisted almost at the exclusion of the other two on the insulated surfaces of pads; they were the driest and most compacted habitats. *Arctagrostis latifolia* and *Festuca rubra* persisted on the slopes of the pad margins and on margins of pit berms. Those habitats were probably the more favorable among those of gravel fill, because the slopes were less compacted and possibly sheltered better by snow accumulations during winter. Standing dead was more dense and taller on pad slopes at most sites, compared to that on pad surfaces. *Poa pratensis* was unable to survive except in a few niches, i.e., thermokarst depressions on non-insulated portions of pads and as occasional clumps along the slopes of the Tunalik airstrip. It was usually heavily grazed if grazing occurred at all in the vicinity. This attested to that grass species' relatively high palatability, especially for geese.

The airstrips at the three NPRA locations had not been part of the 1984 investigation; and regrettably, we did not include them in our 1991 survey. Gravel fill for the airstrips was insulated and had remained stable since the exploratory drilling ended. At Tunalik, and perhaps at Lisburne and Inigok, it was the only gravel fill that had not been seeded and fertilized during the rehabilitation phase of site closure. However, at

Tunalik, the project camp was on the airstrip, and some rather significant features were observed that indicated the airstrips should be included in future sampling. *Phippsia algida* and *Sagina intermedia* were two very aggressive invading species on the Tunalik airstrip. From a distance, the Tunalik airstrip looked barren, but it was actually carpeted with these two vascular plant species. On similar gravel fill habitats where seeding and fertilizing occurred, neither of these species was found in significant numbers. This indicated that seeding and fertilizing may exclude some indigenous vascular plant colonizers from gravel fill. Along the margins of the airstrip, there were several indigenous vascular plants producing vigorous canopies that seemed to be capable of expanding their territories. These findings were evidence that there are indigenous plants in the region that can form stands even on relatively harsh substrates.

Lisburne had the greatest percentage of forb colonizers of the three pads examined in NPRA in 1991 on both the pad surface (15% vs. about 2%) and the slopes (29% vs. about 4%). Prominent forb colonizers at Lisburne were: *Epilobium latifolium, Astragalus alpinus* var. *alpinus, Papaver macounii, Androsaceae septentrionalis,* and *Aster sibiricus.*

The species found dominating gravel fill should be considered for vegetating abandoned gravel pads and roads, but it is important to be mindful of geographic distribution of these species. Those developing well in the Lisburne area were not prominent in the coastal sites, and vice versa. *Poa glauca* and *Festuca rubra* were the top-ranking seeded grasses on insulated pads at Tunalik and Inigok; but at Lisburne, the seeded *Festuca rubra* was outranked by *Agropyron boreale*, a natural invader on the insulated pad. Nearer the coast, on pad slopes at Tunalik and Inigok, *Arctagrostis latifolia* and *Festuca rubra* were the top colonizers, followed by *Poa glauca* among the seeded grasses. However, farthest from the coast at Lisburne, *Festuca rubra* was the most common grass, followed by *Poa glauca. Arctagrostis latifolia* rated in third place and was equal to *Agropyron boreale.*

### Plant Cover

Plant cover is generally used to indicate dominance of species or growth forms. Within the open stands on gravel pads in NPRA, there was a preponderance of moss cover, especially on non-insulated portions of the pad at Tunalik. This moss was not the sphagnum of bogs nor the species typically found in climax tundra. It was a small colonizing form that is often found forming carpets where moisture from the roof drains under the edges of buildings at Prudhoe Bay. In time, these colonies around buildings trap sufficient organic debris and fine soil particles to form a thin soil layer, which can be subsequently invaded by forbs and grasses. There was reason to believe that this soil trapping process was occurring in the thermokarst areas of the Tunalik and Inigok drilling pads, where the accumulation of organic matter from the moss itself and that trapped from the air was generating favorable conditions for higher plants. The practice of judging revegetation success only on the basis of vascular plant cover seems incongruous to the overall objective to improve tundra habitat conditions. Accumulations of moss cover on gravel fill should be an indicator of a positive trend for the community.

As one would expect, the basal cover means were less than the canopy cover means, because the space occupancy exhibited by vegetation is less at the base of the plant than in the canopy. If various components comprising the total biological cover ( i.e., litter, standing dead, and leaf canopy cover) are measured separately, it is possible to have more than 100% cover, which is what happened for some locations in this survey. The two cover-sampling techniques used in this study were not designed to measure the same parameters; therefore, the absolute values should not be compared. One is designed to measure canopy cover and the other one basal cover.

The walking-point data indicated vascular-plant basal cover was in the range of 3.5% to 8%, similar to grasslands, which typically produce <10% basal vascular plant cover. The canopy cover was probably less than for the surrounding tundra, even though cover was not measured on the tundra. Differences in cover among habitats on pads was believed to be an expression of variations in the quality of the substrate for providing moisture and nutrients to these plants.

Many of the grass plants on the insulated portions of the Inigok and Tunalik drilling pads appeared dry and almost dead in July of 1991. During the establishment years of 1981 and 1982, the seeding at Inigok was observed, and the grasses were green and vigorous, even though the stand was uneven. Part of this decline in succulence was probably due to natural maturation of the grass plants. Some thinning of the stand may have also been due to depleted supplies of nutrients, which had been augmented with fertilization at the time of seeding. However, monitoring of the fertility of fill is needed to verify that.

Rock cover on the surface of gravel pads was included in our measurements as a component of what is normally measured as bare ground, because rock represents surface that cannot support vegetation until becoming covered with either moss or soil. For short-range land-management considerations, the area of surface covered by rock will limit the amount of vegetation that a site can support. Therefore, when setting standards for evaluating vegetation goals on gravel fill, rock cover should be taken into account, and expectations possibly adjusted downward.

It was encouraging to observe that moss was beginning to cover the gravel stones in thermokarst depressions on the Inigok and Tunalik pads. This would, in time, produce a substrate in which vascular plants could take root. This is another reason for including moss in the evaluation of revegetation success in this region; i.e., it is a positive indicator of succession.

### Photoplots

There were relatively few photoplots that were retakes of earlier scenes in this area. However, those that were retaken in 1991 illustrated improvements in the vegetation cover at these sites. Natural colonization, as well as maturation of seeded stands, was occurring.

### Wildlife Observations

The largest number of birds sighted were at the Inigok location. There may be several reasons that site attracted more birds than others examined in the survey. Inigok occurs near the boundary of the Foothill and Coastal Plain physiographic provinces; therefore, birds preferring habitat provided by either region might be found there. The saline waters of the reserve pit with its sandy, sparsely vegetated berms provide a unique interim habitat not too different from the seashore (Fig. 21). More waterbirds were observed in the reserve pit when the project team arrived than in the adjacent lake system. Twenty-one mature ducks and five ducklings were counted at one time in the reserve pit. Part of the reason for the high bird use of the reserve pit may have been food supplies. On 19 July 1991, a number of Red-necked Phalaropes were observed feeding in a portion of the reserve pit next to the mud deposit, which still retained the odor of sulfur encountered during the drilling operations. There may have been a high population of insects associated with those muds, which were probably richer in mineral nutrients than the sandy soils common to the area. Invertebrates and plants had colonized within the reserve pit since 1984, and the water level of the pit had dropped due to erosion of the berm of the flare pit.

The proximity to the complex of deep-water lakes at Inigok also provided overwintering habitat for fish that loons fed upon. Lake trout were caught and examined in 1984 to determine if fluids leaking from the reserve pit into the lake had affected the fish. In 1991, trout fry that had probably been dropped by a bird on the drilling pad next to the reserve pit were observed, as well as live fish in a pool near the drilling pad. This indicated that reproduction of the lake trout was continuing in the lake even though reserve pit fluids had leaked into the lake.

At Inigok, winter feces of ptarmigan were found most often in areas where *Festuca rubra* was growing abundantly. Some of these feces contained the florets of *Festuca rubra*, indicating that the birds were feeding on this seeded grass. Feces and feathers of geese were abundant on the sandy berm of the reserve pit. It was evident that these birds had grazed heavily on the seeded grass *Poa glauca* and the naturally colonizing *Arctophila fulva*, both of which occurred near the reserve pit. The *Poa glauca* stand was suffering from excessive grazing and had failed to establish a continuous cover on the reserve pit berms due to the constant traffic and grazing by geese. Away from the reserve pit, this grass was not overgrazed. *Arctophila fulva* occurring abundantly in the flooded area next to the west margin of the reserve pit was heavily grazed, but the same species in pools on the opposite side of the drilling pad was not grazed. This indicated that the birds were attracted to the reserve pit and the sandy berms, which may have been warm resting areas. They fed on the grasses which were most available to them at that location and did not appear to seek forage from the same plant species when they were more distant from the reserve pit. Clearly, the geese selected habitat that offered more than just a supply of food, because the quantity of forage available along the margins of the reserve pit was less than that in most other areas around the drilling pad. The combination of sandy berms next to the water body of the reserve pit probably attracted the birds to this location, which served as a resting site during early breakup. Elevated ground adjacent to water seems to be preferred resting sites for geese.

Ground squirrels had burrowed extensively in the vicinity of the wellhead at Inigok. As were Red-necked Phalaropes, squirrels were also attracted to the sulfur-smelling drilling muds near the well itself. The amount of forage was unlikely to have been the attraction, because there was less plant colonization there than at other microsites. Also, burrowing may have been relatively easy in the drilling wastes.

Feces from lemmings covered the surface of the soil and moss layer in the thermokarst depressions on the non-insulated surface of the Inigok drilling pad. Presumably, these animals were attracted to the forage because it was available under snow cover that drifts into the depressions and because these plants were more succulent than those either in dry areas on the pad or in unfertilized locations. With concentrated grazing and defecating in these microhabitats, it would appear that the nutrient cycling rate was maintained at a higher level than on insulated portions of the pad, where grazing did not occur and standing dead of the grasses had accumulated. The combination of less available soil moisture and slower nutrient turnover on the insulated portions of the drilling pad resulted in distinct plant communities.

### Evidences of Human Uses at Locations

Since 1984, there has been an increase in wariness of caribou in the region along the Dalton Highway between the Brooks Range and the coast, according to observations and conversations with truck drivers. This response can be attributed to increased levels of hunting along that portion of the Dalton Highway, which seems to be a direct result of no longer restricting travel on the road. The checkpoint that was formerly near Mosquito Creek was effective in turning back people without vehicle permits. The checkpoint was moved to the Chandalar Shelf and enforcement became lax by 1987. In 1989, the checkpoint was no longer staffed during the summer. During late August and September, there are many private vehicles on the road, and hunters can be observed stalking caribou within sight of the road.

The changing behavior of caribou herds along the northern reaches of the Trans-Alaska Pipeline is most likely related to hunting pressure. Caribou in the oil fields do not show overt fear responses to humans, but those along the Dalton Highway do. When the pipeline was under construction, there was one occasion when traffic was held up to allow blasting in a section south of Franklin Bluffs. A number of people with the RATE project, including University of Alaska Fairbanks and other universities, employees of the U.S. Army Cold Regions Research and Engineering Laboratory, the U.S. Fish and Wildlife Service, and the U.S. Energy and Development Research Administration (now Department of Energy), observed a band of caribou grazing next to the blasting site. When the charges were set off, approximately 0.2 km of trench was opened, throwing debris into the air with a loud noise. The caribou essentially ignored the blast and continued grazing; a few lifted their heads, but none ran away. This lack of response to industrial activity is typical. As a rule, caribou in this region are not concerned with vehicles and structures associated with oil and gas production, but they do recoil from humans on foot.

In the 1991 survey of NPRA locations, the least amount of human activity was at Tunalik. The most frequent use of NPRA sites was at Inigok, where there was a cabin and boat. At Lisburne there is probably periodic seasonal use of the airstrip and apron as a base camp for geological surveys in the locale. Limited use of Tunalik is easy to understand, because there is little there in the way of wildlife or geological interest to attract humans. At Inigok there is relatively abundant seasonal occupancy of the area by migratory waterfowl and other wildlife, including lake trout. These are resources that would be attractive to humans. The Lisburne location is periodically used by caribou, moose, and bear, all of which could be inducements to bring humans to the location. There are grayling in the creek downslope from the drilling site. However, it is unlikely that the wildlife at Lisburne were responsible for most of the human visits to the area. Those wildlife resources are not unique to Alaska, and certainly the cost of travel to this remote site would be unjustified simply to hunt or fish. The attraction to Lisburne was the airstrip, which provided access via large fixed-wing aircraft. That meant supplies and equipment needed for large parties of field geologists could be located at this site. In other words, it increases the accessibility to a remote region which has value for geological purposes.

## CONCLUSIONS

### Water Electrical Conductivities

The salinity of the reserve pit at Inigok increased slightly between 1984 and 1991. There was no increase in salinity for the lakes near the drilling site, and salt concentrations had declined in the inlet water where the leakage from the reserve pit empties into the lake.

There was a net decrease in salinity of the reserve pit at Tunalik and in the area affected by leakage from the pit. This leakage initially killed vegetation in the

*Figure 21. Overgrazed berm on west side of Inigok reserve pit (17 July 1991).*

drainage. However, the effects from that initial damage have diminished since 1984, and vegetation has recolonized from the outer margins of the damaged area

The vegetation and water at the Lisburne location were apparently not adversely affected by the reserve pit fluids. The reserve pit water was within the background range for water in the region, but contained more dissolved salts than the adjacent steam and pools in thermokarst depressions.

Recolonization of vegetation and invertebrates in areas affected by reserve pit leaks at the Tunalik and Inigok locations was evidence that at least some drilling wastes do not permanently impact habitats in this region. It also provides evidence that under some conditions, biological recovery can begin in a relatively short time after fluids from reserve pits have leaked onto tundra sites.

### Plant Species Lists

A total of 125 indigenous vascular plant species were discovered colonizing the 11 gravel fill sites examined across the Alaska North Slope. The largest number of plant species (58) was found in 1991 on the Lisburne drilling pad in the foothills of the Brooks Range. The lowest number of species (four) was found on the Inigok drilling pad in 1984. No single vascular plant species was found colonizing all the sites.

### Botanical Species Composition and Cover

The use of fertilizer can have decided impacts on the composition of plant communities developing on gravel. The presence of *Descurainia sophioides* and *Tanacetum bipinnatum* on fertilizer spills at the Tunalik airstrip was evidence of that. There were also marked differences between the vegetation on the areas that were seeded and fertilized and those that were not.

Vascular plant canopy and basal cover were highest on the pad slopes, followed by the non-insulated pad surfaces, and were lowest on the insulated pad surfaces. Vascular plant basal and canopy cover were higher than moss cover on the pad slopes, but moss cover on the pad surfaces generally exceeded that of vascular plants by three to nine times. Moss is an important colonizer capable of improving the substrate conditions for higher plants in this region.

Among the species of grasses seeded, *Arctagrostis latifolia* and *Festuca rubra* survived best on the slopes of compacted gravel fill, and *Poa glauca* usually dominated the pad surfaces.

Among natural colonizers, *Agropyron boreale* is a promising grass for vegetating gravel fill in the foothills region. On the coastal plain, *Sagina intermedia* is a forb of importance, while *Epilobium latifolium* is a promising forb throughout the region. In the foothills, *Salix alaxensis* is a prominent colonizing shrub. *Salix glauca* and *Salix ovalifolia* were active colonizers at the Inigok and Sagavanirktok River delta sites, respectively.

The revegetation example at East Dock demonstrated that soil factors beyond the scope of usual considerations can substantially influence the success of vegetating gravel fill. These factors include using saline topsoil and inadvertently compacting the site.

### Wildlife Observations

Vascular plant species diversity was not always necessary for a habitat to be attractive to wildlife. For example, in the area around the reserve pit at Inigok, where plant species diversity was lowest of all sites examined, animal species diversity was the highest.

### Human Uses

Human attractions to sites may be related to the terrain features, presence and type of wildlife, economic resources, and recreational interests. Accessibility to formerly remote locations by vehicles and aircraft have been important factors at the NPRA locations and especially along the Dalton Highway. This accessibility and attendant increase in human use of areas must be considered when evaluating changes in habitats and biological resources at these locations.

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# Appendices

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|---|---|
| Appendix A: | Soil and Water Data |
| Appendix B: | Site Species List |
| Appendix C: | Species Conposition and Cover Data |
| Appendix D: | Photoplot Data |
| Appendix E: | NPRA Drilling Site Maps |

# APPENDIX A

## SOIL AND WATER DATA

Table A-1 presents substrate bulk density data for samples taken during July 1991 from exploratory wellsites in NPRA, Alaska. Table A-2 lists water temperature, pH, and electrical conductivities recorded at the three sites during the same period.

Table A-1. Substrate bulk density data for samples taken from three sites at NPRA, July 1991

| SAMPLE NO.*** | SITE | SOIL DESCRIPTION** | DEPTH | DATE | VOLUME (CC) | SAMPLE WT. + SACK FIELD | SAMPLE WT. + SACK OVEN DRY* | SACK WT. | GRAMS SAMPLE WEIGHT FIELD | GRAMS SAMPLE WEIGHT OVEN DRY* | GRAMS WATER | % WATER BY WT | BULK DENSITY OVEN DRY SOIL GRAMS/CC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 145 | INIGOK | PAD SITE #1, 2" OF INSUL. @ 24" DEPTH, SURFACE 1 | 0"-4" | 7/17/91 | 800 | 1738.0 | 1711.2 | 14.4 | 1723.6 | 1696.8 | 26.8 | 1.6 | 2.1 |
| 146 | INIGOK | PAD SITE #1, 2" OF INSUL. @ 24" DEPTH, SURFACE 2 | 0"-4" | 7/17/91 | 970 | 2154.4 | 2101.9 | 14.9 | 2139.5 | 2087.0 | 52.5 | 2.5 | 2.2 |
| 147 | INIGOK | PAD SITE #1, 2" OF INSUL. @ 24" DEPTH, SURFACE 3 | 0"-4" | 7/17/91 | 770 | 1855.5 | 1819.5 | 14.4 | 1841.1 | 1805.1 | 36.0 | 2.0 | 2.3 |
| 148 | INIGOK | SITE #2 WET AREA, RUN-OFF FROM RESERVE PIT | 0"-5" | 7/19/91 | 620 | 1269.0 | 1044.4 | 14.8 | 1254.2 | 1029.6 | 224.6 | 21.8 | 1.7 |
| 149 | INIGOK | UPLAND SITE #1 TUSSOCK TUNDRA, A1 & A2 | 0"-4" | 7/19/91 | 480 | 443.4 | 279.1 | 13.9 | 429.5 | 265.2 | 164.3 | 62.0 | 0.6 |
| 150 | INIGOK | UPLAND SITE #1 TUSSOCK TUNDRA, BW | 4"-7" | 7/19/91 | 380 | 355.8 | 202.2 | 14.4 | 341.4 | 187.8 | 153.6 | 81.8 | 0.5 |
| 151 | INIGOK | UPLAND SITE #1 TUSSOCK TUNDRA, OB | 7"-10" | 7/19/91 | 370 | 402.6 | 237.7 | 14.2 | 388.4 | 223.5 | 164.9 | 73.8 | 0.6 |
| 152 | INIGOK | PAD SITE #2, EAST 1/3 MIDDLE, UNINSULATED | 0"-5" | 7/19/91 | 540 | 1245.7 | 1175.6 | 14.2 | 1231.5 | 1161.4 | 70.1 | 6.0 | 2.2 |
| 153 | INIGOK | PAD SITE #2, EAST 1/3 MIDDLE, UNINSULATED | 10"-15" | 7/19/91 | 620 | 1264.6 | 1132.7 | 15.1 | 1249.5 | 1117.6 | 131.9 | 11.8 | 1.8 |
| 154 | INIGOK | PAD SITE #2, EAST 1/3 MIDDLE, UNINSULATED | 20"-25" | 7/19/91 | 620 | 1337.9 | 1158.7 | 15.5 | 1322.4 | 1143.2 | 179.2 | 15.7 | 1.8 |
| 155 | INIGOK | PAD SITE #3, NORTHEAST PART OF PAD, UNINSULATED | 0"-6" | 7/19/91 | 690 | 1286.7 | 1228.1 | 15.3 | 1271.4 | 1212.8 | 58.6 | 4.8 | 1.8 |
| 156 | INIGOK | PAD SITE #3, NORTHEAST PART OF PAD, UNINSULATED | 10"-15" | 7/19/91 | 720 | 1252.6 | 1205.4 | 15.9 | 1236.7 | 1189.5 | 47.2 | 4.0 | 1.7 |
| 157 | INIGOK | PAD SITE #3, NORTHEAST PART OF PAD, UNINSULATED | 18"-23" | 7/19/91 | 640 | 1148.3 | 1062.6 | 14.7 | 1133.6 | 1047.9 | 85.7 | 8.2 | 1.6 |
| 158 | INIGOK | PAD SITE #4, 2" OF INSUL. @ 24" DEPTH, W. OF PIT | 0"-5" | 7/19/91 | 610 | 1338.6 | 1316.8 | 14.3 | 1324.3 | 1302.5 | 21.8 | 1.7 | 2.1 |
| 159 | INIGOK | PAD SITE #4, 2" OF INSUL. @ 24" DEPTH, E. OF PIT | 0"-6" | 7/19/91 | 910 | 1821.4 | 1730.2 | 14.6 | 1806.8 | 1715.6 | 91.2 | 5.3 | 1.9 |
| 160 | LISBURNE | UPPER PAD, 2 1/2" OF INSUL. @ 24" DEEP, SURFACE 1 | 0"-4" | 7/23/91 | 430 | 824.2 | 793.2 | 13.6 | 810.6 | 779.6 | 31.0 | 4.0 | 1.8 |
| 161 | LISBURNE | UPPER PAD, 2 1/2" OF INSUL. @ 24" DEEP, SURFACE 2 | 0"-4" | 7/23/91 | 790 | 1773.4 | 1701.4 | 14.1 | 1759.3 | 1687.3 | 72.0 | 4.3 | 2.1 |
| 162 | LISBURNE | UPPER PAD, 2 1/2" OF INSUL. @ 24" DEEP, SURFACE 3 | 0"-4" | 7/23/91 | 490 | 1075.4 | 1022.9 | 13.9 | 1061.5 | 1009.0 | 52.5 | 5.2 | 2.1 |
| 163 | LISBURNE | WELL PAD, 6" OF INSUL. @ 24" DEPTH, SURFACE 1 | 0"-4" | 7/23/91 | 420 | 1078.9 | 1021.0 | 14.7 | 1064.2 | 1006.3 | 57.9 | 5.8 | 2.4 |
| 164 | LISBURNE | WELL PAD, 6" OF INSUL. @ 24" DEPTH, SURFACE 2 | 0"-4" | 7/23/91 | 700 | 1374.1 | 1311.1 | 14.0 | 1360.1 | 1297.1 | 63.0 | 4.9 | 1.9 |
| 165 | LISBURNE | WELL PAD, 6" OF INSUL. @ 24" DEPTH, SURFACE 3 | 0"-4" | 7/23/91 | 690 | 1569.6 | 1503.3 | 13.7 | 1555.9 | 1489.6 | 66.3 | 4.5 | 2.2 |
| 166 | TUNALIK | INSUL. PAD, 2" OF INSUL. @ 24" DEPTH, SURFACE 1 | 0"-4" | 7/25/91 | 490 | 975.2 | 939.4 | 14.4 | 960.8 | 925.0 | 35.8 | 3.9 | 1.9 |
| 167 | TUNALIK | INSUL. PAD, 2" OF INSUL. @ 24" DEPTH, SURFACE 2 | 0"-4" | 7/25/91 | 550 | 1112.5 | 1074.4 | 14.6 | 1097.9 | 1059.8 | 38.1 | 3.6 | 1.9 |
| 168 | TUNALIK | INSUL. PAD, 2" OF INSUL. @ 24" DEPTH, SURFACE 3 | 0"-4" | 7/25/91 | 520 | 1055.3 | 1031.1 | 14.3 | 1041.0 | 1016.8 | 24.2 | 2.4 | 2.0 |
| 169 | TUNALIK | UNINSULATED PAD, SURFACE 1 | 0"-4" | 7/25/91 | 420 | 819.2 | 739.8 | 14.3 | 804.9 | 725.5 | 79.4 | 10.9 | 1.7 |
| 170 | TUNALIK | UNINSULATED PAD, SURFACE 2 | 0"-4" | 7/25/91 | 520 | 1118.6 | 1050.8 | 14.4 | 1104.2 | 1036.4 | 67.8 | 6.5 | 2.0 |
| 171 | TUNALIK | UNINSULATED PAD, SURFACE 3 | 0"-4" | 7/25/91 | 430 | 868.3 | 797.7 | 16.0 | 852.3 | 781.7 | 70.6 | 9.0 | 1.8 |

* Samples were oven dried at 105 degrees C. for 48 hours in the original, opened and rolled-down field collection sacks.

** Information on insulation and depth of installation is from the design and construction report by Husky Oil, 1983.

*** Sample numbers are prefaced by "JDM91S---"

| Table A-2. Listing of water temperature, pH, and electrical conductivities recorded at three Tunalik, Inigok, and Lisburne test wellsites during July 1991. | | | | | |
|---|---|---|---|---|---|
| Date | Temperature °C | pH | E.C. (μmhos/cm) | Location | Notes |
| Tunalik Test Wellsite No. 1 | | | | | |
| 25 Jul | 13.0 | 7.7 | 513 | Fuel pit | |
| 25 Jul | 12.7 | 7.7 | 503 | Reserve pit | |
| 25 Jul | 17.0 | 8.5 | 587 | Below reserve pit breach, leak-affected area | |
| 25 Jul | 18.0 | 6.6 | 1,100 | Soil pit in wet leak-affected area | |
| 25 Jul | 17.1 | 7.0 | 105 | Pool along road upstream from wet leak-affected area | Up slope from exploratory pad |
| Inigok Test Wellsite No. 1 | | | | | |
| 17 Jul | 17.6 | 7.3 | 136 | Lake on north side of leak-affected area | |
| 17 Jul | 15.0 | 8.1 | 263 | Fuel pit | |
| 17 Jul | 15.0 | 8.3 | 3,320 | Reserve pit | |
| 19 Jul | 12.5 | 7.3 | 389 | Low area adjacent to road, east of pad and well | |
| 19 Jul | 11.9 | 8.3 | 324 | Deep frost crack 50 m from wellhead straight out on pad | Many copepods and algae in water |
| 19 Jul | 9.8 | 8.3 | 6,120 | Soil pit in leak-affected area | |
| 20 Jul | n/a | 7.6 | 771 | Pool near road east of pad | |
| 20 Jul | n/a | 7.8 | 406 | 25 ft east of pool near road east of pad | |
| 20 Jul | n/a | 7.6 | 519 | Trough on SE corner of pad | |
| 20 Jul | n/a | 7.8 | 368 | Second trough on SE corner of pad | |
| 20 Jul | n/a | 7.4 | 117 | Thermokarst pool on edge of tussock, SE corner | |
| 20 Jul | n/a | 7.0 | 336 | Thermokarst trough on SE side of pad | |
| 20 Jul | n/a | 6.6 | 304 | Soil pit in lowland control area | |
| 20 Jul | n/a | 7.3 | 224 | Small pool between lake and east edge of pad | |
| 20 Jul | n/a | 6.8 | 163 | Surface water in polygon basin near east edge of pad | |
| 20 Jul | n/a | 7.5 | 135 | Large lake east of pad | |
| 20 Jul | n/a | 7.4 | 208 | Polygon basin 200' from NE corner of pad | |
| 20 Jul | n/a | 6.9 | 549 | Polygon basin 50' from NE corner of pad | |
| 20 Jul | 5.2 | 6.9 | 815 | Thermokarst pool at NE corner of pad | |

| Table A-2. Listing of water temperature, pH, and electrical conductivities recorded at three Tunalik, Inigok, and Lisburne test wellsites during July 1991. | | | | | |
|---|---|---|---|---|---|
| Date | Temperature °C | pH | E.C. (µmhos/cm) | Location | Notes |
| 20 Jul | 3.5 | 7.3 | 1,035 | Ice wedge in photopoint NE corner of pad | |
| 20 Jul | 3.3 | 7.0 | 872 | Rusty ice wedge on N side of NE corner, 15' from photopoint | |
| 20 Jul | 8.8 | 7.3 | 891 | Maynard's photopoint | |
| 20 Jul | 4.4 | 7.2 | 910 | Thermokarst pool 1/3 west of NE corner, near control "X" | |
| 20 Jul | 5.2 | 7.2 | 973 | Thermokarst pool near pool 35' west of NW edge of pad | |
| 20 Jul | 7.2 | 7.2 | 488 | Thermokarst pool on N end of pad at toe of gravel near insulated portion of pad | Looks bad, but not too hot (salty). |
| 20 Jul | n/a | 8.0 | 323 | Inlet to lake, leak-affected area | |
| 20 Jul | n/a | 7.8 | 5,490 | Stagnant pool in leak area | |
| 20 Jul | n/a | 7.7 | 4,330 | Stagnant *Arctophila* pool in leak area | Invertebrates and small fish in water |
| 20 Jul | 9.7 | 8.6 | 13,790 | Stagnant pool in flare pit | *Puccinellia* seedlings in mud |
| 20 Jul | 9.6 | 8.3 | 4,400 | Reserve pit, NW corner | |
| 20 Jul | 10.0 | 7.8 | 2,100 | Pool on W side of pit next to lake | *Arctophila* and *Hippuris* present |
| 20 Jul | 10.0 | 8.1 | 95 | Lake W of reserve pit | |
| 20 Jul | 10.6 | 8.8 | 971 | Pool SW of reserve pit | *Arctophila, Hippurus, Ranunculus* present |
| 20 Jul | 9.8 | 8.3 | 408 | Pool outside W edge of reserve pit berm | *Arctophila, Hippurus, Ranunculus* present |
| 20 Jul | 7.0 | 7.9 | 183 | Thermokarst Pool off SW corner of reserve pit berm | |
| 20 Jul | 8.1 | 7.8 | 232 | Thermokarst pool S of reserve pit | |
| 20 Jul | 8.3 | 8.1 | 309 | *Arctophila* pool outside fuel pit | |
| 20 Jul | 8.9 | 7.9 | 332 | *Arctophila* colony in fuel pit | |
| Lisburne Test Wellsite No. 1 | | | | | |
| 23 Jul | 11.1 | 7.4 | 331 | Stream above pad | |
| 23 Jul | 16.1 | 8.9 | 278 | Flare pit | |

| Table A-2. Listing of water temperature, pH, and electrical conductivities recorded at three Tunalik, Inigok, and Lisburne test wellsites during July 1991. | | | | | |
|---|---|---|---|---|---|
| Date | Temperature ° C | pH | E.C. (μmhos/cm) | Location | Notes |
| 23 Jul | 13.6 | 8.6 | 454 | Reserve pit | |
| 23 Jul | 10.1 | 7.7 | 364 | Stream below pad | |
| 23 Jul | 13.4 | 7.5 | 230 | Water in road culverts | |
| 23 Jul | 16.1 | 7.5 | 186 | Pool against upslope side SE corner of pad | |
| 23 Jul | 16.3 | 9.0 | 234 | Pool on upper pad near photopoint #12 | |

# APPENDIX B

## SITE SPECIES LISTS

Tables B-1 through B-3 list the plant species found during July 1991 in different habitats at three exploratory wellsites in NPRA, Alaska. Table B-4 lists all the species found colonizing the upper surfaces and side slopes on ten man-made gravel structures in the Alaska Arctic during surveys made in 1984, 1987, 1988 and 1991.

Table B-1. Listing of major plant species found in the area of Tunalik Test Well No. 1 in July of 1984 and 1991

| Plant Species | Wet Sedge Meadow | | | | Undisturbed Tussock Tundra | | Pad Surface | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Undisturbed | | Disturbed | | | | | Insulated | | Pad Slope |
| | | | | | | | | Yes | No | |
| | 1984 | 1991 | 1984 | 1991 | 1984 | 1991 | 1984 | 1991 | 1991 | 1991 |
| **Graminoids** | | | | | | | | | | |
| *Alopecurus alpinus* | | | | | T | | P | | | T |
| *Arctagrostis latifolia* | T | T | | P | P | T | P | P | P | P |
| *Arctophila fulva* | T | P | | P | | | P | P | P | |
| *Calamagrostis holmii* | | | | | P | | | | | |
| *Calamagrostis inexpansa* | | | | | | | | | | |
| *Carex aquatilis* | P | P | P | P | | P | P | P | P | P |
| *Carex bigelowii* | | | | P | | | | | | |
| *Dupontia fisheri* | P | P | | | T | | P | | P | |
| *Eriophorum angustifolium* | P | P | P | P | P | T | | | P | T |
| *Eriophorum scheuchzeri* | | P | | P | | | | P | P | P |
| *Eriophorum vaginatum* | T | P | T | P | P | P | P | | | |
| *Festuca rubra* | | | | P | | | P | P | P | P |
| *Hierochloa alpina* | P | | | | P | P | | | | |
| *Juncus biglumis* | P | | P | | | | | | | |
| *Luzula confusa* | P | T | | | | P | | | P | |
| *Luzula wahlenbergii* | P | T | P | | | P | P | | | |
| *Phippsia algida* | | | | P | | | P | P | P | P |
| *Poa arctica* | T | P | | | | T | P | P | P | P |
| *Poa glauca* | | | | | | | P | P | P | P |
| *Poa pratensis* | | | | | | | | | T | |
| **Shrubs** | | | | | | | | | | |
| *Arctostaphylos alpina* | | | | | | T | | | | |
| *Betula nana* | P | P | | | P | P | | | | |
| *Cassiope tetragona* | | | | | P | P | | | | |
| *Ledum decumbens* | T | T | | | P | P | | | | |
| *Rubus chamaemorus* | | T | | | P | P | | | | |
| *Salix brachycarpa ssp. niphoclada* | | | | | | | | | T | |
| *Salix glauca* | | | | | | | | | | T |

P = present; T = trace; blank = absent

Table B-1. (Cont.) Listing of major plant species found in the area of Tunalik Test Well No. 1 in July of 1984 and 1991

| | Wet Sedge Meadow | | | | Undisturbed | | Pad Surface | | | Pad |
|---|---|---|---|---|---|---|---|---|---|---|
| | Undisturbed | | Disturbed | | Tussock Tundra | | | Insulated | | Slope |
| | | | | | | | | Yes | No | |
| Plant Species | 1984 | 1991 | 1984 | 1991 | 1984 | 1991 | 1984 | 1991 | 1991 | 1991 |
| **Shrubs** | | | | | | | | | | |
| *Salix ovalifolia* | P | P | | | P | T | | T | P | T |
| *Salix planifolia ssp. pulchra* | T | T | T | | P | P | | | | T |
| *Vaccinium vitis-idaea* | T | T | | | P | P | | | | |
| **Forbs** | | | | | | | | | | |
| *Artemisia tilesii* | | | | | | | P | | | P |
| *Cerastrium beeringianum* | | | | | | | | T | | T |
| *Cochlearia officinalis* | | | | | | | P | P | P | |
| *Descurainia sophioides* | | | | | | | | P | | |
| *Draba corymbosa (macrocarpa)* | | | | | | | | P | | |
| *Epilobium angustifolium* | | | | | | | P | | | P |
| *Hippuris vulgaris* | | | | | | | | | P | |
| *Pedicularis sudetica* | P | | | | | | | | | |
| *Ranunculus gmelinii ssp. gmelinii* | | P | | P | T | | | | P | |
| *Sagina intermedia* | | | | | | | | P | P | P |
| *Saxifraga cernua* | T | | T | | | | | | | |
| *Senecio congestus* | | | | P | P | | P | P | P | |
| *Stellaria humifusa* | | | | | | | | | P | P |
| **Lichens** | | | | | | | | | | |
| *Alectoria nigricans* | | | | | | P | | | | |
| *Alectoria ochroleuca* | | | | | | P | | | | |
| *Cetraria spp.* | | | | | | P | | | | |
| *Cetraria nivalis* | | | | | | P | | | | |
| *Cladonia alpestris* | | | | | | P | | | | |
| *Cladonia gracilis* | | | | | | P | | | | |
| *Cladonia mitis* | | | | | | P | | | | |
| *Cladonia rangiferina* | | | | | | P | | | | |
| *Peltigera ssp.* | | | | | | P | | P | | |

P = present; T = trace; blank = absent

Table B-1. (Cont.) Listing of major plant species found in the area of Tunalik Test Well No. 1 in July of 1984 and 1991

| | Wet Sedge Meadow | | | | Undisturbed | | Pad Surface | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Insulated | | Pad |
| | Undisturbed | | Disturbed | | Tussock Tundra | | | Yes | No | Slope |
| Plant Species | 1984 | 1991 | 1984 | 1991 | 1984 | 1991 | 1984 | 1991 | 1991 | 1991 |
| **Lichens (Cont.)** | | | | | | | | | | |
| *Stereocaulon spp.* | | | | | | P | | | | |
| *Thamnolia subuliformis* | | | | | | P | | | | |
| **Other** | | | | | | | | | | |
| *Marchantia spp.* | | | | | | | | | P | P |
| Moss | | P | | | | P | | P | P | P |
| Mushroom | | | | | | | | | P | |

P = present; T = trace; blank = absent

Table B-2. Listing of major plant species in the area of Inigok Test Well No. 1 in July of 1984 and 1991

| Plant Species | Wet Sedge Meadow | | | | Tussock Tundra | | Pad | | | | Fuel Pit Berm | Reserve Pit Berm |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Undisturbed | | Disturbed | | Undisturbed | | Surface | Surface Insulation: Yes | Surface Insulation: No | Slopes | | |
| | 1984 | 1991 | 1984 | 1991 | 1984 | 1991 | 1984 | 1991 | 1991 | 1991 | 1991 | 1991 |
| **Graminoids** | | | | | | | | | | | | |
| *Arctagrostis latifolia* | | P | P | P | P | P | P | T | P | P | P | P |
| *Arctophila fulva* | P | P | | P | | | | | T | | P | P |
| *Calamagrostis inexpansa* | | P | P | P | P | P | | | | | | |
| *Carex aquatilis* | P | P | P | P | P | P | P | | P | T | P | P |
| *Carex bigelowii* | P | P | P | | P | P | | T | T | | | |
| *Carex maritima* | | | | | | | | | | | P | P |
| *Dupontia fisheri* | | | | T | | | | | | | | |
| *Eriophorum spp.* | | P | | | | | | | P | | | |
| *Eriophorum angustifolium* | | P | | P | | | | | | | P | P |
| *Eriophorum scheuchzeri* | | P | | P | | | | | | | P | P |
| *Eriophorum vaginatum* | P | P | | T | P | P | | | | | | |
| *Festuca rubra* | | | | | | | P | P | P | P | P | P |
| *Hierochloa alpina* | | P | | | | P | | | | | | |
| *Juncus arcticus* | | | | P | | | | | T | T | P | P |
| *Kobresia myosuroides* | | T | | | | | | | | | | |
| *Luzula confusa* | P | P | | | P | P | | | | | | |
| *Phippsia algida* | | | P | P | | | | | | | | P |
| *Poa arctica* | | P | | P | | | | | | | | |
| *Poa glauca* | | | | | P | | P | P | P | | | |
| *Puccinellia Andersonii* | | | | P | | | | P | P | P | | P |
| **Shrubs** | | | | | | | | | | | | |
| *Andromeda polifolia* | | | | | | P | | | | | | |
| *Arctostaphylos alpina* | | P | | | P | P | | | | | | |
| *Arctostaphylos rubra* | | P | | | | P | | | | | | |
| *Betula nana* | T | P | | | P | P | | | | | | |

P = present; T = trace; blank = absent

Table B-2. (Cont.) Listing of major plant species in the area of Inigok Test Well No. 1 in July of 1984 and 1991

| | Wet Sedge Meadow | | | | Tussock Tundra | | Pad | | | | Fuel | Reserve |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Surface Insulation | | | Pit | Pit |
| | Undisturbed | | Disturbed | | Undisturbed | | Surface | Yes | No | Slopes | Berm | Berm |
| Plant Species | 1984 | 1991 | 1984 | 1991 | 1984 | 1991 | 1984 | 1991 | 1991 | 1991 | 1991 | 1991 |
| **Shrubs (Cont.)** | | | | | | | | | | | | |
| *Cassiope tetragona* | | P | | | P | P | | | | | | |
| *Dryas integrifolia* | | P | | | | P | | | | | | |
| *Empetrum nigrum* | | P | | | T | P | | | | | | |
| *Ledum decumbens* | | P | | | P | P | | | | | | |
| *Rubus chamaemorus* | | P | | | P | P | | | | | | |
| *Salix alaxensis* | | | | | | | | | T | | | |
| *Salix brachycarpa ssp. niphoclada* | | | | P | | | | T | P | | | T |
| *Salix glauca* | | P | | P | | | | T | P | | | |
| *Salix lanata ssp. richardsonii* | T | P | | | | P | | | | | | |
| *Salix planifolia ssp. pulchra* | T | P | | P | P | P | | | | T | P | |
| *Salix reticulata* | P | | | | P | P | | | | | | |
| *Vaccinium uliginosum* | | P | | | P | P | | | | | | |
| *Vaccinium vitis-idaea* | | P | | | P | P | | | | | | |
| **Forbs** | | | | | | | | | | | | |
| *Armeria maritima* | | | | | | | | | P | | | |
| *Artemisia tilesii* | | | | | | | | | | T | | |
| *Astragalus alpinus* | | | | | | | | | | T | | |
| *Caltha palustris* | | | | P | | | | | | | | |
| *Cardamine pratensis* | T | | | | | T | | | | | | |
| *Cardamine umbellatum* | | P | | | | | | | | | | |
| *Descurainia sophioides* | | | | | | | | | | T | P | P |
| *Epilobium davuricum* | | | | P | | | | | | | | P |
| *Epilobium latifolium* | | | | | | | | T | | T | | |
| *Equisetum arvense* | | P | | | | | | | | P | | |
| *Hippuris vulgaris* | | | | P | | | | | | | | |
| *Melandrium apetalum* | | | | | T | | | | | | | |

P = present; T = trace; blank = absent

Table B-2. (Cont.) Listing of major plant species in the area of Inigok Test Well No. 1 in July of 1984 and 1991

| | Wet Sedge Meadow | | | | Tussock Tundra | | Pad | | | | Fuel | Reserve |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Surface Insulation | | | Pit | Pit |
| | Undisturbed | | Disturbed | | Undisturbed | | Surface | Yes | No | Slopes | Berm | Berm |
| Plant Species | 1984 | 1991 | 1984 | 1991 | 1984 | 1991 | 1984 | 1991 | 1991 | 1991 | 1991 | 1991 |
| **Forbs (Cont.)** | | | | | | | | | | | | |
| *Minuartia rubella* | | | | | | | | P | | P | | |
| *Pedicularis capitata* | P | P | | | P | | | | | | | |
| *Pedicularis kanei* | P | | | | P | | | | | | | |
| *Pedicularis sudetica* | | P | | | | T | | | | | | |
| *Petasites frigidus* | | P | | | | P | | | | | | |
| *Polemonium boreale* | | P | | | | | | | | T | | |
| *Polygonum bistora* | | P | | | | P | | | | | | |
| *Polygonum viviparum* | | | | | | P | | | | | | |
| *Potentilla palustris* | | P | | | | | | | | | | |
| *Pyrola grandiflora* | | P | | | | P | | | | | | |
| *Ranunculus spp.* | | P | | | | | | | | | | |
| *Ranunculus hyperboreus* | T | P | P | P | | | | | | | | |
| *Saussurea angustifolia* | | P | | | | P | | | | | | |
| *Saxifraga cernua* | P | P | | P | P | | | | | | | |
| *Saxifrage nivalis* | | | | | P | P | | | | | | |
| *Saxifrage oppositifolia* | | | | | P | | | | | | | |
| *Senecio atropurpureus* | | P | | | | P | | | | | | |
| *Senecio congestus* | | | P | P | | P | | | T | T | P | P |
| *Stellaria humifusa* | | P | | P | | | | | | | | |
| *Tanacetum bipinnatum* | | | | | | | | | | T | | P |
| *Tofieldia coccinea* | | | | | | T | | | | | | |
| **Lichens** | | | | | | | | | | | | |
| *Alectoria nigricans* | | | | | | P | | | | | | |
| *Cetraria cucullata* | | | | | | P | | P | | | | |
| *Cetraria islandica* | | | | | | P | | | | | | |

P = present; T = trace; blank = absent

Table B-2. (Cont.) Listing of major plant species in the area of Inigok Test Well No. 1 in July of 1984 and 1991

| | Wet Sedge Meadow | | | | Tussock Tundra | | Pad | | | | Fuel Pit Berm | Reserve Pit Berm |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Undisturbed | | Disturbed | | Undisturbed | | Surface | Surface Insulation | | Slopes | | |
| | | | | | | | | Yes | No | | | |
| Plant Species | 1984 | 1991 | 1984 | 1991 | 1984 | 1991 | 1984 | 1991 | 1991 | 1991 | 1991 | 1991 |
| **Lichens (Cont.)** | | | | | | | | | | | | |
| *Cladonia gracilis* | | | | | | P | | | | | | |
| *Cladonia mitis* | | | | | | P | | | | | | |
| *Cladonia rangiferina* | | | | | | P | | | | | | |
| *Peltigera ssp.* | | | | | | | | P | P | | | |
| *Thamnolia subuliformis* | | | | | | P | | | | | | |
| Lichen spp. | | | | | | P | | P | P | | | |
| **Other** | | | | | | | | | | | | |
| *Marchantia spp.* | | P | | P | | | | T | | P | P | P |
| Moss spp. | | P | | | | P | | P | P | P | P | P |

P = present; T = trace; blank = absent

Table B-3. Listing of major plant species found in the area of Lisburne Test Well No. 1 in July of 1984 and 1991

| Plant Species | Wet Sedge Meadow Undisturbed 1991 | Wet Sedge Meadow Disturbed 1991 | Upland Moist Meadow 1984 | Upland Moist Meadow 1991 | Pad Surface 1984 | Pad Surface 1991 | Pad Slope 1991 |
|---|---|---|---|---|---|---|---|
| **Graminoids** | | | | | | | |
| *Agropyron boreale ssp. alaskanum* | | | | | P | P | P |
| *Agropyron violaceum* | | | | | | P | P |
| *Arctagrostis latifolia* | P | P | P | P | P | P | P |
| *Arctophila fulva* | | | P | P | | | |
| *Bromus pumpellianus* | | | | | | | T |
| *Calamagrostis inexpansa* | | | | | | P | P |
| *Carex aquatilis* | P | P | | | | P* | P* |
| *Carex bigelowii* | | | | | P | P | |
| *Carex krausei* | | | P | | | | |
| *Carex lugens* | | | P | | | P | |
| *Carex misandra* | | | | | | T | |
| *Eriophorum angustifolium* | P | P | | P | | P* | P* |
| *Eriophorum Scheuchzeri* | | | | | | P* | |
| *Eriophorum vaginatum* | | | P | P | | P* | |
| *Festuca altaica* | | | P | | | | |
| *Festuca baffinensis* | | | | | P | P | |
| *Festuca rubra* | | | | | P | P | P |
| *Hierochloe alpina* | | | | P | | | |
| *Juncus castaneus ssp. castaneus* | | | T | | T | P* | T |
| *Kobresia myosuroides* | | | P | | | | |
| *Luzula arcuata ssp. unalaschcensis* | | | P | | P | | |
| *Luzula confusa* | | | P | P | | | |
| *Poa arctica* | P | P | P | P | P | P* | T* |
| *Poa glauca* | | | | | P | P | P |
| *Trisetum spicatum* | | | P | P | P | P | |
| **Shrubs** | | | | | | | |
| *Arctostaphylos alpina* | | | | T | | | |
| *Arctostaphylos rubra* | | | | | | T | |
| *Betula nana* | | | T | P | | T | T |
| *Cassiope tetragona* | | | | P | | | |
| *Dryas integrifolia* | | | P | P | | T | |
| *Dryas octopetala* | | | | | | | T |
| *Empetrum nigrum* | | | | T | | | |
| *Ledum decumbens* | | | P | P | | | |
| *Potentilla fruticosa* | | | | | | T | |
| *Rhododendron lapponicum* | | | P | P | | | |
| *Rubus chamaemorus* | | | T | P | | | |
| *Salix alaxensis* | | | T | T | P | P | P |
| *Salix arctica* | | | P | P | | P | T |
| *Salix brachycarpa ssp. niphoclada* | | | P | P | | | |
| *Salix glauca* | | | P | P | | | T |
| *Salix lanata ssp. Richardsonii* | | | P | P | | | |

P = present; T = trace; blank = absent

* Found in wet depressions only

Table B-3. (Cont.) Listing of major plant species found in the area of Lisburne Test Well No. 1 in July of 1984 and 1991

| | Wet Sedge Meadow | | Upland | | | | Pad |
|---|---|---|---|---|---|---|---|
| | Undisturbed | Disturbed | Moist Meadow | | Pad Surface | | Slope |
| Plant Species | 1991 | 1991 | 1984 | 1991 | 1984 | 1991 | 1991 |
| **Shrubs** | | | | | | | |
| *Salix phlebophylla* | | | P | | | | |
| *Salix planifolia ssp. pulchra* | | | P | P | P | P | P |
| *Salix reticulata* | | | P | P | | | |
| *Vaccinium uliginosum* | | | | P | | | |
| *Vaccinium vitis-idaea* | | | P | P | | | |
| **Forbs** | | | | | | | |
| *Aconitum delphinifolium ssp. paradoxum* | P | P | P | T | P | | T |
| *Androsace septentrionalis* | | | | | P | P | P |
| *Antennaria friesiana* | | | | | | T | |
| *Arnica lessingii ssp. lessingii* | | | P | | | | P |
| *Artemisia tilesii* | | | | | P | P | P |
| *Aster sibiricus* | | | P | P | P | P | P |
| *Astragalus alpinus spp. alpinus* | | | P | | P | P | P |
| *Astragalus alpinus spp. arcticus* | | | P | | P | | |
| *Boykinia richardsonii* | | | P | | | | |
| *Caltha palustris* | P | P | | | | | |
| *Cardamine hyperborea* | P | P | P | P | | | |
| *Castilleja elegans* | | | | | | | T |
| *Cerastrium beeringianum var. beeringianum* | | | P | | P | T | |
| *Chrysosplenium tetrandrum* | P | P | T | P | T | | |
| *Crepis nana* | | | | | | P | |
| *Delphinium brachycentrum* | | | P | | | | |
| *Descurainia sophioides* | | | | | P | T | |
| *Dodecatheon frigidum* | | | P | | | | |
| *Epilobium angustifolium* | | | | | | P | P |
| *Epilobium latifolium* | | | | | P | P | P |
| *Equisetum arvense* | P | P | T | P | P | P | P |
| *Equisetum variegatum ssp. variegatum* | | | P | | | | |
| *Erigeron spp.* | | | | | | | T |
| *Gentiana spp.* | | | | P | | | |
| *Hedysarum alpinum* | | | T | | | | T |
| *Lagotis glauca* | | | | T | | | |
| *Lupinus arcticus* | T | T | P | T | | | |
| *Minuartia arctica* | | | P | | | T | |
| *Minuartia macrocarpa* | | | P | | | | |
| *Minuartia obtusiloba* | | | | P | | | |
| *Minuartia rubella* | | | | | | T | |
| *Oxytropis campestris ssp. gracilis* | | | P | | P | | |
| *Oxytropis deflexa* | | | | | | P | P |
| *Oxytropis maydelliana* | | | P | | | | |
| *Oxytropis viscida* | | | P | | P | P | P |
| *Papaver lapponicum ssp. porsildii* | | | P | P | P | P | P |

P = present; T = trace; blank = absent

Table B-3. (Cont.) Listing of major plant species found in the area of Lisburne Test Well No. 1 in July of 1984 and 1991

| Plant Species | Wet Sedge Meadow Undisturbed 1991 | Wet Sedge Meadow Disturbed 1991 | Upland Moist Meadow 1984 | Upland Moist Meadow 1991 | Pad Surface 1984 | Pad Surface 1991 | Pad Slope 1991 |
|---|---|---|---|---|---|---|---|
| **Forbs** | | | | | | | |
| *Papaver macounii* | | | | | | P | |
| *Parnassia kotzebuei* | | | P | | | | |
| *Parrya nudicaulis ssp. nudicaulis* | | | P | | | | |
| *Pedicularis langsdorffii* | | | | P | | | |
| *Pedicularis spp.* | | | P | P | | | |
| *Petasites frigidus* | | | P | P | | T | T |
| *Polemonium acutiflorum* | P | P | P | P | | | T |
| *Polemonium boreale* | | | | | P | | |
| *Polygonum bistora spp. plumosum* | | | P | P | | | |
| *Polygonum viviparum* | | | P | P | P | | |
| *Pyrola grandiflora* | | | P | P | | | |
| *Ranunculus gelidus* | | | P | | | | |
| *Ranunculus hyperboreus spp. hyperboreus* | P | P | T | P | T | | |
| *Saussurea angustifolia* | | | P | P | | | T |
| *Saxifraga cernua* | | | P | | P | | |
| *Saxifraga hieracifolia* | | | | T | | | |
| *Saxifraga hirculus* | P | P | P | P | | | |
| *Saxifraga punctata var. nelsoniana* | | | P | P | | | P |
| *Saxifraga tricuspidata* | | | | | | | T |
| *Senecio atropurpureus* | | | P | P | | | |
| *Senecio spp.* | | | | | | | P |
| *Silene acaulis* | | | | | | | T |
| *Stellaria edwardsii* | | | P | P | P | | |
| *Taraxacum ceratophorum* | | | | | | T | T |
| *Tofieldia coccinea* | | | P | P | | | |
| *Valeriana capitata* | P | P | P | P | | | |
| *Viola epipsila* | | | | P | | | T |
| **Lichens** | | | | | | | |
| *Cetraria cucullata* | | | | P | | | |
| *Cetraria islandica* | | | | P | | | |
| *Cladonia gracilis* | | | | P | | | |
| *Cladonia mitis* | | | | P | | | |
| *Cladonia rangiferina* | | | | P | | | |
| *Peltigera spp.* | | | | P | | | |
| *Thamnolia subuliformis* | | | | P | | | |
| **Other** | | | | | | | |
| Moss spp. | | | | P | | | P |

P = present; T = trace; blank = absent

Table B-4. Listing of 125 vascular plant species colonizing upper surfaces and side slopes on ten man-made gravel structures in the Alaska Arctic. Site surveys occurred during the following years: 1984, 1987, 1988, and 1991.

| Physiographic Location | Foothills | | | | | | Coastal Plain | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **FAMILY** <br> Genus species | Lisburne Test Well No. 1 | | Inigok Test Well No. 1 | | Franklin Bluffs Pad | Seabee Test Well No. 1 | Tunalik Test Well No. 1 | | TAP Route M.P. 17 | TAP Route M.P. 18.6 | TAP Route M.P. 19.5 | TAP Route M.P. 34 | | Abandoned Road Sagavan-irktok Delta |
| Year Surveyed | 84 | 91 | 84 | 91 | 87 | 84 | 84 | 91 | 88 | 88 | 88 | 87 | 88 | 87 |
| **BETULACEAE:** | | | | | | | | | | | | | | |
| Betula nana | | • | | | | | | | | | | | | |
| | | | | | | | | | | | | | | |
| **BORAGINACEAE:** | | | | | | | | | | | | | | |
| Myosotis alpestris | | | | | | | | | | | | | • | |
| | | | | | | | | | | | | | | |
| **CARYOPHYLLACEAE:** | | | | | | | | | | | | | | |
| Cerastium beeringianum var. beeringianum | • | • | | | | | | • | | | | | | |
| Melandrium apetalum | | | | | | | | | • | | • | | | |
| Minuartia arctica | | • | | | | | | | | | | | | |
| Minuartia rubella | | • | | • | | | | | • | | | | | • |
| Sagina intermedia | | | | | | | | • | | | | | | • |
| Stellaria edwardsii | • | | | | | | | | | | | • | | |
| Stellaria humifusa | | | | | | | | • | | | | | | |
| Stellaria longipes | | | | | | • | | | • | | | • | | • |
| Stellaria sp. (laeta?) | | | | | | | | | | | | | | • |
| | | | | | | | | | | | | | | |
| **COMPOSITAE:** | | | | | | | | | | | | | | |
| Achillea borealis | | | | | | • | | | | | | | | |
| Antennaria friesiana | | • | | | | | | | | | | | | |
| Artemisia alaskana | | | | | | • | | | • | • | • | • | | |
| Artemisia arctica | | | | | • | | | | • | • | • | • | • | |
| Artemisia glomerata | | | | | | | | | | • | • | | | |
| Artemisia tilesii | • | • | | | | • | • | | | | | | | |
| Aster sibercus | • | • | | | • | | | | • | • | | • | • | |
| Chrysanthemum integrifolium | | | | | | | | | • | | | | | |
| Crepis nana var. nana | | • | | | | | | | • | • | • | • | | |
| Petasites frigidus | | • | | | | | | | | | | | | |
| Senecio atropurpureus | | | | | | | | | • | | | • | | |
| Senecio congestus | | | | • | • | • | • | • | | | | | | |
| Tanacetum bipinnatum | | | | | | | | • | | | | | | |

Table B-4. Listing of 125 vascular plant species colonizing upper surfaces and side slopes on ten man-made gravel structures in the Alaska Arctic. Site surveys occurred during the following years: 1984, 1987, 1988, and 1991.

| Physiographic Location | Foothills | | | | | | Coastal Plain | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| FAMILY<br>Genus species | Lisburne Test Well No. 1 | | Inigok Test Well No. 1 | | Franklin Bluffs Pad | Seabee Test Well No. 1 | Tunalik Test Well No. 1 | | TAP Route M.P. 17 | TAP Route M.P. 18.6 | TAP Route M.P. 19.5 | TAP Route M.P. 34 | | Abandoned Road Sagavan-irktok Delta |
| Year Surveyed | 84 | 91 | 84 | 91 | 87 | 84 | 84 | 91 | 88 | 88 | 88 | 87 | 88 | 87 |
| Taraxacum ceratophorum | | • | | | | | | | | | | | | |
| | | | | | | | | | | | | | | |
| CRUCIFERAE: | | | | | | | | | | | | | | |
| Arabis arenicola var. pubescens | | | | | | | | | | • | • | | | |
| Braya humilis | | | | | | | | | | • | | | | |
| Braya pilosa | | | | | | | | | | | | | | • |
| Braya purpurascens | | | | | | | | | • | | • | | | |
| Cochlearia officinalis subsp. arctica | | | | | | | • | • | | | | | | • |
| Descurainia sophioides | • | • | | | • | • | | • | | • | | | | |
| Draba macrocarpa | | | | | | | | • | | | | | | |
| Eutrema edwardsii | | | | | | | | | • | | | | | • |
| Parrya nudicaulis | | | | | | | | | • | | | | | |
| | | | | | | | | | | | | | | |
| CYPERACEAE: | | | | | | | | | | | | | | |
| Carex aquatilis | | • | • | • | | | • | • | | | | | | • |
| Carex bigelowii | • | • | | • | | | | | | | | | • | • |
| Carex lugens | | • | | | | | | | | | | | | • |
| Carex maritima | | | | | | | | | | | | | | • |
| Carex misandra | | • | | | | | | | | | | | | |
| Eriophorum angustifolium | | • | | | | | | • | | | | | | • |
| Eriophorum scheuchzeri | | • | | | | | | • | | | | | | |
| Eriophorum vaginatum | | • | | | | | • | | | | | | | |
| | | | | | | | | | | | | | | |
| ERICACEAE: | | | | | | | | | | | | | | |
| Arctostaphylos rubra | | • | | | | | | | | | | | | |
| | | | | | | | | | | | | | | |
| EQUISETACEAE: | | | | | | | | | | | | | | |
| Equisetum arvense | • | • | | | | • | | | | | | | | |
| Equisetum scirpoides | | | | | | | | | | | | | | • |
| Equisetum variegatum | | | | | | | | | • | | | | • | |
| | | | | | | | | | | | | | | |

Table B-4. Listing of 125 vascular plant species colonizing upper surfaces and side slopes on ten man-made gravel structures in the Alaska Arctic. Site surveys occurred during the following years: 1984, 1987, 1988, and 1991.

| Physiographic Location | Foothills | | | | | | Coastal Plain | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **FAMILY** <br> Genus species | Lisburne Test Well No. 1 | | Inigok Test Well No. 1 | | Franklin Bluffs Pad | Seabee Test Well No. 1 | Tunalik Test Well No. 1 | | TAP Route M.P. 17 | TAP Route M.P. 18.6 | TAP Route M.P. 19.5 | TAP Route M.P. 34 | | Abandoned Road Sagavanirktok Delta |
| Year Surveyed | 84 | 91 | 84 | 91 | 87 | 84 | 84 | 91 | 88 | 88 | 88 | 87 | 88 | 87 |
| **GENTIANACEAE:** | | | | | | | | | | | | | | |
| Gentiana propinqua | | | | | | | | | | | | • | | |
| | | | | | | | | | | | | | | |
| **GRAMINEAE:** | | | | | | | | | | | | | | |
| Agropyron boreale ssp. alaskanum | • | • | | | | | | | | | | | | |
| Agropyron macrourum | | | | | | • | | | • | • | • | • | • | |
| Alopecurus alpinus | | | | | | | • | | | | | | | • |
| Arctagrostis latifolia | • | • | • | • | • | • | • | • | • | | • | • | • | • |
| Arctophila fulva | | | | • | | | • | • | | | | | | |
| Bromus pumpellianus | | | | | | • | | | | | | | | |
| Calamagrostis holmii | | | | | | • | | | | | | | | |
| Calamagrostis inexpansa | | • | | | | | | | | | | | | |
| Calamagrostis purpurascens | | | | | | | | | | | | • | | |
| Deschampsia caespitosa | | | | | | | | | • | • | | • | • | • |
| Dupontia fisheri | | | | • | | | • | • | | | | | | • |
| Festuca baffinensis | • | • | | | | | | | | | | | | • |
| Festuca rubra | • | • | • | • | | • | • | • | • | • | • | | • | |
| Festuca vivipara | | | | | | | | | | | | | | • |
| Lolium multiflorum | | | | | | | | | | • | | | | |
| Phippsia algida | | | | | | | • | • | | | | | | |
| Poa arctica | • | • | | | | • | • | • | | | • | | | |
| Poa glauca | • | • | • | • | | • | • | • | • | • | | • | | |
| Poa pratensis var."Nugget" | | | | | • | | | • | • | • | | • | • | |
| Puccinellia arctica | | | | • | | | | | | | | | | |
| Puccinellia langeana | | | | | | | | | | | | | | • |
| Trisetum spicatum | • | • | | | | | | • | • | • | • | | | • |
| | | | | | | | | | | | | | | |
| **HALORAGACEAE:** | | | | | | | | | | | | | | |
| Hippuris vulgaris | | | | | | | | • | | | | | | |
| | | | | | | | | | | | | | | |
| **JUNCACEAE:** | | | | | | | | | | | | | | |

Table B-4. Listing of 125 vascular plant species colonizing upper surfaces and side slopes on ten man-made gravel structures in the Alaska Arctic. Site surveys occurred during the following years: 1984, 1987, 1988, and 1991.

| Physiographic Location | Foothills | | | | | | Coastal Plain | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **FAMILY**<br>Genus species | Lisburne Test Well No. 1 | | Inigok Test Well No. 1 | | Franklin Bluffs Pad | Seabee Test Well No. 1 | Tunalik Test Well No. 1 | | TAP Route M.P. 17 | TAP Route M.P. 18.6 | TAP Route M.P. 19.5 | TAP Route M.P. 34 | | Abandoned Road Sagavan-irktok Delta |
| Year Surveyed | 84 | 91 | 84 | 91 | 87 | 84 | 84 | 91 | 88 | 88 | 88 | 87 | 88 | 87 |
| Juncus arcticus | | | | • | | | | | | | | | | |
| Juncus castaneus subsp. castaneus | • | • | | | | | | | | | | • | | |
| Juncus triglumis | | | | | | | | | • | | | | | |
| Luzula arctuata subsp. unalaschensis | • | | | | | | | | | | | | | |
| Luzula confusa | | | | | | | | • | | | | | | |
| Luzula whalenbergii subsp. whalenbergii | | | | | | | • | | | | | | | |
| | | | | | | | | | | | | | | |
| **LEGUMINOSAE:** | | | | | | | | | | | | | | |
| Astragalus alpinus subsp. alpinus | • | • | | | | • | | | • | | | • | • | • |
| Astragalus alpinus subsp. arcticus | • | | | | | | | | | | | | | |
| Astragalus nutzotinensis | | | | | | | | | • | • | • | | | |
| Hedysarum alpinum | | | | | | | | | | | | | • | |
| Hedysarum hedsyaroides | | | | | | | | | | | | • | | |
| Hedysarum mackenzii | | | | | | | | | | | • | • | • | |
| Oxytropis borealis | • | • | | | | | | | • | • | • | • | | • |
| Oxytropis campestris subsp. gracilis | • | | | | | | | | | | | | • | |
| Oxytropis deflexa var. foliolosa | | • | | | | | | | | | | | | |
| Oxytropis nigrescens | | | | | | | | | | | • | | | |
| | | | | | | | | | | | | | | |
| **ONAGRACEAE:** | | | | | | | | | | | | | | |
| Epilobium angustifolium | | • | | | | | • | | | • | | | | |
| Epilobium latifolium | • | • | | • | • | • | | | • | | • | • | • | • |
| | | | | | | | | | | | | | | |
| **PAPAVERACEAE:** | | | | | | | | | | | | | | |
| Papaver lapponicum subsp. porsildii | • | • | | | | | | | | | | | | |
| Papaver macounii | | • | | | | | | | • | | | | | |
| | | | | | | | | | | | | | | |
| **PLUMBAGINACEAE:** | | | | | | | | | | | | | | |
| Armeria maritima | | | | • | | | | | | | • | | | |
| | | | | | | | | | | | | | | |
| **POLEMONIACEAE:** | | | | | | | | | | | | | | |

Table B-4. Listing of 125 vascular plant species colonizing upper surfaces and side slopes on ten man-made gravel structures in the Alaska Arctic. Site surveys occurred during the following years: 1984, 1987, 1988, and 1991.

| Physiographic Location | Foothills | | | | | | Coastal Plain | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| FAMILY<br>Genus species | Usburne Test Well No. 1 | | Inigok Test Well No. 1 | | Franklin Bluffs Pad | Seabee Test Well No. 1 | Tunalik Test Well No. 1 | | TAP Route M.P. 17 | TAP Route M.P. 18.6 | TAP Route M.P. 19.5 | TAP Route M.P. 34 | | Abandoned Road Sagavan-irktok Delta |
| Year Surveyed | 84 | 91 | 84 | 91 | 87 | 84 | 84 | 91 | 88 | 88 | 88 | 87 | 88 | 87 |
| Polemonium acutiflorum | | | | • | | • | | • | | | | | | |
| Polemonium boreale | | • | | | | | | | | | | | | |
| | | | | | | | | | | | | | | |
| POLYGONACEAE: | | | | | | | | | | | | | | |
| Polygonum viviparum | • | | | | | | | | • | | | | | |
| | | | | | | | | | | | | | | |
| PRIMULACEAE: | | | | | | | | | | | | | | |
| Androsace septentrionalis | • | • | | | | | | | | | | | | |
| | | | | | | | | | | | | | | |
| RANUNCULACEAE: | | | | | | | | | | | | | | |
| Aconitum delphinifolium subsp. paradoxum | • | | | | | | | | | | | | | |
| Ranunculus gmelinii subsp. gmelinii | | | | | • | | | • | | | | | | |
| Ranunculus hyperboreus subsp. hyperboreus | • | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | |
| ROSACEAE: | | | | | | | | | | | | | | |
| Dryas integrifolia subsp. integrifolia | | • | | | | | | | • | | | | | • |
| Potentilla fruticosa | | • | | | | | | | | | | | | |
| | | | | | | | | | | | | | | |
| SALICACEAE: | | | | | | | | | | | | | | |
| Salix alaxensis var. alaxensis | • | • | | • | | • | | | | | • | | | |
| Salix arctica | | • | | | | | | | • | | | | | • |
| Salix brachycarpa ssp. niphoclada | | | | • | | • | | • | | | | • | | |
| Salix glauca | | | | • | | | | | | | | | | |
| Salix lanata ssp. richardsonii | | | | | | | | | | | | | • | |
| Salix ovalifolia | | | | | | | | • | • | | | | | • |
| Salix planifolia ssp. pulchra var. pulchra | • | • | | • | | • | | | | | | | | |
| Salix reticulata | | | | | | | | | • | | | | | |
| | | | | | | | | | | | | | | |
| SAXIFRAGACEAE: | | | | | | | | | | | | | | |
| Chrysosplenium tetrandrum | • | | | | | | | | | | | | | |
| Parnassia palustris | | | | | | | | | | | | • | | |

Table B-4. Listing of 125 vascular plant species colonizing upper surfaces and side slopes on ten man-made gravel structures in the Alaska Arctic. Site surveys occurred during the following years: 1984, 1987, 1988, and 1991.

| Physiographic Location | Foothills | | | | | | Coastal Plain | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **FAMILY**<br>Genus species | Lisburne Test Well No. 1 | | Inigok Test Well No. 1 | | Franklin Bluffs Pad | Seabee Test Well No. 1 | Tunalik Test Well No. 1 | | TAP Route M.P. 17 | TAP Route M.P. 18.6 | TAP Route M.P. 19.5 | TAP Route M.P. 34 | | Abandoned Road Sagavan-irktok Delta |
| Year Surveyed | 84 | 91 | 84 | 91 | 87 | 84 | 84 | 91 | 88 | 88 | 88 | 87 | 88 | 87 |
| Saxifraga cernua | • | | | | | | | | | | | | | |
| Saxifraga hirculus | | | | | | | | | • | | | | | |
| Saxifraga oppositifolia | | | | | | | | | • | | | • | | |
| | | | | | | | | | | | | | | |
| **SCROPHULARIACEAE:** | | | | | | | | | | | | | | |
| Castelleja caudata | | • | | | | | | | | | | • | | |
| Pedicularis verticilliata | | | | | | | | | | | | • | • | • |
| | | | | | | | | | | | | | | |
| **VIOLACEAE:** | | | | | | | | | | | | | | |
| Viola epipsila | | • | | | | | | | | | | | | |
| | | | | | | | | | | | | | | |
| **TOTAL FAMILIES** Physiographic Location<br>**TOTAL** Genera<br>**TOTAL** species | 22<br>46<br>72 | | | | | | 21<br>54<br>86 | | | | | | | |
| **TOTAL FAMILIES** | 15 | 18 | 2 | 9 | 5 | 9 | 6 | 10 | 13 | 5 | 8 | 10 | 9 | 10 |
| **TOTAL** Genera | 25 | 33 | 4 | 14 | 8 | 16 | 14 | 21 | 27 | 15 | 16 | 21 | 16 | 23 |
| **TOTAL** species | 30 | 45 | 4 | 18 | 8 | 20 | 15 | 26 | 33 | 18 | 19 | 25 | 17 | 28 |

# APPENDIX C

## PLANT SPECIES COMPOSITION AND CANOPY COVER DATA

A listing of plant species compostion data, basal cover data, and canopy cover data at three exporatory wellsites in NPRA, Alaska in July 1991.

Table C-1. Summary of basal cover from walking point data samples for three abandoned NPRA exploration wellsites, July 1991

| | | Insulated Pad | | Non-Insulated Pad | | Pad Slopes | |
|---|---|---|---|---|---|---|---|
| Site | Cover Type | Points | % | Points | % | Points | % |
| **Tunalik Test Wellsite No. 1** | | | | | | | |
| | Live Vascular | 7 | 5.74 | 10 | 8.93 | 15 | 13.76 |
| | Dead | 15 | 12.30 | 17 | 15.18 | 59 | 54.13 |
| | Moss | 48 | 39.34 | 57 | 50.89 | 6 | 5.50 |
| | Lichen | 9 | 7.38 | 0 | 0.00 | 0 | 0.00 |
| | Rock | 23 | 18.85 | 9 | 8.04 | 12 | 11.01 |
| | Bare | 20 | 16.39 | 15 | 13.39 | 17 | 15.60 |
| | Feces | 0 | 0.00 | 4 | 3.57 | 0 | 0.00 |
| | Totals | 122 | 100 | 112 | 100 | 109 | 100 |
| **Inigok Test Wellsite No. 1** | | | | | | | |
| | Live Vascular | 10 | 4.33 | 5 | 3.40 | 4 | 6.06 |
| | Dead | 19 | 8.23 | 29 | 19.73 | 59 | 89.39 |
| | Moss | 100 | 43.29 | 100 | 68.03 | 0 | 0.00 |
| | Liverwort | 1 | 0.43 | 0 | 0.00 | 0 | 0.00 |
| | Lichen | 7 | 3.03 | 3 | 2.04 | 1 | 1.52 |
| | Rock | 74 | 32.03 | 7 | 4.76 | 1 | 1.52 |
| | Bare | 19 | 8.23 | 2 | 1.36 | 1 | 1.52 |
| | Feces | 1 | 0.43 | 1 | 0.68 | 0 | 0.00 |
| | Totals | 231 | 100 | 147 | 100 | 66 | 100 |
| **Lisburne Test Wellsite No. 1** | | | | | | | |
| | Live Vascular | 5 | 3.38 | | | 9 | 8.26 |
| | Dead | 5 | 3.38 | | | 35 | 32.11 |
| | Moss | 19 | 12.84 | | | 7 | 6.42 |
| | Rock | 78 | 52.70 | | | 39 | 35.78 |
| | Bare | 41 | 27.70 | | | 19 | 17.43 |
| | Totals | 148 | 100 | | | 109 | 100 |

Table C-2. Canopy cover class and percentage data for 31 Daubenmire plots on the insulated drilling pad surface at Tunalik Test Wellsite No. 1, 26 July 1991

| | Grass | | Forbs | | Dead | | Moss | | Dead Moss | | Lichen | | Rock | | Bare | | Feces | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Class | % | Class | % | Class | % | Class | % | Class | % | Class | % | Class | % | Class | % | Class | % |
| | 4 | 37.500 | 1 | 3.125 | 3 | 18.750 | 5 | 62.500 | 3 | 18.750 | 1 | 3.125 | 3 | 18.750 | 4 | 37.500 | 1 | 3.125 |
| | 3 | 18.750 | 1 | 3.125 | 2 | 9.375 | 3 | 18.750 | 5 | 62.500 | 1 | 3.125 | 2 | 9.375 | 2 | 9.375 | 1 | 3.125 |
| | 1 | 3.125 | | 0.000 | 2 | 9.375 | 2 | 9.375 | 4 | 37.500 | 3 | 18.750 | 1 | 3.125 | 5 | 62.500 | 1 | 3.125 |
| | 1 | 3.125 | | 0.000 | 2 | 9.375 | 3 | 18.750 | 2 | 9.375 | 1 | 3.125 | 3 | 18.750 | 6 | 84.375 | 1 | 3.125 |
| | 1 | 3.125 | | 0.000 | 1 | 3.125 | 2 | 9.375 | 2 | 9.375 | 3 | 18.750 | 2 | 9.375 | 1 | 3.125 | 1 | 3.125 |
| | 2 | 9.375 | | 0.000 | 2 | 9.375 | 3 | 18.750 | 1 | 3.125 | 4 | 37.500 | 1 | 3.125 | 1 | 3.125 | | 0.000 |
| | 3 | 18.750 | | 0.000 | 3 | 18.750 | 5 | 62.500 | 3 | 18.750 | 2 | 9.375 | 3 | 18.750 | 1 | 3.125 | | 0.000 |
| | 3 | 18.750 | | 0.000 | 2 | 9.375 | 4 | 37.500 | 3 | 18.750 | 2 | 9.375 | 3 | 18.750 | 2 | 9.375 | | 0.000 |
| | 2 | 9.375 | | 0.000 | 3 | 18.750 | 4 | 37.500 | 1 | 3.125 | | 0.000 | 2 | 9.375 | 2 | 9.375 | | 0.000 |
| | 3 | 18.750 | | 0.000 | 1 | 3.125 | 3 | 18.750 | 2 | 9.375 | | 0.000 | 3 | 18.750 | 1 | 3.125 | | 0.000 |
| | 1 | 3.125 | | 0.000 | 1 | 3.125 | 3 | 18.750 | 1 | 3.125 | | 0.000 | 3 | 18.750 | 2 | 9.375 | | 0.000 |
| | 1 | 3.125 | | 0.000 | 3 | 18.750 | 4 | 37.500 | | 0.000 | | 0.000 | 4 | 37.500 | 3 | 18.750 | | 0.000 |
| | 3 | 18.750 | | 0.000 | 2 | 9.375 | 5 | 62.500 | | 0.000 | | 0.000 | 4 | 37.500 | 3 | 18.750 | | 0.000 |
| | 3 | 18.750 | | 0.000 | 3 | 18.750 | 3 | 18.750 | | 0.000 | | 0.000 | 3 | 18.750 | 2 | 9.375 | | 0.000 |
| | 1 | 3.125 | | 0.000 | 2 | 9.375 | 4 | 37.500 | | 0.000 | | 0.000 | 3 | 18.750 | 1 | 3.125 | | 0.000 |
| | 1 | 3.125 | | 0.000 | 3 | 18.750 | 1 | 3.125 | | 0.000 | | 0.000 | 4 | 37.500 | 2 | 9.375 | | 0.000 |
| | 4 | 37.500 | | 0.000 | 3 | 18.750 | 4 | 37.500 | | 0.000 | | 0.000 | 4 | 37.500 | | 0.000 | | 0.000 |
| | 4 | 37.500 | | 0.000 | 1 | 3.125 | 3 | 18.750 | | 0.000 | | 0.000 | 3 | 18.750 | | 0.000 | | 0.000 |
| | 2 | 9.375 | | 0.000 | 1 | 3.125 | 2 | 9.375 | | 0.000 | | 0.000 | 3 | 18.750 | | 0.000 | | 0.000 |
| | 4 | 37.500 | | 0.000 | 4 | 37.500 | 3 | 18.750 | | 0.000 | | 0.000 | 4 | 37.500 | | 0.000 | | 0.000 |
| | 3 | 18.750 | | 0.000 | 3 | 18.750 | 4 | 37.500 | | 0.000 | | 0.000 | 3 | 18.750 | | 0.000 | | 0.000 |
| | 1 | 3.125 | | 0.000 | 3 | 18.750 | 3 | 18.750 | | 0.000 | | 0.000 | 1 | 3.125 | | 0.000 | | 0.000 |
| | 4 | 37.500 | | 0.000 | 1 | 3.125 | 3 | 18.750 | | 0.000 | | 0.000 | 3 | 18.750 | | 0.000 | | 0.000 |
| | 3 | 18.750 | | 0.000 | 2 | 9.375 | 5 | 62.500 | | 0.000 | | 0.000 | 3 | 18.750 | | 0.000 | | 0.000 |
| | 3 | 18.750 | | 0.000 | 2 | 9.375 | 4 | 37.500 | | 0.000 | | 0.000 | 5 | 62.500 | | 0.000 | | 0.000 |
| | 4 | 37.500 | | 0.000 | 3 | 18.750 | 3 | 18.750 | | 0.000 | | 0.000 | 2 | 9.375 | | 0.000 | | 0.000 |
| | 2 | 9.375 | | 0.000 | 2 | 9.375 | 4 | 37.500 | | 0.000 | | 0.000 | 2 | 9.375 | | 0.000 | | 0.000 |
| | 2 | 9.375 | | 0.000 | 3 | 18.750 | 5 | 62.500 | | 0.000 | | 0.000 | 2 | 9.375 | | 0.000 | | 0.000 |
| | 4 | 37.500 | | 0.000 | 3 | 18.750 | 4 | 37.500 | | 0.000 | | 0.000 | 4 | 37.500 | | 0.000 | | 0.000 |
| | | 0.000 | | 0.000 | | 0.000 | | 0.000 | | 0.000 | | 0.000 | 2 | 9.375 | | 0.000 | | 0.000 |
| | | 0.000 | | 0.000 | | 0.000 | | 0.000 | | 0.000 | | 0.000 | 3 | 18.750 | | 0.000 | | 0.000 |
| Total | | 503.125 | | 6.250 | | 375.000 | | 887.500 | | 193.750 | | 103.125 | | 596.875 | | 293.750 | | 15.625 |
| Mean | | 16.230 | | 0.202 | | 12.097 | | 28.629 | | 6.250 | | 3.327 | | 20.161 | | 9.476 | | 0.504 |
| SD | | 13.366 | | 0.780 | | 8.218 | | 19.079 | | 13.477 | | 8.106 | | 13.303 | | 19.085 | | 1.168 |

Table C-3. Canopy cover class and percentage data for 28 Daubenmire plots on the non-insulated drilling pad surface at Tunalik Test Wellsite No. 1, 26 July 1991

| | Grass | | Shrubs | | Forbs | | Dead | | Moss | | Lichen | | Rock | | Bare | | Feces | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Class | % | Class | % | Class | % | Class | % | Class | % | Class | % | Class | % | Class | % | Class | % |
| | 2 | 9.375 | 1 | 3.125 | 1 | 3.125 | 3 | 18.750 | 5 | 62.500 | 1 | 3.125 | 1 | 3.125 | 3 | 18.750 | 1 | 3.125 |
| | 3 | 18.750 | 1 | 3.125 | 2 | 9.375 | 1 | 3.125 | 4 | 37.500 | 1 | 3.125 | 1 | 3.125 | 1 | 3.125 | 2 | 9.375 |
| | 1 | 3.125 | | 0.000 | 1 | 3.125 | 2 | 9.375 | 5 | 62.500 | | 0.000 | 2 | 9.375 | 1 | 3.125 | 2 | 9.375 |
| | 4 | 37.500 | | 0.000 | 1 | 3.125 | 5 | 62.500 | 4 | 37.500 | | 0.000 | 1 | 3.125 | 7 | 96.375 | 1 | 3.125 |
| | 1 | 3.125 | | 0.000 | 1 | 3.125 | 1 | 3.125 | 4 | 37.500 | | 0.000 | 1 | 3.125 | 2 | 9.375 | 1 | 3.125 |
| | 4 | 37.500 | | 0.000 | 1 | 3.125 | 2 | 9.375 | 6 | 84.375 | | 0.000 | 2 | 9.375 | 5 | 62.500 | 1 | 3.125 |
| | 3 | 18.750 | | 0.000 | 1 | 3.125 | 1 | 3.125 | 6 | 84.375 | | 0.000 | 4 | 37.500 | 1 | 3.125 | 1 | 3.125 |
| | 2 | 9.375 | | 0.000 | 1 | 3.125 | 2 | 9.375 | 6 | 84.375 | | 0.000 | 2 | 9.375 | 2 | 9.375 | 1 | 3.125 |
| | 1 | 3.125 | | 0.000 | 1 | 3.125 | 1 | 3.125 | 6 | 84.375 | | 0.000 | 2 | 9.375 | 4 | 37.500 | 1 | 3.125 |
| | 1 | 3.125 | | 0.000 | 1 | 3.125 | 2 | 9.375 | 6 | 84.375 | | 0.000 | 1 | 3.125 | 4 | 37.500 | 1 | 3.125 |
| | 2 | 9.375 | | 0.000 | 2 | 9.375 | 1 | 3.125 | 5 | 62.500 | | 0.000 | 1 | 3.125 | 1 | 3.125 | 3 | 18.750 |
| | 1 | 3.125 | | 0.000 | | 0.000 | 1 | 3.125 | 1 | 3.125 | | 0.000 | 3 | 18.750 | 7 | 96.375 | | 0.000 |
| | 3 | 18.750 | | 0.000 | | 0.000 | 1 | 3.125 | 3 | 18.750 | | 0.000 | 1 | 3.125 | 5 | 62.500 | | 0.000 |
| | 2 | 9.375 | | 0.000 | | 0.000 | 2 | 9.375 | 5 | 62.500 | | 0.000 | 3 | 18.750 | 1 | 3.125 | | 0.000 |
| | 3 | 18.750 | | 0.000 | | 0.000 | 3 | 18.750 | 6 | 84.375 | | 0.000 | 1 | 3.125 | 3 | 18.750 | | 0.000 |
| | 3 | 18.750 | | 0.000 | | 0.000 | 2 | 9.375 | 5 | 62.500 | | 0.000 | 1 | 3.125 | 1 | 3.125 | | 0.000 |
| | 3 | 18.750 | | 0.000 | | 0.000 | 3 | 18.750 | 1 | 3.125 | | 0.000 | 2 | 9.375 | 2 | 9.375 | | 0.000 |
| | 3 | 18.750 | | 0.000 | | 0.000 | 1 | 3.125 | 5 | 62.500 | | 0.000 | 1 | 3.125 | 7 | 96.375 | | 0.000 |
| | 2 | 9.375 | | 0.000 | | 0.000 | 1 | 3.125 | 2 | 9.375 | | 0.000 | 1 | 3.125 | 4 | 37.500 | | 0.000 |
| | 3 | 18.750 | | 0.000 | | 0.000 | 1 | 3.125 | 6 | 84.375 | | 0.000 | 2 | 9.375 | 2 | 9.375 | | 0.000 |
| | 3 | 18.750 | | 0.000 | | 0.000 | 2 | 9.375 | 4 | 37.500 | | 0.000 | 1 | 3.125 | | 0.000 | | 0.000 |
| | 4 | 37.500 | | 0.000 | | 0.000 | 1 | 3.125 | 4 | 37.500 | | 0.000 | 1 | 3.125 | | 0.000 | | 0.000 |
| | 4 | 37.500 | | 0.000 | | 0.000 | 1 | 3.125 | 5 | 62.500 | | 0.000 | 2 | 9.375 | | 0.000 | | 0.000 |
| | 3 | 18.750 | | 0.000 | | 0.000 | 1 | 3.125 | 5 | 62.500 | | 0.000 | 2 | 9.375 | | 0.000 | | 0.000 |
| | 2 | 9.375 | | 0.000 | | 0.000 | | 0.000 | 2 | 9.375 | | 0.000 | | 0.000 | | 0.000 | | 0.000 |
| | 4 | 37.500 | | 0.000 | | 0.000 | | 0.000 | 1 | 3.125 | | 0.000 | | 0.000 | | 0.000 | | 0.000 |
| | 4 | 37.500 | | 0.000 | | 0.000 | | 0.000 | 4 | 37.500 | | 0.000 | | 0.000 | | 0.000 | | 0.000 |
| | 3 | 18.750 | | 0.000 | | 0.000 | | 0.000 | | 0.000 | | 0.000 | | 0.000 | | 0.000 | | 0.000 |
| Total | | 503.125 | | 6.250 | | 46.875 | | 225.000 | | 1362.500 | | 6.250 | | 190.625 | | 620.375 | | 62.500 |
| Mean | | 17.969 | | 0.223 | | 1.674 | | 8.036 | | 48.661 | | 0.223 | | 6.808 | | 22.156 | | 2.232 |
| SD | | 11.926 | | 0.820 | | 2.619 | | 12.011 | | 29.676 | | 0.820 | | 7.798 | | 31.777 | | 4.154 |

Table C-4. Canopy cover class and percentage data for 30 Daubenmire plots on the drilling pad slopes at Tunalik Test Wellsite No. 1, 27 July 1991

| | Grass | | Shrubs | | Forbs | | Dead | | Moss | | Lichen | | Rock | | Bare | | Feces | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Class | % | Class | % | Class | % | Class | % | Class | % | Class | % | Class | % | Class | % | Class | % |
| | 4 | 37.500 | | | 1 | 3.125 | 5 | 62.500 | 1 | 3.125 | | | 1 | 3.125 | 4 | 37.500 | 1 | 3.125 |
| | 3 | 18.750 | | | | 0.000 | 3 | 18.750 | 1 | 3.125 | | | 2 | 9.375 | 7 | 96.375 | 1 | 3.125 |
| | 1 | 3.125 | | | | 0.000 | 3 | 18.750 | 1 | 3.125 | | | 1 | 3.125 | 4 | 37.500 | 1 | 3.125 |
| | 3 | 18.750 | | | | 0.000 | 6 | 84.375 | 1 | 3.125 | | | 3 | 18.750 | 2 | 9.375 | 1 | 3.125 |
| | 5 | 62.500 | | | | 0.000 | 4 | 37.500 | 1 | 3.125 | | | 3 | 18.750 | 4 | 37.500 | 1 | 3.125 |
| | 4 | 37.500 | | | | 0.000 | 3 | 18.750 | 1 | 3.125 | | | 3 | 18.750 | 2 | 9.375 | | 0.000 |
| | 3 | 18.750 | | | | 0.000 | 6 | 84.375 | 1 | 3.125 | | | 4 | 37.500 | 3 | 18.750 | | 0.000 |
| | 4 | 37.500 | | | | 0.000 | 4 | 37.500 | 1 | 3.125 | | | 1 | 3.125 | 4 | 37.500 | | 0.000 |
| | 2 | 9.375 | | | | 0.000 | 4 | 37.500 | 1 | 3.125 | | | 1 | 3.125 | 5 | 62.500 | | 0.000 |
| | 1 | 3.125 | | | | 0.000 | 5 | 62.500 | 1 | 3.125 | | | 3 | 18.750 | 1 | 3.125 | | 0.000 |
| | 5 | 62.500 | | | | 0.000 | 4 | 37.500 | 1 | 3.125 | | | 1 | 3.125 | 1 | 3.125 | | 0.000 |
| | 3 | 18.750 | | | | 0.000 | 2 | 9.375 | 1 | 3.125 | | | 2 | 9.375 | 1 | 3.125 | | 0.000 |
| | 2 | 9.375 | | | | 0.000 | 5 | 62.500 | 1 | 3.125 | | | 2 | 9.375 | 2 | 9.375 | | 0.000 |
| | 3 | 18.750 | | | | 0.000 | 3 | 18.750 | 1 | 3.125 | | | 2 | 9.375 | 2 | 9.375 | | 0.000 |
| | 1 | 3.125 | | | | 0.000 | 6 | 84.375 | 1 | 3.125 | | | 2 | 9.375 | 1 | 3.125 | | 0.000 |
| | 4 | 37.500 | | | | 0.000 | 1 | 3.125 | | 0.000 | | | 1 | 3.125 | 3 | 18.750 | | 0.000 |
| | 4 | 37.500 | | | | 0.000 | 6 | 84.375 | | 0.000 | | | 2 | 9.375 | 1 | 3.125 | | 0.000 |
| | 5 | 62.500 | | | | 0.000 | 5 | 62.500 | | 0.000 | | | 2 | 9.375 | 4 | 37.500 | | 0.000 |
| | 2 | 9.375 | | | | 0.000 | 4 | 37.500 | | 0.000 | | | 3 | 18.750 | 3 | 18.750 | | 0.000 |
| | 4 | 37.500 | | | | 0.000 | 6 | 84.375 | | 0.000 | | | 1 | 3.125 | 4 | 37.500 | | 0.000 |
| | 6 | 84.375 | | | | 0.000 | 5 | 62.500 | | 0.000 | | | | 0.000 | | 0.000 | | 0.000 |
| | 3 | 18.750 | | | | 0.000 | 4 | 37.500 | | 0.000 | | | | 0.000 | | 0.000 | | 0.000 |
| | 6 | 84.375 | | | | 0.000 | 6 | 84.375 | | 0.000 | | | | 0.000 | | 0.000 | | 0.000 |
| | 5 | 62.500 | | | | 0.000 | 6 | 84.375 | | 0.000 | | | | 0.000 | | 0.000 | | 0.000 |
| | 4 | 37.500 | | | | 0.000 | 5 | 62.500 | | 0.000 | | | | 0.000 | | 0.000 | | 0.000 |
| | 4 | 37.500 | | | | 0.000 | 6 | 84.375 | | 0.000 | | | | 0.000 | | 0.000 | | 0.000 |
| | 3 | 18.750 | | | | 0.000 | 3 | 18.750 | | 0.000 | | | | 0.000 | | 0.000 | | 0.000 |
| | 3 | 18.750 | | | | 0.000 | 4 | 37.500 | | 0.000 | | | | 0.000 | | 0.000 | | 0.000 |
| | 3 | 18.750 | | | | 0.000 | 2 | 9.375 | | 0.000 | | | | 0.000 | | 0.000 | | 0.000 |
| | 3 | 18.750 | | | | 0.000 | 6 | 84.375 | | 0.000 | | | | 0.000 | | 0.000 | | 0.000 |
| Total | | 906.250 | | 0.000 | | 3.125 | | 1418.750 | | 46.875 | | 0.000 | | 218.750 | | 493.250 | | 15.625 |
| Mean | | 30.208 | | | | 0.104 | | 47.292 | | 1.563 | | | | 7.292 | | 16.442 | | 0.521 |
| SD | | 22.919 | | | | 0.571 | | 28.188 | | 1.589 | | | | 8.813 | | 22.726 | | 1.185 |

Table C-5. Canopy cover class and percentage data for 15 Daubenmire plots on the insulated drilling pad surface at Inigok Test Wellsite No. 1, 18 July 1991

| | Grass | | Shrub | | Forbs | | Dead | | Moss | | Lichen | | Rock | | Bare | | Feces | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Class | % | Class | % | Class | % | Class | % | Class | % | Class | % | Class | % | Class | % | Class | % |
| | 2 | 9.375 | | | | | 3 | 18.750 | 2 | 9.375 | 1 | 3.125 | 5 | 62.500 | 3 | 18.750 | 1 | 3.125 |
| | 1 | 3.125 | | | | | 3 | 18.750 | 5 | 62.500 | 1 | 3.125 | 4 | 37.500 | 1 | 3.125 | | 0.000 |
| | 2 | 9.375 | | | | | 3 | 18.750 | 2 | 9.375 | 2 | 9.375 | 5 | 62.500 | 3 | 18.750 | | 0.000 |
| | 1 | 3.125 | | | | | 2 | 9.375 | 4 | 37.500 | | 0.000 | 4 | 37.500 | 5 | 62.500 | | 0.000 |
| | 2 | 9.375 | | | | | 4 | 37.500 | 5 | 62.500 | | 0.000 | 4 | 37.500 | 2 | 9.375 | | 0.000 |
| | 2 | 9.375 | | | | | 3 | 18.750 | 5 | 62.500 | | 0.000 | 4 | 37.500 | 2 | 9.375 | | 0.000 |
| | 1 | 3.125 | | | | | 3 | 18.750 | 4 | 37.500 | | 0.000 | 3 | 18.750 | 2 | 9.375 | | 0.000 |
| | 2 | 9.375 | | | | | 3 | 18.750 | 4 | 37.500 | | 0.000 | 5 | 62.500 | 4 | 37.500 | | 0.000 |
| | 1 | 3.125 | | | | | 2 | 9.375 | 4 | 37.500 | | 0.000 | 4 | 37.500 | 3 | 18.750 | | 0.000 |
| | 2 | 9.375 | | | | | 2 | 9.375 | 6 | 84.375 | | 0.000 | 4 | 37.500 | 3 | 18.750 | | 0.000 |
| | 1 | 3.125 | | | | | 3 | 18.750 | 5 | 62.500 | | 0.000 | 4 | 37.500 | 1 | 3.125 | | 0.000 |
| | 2 | 9.375 | | | | | 3 | 18.750 | 4 | 37.500 | | 0.000 | 4 | 37.500 | 1 | 3.125 | | 0.000 |
| | 2 | 9.375 | | | | | 2 | 9.375 | 5 | 62.500 | | 0.000 | 4 | 37.500 | 3 | 18.750 | | 0.000 |
| | 1 | 3.125 | | | | | 2 | 9.375 | | 0.000 | | 0.000 | 4 | 37.500 | 1 | 3.125 | | 0.000 |
| | 2 | 9.375 | | | | | 2 | 9.375 | | 0.000 | | 0.000 | 3 | 18.750 | 6 | 84.375 | | 0.000 |
| Total | | 103.125 | | 0.000 | | 0.000 | | 243.750 | | 603.125 | | 15.625 | | 600.000 | | 318.750 | | 3.125 |
| Mean | | 6.875 | | | | | | 16.250 | | 40.208 | | 1.042 | | 40.000 | | 21.250 | | 0.208 |
| SD | | 3.169 | | | | | | 7.489 | | 26.195 | | 2.552 | | 13.321 | | 23.481 | | 0.807 |

Table C-6. Canopy cover class and percentage data for 19 Daubenmire plots on the non-insulated drilling pad surface at Inigok Test Wellsite No. 1, 18 July 1991

| | Grass | | Shrub | | Dead | | Moss | | Peltigera | | Liverwort | | Rock | | Bare | | Feces | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Class | % | Class | % | Class | % | Class | % | Class | % | Class | % | Class | % | Class | % | Class | % |
| | 3 | 18.750 | 1 | 3.125 | 4 | 37.500 | 5 | 62.500 | 3 | 18.750 | 1 | 3.125 | 1 | 3.125 | 1 | 3.125 | 1 | 3.125 |
| | 3 | 18.750 | | 0.000 | 2 | 9.375 | 7 | 96.375 | 1 | 3.125 | | 0.000 | 2 | 9.375 | | 0.000 | 2 | 9.375 |
| | 2 | 9.375 | | 0.000 | 3 | 18.750 | 6 | 84.375 | | 0.000 | | 0.000 | 3 | 18.750 | | 0.000 | 1 | 3.125 |
| | 3 | 18.750 | | 0.000 | 3 | 18.750 | 6 | 84.375 | | 0.000 | | 0.000 | 1 | 3.125 | | 0.000 | 1 | 3.125 |
| | 4 | 37.500 | | 0.000 | 4 | 37.500 | 5 | 62.500 | | 0.000 | | 0.000 | 4 | 37.500 | | 0.000 | 1 | 3.125 |
| | 4 | 37.500 | | 0.000 | 3 | 18.750 | 4 | 37.500 | | 0.000 | | 0.000 | 4 | 37.500 | | 0.000 | 1 | 3.125 |
| | 1 | 3.125 | | 0.000 | 1 | 3.125 | 6 | 84.375 | | 0.000 | | 0.000 | 3 | 18.750 | | 0.000 | | 0.000 |
| | 3 | 18.750 | | 0.000 | 3 | 18.750 | 6 | 84.375 | | 0.000 | | 0.000 | 4 | 37.500 | | 0.000 | | 0.000 |
| | 3 | 18.750 | | 0.000 | 4 | 37.500 | 5 | 62.500 | | 0.000 | | 0.000 | 4 | 37.500 | | 0.000 | | 0.000 |
| | 2 | 9.375 | | 0.000 | 3 | 18.750 | 4 | 37.500 | | 0.000 | | 0.000 | 3 | 18.750 | | 0.000 | | 0.000 |
| | 1 | 3.125 | | 0.000 | 3 | 18.750 | 5 | 62.500 | | 0.000 | | 0.000 | 2 | 9.375 | | 0.000 | | 0.000 |
| | 1 | 3.125 | | 0.000 | 2 | 9.375 | 7 | 96.375 | | 0.000 | | 0.000 | 4 | 37.500 | | 0.000 | | 0.000 |
| | 1 | 3.125 | | 0.000 | 2 | 9.375 | 5 | 62.500 | | 0.000 | | 0.000 | 4 | 37.500 | | 0.000 | | 0.000 |
| | 2 | 9.375 | | 0.000 | 3 | 18.750 | 5 | 62.500 | | 0.000 | | 0.000 | | 0.000 | | 0.000 | | 0.000 |
| | 1 | 3.125 | | 0.000 | 3 | 18.750 | 6 | 84.375 | | 0.000 | | 0.000 | | 0.000 | | 0.000 | | 0.000 |
| | 2 | 9.375 | | 0.000 | 4 | 37.500 | 4 | 37.500 | | 0.000 | | 0.000 | | 0.000 | | 0.000 | | 0.000 |
| | 2 | 9.375 | | 0.000 | 4 | 37.500 | 4 | 37.500 | | 0.000 | | 0.000 | | 0.000 | | 0.000 | | 0.000 |
| | 2 | 9.375 | | 0.000 | 6 | 84.375 | 2 | 9.375 | | 0.000 | | 0.000 | | 0.000 | | 0.000 | | 0.000 |
| | 3 | 18.750 | | 0.000 | 3 | 18.750 | 5 | 62.500 | | 0.000 | | 0.000 | | 0.000 | | 0.000 | | 0.000 |
| Total | | 259.375 | | 3.125 | | 471.875 | | 1211.500 | | 21.875 | | 3.125 | | 306.250 | | 3.125 | | 25.000 |
| Mean | | 13.651 | | 0.164 | | 24.836 | | 63.763 | | 1.151 | | 0.164 | | 16.118 | | 0.164 | | 1.316 |
| SD | | 10.428 | | 0.717 | | 18.056 | | 23.546 | | 4.321 | | 0.717 | | 16.247 | | 0.717 | | 2.402 |

Table C-7. Canopy cover class and percentage data for 35 Daubenmire plots read on the drilling pad slopes at Inigok Test Wellsite No. 1, 19 July 1991

| | Grass | | Shrub | | Forbs | | Dead | | Moss | | Lichen | | Rock | | Bare | | Feces | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Class | % | Class | % | Class | % | Class | % | Class | % | Class | % | Class | % | Class | % | Class | % |
| | 5 | 62.500 | | | 1 | 3.125 | 5 | 62.500 | 1 | 3.125 | | | 2 | 9.375 | 2 | 9.375 | 1 | 3.125 |
| | 5 | 62.500 | | | 5 | 62.500 | 5 | 62.500 | 1 | 3.125 | | | 5 | 62.500 | 4 | 37.500 | 1 | 3.125 |
| | 4 | 37.500 | | | 2 | 9.375 | 5 | 62.500 | 2 | 9.375 | | | 4 | 37.500 | 3 | 18.750 | | 0.000 |
| | 4 | 37.500 | | | 1 | 3.125 | 6 | 84.375 | 2 | 9.375 | | | 3 | 18.750 | 1 | 3.125 | | 0.000 |
| | 4 | 37.500 | | | 2 | 9.375 | 4 | 37.500 | 1 | 3.125 | | | 1 | 3.125 | 2 | 9.375 | | 0.000 |
| | 4 | 37.500 | | | 2 | 9.375 | 4 | 37.500 | 1 | 3.125 | | | | 0.000 | 3 | 18.750 | | 0.000 |
| | 2 | 9.375 | | | | 0.000 | 7 | 96.375 | 1 | 3.125 | | | | 0.000 | 4 | 37.500 | | 0.000 |
| | 3 | 18.750 | | | | 0.000 | 6 | 84.375 | 3 | 18.750 | | | | 0.000 | | 0.000 | | 0.000 |
| | 4 | 37.500 | | | | 0.000 | 6 | 84.375 | 1 | 3.125 | | | | 0.000 | | 0.000 | | 0.000 |
| | 3 | 18.750 | | | | 0.000 | 5 | 62.500 | 1 | 3.125 | | | | 0.000 | | 0.000 | | 0.000 |
| | 4 | 37.500 | | | | 0.000 | 6 | 84.375 | 3 | 18.750 | | | | 0.000 | | 0.000 | | 0.000 |
| | 5 | 62.500 | | | | 0.000 | 5 | 62.500 | 4 | 37.500 | | | | 0.000 | | 0.000 | | 0.000 |
| | 4 | 37.500 | | | | 0.000 | 6 | 84.375 | 2 | 9.375 | | | | 0.000 | | 0.000 | | 0.000 |
| | 4 | 37.500 | | | | 0.000 | 5 | 62.500 | 3 | 18.750 | | | | 0.000 | | 0.000 | | 0.000 |
| | 3 | 18.750 | | | | 0.000 | 6 | 84.375 | | 0.000 | | | | 0.000 | | 0.000 | | 0.000 |
| | 3 | 18.750 | | | | 0.000 | 7 | 96.375 | | 0.000 | | | | 0.000 | | 0.000 | | 0.000 |
| | 4 | 37.500 | | | | 0.000 | 6 | 84.375 | | 0.000 | | | | 0.000 | | 0.000 | | 0.000 |
| | 4 | 37.500 | | | | 0.000 | 7 | 96.375 | | 0.000 | | | | 0.000 | | 0.000 | | 0.000 |
| | 2 | 9.375 | | | | 0.000 | 2 | 9.375 | | 0.000 | | | | 0.000 | | 0.000 | | 0.000 |
| | 4 | 37.500 | | | | 0.000 | 5 | 62.500 | | 0.000 | | | | 0.000 | | 0.000 | | 0.000 |
| | 2 | 9.375 | | | | 0.000 | 7 | 96.375 | | 0.000 | | | | 0.000 | | 0.000 | | 0.000 |
| | 5 | 62.500 | | | | 0.000 | 6 | 84.375 | | 0.000 | | | | 0.000 | | 0.000 | | 0.000 |
| | 3 | 18.750 | | | | 0.000 | 4 | 37.500 | | 0.000 | | | | 0.000 | | 0.000 | | 0.000 |
| | 3 | 18.750 | | | | 0.000 | 7 | 96.375 | | 0.000 | | | | 0.000 | | 0.000 | | 0.000 |
| | 4 | 37.500 | | | | 0.000 | 4 | 37.500 | | 0.000 | | | | 0.000 | | 0.000 | | 0.000 |
| | 4 | 37.500 | | | | 0.000 | 6 | 84.375 | | 0.000 | | | | 0.000 | | 0.000 | | 0.000 |
| | 4 | 37.500 | | | | 0.000 | 6 | 84.375 | | 0.000 | | | | 0.000 | | 0.000 | | 0.000 |
| | 4 | 37.500 | | | | 0.000 | 6 | 84.375 | | 0.000 | | | | 0.000 | | 0.000 | | 0.000 |
| | 4 | 37.500 | | | | 0.000 | 6 | 84.375 | | 0.000 | | | | 0.000 | | 0.000 | | 0.000 |
| | 3 | 18.750 | | | | 0.000 | 6 | 84.375 | | 0.000 | | | | 0.000 | | 0.000 | | 0.000 |
| | 3 | 18.750 | | | | 0.000 | 7 | 96.375 | | 0.000 | | | | 0.000 | | 0.000 | | 0.000 |
| | 3 | 18.750 | | | | 0.000 | 7 | 96.375 | | 0.000 | | | | 0.000 | | 0.000 | | 0.000 |
| | 4 | 37.500 | | | | 0.000 | 6 | 84.375 | | 0.000 | | | | 0.000 | | 0.000 | | 0.000 |
| | 3 | 18.750 | | | | 0.000 | 5 | 62.500 | | 0.000 | | | | 0.000 | | 0.000 | | 0.000 |
| | 4 | 37.500 | | | | 0.000 | 7 | 96.375 | | 0.000 | | | | 0.000 | | 0.000 | | 0.000 |
| Total | | 1140.625 | | 0.000 | | 96.875 | | 2611.625 | | 143.750 | | 0.000 | | 131.250 | | 134.375 | | 6.250 |
| Mean | | 32.589 | | | | 2.768 | | 74.618 | | 4.107 | | | | 3.750 | | 3.839 | | 0.179 |
| SD | | 14.896 | | | | 10.739 | | 21.735 | | 8.049 | | | | 12.449 | | 9.679 | | 0.736 |

Table C-8. Canopy cover class and percentage data for 25 Daubenmire plots on the drilling pad surface at Lisburne Test Wellsite No. 1, 23 July 1991

| | Grass | | Shrubs | | Forbs | | Dead | | Moss | | Lichen | | Rock | | Bare | | Feces | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Class | % | Class | % | Class | % | Class | % | Class | % | Class | % | Class | % | Class | % | Class | % |
| | 1 | 3.125 | | | 1 | 3.125 | 2 | 9.375 | 3 | 18.750 | | | 5 | 62.500 | 4 | 37.500 | | |
| | 3 | 18.750 | | | 2 | 9.375 | 2 | 9.375 | 3 | 18.750 | | | 6 | 84.375 | 2 | 9.375 | | |
| | 3 | 18.750 | | | 2 | 9.375 | 2 | 9.375 | 3 | 18.750 | | | 6 | 84.375 | 2 | 9.375 | | |
| | 2 | 9.375 | | | 1 | 3.125 | 1 | 3.125 | 2 | 9.375 | | | 4 | 37.500 | 4 | 37.500 | | |
| | 1 | 3.125 | | | 1 | 3.125 | 1 | 3.125 | 1 | 3.125 | | | 4 | 37.500 | 5 | 62.500 | | |
| | 1 | 3.125 | | | 3 | 18.750 | 1 | 3.125 | 2 | 9.375 | | | 3 | 18.750 | 6 | 84.375 | | |
| | 4 | 37.500 | | | 3 | 18.750 | 2 | 9.375 | | 0.000 | | | 4 | 37.500 | 3 | 18.750 | | |
| | 1 | 3.125 | | | | 0.000 | 2 | 9.375 | | 0.000 | | | 5 | 62.500 | 5 | 62.500 | | |
| | 2 | 9.375 | | | | 0.000 | 3 | 18.750 | | 0.000 | | | 4 | 37.500 | 2 | 9.375 | | |
| | 3 | 18.750 | | | | 0.000 | 3 | 18.750 | | 0.000 | | | 2 | 9.375 | 5 | 62.500 | | |
| | 3 | 18.750 | | | | 0.000 | 1 | 3.125 | | 0.000 | | | 4 | 37.500 | 3 | 18.750 | | |
| | 1 | 3.125 | | | | 0.000 | 1 | 3.125 | | 0.000 | | | 3 | 18.750 | 6 | 84.375 | | |
| | 1 | 3.125 | | | | 0.000 | 1 | 3.125 | | 0.000 | | | 2 | 9.375 | 7 | 96.375 | | |
| | 3 | 18.750 | | | | 0.000 | 1 | 3.125 | | 0.000 | | | 4 | 37.500 | 6 | 84.375 | | |
| | 2 | 9.375 | | | | 0.000 | 1 | 3.125 | | 0.000 | | | 3 | 18.750 | 6 | 84.375 | | |
| | 1 | 3.125 | | | | 0.000 | 2 | 9.375 | | 0.000 | | | 3 | 18.750 | 6 | 84.375 | | |
| | 3 | 18.750 | | | | 0.000 | 1 | 3.125 | | 0.000 | | | 3 | 18.750 | 6 | 84.375 | | |
| | 2 | 9.375 | | | | 0.000 | 2 | 9.375 | | 0.000 | | | 3 | 18.750 | 6 | 84.375 | | |
| | 3 | 18.750 | | | | 0.000 | 2 | 9.375 | | 0.000 | | | 4 | 37.500 | 6 | 84.375 | | |
| | | 0.000 | | | | 0.000 | 2 | 9.375 | | 0.000 | | | 3 | 18.750 | 5 | 62.500 | | |
| | | 0.000 | | | | 0.000 | | 0.000 | | 0.000 | | | 3 | 18.750 | 3 | 18.750 | | |
| | | 0.000 | | | | 0.000 | | 0.000 | | 0.000 | | | 3 | 18.750 | 4 | 37.500 | | |
| | | 0.000 | | | | 0.000 | | 0.000 | | 0.000 | | | 4 | 37.500 | 3 | 18.750 | | |
| | | 0.000 | | | | 0.000 | | 0.000 | | 0.000 | | | 4 | 37.500 | 2 | 9.375 | | |
| | | 0.000 | | | | 0.000 | | 0.000 | | 0.000 | | | 4 | 37.500 | 2 | 9.375 | | |
| Total | | 228.125 | | 0.000 | | 65.625 | | 150.000 | | 78.125 | | 0.000 | | 856.250 | | 1255.750 | | 0.000 |
| Mean | | 9.125 | | | | 2.625 | | 6.000 | | 3.125 | | | | 34.250 | | 50.230 | | |
| SD | | 9.586 | | | | 5.538 | | 5.331 | | 6.442 | | | | 20.541 | | 32.181 | | |

Table C-9. Canopy cover class and percentage data for 25 Daubenmire plots on the drilling pad slopes at Lisburne Test Wellsite No. 1, 23 July 1991

| | Grass | | Shrubs | | Forbs | | Dead | | Moss | | Lichen | | Rock | | Bare | | Feces | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Class | % | Class | % | Class | % | Class | % | Class | % | Class | % | Class | % | Class | % | Class | % |
| | 2 | 9.375 | | | 3 | 18.750 | 2 | 9.375 | 2 | 9.375 | | | 5 | 62.500 | 2 | 9.375 | | |
| | 3 | 18.750 | | | 3 | 18.750 | 4 | 37.500 | 1 | 3.125 | | | 3 | 18.750 | 2 | 9.375 | | |
| | 3 | 18.750 | | | 4 | 37.500 | 4 | 37.500 | 1 | 3.125 | | | 3 | 18.750 | 1 | 3.125 | | |
| | 4 | 37.500 | | | 2 | 9.375 | 5 | 62.500 | 2 | 9.375 | | | 3 | 18.750 | 1 | 3.125 | | |
| | 4 | 37.500 | | | 4 | 37.500 | 5 | 62.500 | 2 | 9.375 | | | 2 | 9.375 | 3 | 18.750 | | |
| | 3 | 18.750 | | | 2 | 9.375 | 3 | 18.750 | 1 | 3.125 | | | 4 | 37.500 | 1 | 3.125 | | |
| | 3 | 18.750 | | | 5 | 62.500 | 3 | 18.750 | 2 | 9.375 | | | 2 | 9.375 | 2 | 9.375 | | |
| | 3 | 18.750 | | | 2 | 9.375 | 5 | 62.500 | 3 | 18.750 | | | 2 | 9.375 | 2 | 9.375 | | |
| | 3 | 18.750 | | | 3 | 18.750 | 4 | 37.500 | | 0.000 | | | 3 | 18.750 | 2 | 9.375 | | |
| | 4 | 37.500 | | | 4 | 37.500 | 4 | 37.500 | | 0.000 | | | 3 | 18.750 | 1 | 3.125 | | |
| | 3 | 18.750 | | | 4 | 37.500 | 5 | 62.500 | | 0.000 | | | 3 | 18.750 | 4 | 37.500 | | |
| | 4 | 37.500 | | | 3 | 18.750 | 3 | 18.750 | | 0.000 | | | 5 | 62.500 | 1 | 3.125 | | |
| | 5 | 62.500 | | | 2 | 9.375 | 4 | 37.500 | | 0.000 | | | 3 | 18.750 | 2 | 9.375 | | |
| | 3 | 18.750 | | | 2 | 9.375 | 3 | 18.750 | | 0.000 | | | 5 | 62.500 | | 0.000 | | |
| | 3 | 18.750 | | | 2 | 9.375 | 3 | 18.750 | | 0.000 | | | 6 | 84.375 | | 0.000 | | |
| | 2 | 9.375 | | | 4 | 37.500 | 2 | 9.375 | | 0.000 | | | 5 | 62.500 | | 0.000 | | |
| | 3 | 18.750 | | | 4 | 37.500 | 2 | 9.375 | | 0.000 | | | 4 | 37.500 | | 0.000 | | |
| | 5 | 62.500 | | | 4 | 37.500 | 4 | 37.500 | | 0.000 | | | 5 | 62.500 | | 0.000 | | |
| | 2 | 9.375 | | | 3 | 18.750 | 1 | 3.125 | | 0.000 | | | 4 | 37.500 | | 0.000 | | |
| | 3 | 18.750 | | | 5 | 62.500 | 4 | 37.500 | | 0.000 | | | 2 | 9.375 | | 0.000 | | |
| | 2 | 9.375 | | | 1 | 3.125 | 5 | 62.500 | | 0.000 | | | 2 | 9.375 | | 0.000 | | |
| | 3 | 18.750 | | | 1 | 3.125 | 4 | 37.500 | | 0.000 | | | 4 | 37.500 | | 0.000 | | |
| | 2 | 9.375 | | | 2 | 9.375 | 1 | 3.125 | | 0.000 | | | 3 | 18.750 | | 0.000 | | |
| | 3 | 18.750 | | | | 0.000 | 3 | 18.750 | | 0.000 | | | 3 | 18.750 | | 0.000 | | |
| | 4 | 37.500 | | | | 0.000 | | 0.000 | | 0.000 | | | | 0.000 | | 0.000 | | |
| Total | | 603.125 | | 0.000 | | 553.125 | | 759.375 | | 65.625 | | 0.000 | | 762.500 | | 128.125 | | 0.000 |
| Mean | | 24.125 | | | | 22.125 | | 30.375 | | 2.625 | | | | 30.500 | | 5.125 | | |
| SD | | 14.865 | | | | 18.040 | | 20.522 | | 4.831 | | | | 22.933 | | 8.360 | | |

Table C-10. Species compostion data from walking point samples, Inigok Test Wellsite No. 1 and Tunalik Test Wellsite No. 1 in NPRA, July 1991

| Site | Species | Insulated Pad | | Non-Insulated Pad | | Pad Slopes | |
|---|---|---|---|---|---|---|---|
| | | Points | % | Points | % | Points | % |
| **Inigok Test Wellsite No. 1** | | | | | | | |
| | Gramnoids: | | | | | | |
| | *Arctagrostis latifolia* | 0 | 0.00 | 26 | 17.57 | 37 | 56.06 |
| | *Carex aquatilis* | 0 | 0.00 | 4 | 2.70 | 0 | 0.00 |
| | *Festuca rubra* | 10 | 4.35 | 109 | 73.65 | 27 | 40.91 |
| | *Poa glauca* | 216 | 93.91 | 9 | 6.08 | 0 | 0.00 |
| | *Puccinellia andersonii* | 3 | 1.30 | 0 | 0.00 | 0 | 0.00 |
| | Total for Gramnoids | 229 | 99.57 | 148 | 100.00 | 64 | 96.97 |
| | Shrubs: | | | | | | |
| | *Salix glauca* | 1 | 0.43 | 0 | 0.00 | 0 | 0.00 |
| | Forbs: | | | | | | |
| | *Equisetum arvense* | 0 | 0.00 | 0 | 0.00 | 2 | 3.03 |
| | Total points | 230 | 100.00 | 148 | 100.00 | 66 | 100.00 |
| **Tunalik Test Wellsite No. 1** | | | | | | | |
| | Gramnoids: | | | | | | |
| | *Arctagrostis latifolia* | 1 | 0.80 | 1 | 0.89 | 44 | 39.64 |
| | *Arctophila fulva* | 0 | 0.00 | 29 | 25.89 | 0 | 0.00 |
| | *Carex aquatilis* | 0 | 0.00 | 15 | 13.39 | 4 | 3.60 |
| | *Dupontia fisheri* | 0 | 0.00 | 1 | 0.89 | 0 | 0.00 |
| | *Eriophorum scheuchzeri* | 0 | 0.00 | 0 | 0.00 | 1 | 0.90 |
| | *Festuca rubra* | 21 | 16.80 | 4 | 3.57 | 32 | 28.83 |
| | *Phippsia algida* | 18 | 14.40 | 20 | 17.86 | 5 | 4.50 |
| | *Poa glauca* | 83 | 66.40 | 36 | 32.14 | 24 | 21.62 |
| | Total for Gramnoids | 123 | 98.40 | 106 | 94.64 | 110 | 99.10 |
| | Forbs: | | | | | | |
| | *Tanacetum bipinnatum* | 0 | 0.00 | 1 | 0.89 | 0 | 0.00 |
| | *Cochlearia officinalis* | 1 | 0.80 | 1 | 0.89 | 0 | 0.00 |
| | *Draba corymbosa (macrocarpa)* | 1 | 0.80 | 0 | 0.00 | 0 | 0.00 |
| | *Ranunculus gmelini* | 0 | 0.00 | 4 | 3.57 | 0 | 0.00 |
| | *Stellaria humifusa* | 0 | 0.00 | 0 | 0.00 | 1 | 0.90 |
| | Total for Forbs | 2 | 1.60 | 6 | 5.36 | 1 | 0.90 |
| | Total Points | 125 | 100.00 | 112 | 100.00 | 111 | 100.00 |

Table C-11. Species compostion data from walking point samples, Lisburne Test Wellsite No. 1 in NPRA, 21-23 July 1991

| | Insulated Pad | | Pad Slopes | |
|---|---|---|---|---|
| Species | Points | % | Points | % |
| Graminoids | | | | |
| *Agropyron boreale* | 19 | 12.93 | 3 | 2.75 |
| *Arctagrostis latifolia* | 2 | 1.36 | 3 | 2.75 |
| *Carex aquatilis* | 1 | 0.68 | 0 | 0.00 |
| *Festuca baffinensis* | 1 | 0.68 | 0 | 0.00 |
| *Festuca rubra* | 8 | 5.44 | 67 | 61.47 |
| *Poa glauca* | 91 | 61.90 | 4 | 3.67 |
| *Trisetum spicatum* | 2 | 1.36 | 0 | 0.00 |
| Total for Gramnoids | 124 | 84.35 | 77 | 70.64 |
| Shrubs: | | | | |
| *Salix alaxensis* | 1 | 0.68 | 0 | 0.00 |
| Forbs: | | | | |
| *Androsace septentrionalis* | 3 | 2.04 | 0 | 0.00 |
| *Artimesia tilesii* | 1 | 0.68 | 0 | 0.00 |
| *Aster sibiricus* | 0 | 0.00 | 2 | 1.83 |
| *Astragalus alpinus ssp. alpinus* | 9 | 6.12 | 10 | 9.17 |
| *Cerastium beeringianum var. beeringianum* | 1 | 0.68 | 0 | 0.00 |
| *Epilobium angustifolium* | 0 | 0.00 | 1 | 0.92 |
| *Epilobium latifolium* | 2 | 1.36 | 17 | 15.60 |
| *Oxytropis deflexa* | 1 | 0.68 | 2 | 1.83 |
| *Papaver lapponicum ssp. porsildii* | 1 | 0.68 | 0 | 0.00 |
| *Papaver macounii* | 4 | 2.72 | 0 | 0.00 |
| Total for Forbs | 22 | 14.97 | 32 | 29.36 |
| Total points | 147 | 100.00 | 109 | 100.00 |

## APPENDIX D

## PHOTOPLOT DATA

A listing of the photoplots extablished and photos taken during July 1991 at three exploratory wellsites in NPRA, Alaska.

Table D-1. Preliminary listing of photoplot data[1] for three NPRA sites examined during the 1991 field season -- includes 43 camera points and 143 views.

| Photoplot Name (and/or subject) | View | 1991 Film I.D.[1] | Original Date | Most Recent Date |
|---|---|---|---|---|
| Inigok PP #1 | Frost Wedge | M-20-91 (1,2) | 17 July 1991 | 17 July 1991 |
| Inigok PP #2 | SW Inigok | M-20-91 (5) | 17 July 1991 | 17 July 1991 |
| Inigok PP #2 | West Wellhead | M-20-91 (6) | 17 July 1991 | 17 July 1991 |
| Inigok PP #2 | NW | M-20-91 (7) | 17 July 1991 | 17 July 1991 |
| Inigok PP #3 | South-Cabin | M-20-91 (10) | 17 July 1991 | 17 July 1991 |
| Inigok PP #3 | West-Wellhead | M-20-91 (11) | 17 July 1991 | 17 July 1991 |
| Inigok PP #4 | Toward Cabin | M-21-91 (1) | 17 July 1991 | 17 July 1991 |
| Inigok PP #4 (Close) | Wellhead | M-21-91 (3,4) | 17 July 1991 | 17 July 1991 |
| Inigok PP #4 (Fru,Dso,Pucc.) | Wellhead | M-21-91 (5) | 17 July 1991 | 17 July 1991 |
| Inigok PP #5 (Pad edge) | SE | M-21-91 (16) | 17 July 1991 | 17 July 1991 |
| Inigok PP #5 | S-Cabin | M-21-91 (17) | 17 July 1991 | 17 July 1991 |
| Inigok PP #5 | SW-Wellhead | M-21-91 (18) | 17 July 1991 | 17 July 1991 |
| Inigok PP #6 (Horizontal) | NE Corner-- Salt Spill?? | M-21-91 (21) | 17 July 1991 | 17 July 1991 |
| Inigok PP #6 (Vertical) | NE Corner-- Salt Spill?? | M-21-91 (22) | 17 July 1991 | 17 July 1991 |
| Inigok PP #7 (28 mm lens) (Burned debris from pad) | Centered on tip of peninsula | M-21-91 (23) | 17 July 1991 | 17 July 1991 |
| Inigok PP #8, Wave-cut edge in NE Corner of Reserve Pit | NW | M-21-91 (24) | 10 July 1984 | 17 July 1991 |
| Inigok PP #9, SW Reserve Pit Berm (Vertical) | NW | M-21-91 (34) | 10 July 1984 | 17 July 1984 |
| Inigok PP #9 (AFU invading berm) | W--Sand dune | M-21-91 (35) | 17 July 1991 | 17 July 1984 |
| Inigok PP #10 (West Corner of Pad--across leak area) | West--Sand dunes | M-21-91 (36) | 17 July 1991 | 17 July 1991 |
| Inigok PP #10 (Along outer edge of reserve pit) | West | M-22-91 (1) | 17 July 1991 | 17 July 1991 |
| Inigok PP #10 (across lake) | NW | M-22-91 (2) | 17 July 1991 | 17 July 1991 |
| Inigok PP #10 (across lake) | North--dunes | M-22-91 (3) | 17 July 1991 | 17 July 1991 |
| Inigok PP #10 (edge of pad) | NE | M-22-91 (4) | 17 July 1991 | 17 July 1991 |
| Inigok PP #10 (across pad) | E--old camp | M-22-91 (5) | 17 July 1991 | 17 July 1991 |
| Inigok PP #10 (across pad) | E--Wellhead | M-22-91 (6) | 17 July 1991 | 17 July 1991 |
| Inigok PP #10 (across pit) | South--cabin | M-22-91 (7,8) | 17 July 1991 | 17 July 1991 |

| Photoplot Name (and/or subject) | View | 1991 Film I.D.[1] | Original Date | Most Recent Date |
|---|---|---|---|---|
| Inigok PP #11 (across thermokarst) (vertical) | Cabin | M-22-91 (9) | 17 July 1991 | 17 July 1991 |
| Inigok PP #11 (across thermokarst (horizontal) | Cabin | M-22-91 (10) | 17 July 1991 | 17 July 1991 |
| Inigok PP #11 | Wellhead | M-22-91 (12) | 17 July 1991 | 17 July 1991 |
| Inigok PP #11 (toward lake edge) | NE | M-22-91 (13) | 17 July 1991 | 17 July 1991 |
| Inigok PP #11 (toward Lake) (Maynard and Warren) | PP #12 | M-22-91 (14) | 17 July 1991 | 17 July 1991 |
| Inigok PP #12 (Polygon on pad) | Cabin (left) Well (right | M-22-91 (15,16) | 17 July 1991 | 17 July 1991 |
| Inigok PP #13 (Old tundra fire) | Toward Wellhead | M-23-91 (30,31,32,33) | 30 Aug 1978 | 17 July 1991 |
| Lisburne PP #1 (Toward well) | NW | M-28-91 (13) | 21 July 1991 | 21 July 1991 |
| Lisburne PP #1 (Toward Notch on horizon) | North | M-28-91 (14,18) | 21 July 1991 | 21 July 1991 |
| Lisburne PP #1 (along edge between middle and upper pads) | East | M-28-91 (15,16) | 21 July 1991 | 21 July 1991 |
| Lisburne PP #2 (from road across stream) | East--drilling pad | M-29-91 (35,36,37) | 8 Aug 1979 | 22 July 1991 |
| Lisburne PP #3 (from road east side of bridge) | SE--drilling pad | M-30-91 (1,2,3) | 8 Aug 1979 | 22 July 1991 |
| Lisburne PP #4 (from road across stream) | S-helicopter hill | M-30-91 (4) | 8 Aug 1979 | 22 July 1991 |
| Lisburne PP #5 (Toward reserve pit from road) | SE? | M-30-91 (24) | 22 July 1991 | 22 July 1991 |
| Lisburne PP #5 (Toward wellhead from road) | SE | M-30-91 (25) | 22 July 1991 | 22 July 1991 |
| Lisburne PP #5 (Toward valley gap from road) | East | M-30-91 (26) | 22 July 1991 | 22 July 1991 |
| Lisburne PP #5 (Toward west end of drilling pad) | South | M-30-91 (27) | 22 July 1991 | 22 July 1991 |
| Lisburne PP #6 (from corner of drilling pad) | Edge of hill | M-30-91 (28) | 22 July 1991 | 22 July 1991 |
| Lisburne PP #6 (from corner of drilling pad) | Toward "V" | M-30-91 (29) | 22 July 1991 | 22 July 1991 |
| Lisburne PP #6 (from corner of drilling pad) | Toward wellhead | M-30-91 (30) | 22 July 1991 | 22 July 1991 |
| Lisburne PP #6 (from corner of drilling pad) | Toward valley center | M-30-91 (31) | 22 July 1991 | 22 July 1991 |

| Photoplot Name (and/or subject) | View | 1991 Film I.D.[1] | Original Date | Most Recent Date |
|---|---|---|---|---|
| Lisburne PP #6 (from corner of drilling pad) | Toward 2nd "V", SE | M-30-91 (32) | 22 July 1991 | 22 July 1991 |
| Lisburne PP #6 (from corner of drilling pad) | Toward south valley and culvert | M-30-91 (33) | 22 July 1991 | 22 July 1991 |
| Lisburne PP #7 | Toward airstrip | M-30-91 (34) | 22 July 1991 | 22 July 1991 |
| Lisburne PP #7 | Toward edge of hill NW of pad | M-30-91 (35) | 22 July 1991 | 22 July 1991 |
| Lisburne PP #7 | Toward NW end of flare pit | M-30-91 (36) | 22 July 1991 | 22 July 1991 |
| Lisburne PP #7 | Toward wellhead | M-31-91 (1) | 22 July 1991 | 22 July 1991 |
| Lisburne PP #7 | Toward Valley south | M-31-91 (2) | 22 July 1991 | 22 July 1991 |
| Lisburne PP #7 (foreground) | Toward "finger" | M-31-91 (3) | 22 July 1991 | 22 July 1991 |
| Lisburne PP #7 (general) | Toward "finger" | M-31-91 (4) | 22 July 1991 | 22 July 1991 |
| Lisburne PP #7 | Toward valley East | M-31-91 (5) | 22 July 1991 | 22 July 1991 |
| Lisburne PP #13 (east edge of reserve pit) | SW toward valley | M-31-91 (6) | 22 July 1991 | 22 July 1991 |
| Lisburne PP #13 (east edge of reserve pit) | Hill to west | M-31-91 (7) | 22 July 1991 | 22 July 1991 |
| Lisburne PP #13 (east edge of reserve pit) | Hills to NW | M-31-91 (8) | 22 July 1991 | 22 July 1991 |
| Lisburne PP #14 (along inside of reserve pit berm) (vertical) | West | M-31-91 (9) | 22 July 1991 | 22 July 1991 |
| Lisburne PP #14 (from cutting pile ) (vertical) | Peak | M-31-91 (10) | 22 July 1991 | 22 July 1991 |
| Lisburne PP #14 (from cutting pile) (vertical) | North | M-31-91 (11) | 22 July 1991 | 22 July 1991 |
| Lisburne PP #14 (from cutting pile) (vertical) | NE | M-31-91 (12) | 22 July 1991 | 22 July 1991 |
| Lisburne PP #14 (from cutting pile) (vertical) | East | M-31-91 (13) | 22 July 1991 | 22 July 1991 |
| Lisburne PP #14 (from cutting pile) (horizontal) | North | M-31-91 (14) | 22 July 1991 | 22 July 1991 |
| Lisburne PP #15 (west edge of reserve pit where it might fail) | North | M-31-91 (15) | 22 July 1991 | 22 July 1991 |

| Photoplot Name (and/or subject) | View | 1991 Film I.D.[1] | Original Date | Most Recent Date |
|---|---|---|---|---|
| Lisburne PP #16 (along outer edge of reserve pit) | East | M-31-91 (16) | 17 July 1984 | 22 July 1991 |
| Lisburne PP #16 (possible seep area outside reserve pit) | NE? | M-31-91 (18) | 22 July 1991 | 22 July 1991 |
| Ground squirrel use of buried pipe west corner of Lisburne pad | West | M-31-91 (19,20) | 22 July 1991 | 22 July 1991 |
| Lisburne PP #9 (from NW corner of pad) | West -- culvert & hilltop | M-31-91 (21) | 22 July 1991 | 22 July 1991 |
| Lisburne PP #9 (from NW corner of pad) | Pad edge--NW | M-31-91 (22) | 22 July 1991 | 22 July 1991 |
| Lisburne PP #9 (from NW corner of pad) | East | M-31-91 (23) | 22 July 1991 | 22 July 1991 |
| Lisburne PP #9 (from NW corner of pad) | N-side of valley on SE | M-31-91 (24) | 22 July 1991 | 22 July 1991 |
| Lisburne PP #9 (from NW corner of pad) (close) | South | M-31-91 (25) | 22 July 1991 | 22 July 1991 |
| Lisburne PP #10 (west corner of pad) | open 'v' on horizon | M-31-91 (26) | 22 July 1991 | 22 July 1991 |
| Lisburne PP #10 (west corner of pad) | NE corner of pad | M-31-91 (27) | 22 July 1991 | 22 July 1991 |
| Lisburne PP #10 (west corner of pad) | NW toward PP #9 | M-31-91 (28) | 22 July 1991 | 22 July 1991 |
| Lisburne PP #12 (upper pad near thermokarst depression) | West -- airstrip & point | M-31-91 (29) | 22 July 1991 | 22 July 1991 |
| Lisburne PP #12 (upper pad near thermokarst depression) | NW -- small knob on horizon | M-31-91 (30) | 22 July 1991 | 22 July 1991 |
| Lisburne PP #12 (upper pad near thermokarst depression | Toward PP #8 on upper pad | M-31-91 (31) | 22 July 1991 | 22 July 1991 |
| Lisburne PP #12 (upper pad near thermokarst depression) | E--left side of valley gap | M-31-91 (32) | 22 July 1991 | 22 July 1991 |
| Lisburne PP #12 (upper pad near thermokarst depression) | SW--valley gap | M-31-91 (33) | 22 July 1991 | 22 July 1991 |
| Lisburne PP #11 (SW corner of uppermost pad) | Peak over airstrip | M-32-91 (3) | 22 July 1991 | 22 July 1991 |
| Lisburne PP #11 (SW corner of uppermost pad) | NW--edge of pad | M-32-91 (4) | 22 July 1991 | 22 July 1991 |
| Lisburne PP #11 (SW corner of uppermost pad) | West--edge of pad | M-32-91 (5) | 22 July 1991 | 22 July 1991 |
| Lisburne PP #8 (NE corner of uppermost pad) | West over wellhead | M-32-91 (6) | 22 July 1991 | 22 July 1991 |

| Photoplot Name (and/or subject) | View | 1991 Film I.D.[1] | Original Date | Most Recent Date |
|---|---|---|---|---|
| Lisburne PP #8 (NE corner of uppermost pad) | NW--knoll on horizon over flare pit | M-32-91 (7) | 22 July 1991 | 22 July 1991 |
| Lisburne PP #8 (NE corner of uppermost pad) (close) | East | M-32-91 (8) | 22 July 1991 | 22 July 1991 |
| Lisburne PP #8 (NE corner of uppermost pad) | South across thermokarst | M-32-91 (9) | 22 July 1991 | 22 July 1991 |
| Lisburne PP #8 (NE corner of uppermost pad) | SW--gap (across upper pad) | M-32-91 (10) | 22 July 1991 | 22 July 1991 |
| Lisburne PP #8 (NE corner of uppermost pad) | West--along edge of upper pad | M-32-91 (11) | 22 July 1991 | 22 July 1991 |
| Tunalik PP #1 (west corner of fuel pit) | N--along west edge | M-38-91 (23 | 24 July 1991 | 24 July 1991 |
| Tunalik PP #1 (west corner of fuel pit) | N-along edge of fuel pit | M-38-91 (24) | 24 July 1991 | 24 July 1991 |
| Tunalik PP #1 (west corner of fuel pit) | NE--across fuel & flare pits | M-38-91 (25) | 24 July 1991 | 24 July 1991 |
| Tunalik PP #1 (west corner of fuel pit) | E--along front edge of pit | M-38-91 (26) | 24 July 1991 | 24 July 1991 |
| Tunalik PP #1 (east corner of fuel pit | SE--across pad | M-38-91 (27) | 24 July 1991 | 24 July 1991 |
| Tunalik PP #1 (east corner of fuel pit) | SW--end of airstrip | M-38-91 (28) | 24 July 1991 | 24 July 1991 |
| Tunalik PP #1 (east corner of fuel pit) | West--thermokarst tundra | M-38-91 (30) | 24 July 1991 | 24 July 1991 |
| Tunalik PP #2 | N--fuel pit berm | M-38-91 (31) | 24 July 1991 | 24 July 1991 |
| Tunalik PP #2 | E--wellhead | M-38-91 (32) | 24 July 1991 | 24 July 1991 |
| Tunalik PP #2 | SW-mound on airstrip | M-38-91 (33) | 24 July 1991 | 24 July 1991 |
| Tunalik PP #2 | NW--across fuel pit corner | M-38-91 (34) | 24 July 1991 | 24 July 1991 |
| Tunalik PP #3 | SW--across thermokarst area of pilings | M-38-91 (35) | 24 July 1991 | 24 July 1991 |
| Tunalik PP #3 | E--wellhead | M-38-91 (36) | 24 July 1991 | 24 July 1991 |
| Tunalik PP #3 | ENE--across corner of reserve pit | M-38-91 (37) | 24 July 1991 | 24 July 1991 |

| Photoplot Name (and/or subject) | View | 1991 Film I.D.[1] | Original Date | Most Recent Date |
|---|---|---|---|---|
| Tunalik PP #4 (from piling) | NW | M-39-91 (6) | 24 July 1991 | 24 July 1991 |
| Tunalik PP #4 (from piling) | West | M-39-91 (7) | 24 July 1991 | 24 July 1991 |
| Tunalik PP #4 (from piling) | SW | M-39-91 (8) | 24 July 1991 | 24 July 1991 |
| Tunalik PP #4 (from piling) | South | M-39-91 (9) | 24 July 1991 | 24 July 1991 |
| Tunalik PP #5 (insulated pad) | W--well on right | M-39-91 (11) | 24 July 1991 | 24 July 1991 |
| Tunalik PP #5 (insulated pad) | NW--well on left | M-39-91 (12) | 24 July 1991 | 24 July 1991 |
| Tunalik PP #5 (insulated pad) | centered on SE corner of reserve pit | M-39-91 (13) | 24 July 1991 | 24 July 1991 |
| Tunalik PP #5 (insulated pad) | E-pipe in tundra | M-39-91 (14) | 24 July 1991 | 24 July 1991 |
| Tunalik PP #5 (insulated pad) | SW--mound on airstrip | M-39-91 (15) | 24 July 1991 | 24 July 1991 |
| Tunalik PP #6 | N--breach in pit berm | M-39-91 (16) | 24 July 1991 | 24 July 1991 |
| Tunalik PP #6 | NE-across leak area | M-39-91 (17) | 24 July 1991 | 24 July 1991 |
| Tunalik PP #6 | SE-pipe in drum on tundra | M-39-91 (18) | 24 July 1991 | 24 July 1991 |
| Tunalik PP #6 | SE--along E-edge of pad | M-39-91 (19,20) | 24 July 1991 | 24 July 1991 |
| Tunalik PP #6 | W--along front of reserve pit | M-39-91 (21) | 24 July 1991 | 24 July 1991 |
| Tunalik PP #7 | West-through breach into pit | M-39-91 (22) | 24 July 1991 | 24 July 1991 |
| Tunalik PP #7 | SW--toward wellhead | M-39-91 (23) | 24 July 1991 | 24 July 1991 |
| Tunalik PP #7 | NW--AFU colony in trough centered | M-39-91 (28) | 24 July 1991 | 24 July 1991 |
| Tunalik PP #8 | SW--wellhead | M-39-91 (29) | 24 July 1991 | 24 July 1991 |
| Tunalik PP #8 | NW--reserve/flare pit berm | M-39-91 (30) | 24 July 1991 | 24 July 1991 |
| Tunalik PP #8 (vertical) | E--south flare pit berm | M-39-91 (31) | 24 July 1991 | 24 July 1991 |
| Tunalik PP #9 (road curve) | North | M-39-91 (32) | 24 July 1991 | 24 July 1991 |

| Photoplot Name (and/or subject) | View | 1991 Film I.D.[1] | Original Date | Most Recent Date |
|---|---|---|---|---|
| Tunalik PP #9 (road curve) | Airstrip | M-39-91 (33) | 24 July 1991 | 24 July 1991 |
| Tunalik PP #9 (road curve) | Wellhead | M-39-91 (34) | 24 July 1991 | 24 July 1991 |
| Tunalik PP #10 (leak area) | Breach | M-41-91 (1,2,22) | 15 July 1984 | 25 July 1991 |
| Tunalik PP #11 (leak area) | N--edge of flare pit berm | M-41-91 (26) | 15 July 1984 | 25 July 1991 |
| Tunalik PP #12 (mound south end insulated pad) | East | M-44-91 (1) | 25 July 1991 | 25 July 1991 |
| Tunalik PP #12 (mound south end insulated pad) | N--wellhead | M-44-91 (2) | 25 July 1991 | 25 July 1991 |
| Tunalik PP #12 (mound south end insulated pad) | NW corner reserve pit | M-44-91 (3) | 25 July 1991 | 25 July 1991 |
| Tunalik PP #12 (mound south end insulated pad) | W--along edge of pad | M-44-91 (4) | 25 July 1991 | 25 July 1991 |
| Tunalik PP X (east end airstrip) | E--Fertilizer spill | M-47-91 (1) | 27 July 1991 | 27 July 1991 |
| Tunalik PP X (east end airstrip) (close) | West | M-47-91 (2) | 27 July 1991 | 27 July 1991 |
| Tunalik PP X (east end airstrip) (general) | West | M-47-91 (3) | 27 July 1991 | 27 July 1991 |
| Tunalik PP X (east end airstrip) (general) | NW | M-47-91 (4) | 27 July 1991 | 27 July 1991 |
| Tunalik PP X (east end airstrip) | South--lake | M-47-91 (5) | 27 July 1991 | 27 July 1991 |
| Tunalik AFU PP (airstrip trench) | East => West | M-47-91 (6) | 27 July 1991 | 27 July 1991 |

1. Note: Occassionally some numbers of photo frames are found incorrect upon checking slide numbers from photo laboratory against record book. These are preliminary data from camera notebook and have not been checked against the finished 35 mm slides.

## APPENDIX E

## NPRA DRILLING SITE MAPS

The three maps in the map pocket show photopoint and soil sample locations for the three NPRA drilling sites (Lisburne, Inigok, and Tunalik)