NORTHERN ALASKA RESEARCH STUDIES

Long-Term Gravel Vegetation Project, 1991 Annual Report

by

Jay D. McKendrick

Gwendo-Lyn Turner

Peter C. Scorup

Warren E. Fiscus

University of Alaska Fairbanks,

Alaska Agricultural and Forestry Experiment Station

Prepared for

BP Exploration (Alaska) Inc.

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Prepared by
University of Alaska Fairbanks
Alaska Agricultural and Forestry Experiment Station
533 East Fireweed
Palmer, Alaska 99645

Prepared for
BP Exploration (Alaska) Inc.
Environmental and Regulatory Affairs Department
P.O. Box 196612
Anchorage, Alaska 99519-6612

Executive Summary

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. Concern for losses of tundra habitat buried by gravel fill have been raised (Walker et al. 1987), with the loss of forage plants and useful habitat for animals being the primary foundation for those concerns. Such losses could be mitigated by establishing useful, functioning plant communities on these fills after they are no longer needed for oil and gas production. Therefore, in 1989, BP Exploration (Alaska) Inc. and the University of Alaska Fairbanks initiated a ten-year study of rehabilitating abandoned gravel fill sites used during exploration and production of oil and gas in arctic Alaska.

The project consists of three research areas (phases). The first is to test the effectiveness of modifying gravel fill to improve conditions for plant growth. The second is to identify indigenous plants in the Alaska Arctic that are adapted to colonizing gravel fill. The third phase is to monitor long-term aspect and plant community changes on gravel fill at exploratory and production sites. The first two phases are conducted mainly on the gravel fill at a former drilling site in the Prudhoe Bay Oil Field: BP Put River No. 1. The third phase involves studies of gravel fill at four locations in the National Petroleum Reserve in Alaska (NPRA) and at several locations along the Sagavanirktok River. Most results of the third phase are contained in a separate document prepared to describe details of studies on several gravel fills in NPRA. This report includes progress mainly for the first two phases of research, during the period 1989 through 1991.

At the time of this report, experiments had been underway on the BP Put River No. 1 gravel pad for two field seasons, under Phases I and II of this study. The major accomplishments include collecting seed during 1989, 1990, and 1991 for plantings in subsequent seasons. Respectively, these collections consisted of 42, 62, and 55 indigenous vascular arctic plants. In 1991 we also obtained seven species of arctic plants from the Tyumen region in Russia. Mixtures of 34 and 28 species were seeded on gravel modification plots in 1990 and 1991, respectively, from these collections. In addition, 63 rows of individual plant species have been planted in the botanical garden on the BP Put River No. 1 gravel pad. Under Phase III, the first re-examination of three abandoned drilling sites in NPRA occurred during July of 1991. A fourth NPRA site was surveyed during July, 1992, to complete the first of three scheduled evaluations to monitor long-term changes on abandoned gravel fill.

The most significant influence to date on the physical characteristics of gravel has been the addition of topsoil. It alters the bulk density and moisture content of the upper root zone and improves the production of plant cover. Tillage also reduces bulk density and seems to improve plant cover. Preliminary evidence indicates these treatments may also affect the uptake of certain minerals by plants. Snow fencing markedly altered the accumulation of snow, but it did not appear to affect plant canopy and basal cover values in the growing season subsequent to year of establishment.

Seed production was exceptionally abundant for many plant species of value to this project in the 1989 growing season. Just the opposite was true for the 1991 growing season, when few plants in the region produced mature seed. Examining temperature data revealed a fourfold difference in the cumulative, positive degree-hours (i.e., > 0°C or above freezing) at a coastal site between 1989 and 1991. The temperature patterns in the foothills between these two years were similar to those recorded on the coastal plain. Compared to locations near the coast, the air temperatures in the foothills consistently ranked higher, in terms of daily maximums and indicated a greater input of solar heat. However, among-year comparisons revealed the heating of air on the coastal plain in 1989 exceeded the heating of air in the foothills in 1991. The absolute diurnal variation was also greater in the foothills, and more hours of temperatures at or below freezing occurred during the growing season at the foothill site than on the coastal plain. In contrast, soil temperatures near the coast were consistently warmer during the growing season than in the foothills. Plant seed production was consistently greater in the foothills, suggesting that air temperatures, more than soil temperatures, were affecting the sexual reproductive performance of established vascular plant species.

One hundred twenty-five vascular plant species were found colonizing on gravel fill among ten locations examined on Alaska's North Slope (McKendrick 1991). No one species occurred at all ten study sites, and all but two of these plant species were perennials. The two exceptions were biennials. In addition to these 125 colonizers, approximately 50 other species of indigenous vascular plants were identified that may have potential for colonizing gravel fill in the Alaska Arctic. Approximately 100 of these species merit closer examination for potential applications to vegetating disturbed sites in the Arctic. Grasses are the largest group of colonizers, but a forb, *Epilobium latifolium*, was most widely distributed among the locations. In addition to grasses, the colonizing plants with promise include species of legumes, mustards, composites, and pinks, offering a wide array that could be used to beautify abandoned gravel fill as well as enhance them for wildlife.

Long-term study plans involve seeding approximately 100 species in the botanical garden at the BP Put River No. 1 gravel pad. Nearly two-thirds of that goal was achieved following the 1991 field season. The significance of the diversity of indigenous botanical materials which are believed capable of colonizing gravel substrates in the Alaska Arctic cannot be overemphasized. This is particularly important when considering the popular notion that the arctic tundra inherently lacks resilience to physical disturbances associated with modern man.

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INTRODUCTION

The Gravel Vegetation Study is a three-phase investigation of rehabilitating abandoned gravel fill sites used during exploration and production of oil and gas in arctic Alaska. The three phases of research include: 1) modifying gravel fill to improve conditions for plant growth, 2) identifying indigenous plant species that survive on gravel fill, and 3) monitoring long-term evolution of plant communities and environmental conditions on gravel fill in the Alaska Arctic.

There are areas of overlap among these three phases of research. For instance, in order to measure effects of modifying gravel fill (Phase I) on plant community development, plant indicators must be used. That can be accomplished best by planting species adapted to gravel substrates which are indigenous to the region. Clearly, the objective of Phase II is to identify those plant species. Because both research efforts are occurring simultaneously, it is not possible to wait for the results from Phase II to decide what to plant to measure gravel modification effects in Phase I. Therefore, the two phases must be integrated, for example, by seeding plots to satisfy the requirements for Phase I while seeding some of the same plant species in the botanical garden to meet requirements for Phase II. It is important to recognize the distinction between these two efforts. For Phase I, plants are used to measure differences among various micro-environments created by modifying gravel, and in Phase II, plant survival and growth are measured to evaluate relative performances among species in a uniform environment. From the preparatory work needed to supply the seeds for both of these experiments, additional useful data about seeds of indigenous plant species in the Arctic are obtained that will be needed when setting seeding standards for actual rehabilitation projects.

In this report, we present information and progress primarily on the first two phases. Progress and findings from the third phase, monitoring long-term evolution of gravel fill habitats in the Alaska Arctic, is a separate, comprehensive report in itself.

RATIONALE

Rehabilitating gravel pads and roads in arctic Alaska after those structures are no longer required for oil and gas exploration and production is an important issue for regulatory agencies as well as industry. Compliance standards have not yet been established; permits simply require each site to be rehabilitated to the satisfaction of the permitting agency. This latitude for deciding is desirable, because it will be years, and perhaps decades, before some of these structures are abandoned. Anticipating technology and land agencies' wishes for site rehabilitation that far into the future is very difficult. However, this also leaves agency and industry personnel in an uncomfortable position, open to criticism and possibly even litigation from third-party interests who were most likely not involved with the original planning and development of these projects. It can only be assumed that establishing a functional plant community on gravel fill will be fundamental to future rehabilitation needs, because the stands of vegetation will improve the appearance of these gravel structures and potentially provide habitat for wildlife.

Total removal of gravel is one option, but that would still leave the problem of rehabilitating the dead tundra vegetation which is under these areas of gravel fill. An even greater problem with gravel removal is where to dispose of the fill. It is not always possible to return the gravel to the original mine site. Most of the gravel for the first structures in the Prudhoe Bay region came from river channels. Because stream flow in some source areas has redeposited gravel into the removal site, there is no longer a void in which to place gravel. Returning gravel to river sites could also violate federal wetland regulations and statutes and possibly damage stream channels. Current construction of gravel structures is accomplished with material mined from deep pits, some of which are subsequently flooded and converted to overwintering habitat for fish, a habitat that is rare in the region. Thus, placing used gravel into those sites would violate state fish habitat protection regulations and laws.

The most plausible approach to gravel removal would be to reuse it in some other project that required roads and pads. That means leaving fill in place until it is needed elsewhere. Recent studies (LGL Alaska Research Associates, Inc. 1990, 1991 and Troy Ecological Research Associates 1991) have indicated that in certain seasons some wildlife species use gravel structures and disturbed sites more than they use the adjacent undisturbed tundra. Thus, some of the negative perceptions about gravel fill and losses of wildlife habitat may be overstated. Developing vegetation on gravel structures that would provide habitat for wildlife is an appealing alternative. Obtaining information that will help agencies and industry select *acceptable* and *attainable* vegetation objectives for gravel fill in arctic tundra is the overall goal of this gravel vegetation research project.

Experience in this region has revealed that it requires a minimum of three growing seasons just to determine if mature plants will result from a seeding. Furthermore, some of the most significant plant responses have occurred at test sites seven, ten, or more, years after seeds were planted. To acquire as much information on long-term vegetation changes as possible, this experiment was designed as a ten-year study. The study officially began in 1989, but relevant information was first collected in 1984, while gravel fill used during the second exploration of the National Petroleum Reserve in Alaska (NPRA) was being evaluated (McKendrick 1986). Observations of plant-gravel associations in arctic Alaska began 20 years ago while project personnel were working on a tundra revegetation project in the Prudhoe Bay Oil Field.

Modifying Gravel Fill to Improve Conditions for Plant Growth

Five factors were selected to modify gravel pads for improving their suitability to support vegetation. These five factors included varying: 1) thickness of the gravel fill, 2) compaction, 3) snow cover, 4) topsoil content, and 5) seeded grass. These five factors are variables in the project. Effectiveness of these factors and various combinations of treatments are evaluated by: 1) measuring physical and chemical conditions of the gravel substrate and 2) monitoring plant communities resulting from seeding and natural colonization.

This research is occurring on a restructured exploratory drilling pad near the Putuligayuk (Put) River in the Prudhoe Bay Oil Field (Figs. 1 and 2). Gravel from the nearby Putuligayuk River was used to construct the pad in 1969. It was here that British Petroleum discovered its portion of the Prudhoe Bay Oil Field. After the exploratory drilling ended, the location remained unused until this study began in 1989.

Most gravel structures in the Alaska Arctic are about 1.5 m (5 ft) thick in order to protect the underlying frozen soil (permafrost) and to provide a stable surface for equipment and buildings. Results of a recent study of vegetation on gravel pads indicated an inverse relationship between gravel thickness and plant establishment (Jorgenson 1988). Thicknesses greater than 0.6 m were considered inferior to those 0.6 m and less. There are various physical conditions of the gravel fill that may contribute to this relationship, including moisture availabilities, exposure to winds, lack of snow cover to shelter seedlings during winter, etc. In this project, three thicknesses of gravel were selected for evaluation: 0.6, 0.9, and 1.5 m.

The tundra landscape on the Arctic Coastal Plain is flat and subjected to strong winds that remove snow from elevated areas and deposit it in depressions. Typically, the standing dead plant material from several previous years remains in the tundra plant communities and traps snow. Thus, once a stable plant community forms, the vegetation provides a mechanism for accumulating snow and protecting the overwintering plant parts from desiccation and injury. This is opposite the condition on barren, elevated gravel pads, where snow can be easily scoured from the surface during winter storms. The effectiveness of wind breaks on gravel fill was noted at one location, where small portable buildings created a temporary shelter (1973 to 1984). In that sheltered area, a natural stand of grasses formed and still persists even though the buildings

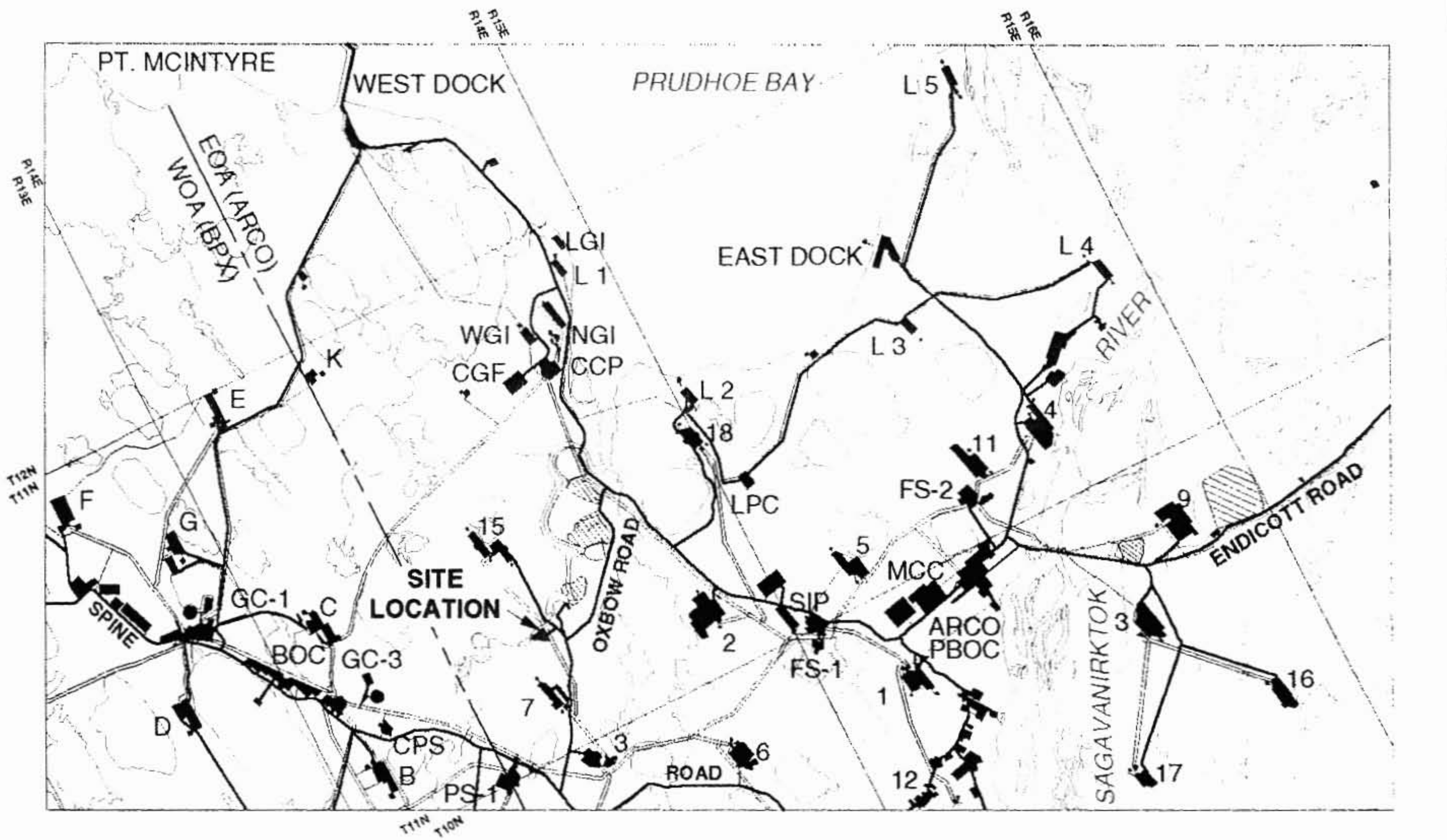

Figure 1

BP PUT RIVER No. 1
GRAVEL VEGETATION SITE

PRUDHOE BAY OIL FIELD

FOR INFORMATION CONTACT BP EXPLORATION CARTOGRAPHY DEPARTMENT ANCHORAGE OFFICE

LEGEND

BP EXPLORATION

FIGURE 2
BP PUT RIVER NO. 1
GRAVEL VEGETATION SITE
7/10/91

have been removed for eight years. We concluded that providing temporary protection by encouraging retention of snow cover during the years when plants are becoming established may accelerate formation of plant communities on gravel fill. Two approaches were included in this project to test effects of trapping snow. One was to use physical structures, and the other was to plant a thin stand of grass that would develop standing dead to trap snow, but which would not fully occupy the site and obstruct natural colonization by other vascular plants species. Initially, 0.6-m-high gravel berms were used as the physical structures, but these proved to be ineffective and were replaced by 1.2-m snow fencing.

To be useful for oil and gas exploration and production in the Arctic, gravel fill must shed water and be firm enough to support traffic and the weight of structures. Therefore, gravel fill is compacted to reduce air spaces. This improves the gravel for traffic and supporting loads, but it renders it less hospitable to plant growth because the pore space, essential for aeration and water penetration to supply plant roots, has been reduced. Therefore, tillage of compacted gravel to reverse effects from compaction and restore air spaces was included as a factor in the project.

Typical gravel fill contains relatively few silt- and clay-sized particles. Hence, it has relatively low capacity for retaining moisture and nutrients to support plant growth. Previous work on mine spoils near Fairbanks, Alaska, indicated that as little as 10% silt and clay in the gravel spoils was positively associated with relatively dense stands of trees and other plants colonizing such wastes (Holmes 1982). Investigation of gravel from various sites in the Prudhoe Bay region showed that combined sand, silt, and clay contents varied between 19% and 33% (McKendrick and Holmes 1989). More detailed analyses may reveal that, for the most part, this fraction consists mainly of sand and relatively little silt and clay. Thus, the fine fractions of these gravel fills may contain low proportions of the types and sizes of soil particles that are most suited to retaining available moisture and nutrients for plant roots. There is also considerable variation in the quality of fine fractions among different sources of gravel in the region. 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. Addition of topsoil to increase the proportion of fine soil particles in the surface of gravel fill was therefore incorporated into this project.

Identifying Indigenous Plant Species to Colonize Gravel Fill

The second phase of the study — to determine indigenous plant species adapted to colonizing gravel fill — is required to identify plant materials for vegetating gravel fill. Because most gravel fill is located in moist and wet tundra habitats, which do not contain plant species adapted to the xeric conditions of gravel fill, there usually are no nearby stands of plants to provide recruits to the gravel. Throughout arctic Alaska, however, there are natural xeric and gravel environments along streams and elevated rocky ridges. In these environments, species of vascular plants occur which are adapted to conditions similar to those of gravel fill. The goal of this phase of the project is to identify, collect, and test the suitability of these species for vegetating gravel structures. Once key plant species are identified, efforts to develop supplies of seed for implementing rehabilitation projects can be undertaken.

METHODS

To test each of the factors selected to modify gravel fill, a split-plot factorial experiment was designed. It consists of: three gravel thickness (0.6, 0.9, 1.5 m); two levels of topsoil (8 cm and none); two levels of compaction (tilling and none); snow capture (snow-fenced and not snow-fenced); and two levels of grass (sparsely seeding *Poa glauca* and not seeding) (Fig. 3). The design is complete, with all possible combinations among treatments. However, installing the plots required heavy equipment to restructure the gravel pad. Since maneuvering the machinery around the limited area of the test plots was restricted, random allocation of treatments within blocks was impossible. Therefore, the layout had to be a split-plot for the variables topsoil, tillage, and the three replications.

To identify adapted plant species, appropriate sites were searched for likely candidates. After promising species were identified based on their growth characteristics and seed production potentials, collections of seed were harvested and planted in a botanical garden. Plants that survive will be observed with respect to their aggressiveness to occupy gravel and produce seed under "cultivated" conditions in the Arctic.

Modifying Gravel Fill

To prepare the BP Put River No. 1 gravel pad for this research, cores were systematically drilled on the pad, to measure depths of gravel, in late winter of 1989. Based on those data, the pad was restructured

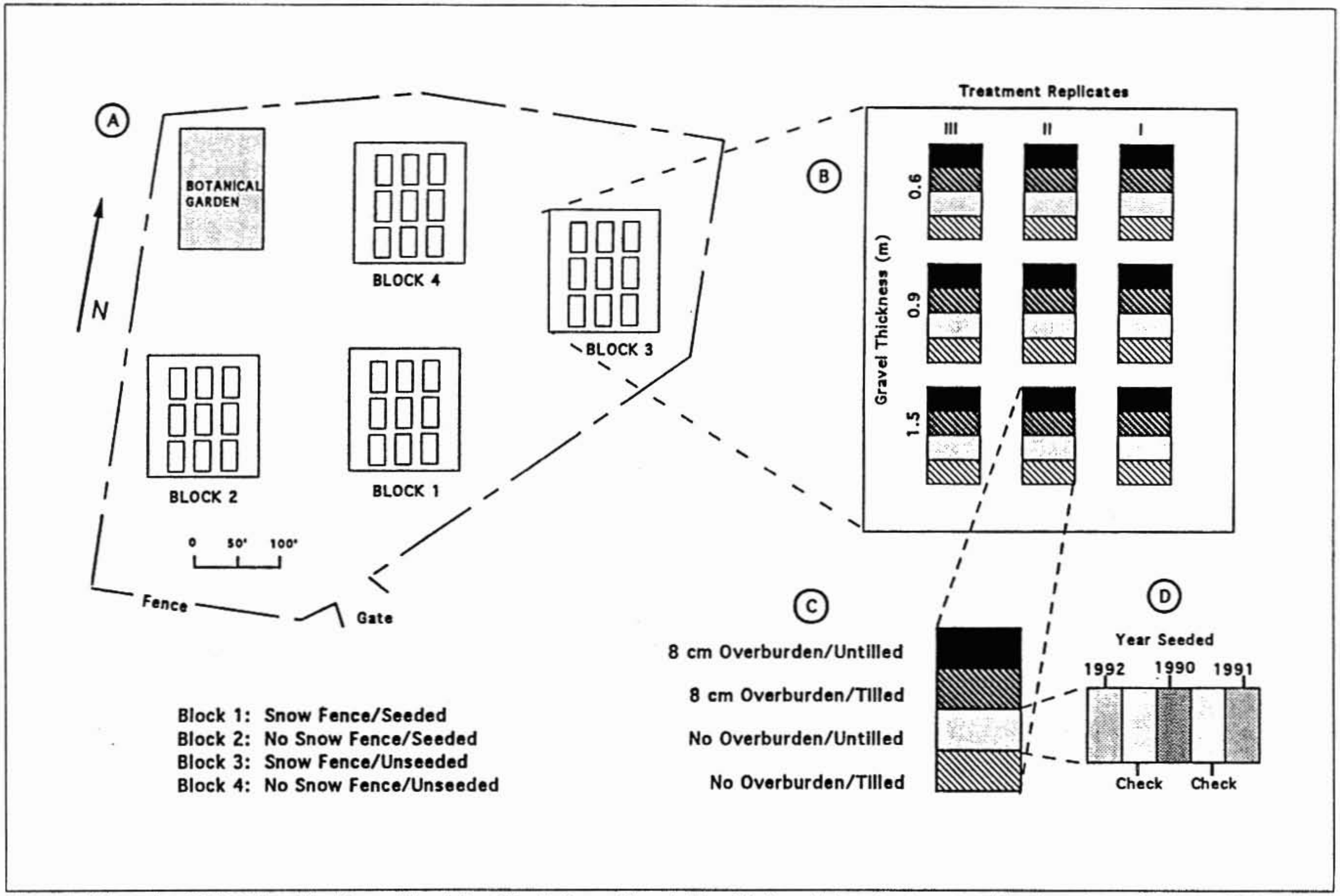

Figure 3. Schematic of BP Put River No. 1 Gravel Vegetation Site: A) General layout of four blocks, which are treatment combinations of snow fencing and light seeding with Poa glauca *(Tundra bluegrass), and a botanical garden containing rows seeded to indigenous vascular plant species; B) Detailed block layout containing all combinations of three gravel thicknesses, overburden additions, tillage, and three treatment replicates; C) Four component combinations of overburden and tillage; and D) Three distinct seeding mixtures of indigenous vascular plant species plus unseeded check zones.*

into four blocks, each with gravel lifts 0.6, 0.9, and 1.5 m thick (Fig. 3). Each lift was compacted to imitate normal work pad conditions and split into three equal portions (replicates). An 8-cm layer of topsoil was applied to half of each replicate. Half of each topsoil and non-topsoil treatment was tilled to reduce effects of compaction. There are 144 experimental units among these four blocks. Two of the blocks were sparsely planted with *Poa glauca* (glaucous bluegrass), variety Tundra at 13 seeds/m^2, to provide microsite snow cover. Gravel berms (0.6 m high) for collecting snow were constructed on two blocks, one of which was planted with *Poa glauca*. These berms proved ineffective, failing to create snow cover across the plots. Therefore, 1.2-m snow fences were installed in October 1990 (Fig. 4). These fences proved effective for capturing snow. All treatment areas in all four blocks were fertilized with N-P-K at 57-35-35 kg/ha (elemental equivalent). Each of the 144 experimental units was further divided into fifths — three different planting plots, each separated by a "control" plot — for a total of 720 plots from which vegetative data are collected (Fig. 3). Planting years consist of 1990, 1991, and 1993, with two plots left unplanted as check plots.

The entire experimental area was fenced to exclude vehicle traffic, grazing caribou, and other unwanted intrusions. The perimeter fence has proven effective; however, a bear entered the area, presumably by crawling between the bars on the metal gate, and wandered about the enclosure during the spring of 1991. In spring, geese also fly into the area and graze on the seeded plots that are barren, i.e., blocks without snow fencing.

Measuring Physical and Chemical Conditions of the Gravel

Soil (Gravel) Sampling. To measure the effects of modifications on the gravel fill, substrate samples were collected for physical and chemical analyses in the laboratory. On 12 July 1990, a baseline collection of gravel was taken from each of the 144 experimental units at the site. Gravel/soil samples were collected from at least six different locations of the unplanted portions of each experimental unit. These six subsamples were combined, then placed in two 1-gallon Ziploc® bags. The samples were taken to the University of Alaska Fairbanks 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 split with a soil sample splitter, and has been stored for further analysis. The >2-mm fraction was discarded.

During the summer and autumn of 1991, an abnormal red color was observed in the leaves of some plants in plots on the gravel pad. This color is sometimes an indicator of either phosphorus or potassium deficiency, and it can be induced by low temperatures. All three conditions were plausible. Gravel was sampled from planted, and unplanted portions of 12 experimental units, and leaf tissue samples were taken from four experimental units for laboratory analyses.

By definition, ***bulk density*** is the specific weight of structured soil, which contains air spaces and natural pores. This measure is not to be confused with the *specific weight* of soil solids. Bulk density is expressed as grams oven-dry weight per centimeter^3. 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 inversely 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 1.0 g/cm^3, i.e., they are lighter than water. A bulk density of 0.1 g/cm^3 is not uncommon for peat soils. For very stony soil, the bulk density will approach, and often exceed, 2.0 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 2.65 g/cm^3.

Soil bulk density is calculated from measurements of a volume of soil divided by its oven-dried weight. In our work, volume was measured with a VOLU-VESSEL, a device which consists of a transparent, sealable graduated cylinder with a thin-walled bladder at the bottom and a hand aspirator at the top. To use the device, the cylinder was secured over a 10-cm-diameter hole in a metal plate. The plate was held in place at each sampling site by steel pins driven into the soil. After partially filling the graduated cylinder with water, the cylinder was pressurized by pumping air from the aspirator and forcing water from the cylinder into the bladder, which expanded to occupy any void below the hole in the metal plate. Because soil surfaces are uneven and do not conform exactly to the surface of the metal plate, two measurements were taken: 1) to establish a reference volume of the undisturbed soil, and 2) to measure the volume of the sample removed from the soil (gravel) surface. By subtraction, the sample volume is calculated.

Volumes were obtained by aspirating the hand pump until a stable water level was observed in the graduated cylinder. After the first reading was obtained, soil (or gravel) under the hole in the plate was carefully excavated. 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 labelled, doubled resealable (Ziploc®) bags. Then the second volume reading was taken, to measure the volume of the gravel that had been excavated. Volume of the excavated gravel sample was calculated by the difference between water volumes of the first and second readings. The weight of the gravel was determined after drying 48 hours at 105°C. Bulk density was calculated by dividing the field-measured volumes (cubic centimeters) by the laboratory oven-dried weights (grams) of the respective excavated samples.

In the course of obtaining bulk density data, soil moisture was also measured (gravimetrically) for all soil and gravel samples. Samples which had been sealed into plastic bags at the time of collection were taken to the laboratory. Fresh weights were measured, and 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. This is the standard method for measuring soil moisture. Technical reports on studies from the Alaska Arctic and elsewhere by environmental scientists and technicians often contain soil moisture data that has been incorrectly calculated, i.e., (weight of water/ (weight of soil+water)) x 100). The magnitude of the error increases with increasing wetness of the soil; thus, the seriousness of these errors becomes most pronounced for data from arctic wetland soils. In those soils, 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 may never exceed 100%, a percentage that should appear relatively frequently in data for wet soils of the Alaska Arctic.

Other measurements are planned to evaluate the conditions of the gravel substrate, including: moisture desorption curves to measure water-holding capacities at various moisture tensions and particle size analysis of the fine fraction to determine texture. Cation-exchange-capacities, pH, and availabilities of nitrogen, phosphorus, and potassium will be used to measure nutrient-holding and supplying capacities of the fine fraction. In some instances, organic matter may be a significant feature to measure. The gravel and overburden from the BP Put River No. 1 gravel pad site have been sampled and prepared for laboratory analyses. Data from those samples will be used to determine baseline conditions prior to the initial application of fertilizer in the fall of 1989. The relevant samples have been archived, and these measurements will be obtained as labor allocations shift from field plot establishment and seed collection to monitoring vegetation responses.

Routine soil fertility and salinity measurements will be conducted in the laboratory in Palmer. Samples for these analyses have been collected, prepared for laboratory analyses, and placed in storage. After all the samples have been collected, they will be submitted for laboratory analysis. Moisture desorption curves will be performed at another laboratory. The particle size analyses are scheduled to be conducted in-house. The moisture desorption curves and particle size analyses are physical measurements and are not affected by storage time of samples. Efforts for the seed collecting, cleaning, and testing were allocated for the first 3 years of the project in order to establish the sequence of plantings on the gravel plots. The timing of seeding is critical to the success of the long-term evaluation of vegetation. Obtaining gravel physical data is not time-dependent, because those features remain unchanged during storage.

Measuring Snow Cover. To measure the effectiveness of snow fencing for capturing snow during winter on the plots, a snow survey was conducted on 7 and 8 May, 1991. Standard snow survey equipment, loaned to us by the USDA Soil Conservation Service, Anchorage, Alaska, was used. The equipment consisted of a tube with cutter, used for extracting cores from the snowpack, and a cradle and scale, used for weighing the core and tube. The diameter of the tube and the scale were designed to weigh snow cores in units equal to inches of water, which were then converted to metric units. This measure was obtained from the net weight of the core, i.e., by subtracting the weight of the empty tube (tare weight) from the weight of the tube and snow core. Data obtained during this snow survey included: location, depth of snow, length

Figure 4. Installation of posts for a snow fence on Block 1 of the BP Put River No. 1 gravel pad experimental area (25 September 1990).

of core, weight of tube and core, tare weight, centimeters of water, and percent density of snow. Percent density was calculated by dividing the water content by the depth of snow and multiplying by 100. Core length and percent density were obtained at each sampling location while the snow survey was conducted and used to determine if the extracted core was a reliable sample. Established criteria dictate that sample densities should not vary more than 3% on a uniform site; when a core density differed more than 5%, it was discarded and another sample taken.

Snow freezing in the tube creates problems with sampling and usually occurs when the temperature of the tube is above the freezing point for water. Consequently, care was taken to ensure the tube was clean before each sample was extracted. Gloves were worn at all times to minimize difficulties with snow adhering to the tube because of warming through handling. Also, to reduce chances for snow freezing to the tube's surface, the tube was cooled adequately before use and pushed rapidly through the snowpack without stopping until the cutting edge met the ground surface.

Snow accumulations on plots without snow fences were subsampled and combined, because it was impossible to read the balance accurately if the water content was less than 5 cm in a single sample. Ten subsamples were collected and combined into a tared bucket for weighing. The tare weight was subtracted from the combined weight of the bucket and collection of snow cores to calculate the net weight of snow in the collection of subsamples. Average weight for the subsample was calculated from the net weight of the collection of cores divided by the number of subsamples (10). These data were used to calculate the average centimeters of water contained in the snow.

Monitoring Temperatures. Soil and air temperatures and wind speed and direction among treatments at the BP Put River No. 1 gravel pad were not being monitored in 1991. However, air, water, pond sediment, and soil temperatures at locations used during a previous research project were monitored. Air and soil temperature data from those stations have been used for evaluating year-to-year variations in growing conditions for the current study. These data revealed general growing conditions among years. They have proven useful not only for explaining variations among years in plant growth of species seeded on the gravel pad, but also for interpreting inter-annual variations in growth, flowering, and seed production by natural stands of plants from which seed was harvested for this study.

Air and soil temperatures were monitored from 1988 through 1991 at a coastal site (Big Skookum) and at a site in the foothills of the Brooks Range (MP 62). The locations of these sites are shown in Figure 5. Automated temperature instruments (Datapods®) manufactured by Ominidata, Inc. of Logan, Utah, were used to record temperature data. Each Datapod® has two temperature sensors (thermistors), which were placed to detect temperatures in the air and soil at each site.

Lead wires for sensors measuring air temperatures were taped to wooden stakes in a manner that prevented the sensor from touching these stakes. Solar radiation shields were installed on all air temperature sensors in 1991. These sensors were retained in the field year-round to maintain consistency in locations of sensors among seasons. As early as possible during each growing season, sensors were checked for accuracy with hand-held instruments. This validation was performed as soon as field conditions permitted (after substrates thawed). Any sensors that produced questionable data were replaced.

Moisture inside the Datapod® case prevents the instrument from operating properly; consequently, Datapods® were placed in steel ammunition boxes that could be hermetically sealed. The boxes were fastened to steel fence posts driven through the active layer of either pond mud or tundra soil, depending on the Datapod's® location. Even though these Datapods® were supposed to remain moisture-proof when properly closed, a small can of desiccant granules was placed in each ammunition box and a desiccant capsule was placed inside each Datapod® case to absorb any moisture that may have inadvertently been trapped during installation of these instruments. Whenever the instruments were serviced during the course of the field season, the desiccant supply was replaced if it showed signs of collecting moisture.

Datapods® were programmed to scan sensors at 5-minute intervals. Readings were averaged hourly to give a single datum. These means were stored on E-Prom silicon chips which were removed and replaced with fresh data storage chips when new memory capacity was needed. The E-Prom chip's capacity was 42 days when the Datapod® was programmed as described. The readings were checked periodically to verify that the Datapods® were functioning properly. During data processing, the field records were used to authenticate the instrument measurements to further verify sensor functioning was valid.

Data from the chips were downloaded to a computer at the end of the season. The data files were read from the microchips and saved as ASCII files. The individual file from each microchip was imported into WordPerfect® 5.1 and combined to produce a single annual file for each site. Because the hour of recording represented the mean value of the previous hour, the identifier column was moved one hour later than shown in the raw temperature data. Edited files were saved in the ASCII format and read into SYSTAT® (Wilkinson 1988) and line graphs produced for each site by year. Summaries of positive and negative degree hours were generated for each month in which we obtained complete temperature records. The STATS module in SYSTAT® was used to summarize the temperature data in terms of degree-hours.

Measuring Effects of Modifying Gravel Fill with Plant Indicators

This section contains descriptions of procedures that had to be followed to obtain plants for evaluating various modifications of gravel fill. To measure the effectiveness of these modifications to gravel fill on plant community development, mixtures of indigenous plant seeds were planted in 1990 and 1991 to 1/5 of each of the 144 experimental units (plots - Fig. 3). The plans dictated planting three separate seed mixtures into subdivisions (1/5) of each experimental unit, to allow for as much variation among potential colonizers as possible during the course of this experiment. Because indigenous plant seed for these mixtures had to be found and generally hand-harvested, availability of manpower and facilities to acquire and prepare these mixtures precluded planting all mixtures in a single year. Therefore, the planting portion of the work was spread over a 3-year period. This will permit nine growing seasons to observe the first planting and at least six growing seasons to observe the final planting. The first planting was completed in June, 1990, using seed harvested the previous autumn (1989). The second planting was completed in June of 1991, with seed harvested in the autumn of 1990. Seed was harvested in the autumn of 1991, for the third and final planting, scheduled for June of 1992. Failure of native stands to produce sufficient seed in 1991 prevented planting in 1992. The final seeding was rescheduled for 1993.

This will leave 2/5 of each experimental unit unplanted, except for the light seeding of *Poa glauca*, which was applied to only two of the blocks. These two unplanted plots in each experimental unit will be used to observe voluntary establishment of plants to the area. Initially, invasion by vascular plants will be from seed produced by the naturally occurring stands of gravel colonizers along the nearby Putuligayuk River. As our seeded stands mature, we anticipate they will contribute propagules to the unplanted plots. This results in a total of 720 plots among the 144 experimental units (Fig. 3).

Deriving Seed Mixtures. It is critical for research purposes to know how many viable seeds are applied to a given plot, in order to interpret the results in terms useful for actual rehabilitation projects. It is essentially the foundation for the rest of the experiments. Industry, contractors, and agencies eventually have to write specifications for such work, and they must know how much seed to apply to achieve a desired objective. Therefore, a significant amount of time was spent cleaning seed, measuring germination rates, and assuring that identical amounts of seed were allocated into each plot.

Seeds were collected in the field after ripening but before dispersal. Seeds were harvested by various methods, including hand-picking, cutting with shears, and mechanical harvesting, depending upon the type of seed, plant growth form, and stand density and size. A mechanical harvester was designed and built by project personnel for use in harvesting dense, even stands (Fig. 6). Collections included inflorescences, leaves and other non-seed components of plants. These collections were usually placed in either 1- or 5-gallon plastic buckets during collection and then transferred to cloth bags which were labelled with the species name, harvest date, and location of origin. Very small seeds which could pass between the mesh of the cloth bags were placed in paper bags which had their seams taped. All bags were hung in the field laboratory and air-dried before shipment to Palmer for processing. Drying is important to prevent molding of the wet plant material, which may destroy seed viability, and to terminate the seed filling phase, which must be done in order for seeds to germinate.

At Palmer, the field-collected material was removed from the bags and threshed using a hand scrubber. Threshing removed seeds from flower parts and ovules from ovaries. Extraneous plant material was then separated from the seeds. Hand screens were used for this separation. The openings in the screens range in size from very small to large and in shape from round to linear to accommodate various sizes and shapes of seeds. Appropriately sized and shaped

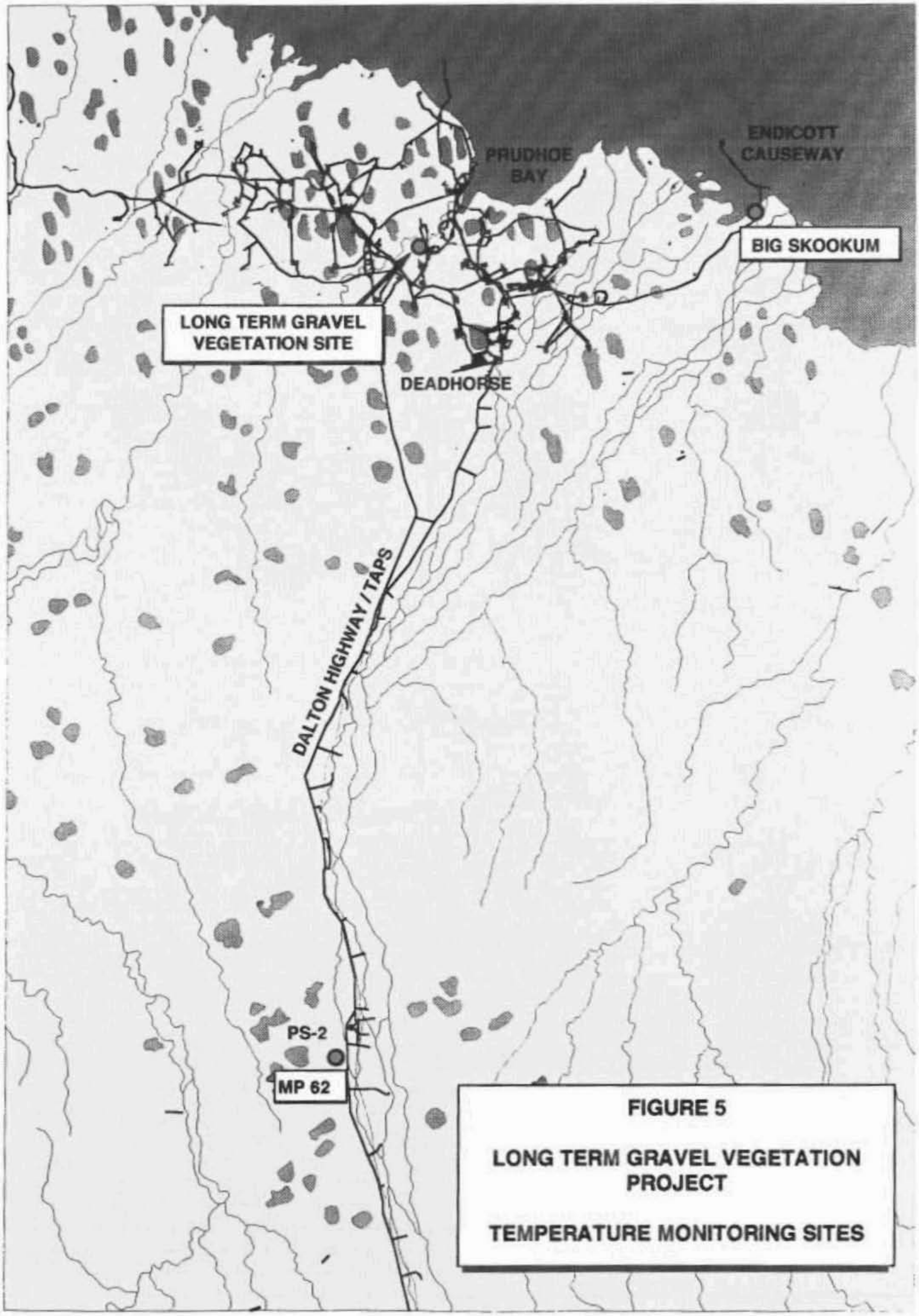

FIGURE 5

LONG TERM GRAVEL VEGETATION PROJECT

TEMPERATURE MONITORING SITES

Figure 6. Collecting *Puccinellia langeana* seed with a mechanical harvester (24 August 1989).

screens were selected, usually on the basis of seed size. A screen size somewhat larger than the seed was initially used to remove the bulk of the vegetative plant material. Pieces of leaves, stems, chaff, and other debris were trapped by the screen and discarded while the seed and finer particles passed through into a collecting pan. This screening process was repeated several times for some seed collections, depending on the nature of these materials.

Another hand screening was needed to separate the seed from the smaller debris. For this, a screen size smaller than the seed was selected. The fine debris consists of soil particles, fragments of vegetative plant parts, and sometimes insect larvae. The rejected portions were periodically examined under a light lens to verify there were no losses of seed among them before being discarded.

After hand screening, the seedlot was passed through a mechanical separator that used a variable air flow to separate the seed from debris by gravity. This separator forces air through a vertically positioned, clear, 9-cm-diameter Lexan cylinder. There were baffles at the top of the cylinder, into which the lightest particles became trapped. The heavier particles were retained in the bottom of the cylinder. This operation required skill and experience to gauge the air flow sufficient to carry only the light material (chaff) and not the seed to the top of the cylinder, where it was caught in baffles. At this point, most seedlots were judged to have been cleaned as much as was practical for our research purposes.

Seeds with long trichomes (hairs) that float easily on air currents in nature had to be delinted (Fig. 7). Without delinting, it would have been difficult and perhaps impossible to handle, test, and plant the seed because these seeds are easily carried with the slightest of air movements. Examples were species of *Salix*, *Epilobium*, *Senecio*, and similar types.

To delint seed, the collection was placed in the delinter, after hand threshing to loosen the ovules from the ovaries. The delinter consisted of a metal cylinder approximately 1 m in length, through which an airflow was maintained from a compressor. Inside the cylinder a power shaft extended the full length and supported a drum with a diameter about 10 cm less that the inside of the cylinder. The outside of the drum had a series of small (about 30-mm diameter) all-thread rods projecting about 5 cm perpendicular from the drum surface. The inside of the cylinder had a similar set of all-thread rods that were offset so that as the drum rotated these small rods intermeshed but did not touch. The interior of the cylinder was accessible from a small portal on the top. Seeds to be delinted were placed in the cylinder and the door sealed. The airflow and power to turn the drum were started and allowed to operate for as long as needed to remove the trichomes from the seed. This required about 30 or more minutes per collection, depending upon the seed and trichomes. The light seeds were forced by the airflow into the area between the drum and the inside of the cylinder, where the all-thread rods were meshing. As these seeds passed among the rods, trichomes were broken and removed. Once the seeds lost their trichomes, their buoyancy decreased, and they fell to the bottom of the cylinder. The cylinder was mounted on a stand at an angle so that one end was lower than the other. By gravity, the seed moved to the lower end of the cylinder, where it was removed through a trap door, after the airflow and power were stopped. Portions to be discarded were examined to ensure seed was not inadvertently lost. Usually, after delinting, seeds were adequately cleaned (Fig. 7). If that was not true, screening was used to further separate ovules from debris.

It was necessary to handle each seedlot in these collections separately to prevent mixing among species and various source areas. Throughout all these operations, it was critical that each vessel, tool, and piece of equipment was thoroughly cleaned between processing the various seedlots. Otherwise collections would have become contaminated with seed from other species, invalidating the scientific integrity of the research.

After each seed collection was cleaned to meet the requirements of the experiment, purity was determined by examining a portion of the seedlot under a light lens. An aliquot of seed was placed on a tray, and the amount of foreign material was estimated with respect to the amount of seed. A few collections were separated by hand, and the portions of impurities and seed were weighed to gravimetrically measure purity. Purity was the percentage of the cleaned collection composed of ovules, i.e., the proportion of the collection that was actually the specified seed and not other seed, vegetative particles of plants, or inert material (Figs. 8, 9, and 10). To become certified, seedlots must be inspected either by government agencies or recognized seed-grower associations, according to state laws. The purity portion of the certification label must list all foreign matter, especially seed from undesirable plants. Our impurities were usually inert material, as opposed to foreign seed. However, when seed was being collected and during threshing and cleaning, inadvertent mixing of plant species occasionally occurred (Fig. 8).

The seedlots were individually weighed after purity was determined. Each seedlot was then placed in a labeled jar(s), and the pertinent data recorded on inventory records. These jars of seed were kept frozen for at least a two-week period prior to undergoing germination tests. Freezing was one step in the conditioning process to prepare seeds for germination tests.

Stratification was also used to induce germination. *Stratification* is the term often used with reference to various conditioning processes used to break dormancy and allow seeds to germinate. The term *stratification* originally was used to describe a method for conditioning temperate and boreal zone tree seeds by alternating layers (strata) of seed and moist sand in a box and storing this in a cold room for several weeks or months to simulate winter conditions in the field. A cold treatment is often needed before plant seeds indigenous to boreal and arctic climatic zones will germinate. There are many treatments and combinations of treatments that will break dormancy of seeds. For this project, we selected a method involving household bleach and a short storage period under refrigeration to prepare seeds for germination. In a previous study, this treatment sequence was tested and found effective for *Arctophila fulva* seed from the study area (McKendrick 1991). However, it may not be the most effective for seed from other plant species in this collection.

Not all of the seeds planted will actually germinate. Some seeds are immature and unable to germinate. Others have been damaged by insects and during handling and have died. Tests for germination percentage in this study produced data ranging from zero to nearly 100%. Before a seed mixture could be formulated, the percentage of ovules (seed) that had the potential to germinate was determined for each seedlot. This information was obtained by performing germination tests on each collection using Alaska Seed Growers, Inc. procedures.

The quantities of seed used for planting were estimated by weighing a known number of seeds and calculating the number of seeds per gram. Because seed size and weight vary among and even within species, it was necessary to determine the number of seeds per gram in each seedlot.

Seed weights were determined during the testing for germination. After the freezing treatment, 320 seeds were removed from each storage jar in the collection. These were weighed on an analytical balance and the weight recorded on the inventory data forms. The 320-seed aliquot from each lot was soaked for 5 minutes in pure laundry bleach (Clorox®), then rinsed in tap water for 5 to 10 minutes. Three hundred seeds from each seedlot were placed in Petri dishes on 8 x 8 cm blotter pads. Each blotter pad had 100 divots in its upper surface, and one seed was placed in each divot. Three Petri dishes were prepared for each seedlot. The extra seeds from the 320-seed aliquot were discarded, after the needs for germination testing were fulfilled. Blotter and seeds were moistened with a solution of distilled water and Captan® (0.5 g Captan® powder/liter water) and given a chill-treatment by placing the Petri dishes in a refrigerator at ≈4.3°C for six days. Then the Petri dishes were placed in a germination cabinet (germinator) to encourage seeds to germinate.

The germinator was set to cycle for a 24-hour period, with 16 hours of light @ 20°C, followed by eight hours of darkness @ 13°C. Progress of these tests was monitored daily. The blotter pads were kept moist with the Captan® solution to control mold. Each day, the number of seeds that had germinated in each Petri dish were counted and recorded on a laboratory form. Germinated seeds were removed from the dishes to prevent seedling growth from overcrowding the blotter and encouraging mold. The tests were continued until germination ceased for three consecutive days. The average number of seeds per hundred that germinated among the three replicates within each seedlot was the measured germination percentage for that seedlot.

Major portions of some seed lots failed to germinate during the testing period, even though the seed appeared fully formed and mature. Seed dormancy was believed to be the cause for these low germination results. Seed dormancy is particularly common for certain plant families such as legumes and crucifers. It is believed to be a survival characteristic for plant species, especially on wildlands (ranges and forests) in marginal climates. It prevents the entire seed crop from germinating simultaneously, which would occur whenever suitable environmental conditions developed. If a portion of seeds remained dormant, the species could survive periods when unfavorable conditions might otherwise eliminate all young seedlings. Seed dormancy is undesirable in agricultural crops, because under cropland conditions, uniform germination is necessary for efficient management of plants. Consequently, efforts to either eliminate or

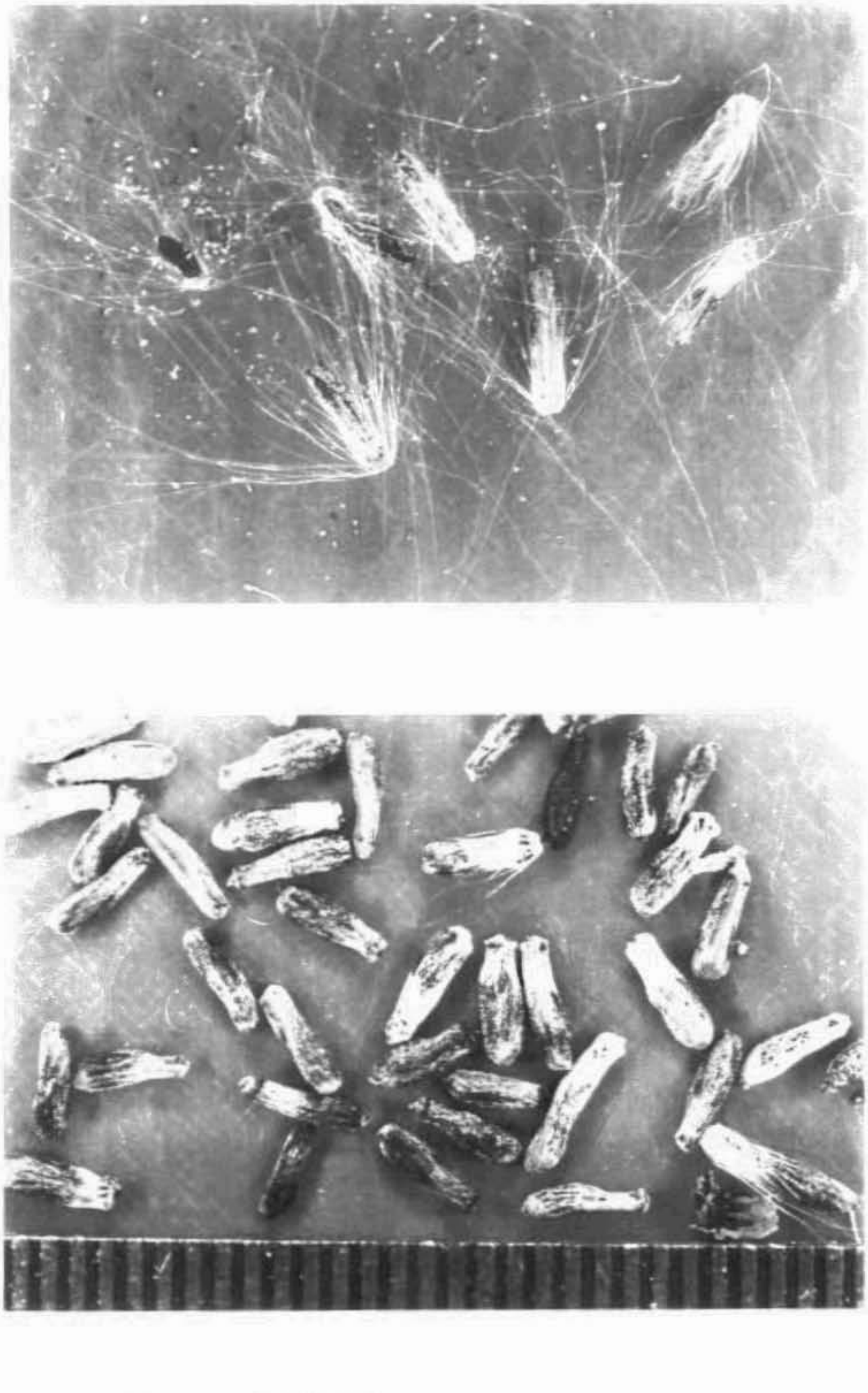

Figure 7. *Salix ovalifolia* seed with trichomes intact (upper) and removed (lower).

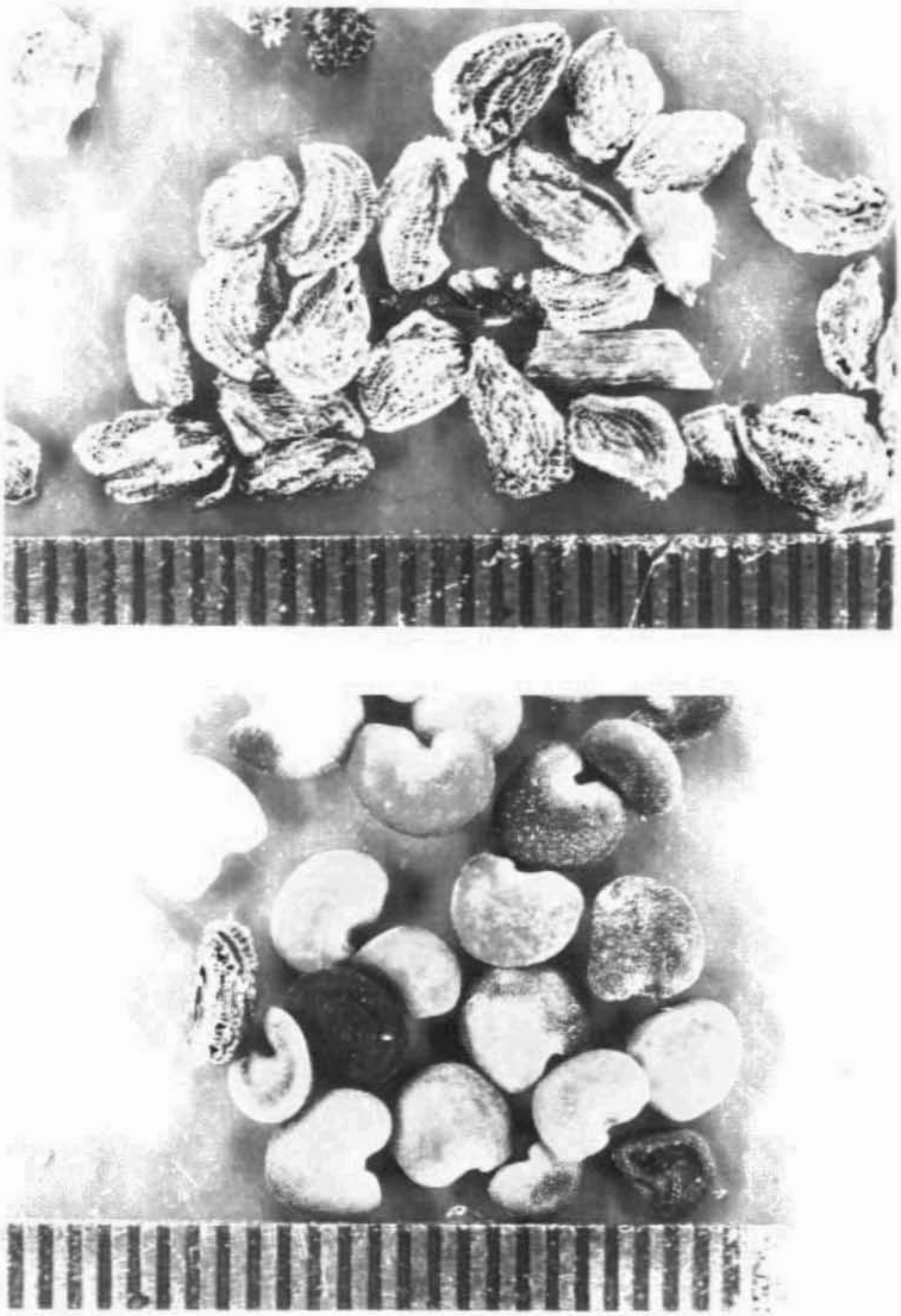

Figure 8. *Pedicularis capitata* (upper) and *Oxytropis borealis* (lower) seeds. Notice the *Pedicularis* seed mixed with *Oxytropis*.

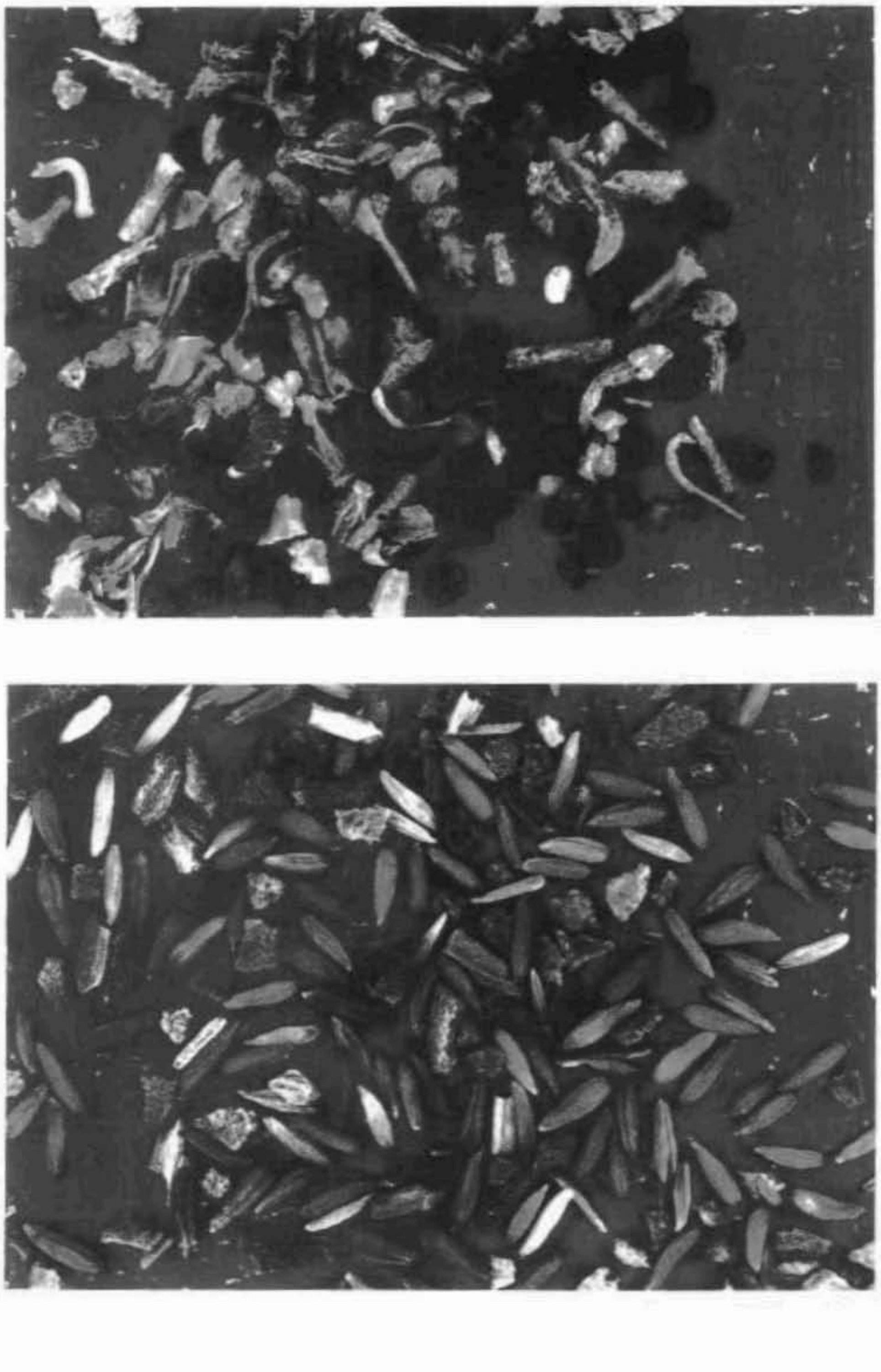

Figure 9. Vegetative fragment impurities in *Minuartia obtusiloba* (upper) and *Epilobium latifolium* (lower) seedlots from two collections of indigenous seed.

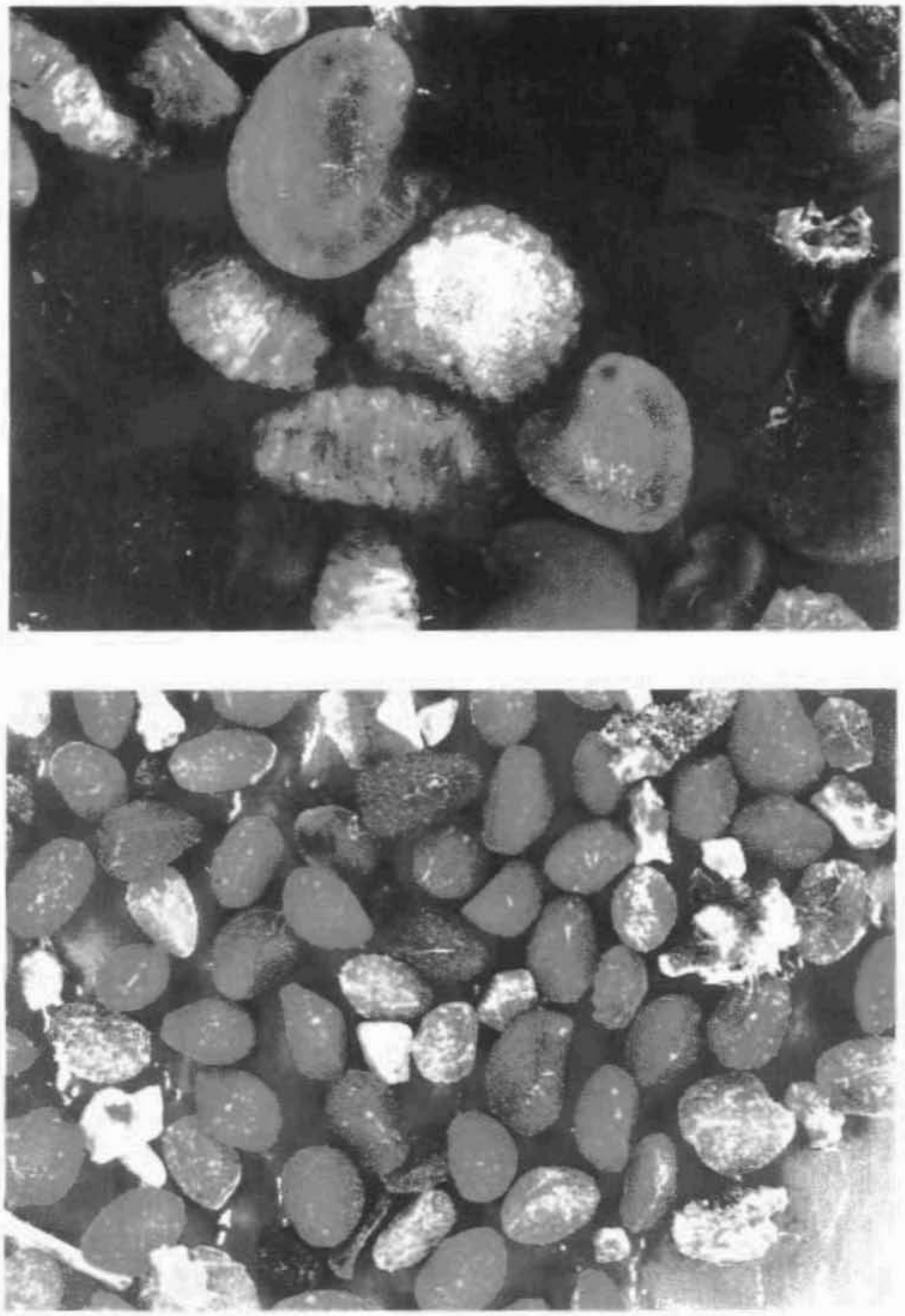

Figure 10. Insect larvae (upper) and sand and plant fragment impurities (lower) in seedlots of *Hedysarum mackenzii* and *Androsacae chamaejasme*, respectively.

sharply reduce dormancy through plant breeding have been developed for agronomic and horticultural plants. An experiment was included in this study to determine if dormancy was a factor that might explain low germination percentages observed for some of these seedlots.

Seed from five species — a grass (*Alopecurus alpinus*), a sedge (*Carex maritima*), one crucifer (*Braya pilosa*), and two legumes (*Hedysarum mackenzii* and *Astragalus eucosmus*) — was selected for testing dormancy-breaking treatments. The experiment included one mechanical and four chemical (including water) treatments to reduce seed dormancy. All plant species were from North Slope indigenous seedlots. The seedlot of *Braya* was collected on 28 August 1972, while we were conducting tundra revegetation experiments at Prudhoe Bay, Alaska. The remainder were from collections of the 1990 seed crop.

In this experiment, seeds were passed through a scarifier two times. Mechanical scarification is used to either weaken or degrade the indurated seedcoat and permit imbibition of oxygen and water. The scarifier is a hand-cranked device in which exteriors of seeds are abraded as the seed passes between two pieces of sandpaper. One strip of sandpaper is held stationary on a pressure plate, and the other is mounted on a rotating drum. The pressure plate is forced toward the rotating drum with an elastic band. The sandpaper surfaces abrade seedcoats, producing openings for air and water to enter so the embryo can germinate.

Chemical scarification is used to degrade seedcoats as well as alter certain biochemical controls that may be inhibiting germination. In addition to wetting seed with tap water, seeds were soaked in three chemicals (household bleach [Clorox®], hydrogen peroxide, concentrated sulfuric acid) and irrigated with a solution of potassium nitrate. The bleach treatment continued 5 minutes, followed by rinsing with tap water to remove the chemical. Seeds were soaked in 35% hydrogen peroxide for 15 minutes, followed by a thorough tap water rinse. The sulfuric acid treatment included soaking seed for either 5 or 15 minutes in 96.5% concentrated H_2SO_4, followed by a 5-minute treatment of sodium bicarbonate (50 g/1,000 ml water), and finally a thorough tap water rinse to remove the chemical residues. The potassium nitrate treatment consisted of wetting the seeds initially with 0.2 g KNO_3/100 ml water, then watering them with the solution as needed during the germination tests.

All seedlots in all germination tests, except those given the potassium nitrate treatment in the dormancy-breaking experiment, were kept moist with a Captan® watering solution during the germination trials. Captan® was inadvertently omitted from the potassium nitrate solution, and the error was not detected until it was too late to correct. This error may not have significantly altered the germination test results, unless mold growth killed embryos before they produced radicals. The appearance of radicals was used as an indication of germination.

In the dormancy-breaking experiment, one treatment with only the Captan® watering solution served as a control. Seeds for germination tests were moistened with the Captan® solution and chilled in a refrigerator @ ≈ 4.3°C for six days before being placed in the germinator. There were two combinations of temperature settings used for the germinator. The warmer setting exposed seeds to a 16-hour light period @ 20°C, followed by an 8-hour dark period @ 13°C. The cooler setting exposed seeds to a 16-hour light period @ 15°C, followed by an 8-hour dark period @ 5°C. All seedlots in our collections were initially tested for germination percentage using the higher setting. However, during the dormancy experiment, the lower setting was used, to more closely represent field conditions of the North Slope. This also provided a limited comparisons of germination percentages between the two temperature settings.

Results from the dormancy experiment were inconsistent among species of plants (Table 1). *Alopecurus*, *Hedysarum*, and *Astragalus* each responded positively to the acid-soaking treatments, even though the period of soaking was reduced for the grass seed to prevent destruction of the ovule. Compared to the control, *Alopecurus* germination increased six to seven times, *Astragalus* germination increased 19 to 27 times, and *Hedysarum* (bare seed and in loments) increased approximately two times with acid scarification.

The potassium nitrate treatment and Clorox®, in combination with the warmer germination cabinet setting, yielded the highest germination for the ≈20-year-old *Braya* seeds. Mechanical scarification improved germination in the bare seeds of the two legumes, *Hedysarum* and *Astragalus*, although not as much as did the acid scarification. Conversely, mechanically scarified seed of *Hedysarum* in loments germinated better than seeds treated with acid. Germination of *Carex maritima* seed increased markedly with the Clorox® treatment, when seeds were germinated at the

Table 1. Summary of germination percentages for five indigenous plant species collected on the Alaska North Slope and treated with one mechanical and five chemical procedures to break dormancy.

Genus species Source Area Date	Captan® & Water Only (Control)	[1]KNO_3 Only	35% H_2O_2 15 Minutes	Clorox® 5 Minutes + Captan® & Water: [2]Warm Test	Clorox® 5 Minutes + Captan® & Water: [3]Cool Test	Mech-anical	96.5 % H_2SO_4: 5 Min.	96.5 % H_2SO_4: 15 Min.
Alopecurus alpinus 1972 Haul Road 10 September 1990	10.5	5.0	7.5	5.3	5.0	5.0	75.5[4]	63.0[4]
Carex maritima East Dock 9 September 1990	0	0.5	1.0	23.6	0	0.5	0.5	1.0
Braya pilosa 1972 Haul Road 28 August 1972	0	20.0	4.5	22.7	5.5	0	0	0
Hedysarum mackenzii (bare seed) MP 369 Dalton Hwy. 6 August 1990	13.5	9.5	15.0	6.0	18.0	24.5	26.5	28.0
Hedysarum mackenzii (seed in loments) MP 369 Dalton Hwy. 6 August 1990	11.5	9.0	10.0	5.0	11.0	31.5	27.0	23.5
Astragalus eucosmus MP 399 Dalton Hwy. 5 August 1990	3.5	2.5	3.5	4.0	7.5	80.0	66.5	94.5

[1] Captan® was planned for this treatment, but was inadvertently omitted.
[2] In this germination test each 24-hour period alternated between 16 hours under lights @ 20°C and 8 hours in darkness @ 13°C.
[3] In this germination test each 24-hour period alternated between 16 hours under lights @ 15°C and 8 hours in darkness at 5°C.
[4] Sulfuric acid treatments for *Alopecurus alpinus* were reduced to 0.5 and 2 minutes, respectively, for the 5- and 15-minute treatments, because the longer treatments destroyed the *Alopecurus* seeds.

warm temperature range. All other treatments of *Carex* seed appeared insignificant for improving the germination for this species. Germination of the bare legume seeds improved slightly under Clorox® treatment with reduced temperatures in the germinator. The hydrogen-peroxide treatment of the bare *Hedysarum mackenzii* seeds may have improved germination slightly; however, germination percentage for this treatment was about the same as that without H_2O_2 under the Clorox® lower temperature regimen. Because all scarification treatments were confounded with temperature settings in the dormancy-breaking experiment, the responses in terms of germination percentages cannot be separated by either scarification treatments or interactions between temperature settings and scarification.

Results of the experiment indicated there was dormancy in seeds from the Arctic, and it could be broken through various methods. It also demonstrated that a single dormancy-breaking treatment would be impractical for a mixture of seed from several species and genera. Even for this study, it would be unproductive to include seed dormancy-breaking treatments to reduce dormancy in our seed mixtures. Such treatments are time-consuming and may be impractical. For instance, by eliminating dormancy, all the seed applied is at risk of dying anytime growing conditions suddenly deteriorate before seedlings become well established. Also, it is possible that a dormancy-breaking treatment may shorten the life of seeds, allowing embryos to die before seed could be transported from the laboratory to the field.

Dormancy was a factor affecting germination percentages and could not be easily quantified in germination tests for the overall study. Therefore, the germination percentages obtained without dormancy-breaking treatments were used to calculate seed application levels. Numbers of pure live seed (PLS) applied per gram were calculated from the germination percentage and the purity for each seedlot, i.e.,

% PLS = % Germination x % Purity

This information was used, in combination with the number of seeds per gram, to calculate how many viable seeds were applied if a given mass of seed was planted to a unit area. For our seeded plots at the BP Put River No. 1 gravel pad, there were 2.97 m^2/plot, and each plot was 1/5 of each experimental unit on the gravel pad. Sixty-five PLS/m^2 was chosen as an arbitrary application in this experiment. For the 1990 planting, at least 2,885 PLS/m^2 were applied. With the site's capacity limited to supporting perhaps only 20 to 30 mature plants per m^2, it was obvious that these seeding applications were more than adequate, assuming all the PLS germinated. However, there are many chances for seeds to fail developing into mature plants.

The first two seed mixtures contained seed of 34 and 28 species, respectively, for the 1990 and 1991 plantings. Several of the collection seedlots were inadequate to provide 65 PLS/m^2 for each of the 144 experimental units and one row in the botanical garden. Therefore, computer spreadsheet formulas were used to calculate the application rates. Given the previously stated 65 PLS/m^2 goal for planting the 144 experimental units, the amount of total seed required was determined by the following formulas:

65 PLS/m^2 X 2.97 m^2/Plot = PLS Number/Plot = 193

193/(Number of Seed/g) = Grams PLS Needed/Plot

Grams PLS Needed/Plot x 144 = Total Grams PLS for Gravel Plots

The amount of seed needed from each seedlot was compared with the amount of seed in the inventory. If there was an adequate supply in the inventory for the gravel plots and the botanical garden, we could use our preselected application of 65 PLS/m^2.

Total Grams of Seed Required/144 = Grams Seed to Weigh/Experimental Unit

If there was insufficient seed to apply 65 PLS/m^2, a lower application was selected by trial and error, until the amount of seed in the inventory was adequate for the application and the botanical garden. This resulted in planting mixtures consisting of unequal applications of PLS/m^2 among various species in the mixture (Appendix E). For example, there was only enough seed of *Castilleja elegans* to apply 16 PLS/m^2 in the 1991 seeding (Table E-2, Appendix E). If seed from one species was harvested from two or more locations, the averages for germination and purity were prorated according to the proportional amount of seed in the planting mixture. This unequal seeding application limited the value of these tests for measuring interspecific competition, but it probably reflected actual conditions in nature. Seed production naturally varies among genera and species of plants among sites and among years. That variation provides unequal quantities of seed for natural colonization of barren sites.

Seeds were measured by weight, based on data obtained from the various laboratory procedures. Consequently, the exact amount of seed from each seedlot had to be weighed into 144 individual units, then added to each mixture. The collections of seeds spanned a large range of seed sizes, shapes, and surface characteristics (Figs. 11 and 12). It was impossible to maintain homogeneity of such a mixture while subdividing it. Therefore, the only sure method of maintaining consistent applications among seeded plots was to prepare individual mixtures of seed for each plot.

To prepare seed mixtures, two sets of jars were numbered consecutively from 1 to 144, one jar for each plot. The number on each pair of jars corresponded to one field plot. One set of jars was used to contain the combined seeds in the mixture for each experimental unit. The other set of jars was used to temporarily contain the aliquots from each seedlot from the time it was weighed until it was added to the mixture. The amount of seed for a given seedlot was weighed and placed into the temporary jars. After all 144 temporary jars had been allocated seed from a given seedlot, the seed was emptied from the temporary jars into the mixture jars. After all seedlots had been added to these mixtures, the mixture jars were capped and prepared for shipment to the field.

Applying Seed Mixtures. At the BP Put River

No. 1 site, 1.22 x 2.44 m plots were measured and staked at the corners. String was stretched along plot perimeters to delineate the area for planting. The surface of the gravel was raked to loosen the upper 2 to 4 cm of the substrate. To ensure an even application of the seed mixture throughout plots, the contents of each jar of seed were blended with about 0.5–0.75 liter of moist sand in a plastic bucket. This diluted the seed within a manageable matrix for the hand application and helped maintain a homogenous mixture during application. This seed/sand mixture was then distributed by hand throughout the plot as evenly as possible. Applying small amounts repeatedly across the planting area resulted in a relatively even distribution of seed. The plot was gently raked after applying the seed and tamped firmly to ensure maximum seed/soil contact (Fig. 13). Finally, the string was removed, but the stakes were left to delineate the area planted.

Measuring Plant Responses. Characteristics of plant communities developing on plots from the three seedings (those completed during 1990 and 1991, and the one proposed for 1993) with mixtures of native plant seed and the stands that form voluntarily on the unplanted portions of the plots are the indicators that will be used to measure the effects of the various gravel-fill manipulations. Types of data selected for this purpose were canopy cover, basal cover, species composition, plant vigor, height, and plant density by species. Only basal and canopy cover data for vegetation forming in the plots planted in 1990 and of unplanted plots in Replicate II were collected in September 1991.

Basal cover and canopy cover were measured using a point frame (Fig. 14). This device consisted of a metal frame with ten holes through which a metal rod was lowered to measure cover. Aerial contacts with plants were recorded as canopy cover, as were live plant leaves lying on the surface of the ground. Multiple contacts per sample point were possible for the canopy cover; however, only the first contact should be counted unless leave area index is desired.

Basal cover data consisted of records for pointer contacts at the ground surface. The basal cover categories were recorded as stem bases of live plants, stem bases of dead plants, rock, barren (soil or sand), mulch, moss, wood (debris), and animal feces. One basal cover datum was obtained for each hole in the frame. After all ten holes on the frame had been read, the frame was moved to another portion of the plot, and the process repeated. In each plot, three locations, i.e., 30 points, were randomly sampled.

The numbers of canopy and basal cover points per category were totalled on the data sheets and checked for accuracy and then entered into computer data files. The printed files were verified for accuracy by comparing with the field data sheets. These data files were summarized by blocks, replicates, and treatments: 1) gravel thickness (three levels), 2) topsoil (two levels), 3) tillage (two levels), 4) snow fence (two levels), and 5) seeded with grass (two levels) (Appendix F).

Samples of tissue were taken from four plots on 12 September 1991 to determine if nutrient deficiencies were affecting plant growth on these plots. Samples were clipped from Replicate III, Block 1 plots on the 0.6-m lift from tilled and untilled gravel plots and from tilled and untilled topsoil plots (Fig. 3). These samples were submitted to the Palmer laboratory for analyses of N, P, K, Ca, Mg, and Na.

Photopoints. Two sets of photopoints were established to record aspect changes of gravel vegetation plots over time. All 144 plots are included in both sets of photopoints.

The first photopoints are at the east end of each treatment, providing a view westward across the plots. The photographer stands at the east end of the plots back sufficiently to allow the entire east edge of the plot to span the lower camera view-frame. A 35-mm camera equipped with a 28-mm (wide-angle) lens is used, permitting all five subplots to be included in the photograph. The first photographs for this set of photopoints were obtained 23 July 1990.

The second set of photopoints is located at the west end of each experimental unit, providing an eastward view across the plots. The photographer stands on a stepladder, in order to include all subplots in the image and to give a less oblique view of the plots than obtained in the first set of photos. A 35-mm camera equipped with a 50-mm (normal) lens is used. The first photographs for this second set of photopoints were obtained 28–29 August 1991.

The east photopoints are located about 4.5 m from the western end of each of the experimental units (Fig. 15). A 35-mm camera with a 50-mm lens and Kodachrome® 64 transparency film was used. A 1.8-m step ladder was used to obtain the correct camera position and avoid including the snow fences in the photos. The view of experimental units was from west to east. It was framed horizontally, with the western end of the experimental unit at the bottom of the field of view such that the experimental unit extended com-

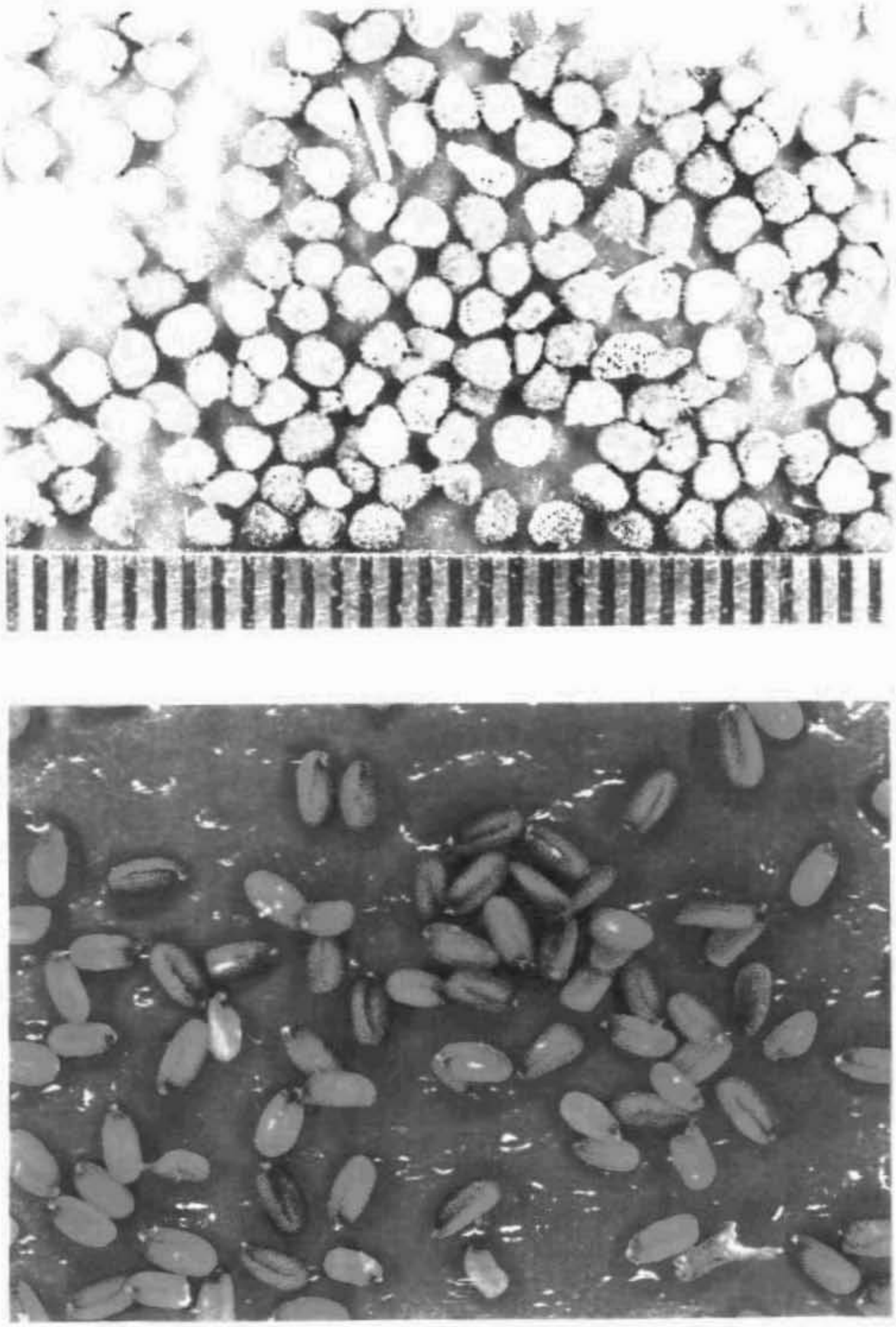

Figure 11. Rough seeds of *Cerastium beeringianum* (upper) and smooth seeds of *Arabis arenicola* (lower) from seedlots collected in 1990 on the Alaska North Slope.

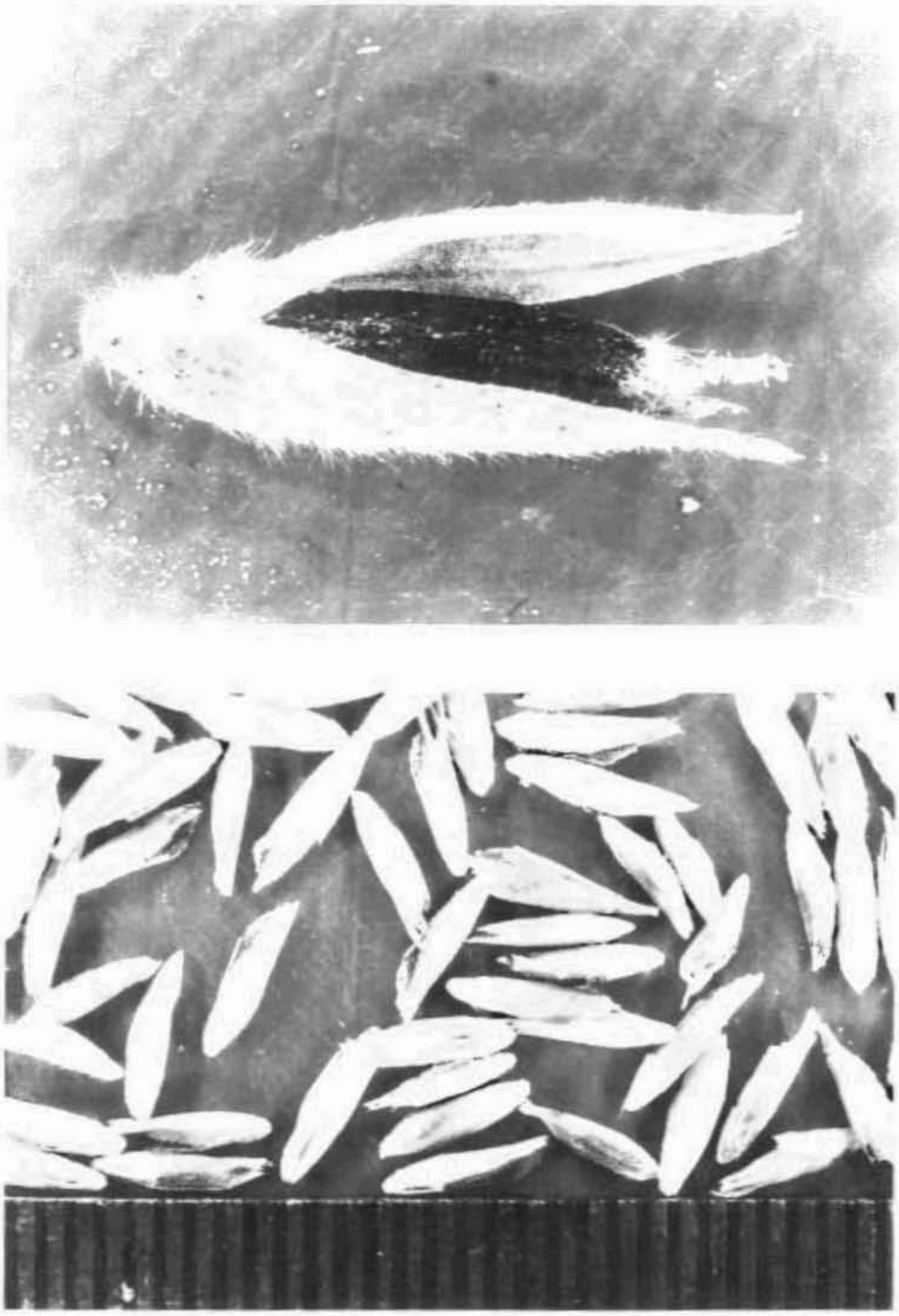

Figure 12. Exposed caryopsis (ovule) in *Elymus arenarius* (200 seeds/g) (upper) and smaller seed of *Puccinellia langeana* (6,400 seeds/g) (lower).

Figure 13. Tamping the surface of the seeded plots with rakes on the BP Put River No. 1 gravel pad (27 June 1991).

Figure 14. A point-frame was used to measure basal and canopy cover on gravel vegetation plots (4 September 1991).

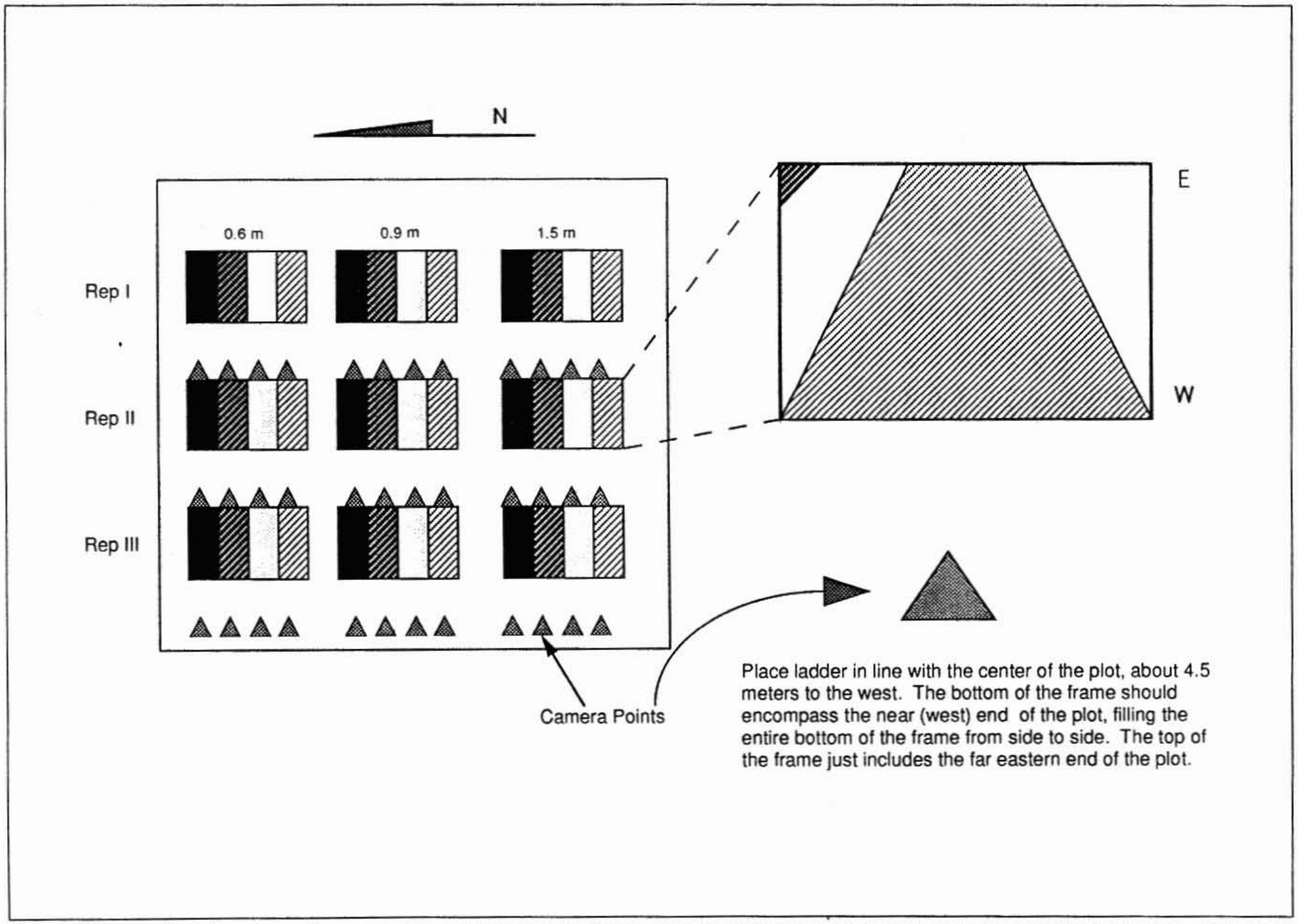

Figure 15. Diagram illustrating view and camera-points relative to plots for photographing the gravel treatment experimental area on the BP Put River No. 1 gravel pad.

pletely across the frame. The camera was positioned so the eastern end of the experimental unit was across the top of the frame, as illustrated in Figure 15. The camera was focused on a stake or other object near the middle of the experimental unit and depth of field checked to ensure as much of the photo as possible was in focus.

At least one duplicate, with a slightly different exposure, of each photopoint was taken for backup. The roll and slide numbers were noted on a field photo data sheet, which included date and photographer's name. The rolls were numbered sequentially so that each slide has a unique roll/slide number. After processing, the slides were labelled by the photographer and archived for reference.

The first set of photopoints was established to generate views of plots from the east edge. These photographs were taken with the photographer standing at the edge of the plot. Each image included all five subplots (1990, 1991, and 1993 plantings, and two unplanted checks) in each experimental unit. A 35-mm single-lens reflex camera with a 50-mm lens was used. Color reversal film was used to produce transparencies. The entire set of photos numbers 144 each time the experiment is photographed.

Identifying Indigenous Plants to Colonize Gravel Fill

Botanical Garden at BP Put River No. 1 Gravel Pad

This phase involved establishing a botanical garden of indigenous colonizing plant species on a portion of the area at the BP Put River No. 1 gravel pad. Because this phase included identifying, collecting, and testing the suitability of species for vegetating gravel structures, the same procedures described for seed acquisition, cleaning, storage, and germination for the gravel plots were used for the botanical garden. Actually, the species in the botanical garden included all species and seedlots used to prepare mixtures for the gravel modification experiment, plus a few others which were not used in the gravel plot mixtures. Because practical application of such a procedure depends on acquiring adequate supplies of indigenous plant seed, the harvesting, handling, storage, and planting of such seeds were fundamental to this phase of the project.

The botanical garden is a rectangular area measuring 31 by 38 m on the northwest side of the BP Put River No. 1 gravel pad (Fig. 3). Fifteen centimeters of topsoil were added to the garden area. It was divided (north-south) into east, mid, and west sections, each approximately 10 by 38 m. Rows were oriented northeast and southwest and spaced approximately 0.7 m apart.

During planting, the soil along the row was loosened with a 10-cm ripping rake. A string was stretched between stakes to mark the ends of each row, and a furrow was formed with the back of a hoe along the string. Seed for each row was mixed with approximately 0.5–0.75 liters of sand, as it was for the gravel plot applications, and then hand sprinkled into the furrow. The seed was covered with soil and tamped. Stakes at the ends of each row were sequentially numbered, with a unique number referring to a specific species/lot planted (Appendix D). Each row in the garden was planted with seed from a single species. Seeding of rows began in the spring of 1990 at the south edge of the east section of the botanical garden.

In 1990, the botanical garden rows were 9.5 m in length. In 1991, rows were shortened from 9.5 to 9.0 m in length to accommodate snow fencing installed during the previous autumn. Snow fences were installed between the sections and on the northeast (prevailing upwind) side during late September 1990, because the gravel berms had proved to be ineffective in creating a snow cover in winter 1989/90.

Seed for the botanical garden in 1990 was prepared by simply using seed remaining after needs for planting the 144 experimental plots had been met. The quantity of seed applied to the botanical garden rows was not recorded. In 1991, the seed for each row in the botanical garden was weighed, and the application was 1.6 PLS/cm of row. That application will be used for the remaining plantings. The application is high compared to the number of plants needed for each row in the botanical garden. However, at the time of planting, field responses were unclear, and abundant amounts of seed were selected to ensure a stand. It was believed that thinning dense stands would be preferred to filling in sparse stands by interseeding during subsequent seasons.

At the end of the growing season in 1990 and 1991, each row of the botanical garden was examined for seedling emergence. Emerged stands were evaluated on a six-level scale from none to dense. Maximum seedling heights were measured and recorded.

Surveys of Gravel Fill Sites Throughout Region

Ten gravel habitats and/or abandoned gravel fills in the National Petroleum Reserve in Alaska (NPRA) and along the Sagavanirktok River were examined for the number of plant species colonizing those sites during the period from July 1984 through July 1991. Observers walked these areas and recorded plant species growing in the gravel. If a plant species was not identified, a portion was collected for later identification. Botanical references used were: Argus (1973), Hultén (1968), Viereck and Little (1972), and Welsh (1974). Species were listed for each site and summarized by families and genera by location. Information from these lists was used to gain an understanding of which plant species were prominent colonizers and well distributed across the region. A paper based on these data was published elsewhere (McKendrick 1991).

RESULTS

Measuring Physical and Chemical Conditions of the Gravel

Soil (Gravel) Sampling

Sampling gravel and overburden material at the BP Put River No. 1 gravel pad began in 1989, with collection of grab samples of these two materials to provide background information prior to imposing any fertilization treatment. There were 14 samples in this collection (27-28 July 1989). Samples were also collected from each of the 144 gravel experimental units on 12 July 1990. These samples were taken after the fertilizer had been applied and were screened to separate the fine soil fractions from the gravel. Sixteen bulk density samples were collected from the upper 10 cm of Replicate II, Plot 2 (Fig. 3), within each of the four blocks on the BP Put River No. 1 gravel pad, 23 August 1991. At the same time, four bulk density samples were taken from the upper 10 cm of the botanical garden surface. Twenty-four gravel samples were collected from Block 1, Replicate III, Plots 1, 2, and 3, on 12 September 1991, to evaluate fertility conditions, because plants were showing signs of stress.

All samples for nutrient analyses were air-dried, sieved to remove particles >2 mm in diameter, and stored in polyethylene bags. Where sufficient material was obtained, samples were split with a soil sample splitter, and half of the collection archived. The samples not archived have been submitted to the Palmer laboratory for standard nutrient analyses. The results were not available in time for inclusion in this report.

Bulk densities and soil moisture percentages are presented in Table 2 for the gravel plots and the botanical garden. The plots with topsoil added averaged 1.6 g/cm^3 (gravel plots) and 1.7 g/cm^3 (botanical garden); without topsoil, the average bulk density was 2.2 g/cm^3. Tilled gravel bulk density was lower than untilled gravel: 2.0 and 2.3 g/cm^3, respectively. There was no difference in bulk densities between tilled and untilled plots that received topsoil applications. Soil moisture averaged about 3.5% in the gravel plots and 12.9% in the plots with topsoil. Untilled topsoil plots contained slightly more moisture than the tilled topsoil plots: 14.0% vs. 11.8% soil moisture. Soil moisture in the botanical garden, which has 15 cm topsoil, averaged 16.1% in the portion seeded in 1990 and 13.3% in the portion seeded in 1991.

The fine-fraction percentages for gravel samples collected in 1990 were summarized by treatment and are presented in Table 3. The mean fine percentage for all experimental units was 44.2%. There were no differences among treatments, except between topsoil thicknesses. With 8 cm of topsoil, fines constituted 63% of the matrix mass, and without topsoil, fines amounted to only 25% of the matrix mass.

Measuring Snow Cover

Snow depths and water contents in the gravel plots were measured on 7 May 1991, and in the botanical garden on 8 May 1991. Data were summarized by treatment block and the botanical garden and are presented in Table 4. Snow depths were markedly different between areas with and without snow fencing. Where there were no snow fences, the upper elevations within the block (i.e., the 0.9 m and 1.5 m gravel thicknesses) had the least snow cover; and within these lifts, the experimental units with topsoil, which had surfaces slightly elevated (about 8 cm from the adjacent ground) were mostly free of snow. With snow fencing, the snow cover averaged about 109 cm. Water content of this snow accumulation averaged 43 cm.

Monitoring Temperatures

Air and soil temperature data collected at a coastal site (Big Skookum) and a foothill site (MP 62) were included in this study. Air temperatures monitored at the two locations during the 1988 through 1991 growing seasons were summarized by generating graphs and calculating the degree-hours greater than zero and equal to or less than zero. Degree-hours were calculated from hourly mean temperatures with the STATS module in SYSTAT® (Wilkinson 1988). Positive

Table 2. Listing of bulk densities (g/cm³) and soil moisture (%) for the upper 10 cm of the 0.9-m gravel lift plots and the botanical garden at the BP Put River No. 1 gravel pad (23 August 1991).

Plot Identification	Treatment	Bulk Density (g/cm^3)	Soil Moisture (%)
Block 1, Rep II, Plot 2	Gravel, Tilled	1.8	4.6
Block 1, Rep II, Plot 2	Gravel, Untilled	2.3	3.8
Block 1, Rep II, Plot 2	Topsoil, Tilled	1.9	9.2
Block 1, Rep II, Plot 2	Topsoil, Untilled	1.6	15.0
Block 2, Rep II, Plot 2	Gravel, Tilled	2.1	2.7
Block 2, Rep II, Plot 2	Gravel, Untilled	2.3	3.4
Block 2, Rep II, Plot 2	Topsoil, Tilled	1.7	9.8
Block 2, Rep II, Plot 2	Topsoil, Untilled	1.6	15.0
Block 3, Rep II, Plot 2	Gravel, Tilled	1.9	2.9
Block 3, Rep II, Plot 2	Gravel, Untilled	2.3	3.5
Block 3, Rep II, Plot 2	Topsoil, Tilled	1.5	12.8
Block 3, Rep II, Plot 2	Topsoil, Untilled	1.5	12.7
Block 4, Rep II, Plot 2	Gravel, Tilled	2.2	3.8
Block 4, Rep II, Plot 2	Gravel, Untilled	2.3	3.4
Block 4, Rep II, Plot 2	Topsoil, Tilled	1.5	16.3
Block 4, Rep II, Plot 2	Topsoil, Untilled	1.7	13.4
Means:	Gravel, Tilled	2.0	3.4
	Gravel, Untilled	2.3	3.5
	Topsoil, Tilled	1.6	11.8
	Topsoil, Untilled	1.6	14.0
Botanical Garden	1990 Planting #1	1.7	16.0
Botanical Garden	1990 Planting #2	1.6	16.2
Botanical Garden	1991 Planting #3	1.8	14.1
Botanical Garden	1991 Planting #4	1.7	12.4
Means:	1990 Plantings	1.7	16.1
	1991 Plantings	1.8	13.1

hourly mean data greater than zero were summed by month, after selecting the subset of data points >0°C. Negative degree hours were summations of hourly means ≤0°C. The hourly means, which consisted of the average temperature measured every 5 minutes, were plotted for the months of July, August, and September for the coastal (Fig. 16), and foothill (Fig. 17) sites. These show the seasonal trends for each of the four years of data. There is a general pattern for air temperatures to decline over the sampling period. The coastal location daily maximum temperatures were lower than those at the foothills location during the growing season, whereas daily minimum temperatures near the coast were often higher than the minimums in the foothills. The range between daily maximum and minimum temperatures was much greater in the foothills

Table 3. Mean percentages and standard error of the means (S.E.M) of fines (<2 mm) for various treatments at the BP Put River No. 1 gravel pad (12 July 1990).

Treatment	Mean (%)	S.E.M.
Block 1	43.89	3.326
Block 2	45.43	3.493
Block 3	44.12	3.218
Block 4	43.48	3.333
All 144 Plots	44.23	1.655
Replicate 1	43.30	2.817
Replicate 2	44.11	2.886
Replicate 3	45.28	2.951
0.6-m Lift Height	43.94	2.899
0.9-m Lift Height	45.08	2.979
1.5-m Lift Height	43.67	2.778
No Topsoil	25.06	0.287
8-cm Topsoil Added	63.40	0.777
No Snow Fence	44.45	2.400
1.2-m Snow Fence	44.01	2.298
No *Poa glauca*	43.80	2.301
Poa glauca Planted	44.66	2.390
Untilled	46.40	2.466
Tilled	42.06	2.197

Table 4. Summary of average snow-depths (cm) and water contents (cm) on gravel plots and the botanical garden at the BP Put River No. 1 gravel pad, 7 and 8 May 1991.

Location	Treatment	Snow Depth (cm)	Water Content (cm)
Block 2 Gravel Plots	No Snow Fencing	<10	2.36
Block 4 Gravel Plots	No Snow Fencing	<10	0.68
Block 1 Gravel Plots	Snow Fencing	113.03	44.20
Block 3 Gravel Plots	Snow Fencing	106.17	40.89
Botanical Garden	Snow Fencing	104.65	42.67

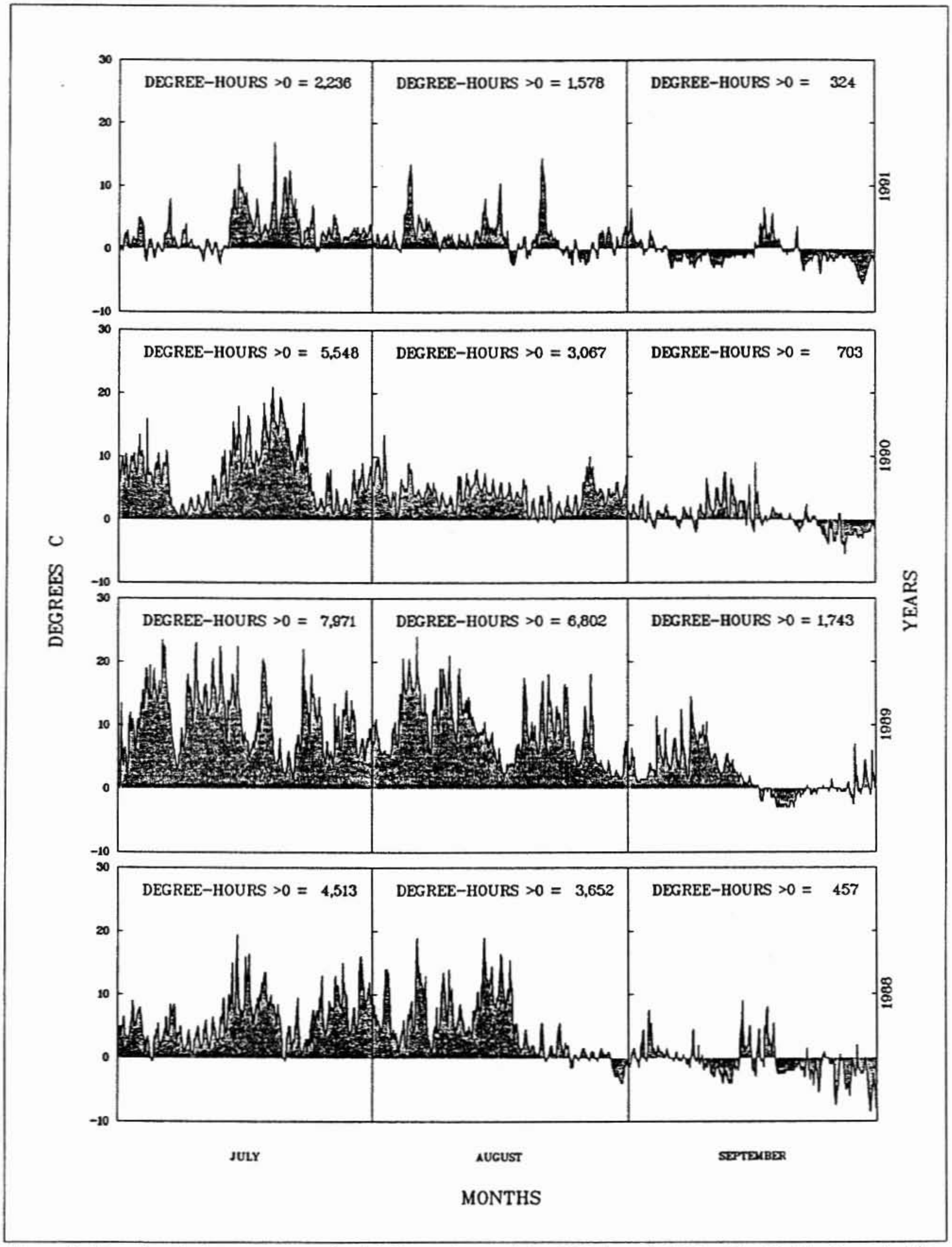

Figure 16. Mean hourly air temperatures for July-September periods, 1988 through 1991, at the Big Skookum site in the Sagavanirktok River delta, near the seacoast.

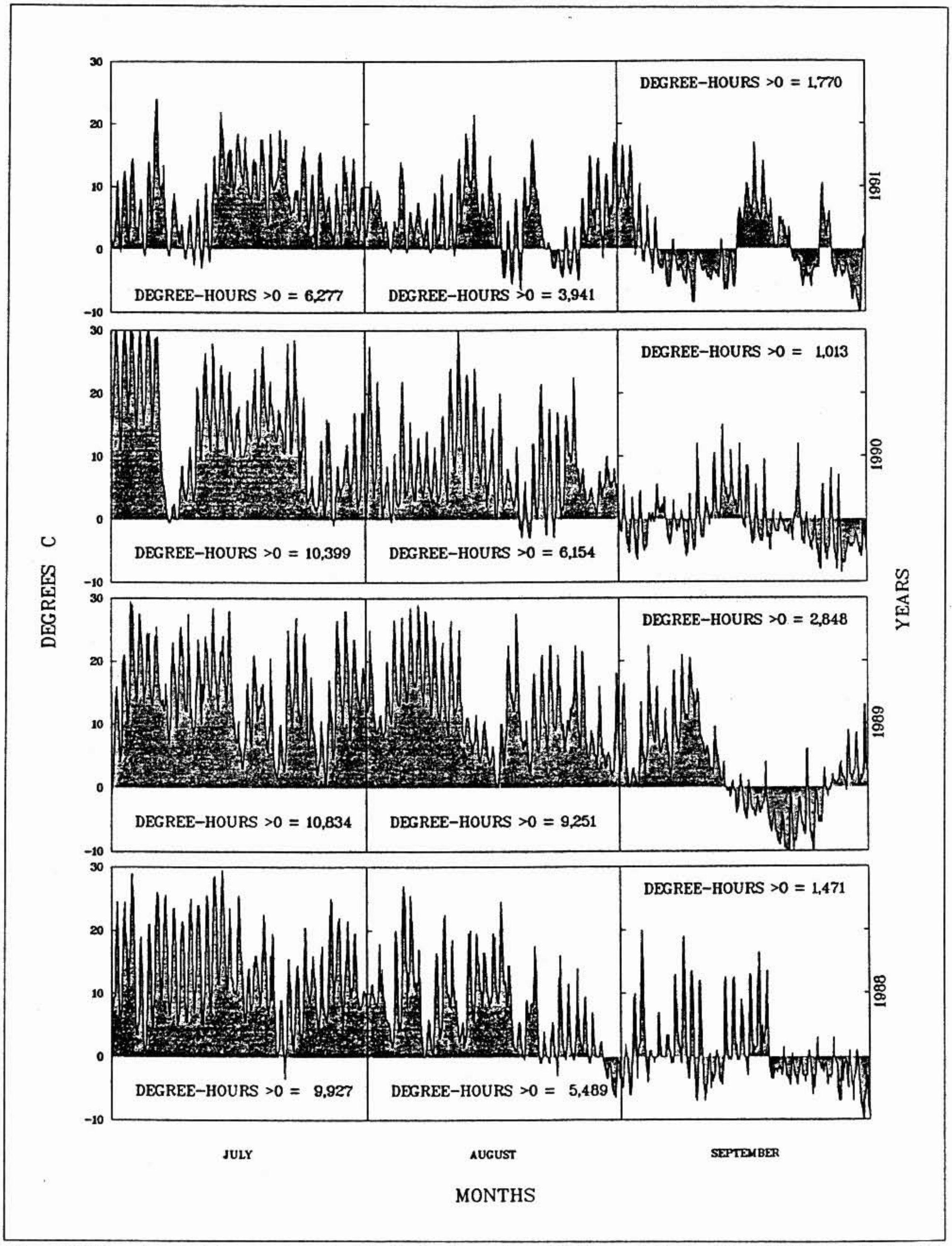

Figure 17. Mean hourly air temperatures for July-September periods, 1988 through 1991, at the MP 62 site in the foothills of the Brooks Range.

than near the coast. Warm and cool periods corresponded between these two locations, i.e., the pattern of occurrence was similar.

Within years, cumulative positive air degree-hours (°C) were substantially greater in the foothills than at the coastal site (Fig. 18). Among years, the positive degree-hours recorded at the coastal site during 1989 exceeded those recorded at the foothill location in 1991. The positive air degree-hours at the foothill location was usually about two times the number at the coastal location, even though the daily temperature at the foothill location fluctuated more than at the coast. Cumulative negative air degree-hours recorded in the foothills also always exceeded that recorded at the coastal location (Fig. 18).

It is important to observe the differences in air temperatures among years. In 1989, the warmest season in our records, air temperatures remained above freezing from the first of July through mid-September on the coastal plain. In contrast, during the coolest season in our records (1991), air temperatures during the July through mid-September period dropped to either freezing or below freezing approximately 26 times.

Substantial inter-annual variations in temperatures were recorded among the four seasons monitored. The cumulative positive air degree-hours for the 1988 and 1990 growing seasons were nearly equal. At the coastal site, the total positive air degree-hours recorded for the 1989 growing season was nearly twice that of the years 1988 and 1990, and almost four times that of 1991 (Figs. 16, 17, and 18). The pattern among years at the foothills location was similar to that for the coastal site, but the relative magnitude among years was proportionally less. The increase between the 1989 and 1988-1990 cumulative positive degree-hours was 125%, as opposed to 150% found at the coastal site.

Cumulative positive soil temperature degree-hours data for the coastal and foothill locations revealed a consistent pattern, with the growing-season soil temperatures near the coast being warmer than those in the foothills (Fig. 18). This was opposite of the air temperatures between these two locations.

Measuring Effects of Modifying Gravel Fill with Plant Indicators

Seed Collections, Germination Tests, and Planting Mixtures

Seed Collections. Complete listings of seed collection inventories, including species harvested, location, date, grams in the cleaned seedlot, and notes about the collection are exhibited in Appendix B. This information was arranged by year in Tables B-1 through B-3 for years 1989, 1990, and 1991, respectively. The numbers of species and seedlots among these collections are summarized in Table 5.

As previously mentioned, the 1989 growing season was unusually warm in the Prudhoe Bay area (Fig. 18). Plants flowered profusely; seeds of *Arctophila fulva* matured at locations where we had previously found none (McKendrick 1990). However, relatively little time was allocated in the autumn of 1989 to seed harvest, although a total of 42 species was harvested. There were 19 species of graminoids (monocotyledonous) in 37 collections, 22 species of forbs (dicotyledonous) in 26 collections and a single collection of a shrub (dicotyledonous) species (Table 5).

Temperatures in 1990 were about average (based on our limited records) for heating degree-hours. There appeared to be some carry-over effects from the previous year, which had been extraordinarily favorable. These effects were exhibited through abundant flowering and seed formation by indigenous plants. Favorable seed production does not guarantee an abundant harvest, however. Strong winds shattered much of the seed crop before it could be harvested. In spite of those conditions, seeds from 62 species were collected. The 1990 seed harvest was principally directed toward forbs and shrubs, because grasses had dominated the previous collection. The 1990 harvest consisted of 21 graminoid species among 40 seedlots, 37 forb species among 62 seedlots, and 4 shrub species among 9 seedlots (Table 5).

Temperature conditions in 1991 were unfavorable for plant growth. Many plant species failed to flower, and seeds did not form or mature. The effects were more pronounced on the coastal plain than in the foothills. To compensate for limited availability of seeds to harvest, a greater seed collecting effort was expended in the autumn of 1991, including use of a helicopter to access sites which had not been previously harvested. The 1991 harvest consisted of 55 vascular plant species among 87 seedlots: 21 graminoid species among 40 seedlots, 29 forb species among 40 seedlots, and 5 shrub species among 7 seedlots (Table 5).

In addition to the Alaska North Slope collections, seeds of arctic species were collected on the Yamal Peninsula and in Yamburg, Russia (western Siberia) in 1991. These included four grass species among four seedlots and 5 forb species among 6 seedlots (Table B-

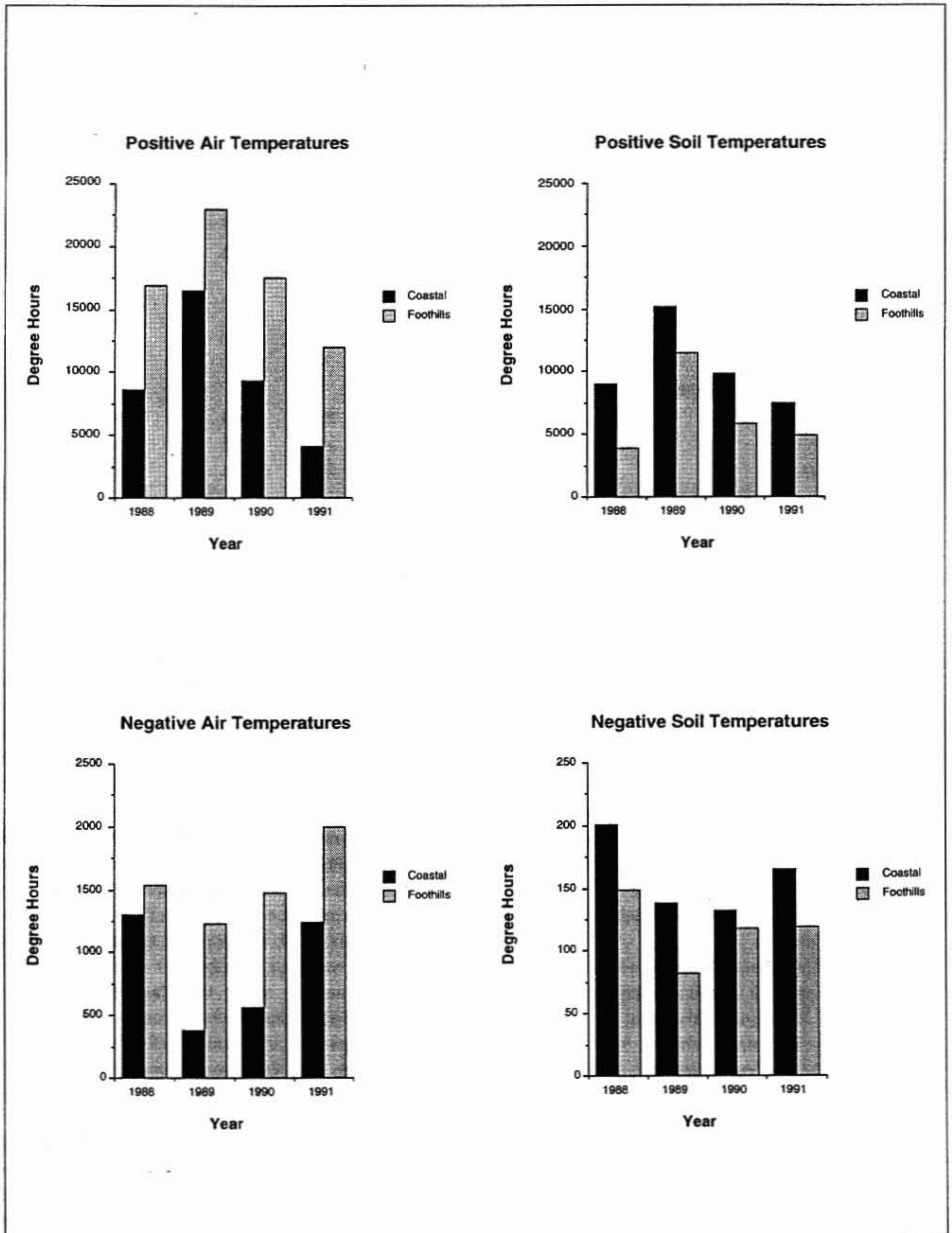

Figure 18. Cumulative positive and negative degree-hours (°C) for July-September periods, 1988 through 1991, at a coastal (Big Skookum) and a foothills (MP 62) location.

Table 5. Number of plant species collected, tested for germination, and planted in gravel vegetation plots and the botanical garden at the BP Put River No. 1 gravel pad for years 1989 through 1991.

	Collection Years					
	1989		1990		1991	
	Species	Seedlots	Species	Seedlots	Species	Seedlots
Seed Collections						
Graminoids	19	37	21	40	21	40
Forbs	22	26	37	62	29	40
Shrubs	1	1	4	9	5	7
Germination Tests						
Graminoids	21	35	21	40	.	.
Forbs	21	26	36	65	.	.
Shrubs	0	0	4	9	.	.
Gravel Plot Plantings						
Graminoids	.	.	17	28	3	4
Forbs	.	.	17	19	22	30
Shrubs	.	.	0	0	3	7
Botanical Garden Plantings						
Graminoids	.	.	17	34	4	6
Forbs	.	.	16	20	22	26
Shrubs	.	.	0	0	4	7

4, Appendix B).

Most of the Alaska collections contained relatively little viable seed for planting. Poor growing conditions resulting from low temperatures were believed responsible for the lack of mature seed produced in 1991. The Siberia collections were small. Consequently, there was not sufficient seed gathered in 1991 for a planting in 1992, except to add rows to the botanical garden. The final planting in the gravel manipulation plots will depend on seed produced during the 1992 growing season.

Germination Tests. Twenty-one graminoid species in 35 seedlots and 21 forb species in 26 seedlots in the 1989 seed collection were tested for germination percentages (Table 5 and Table C-1, Appendix C). The average germination percentage for graminoids from this collection was 81.5%. The lowest percentage (1%) was recorded for *Deschampsia beringensis*, a grass introduced to the Prudhoe Bay region several years ago from southcentral Alaska by other researchers. Seed from indigenous *Deschampsia caespitosa* plants germinated profusely (92% to 95.3%). The highest germination percentage (99%) recorded for graminoids was observed in a seedlot of *Agropyron boreale* that originated from the coastal plain. The average germination percentage for forb seed collected in 1989 was 49.2%. Forb seed germination percentages for seed collected on the coastal plain ranged from 0% in *Androsace chamaejasme* to 99.7% for *Artemisia arctica* (Appendix C).

Twenty-one graminoid species among 40 seedlots, 36 forb species among 65 seedlots, and 4 species of shrubs in 9 seedlots for the 1990 seed collections were tested for germination percentages (Table 5 and Table C-2, Appendix C). In addition, ten special germination tests were conducted on five forb seedlots. One test compared soaking seeds in Clorox® against no Clorox® soaking, another compared germination percentages between large and small seeds within the same species, and three compared germination percentage between seeds of the same species with and without hulls.

Overall germination percentages for graminoids were lower in the 1990 collections compared to those for the 1989 collections: 42.1% and 81.5%, respectively. The mean germination percentage for graminoids in 1990 ranged between 0% for two *Bromus pumpellianus* and one *Calamagrostis* *inexpansa* seedlot (all from the coastal plain) to 93% for one seedlot of *Bromus pumpellianus* from the foothills (Appendix C). The mean germination percentages of forbs collected in 1990 was also lower than for forb seeds harvested in 1989: 33% vs 49.2%, respectively. Germination percentages of 1990 forb seed collections ranged between 0% and 99.3%. A seedlot of *Artemisia arctica* collected near the Kuparuk River Bridge in 1990 yielded the highest germination percentage (99.3%) of forb seeds harvested that year. The mean germination percentage for 1990 shrub seed (51.9%) exceeded that for either graminoids or forbs collected that year. The range in germination percentages for shrubs was similar to that of grasses and forbs. Shrub seed germinations ranged from 0% for *Dryas octopetala* to 92.3% for one collection of *Salix ovalifolia*.

The average germination percentage of *Descurainia sophoides* seeds treated with Clorox® was lower (67.7%) than the non-treated seeds (89.7%). Germination percentage for large *Eutrema edwardsii* seeds was twice that of small seeds (36% to 16%), and there was no difference between hulled an unhulled seedlots of *Hedysarum mackenzii*.

Planting Mixtures. During 21–27 June 1990, 14 species of graminoids from 28 collections and 17 species of forbs from 19 collections were planted in the 144 experimental units (Table 5). There were 8,339 graminoid PLS and 1,130 forb PLS/m^2, for a total of 9,469 PLS/m^2 planted. The 1990 planting was predominantly graminoids, which comprised 88% of the seeds planted in gravel plots that year (Appendix E. Note that seeding rates are given in PLS/ft^2 in Appendix E.).

In 1991, the focus of the gravel plot planting shifted away from graminoids toward shrubs and forbs. During 25–27 June 1991, a total of 28 species, from 41 collections, was planted: 3 graminoids, 22 forbs, and 3 shrubs (Table 5). The number of seeds planted per experimental unit was an order of magnitude lower than the number planted in 1990: a total of 947 PLS/m^2. Of these, 70% were forbs and 15% each graminoid and shrub (Appendix E).

Basal and Canopy Cover of Gravel Vegetation Plots

Point data should have been recorded by plant species, to rank importance of species. However, the plants were immature on the 1990 planting in 1991, and distinguishing among grass species was difficult. Therefore, canopy and basal cover categories were recorded either as grass or forb. Basal and canopy cover data collected in early September 1991 are listed in Appendix F. These data have not been completely analyzed, but vascular plant canopy and basal cover treatment-means are given in Table 6.

The mean canopy cover (graminoid plus forb) was 47% for the 0.6-m gravel thickness, 34% for the 0.9-m thickness, and 35% for the 1.5-m thicknesses. Without topsoil added, the canopy cover averaged 32%, while with topsoil, the mean cover was 51%. Untilled plots produced a mean canopy cover of 26%, and tilled plots averaged 46%. Canopy cover averaged 41% without snow fences and 40% with. Plots without a light planting of *Poa glauca* averaged 36% canopy cover, and those with averaged 48%. Relative amounts of canopy cover between and among the various treatments on the gravel pad are shown in Figures 19 and 20. Forb canopy cover was a magnitude less than graminoid, but generally followed the same pattern, except that it varied less between treatments than did graminoid. The one exception was that forb canopy cover was highest on the 0.9-m lifts, whereas graminoid canopy cover was highest on the 0.6-m lifts (Fig. 19).

Basal cover data are summarized in Figures 21 and 22. Since very few dead plants were present, points for live and dead vascular plant basal cover were combined into a single category of vascular plant basal cover. Most of the basal points encountered rock, followed by bare (sand or soil). Moss was present only on the 0.6-m-gravel-thickness, snow-fenced treatments that had been lightly planted with *Poa glauca* (Block 1, Fig. 3). Mean vascular basal cover was usually 10% or less, except in the experimental units treated with topsoil, where it averaged 11% (Table 6). However, the basal plant cover was overestimated due to errors in recording live leaves on the ground as basal cover rather than canopy cover. The least vascular plant basal cover (2%) was recorded on the plots without topsoil.

The patterns of vascular plant basal cover generally followed those of vascular plant canopy cover (Table 6). The 0.6-m gravel thickness had the highest basal plant cover (10%), whereas the 0.9-m and 1.5-m lifts each averaged 6% basal plant cover. Without topsoil added, the basal plant cover averaged 2%, and with topsoil, the mean cover was 11%. Untilled plots produced a mean basal plant cover of 6%, and tilled plots averaged 9%. Plots without a light planting of *Poa glauca* averaged 5% basal plant cover, and those with averaged 10%. The only treatment that differed from

Table 6. Listing of mean vascular plant canopy (graminoid plus forb) and basal cover by treatment on plots seeded June 1990 at the BP Put River No. 1 gravel pad. Data were collected September 1991 with a point frame.

Gravel Modification Treatments		Mean Canopy Cover (%)	Mean Basal Cover (%)
Gravel Thickness:	0.6 m	47	10
	0.9 m	34	6
	1.5 m	35	6
Topsoil:	None	32	2
	8 cm	51	11
Tillage:	None	26	6
	Tilled	46	9
Snow Fencing:	None	41	7
	1.2 m	40	8
Poa glauca	None	35	5
	Planted	48	10

the canopy cover was the snow fence treatment. Without snow fences, basal plant cover averaged 7% and with snow fences 8%, which was opposite the canopy cover results.

Only Replicate II (Fig. 3) of the unplanted plots was sampled with the point-frame in 1991. This left the sample array unbalanced for statistical testing between unplanted and planted treatments. However, there was no need for a statistical analyses to clarify whether or not there was a difference in plant cover between seeded and unseeded treatments (Figs. 19 and 21). Plots planted to mixtures of native plant seeds contain relatively uniform stands of vegetation. These stands are dense enough to appear on color infrared aerial photography. Where seeding had not occurred, there was only a few scattered volunteers, mostly *Puccinellia langeana*, presumably originating from nearby stands of that species.

Tissue Tests

Results from the laboratory tests of plant tissues collected in September of 1991 are given in Table 7. From T-Test comparisons, it was apparent that nitrogen and calcium were significantly higher in tissues produced by plants where topsoil had been applied. Plants without topsoil contained 0.855% N compared to 2.145% N in tissues from plants grown in topsoil-treated experimental units. Calcium averaged 0.773% in tissues from non-topsoil plants and 1.085% for topsoil-grown plants. Tillage appeared to significantly increase tissue phosphorus and sodium and decrease tissue magnesium concentrations, according to T-Test analyses of the preliminary tissue data (Table 7).

Photopoints

The west photopoints were re-photographed 27 June 1993. The east photopoints (from stepladder) were photographed 28 and 29 August 1991. The slides have been developed and are in the process of being identified and labelled. They will be archived at the Palmer Research Center. Figure 23 is an illustration of a typical view of a plot from a photopoint.

Identifying Plants to Colonize Gravel Fill

Botanical Garden at BP Put River No. 1 Gravel Pad

Thirty-three vascular plant species from 54 seedlots were seeded in Rows 1–33 of the botanical garden on 27 June 1990 (Table 8 and Appendix D). The species seeded included 17 graminoids from 34

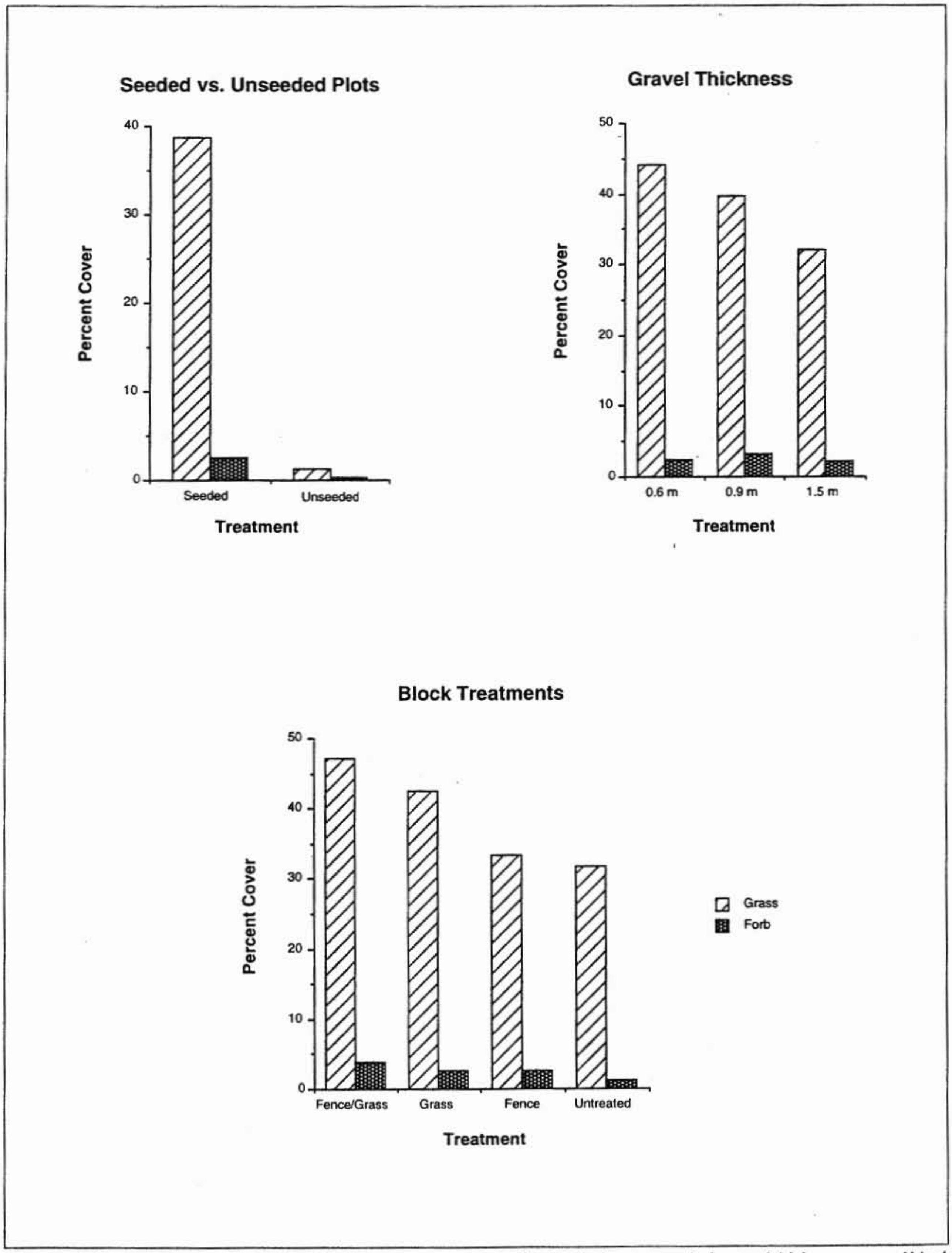

Figure 19. Comparison of graminoid and forb canopy cover means for seeded vs. unseeded, gravel thicknesses, and block treatments on the 1990-seeded plots of the BP Put River No. 1 gravel pad. The plots were measured September 1991.

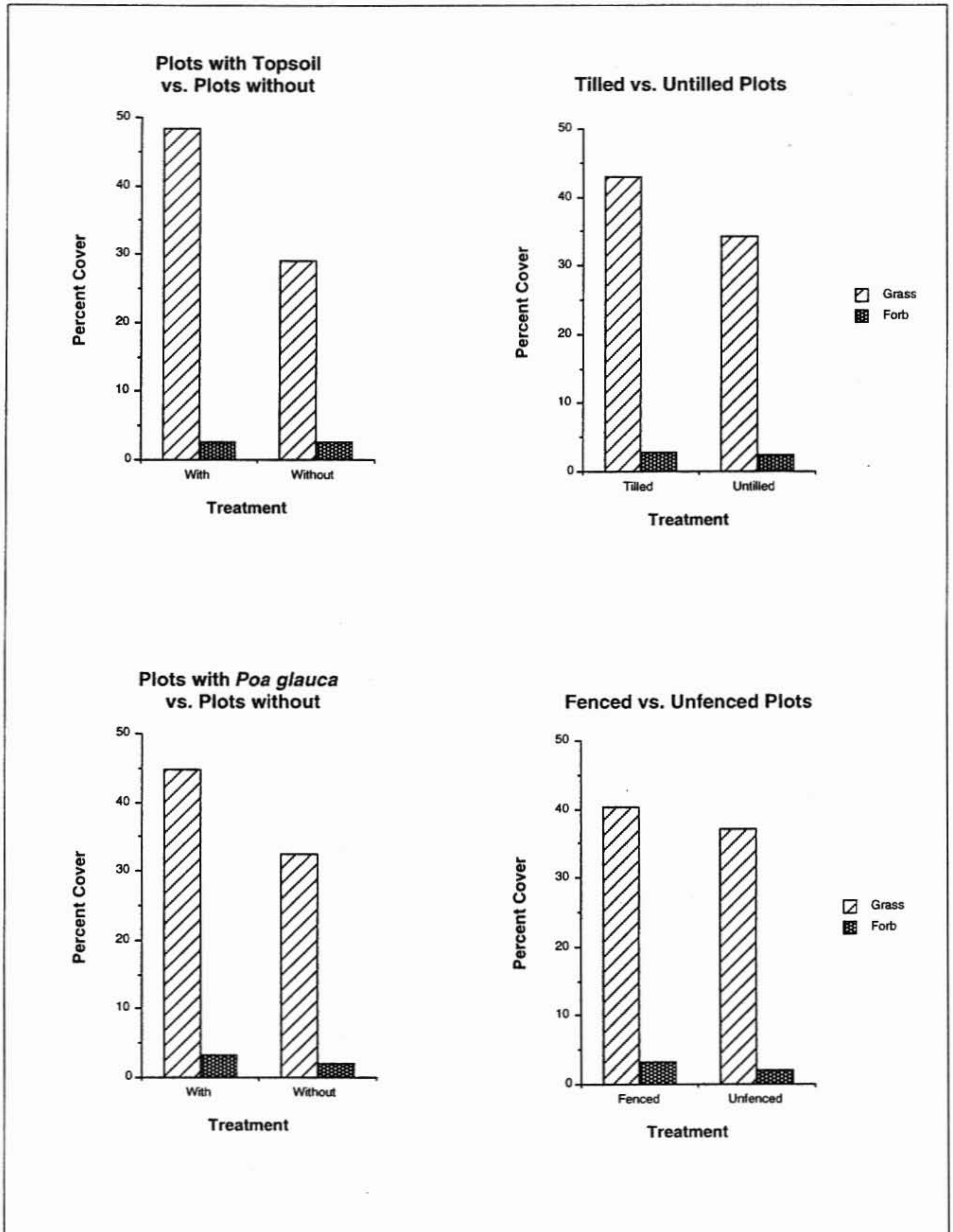

Figure 20. Comparison of graminoid and forb canopy cover means (1991) for topsoil vs. none, tilled vs. untilled, Poa glauca *vs. none and snow fenced vs. none in 1990-seeded plots on the BP Put River No. 1 gravel pad.*

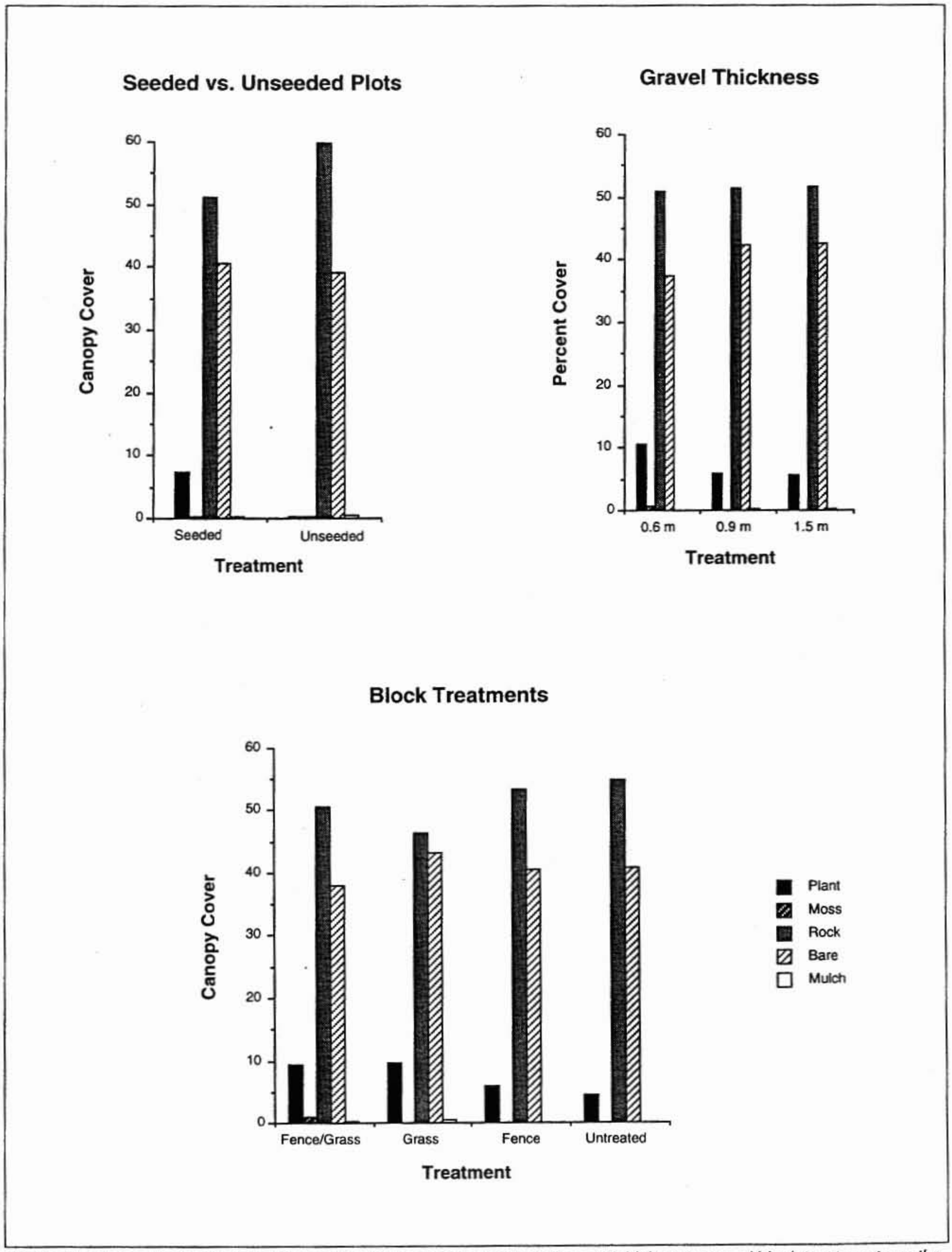

Figure 21. Comparison of basal cover means for seeded vs. unseeded, gravel thicknesses, and block treatments on the BP Put River No. 1 gravel pad. Plots were measured early September 1991 in 1990-seeded plots.

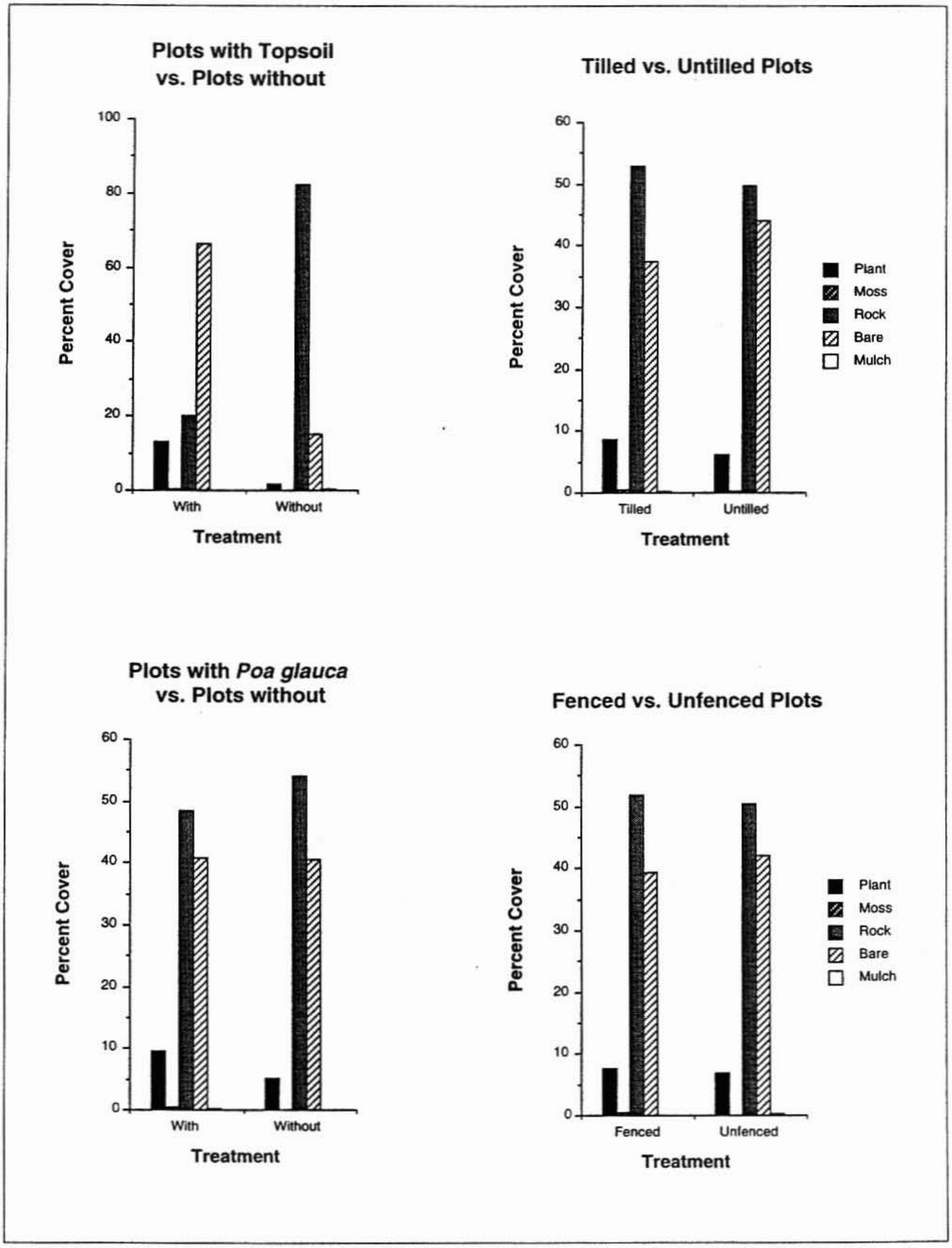

Figure 22. Comparison of basal cover means (1991) for topsoil vs. none, tilling vs. none, seeding lightly with Poa glauca *vs. none, and snow fencing vs. none on 1990-seeded plots at the BP Put River No. 1 gravel pad.*

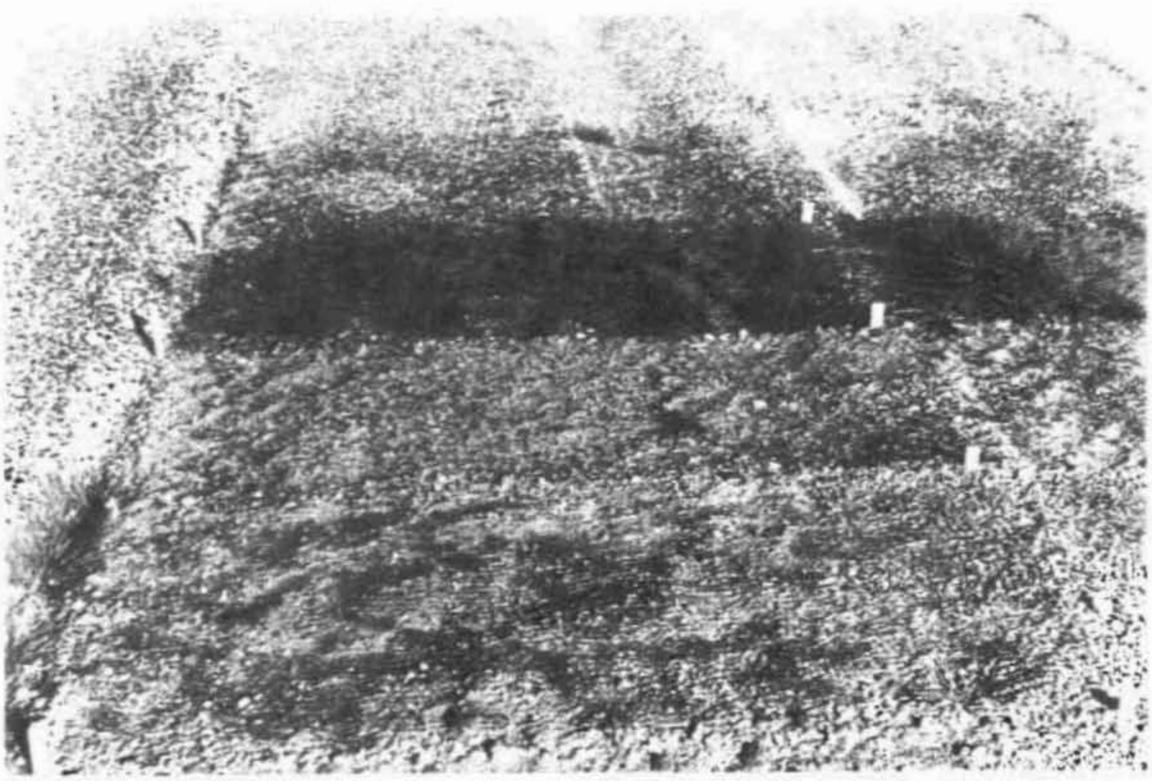

Figure 23. Photoplot - BP Put River No. 1, Block 2, Rep II, Plot 3. The treatment is 0.6 m gravel lift, 8 cm soil, and untilled (28 August 1991).

Figure 24. A 30 May 1991 view of persisting snow accumulation in Block 3, BP Put River No. 1 gravel pad.

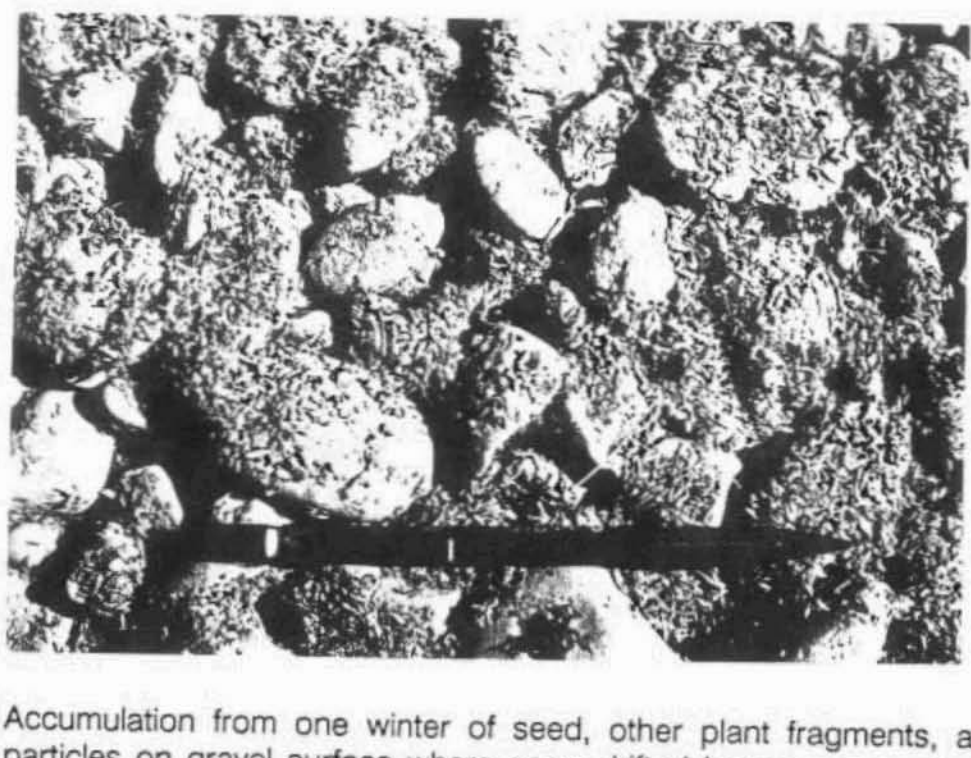

Figure 25. Accumulation from one winter of seed, other plant fragments, and soil particles on gravel surface where snow drifted between snow fences on Block 3, BP Put River No. 1 gravel pad. (21 June 1991)

Table 7. Listing of mean concentrations for six plant nutrients measured in leaf tissues collected from four gravel vegetation plots at the BP Put River No. 1 gravel pad, 12 September 1991.

	Topsoil			Tillage		
	None	8 cm	T-Test	None	Tilled	T-Test
Plant Nutrient	Means (%)[1]		Probability[2]	Means (%)[1]		Probability[2]
Nitrogen	0.855	2.145	0.001*	1.243	1.758	0.368
Phosphorus	0.270	0.193	0.107	0.185	0.278	0.040*
Potassium	0.998	1.085	0.454	0.960	1.123	0.135
Calcium	0.773	1.085	0.000*	0.920	0.938	0.898
Magnesium	0.103	0.090	n/a	0.105	0.088	0.100*
Sodium	367	363	0.865	338	342	0.004*

[1]All values are reported as percentages, except for sodium, which is mg/kg.
[2] * = significant at 95% probability.

seedlots and 16 forbs from 20 seedlots (Table 5). There were five collections planted to half-rows, because seed originated from separate sources. By 29 August 1990, seed in 25 of 39 rows had germinated. Average shoot height was 2.9 cm. By 29 August 1991, all but three of the seedlots planted in 1990 had germinated, and the average height was 6.7 cm (Table 8). The four species which had not germinated consisted of one woodrush, *Luzula arctica*, and two forbs: *Aster sibiricus* and *Armeria maritima* (Little Put River and 72 Haul Road collections). The collection of *Armeria maritima* from ARCO State 1 had germinated, but the stand was very sparse (Table 8). With few exceptions, stands were more vigorous on the east than on the west ends of the rows.

On 27 June 1991, 4 graminoids from 6 seedlots, 22 forbs from 26 seedlots and 4 shrubs from 7 seedlots were planted in Rows 34–63 of the botanical garden (Table 9 and Appendix D). There were nine species planted to half-rows, because seed originated from separate sources. Rows 34–48 were located in the northeast section of the botanical garden. Row 49 was located at the south edge of the mid-section. By 29 August 1991, only six species from eight seedlots had germinated (Table 9). These were all members of the Leguminosae family: *Astragalus aboriginum*, *A. alpinus*, *A. eucosmus*, *A. nutzotinensis*, *Hedysarum mackenzii*, and *Oxytropis borealis*. Only four species of graminoids were included in the 1991 planting at the botanical garden. None of those species germinated during the 1991 growing season, which was very cold.

Species Colonizing on Gravel Sites on Alaska's North Slope

One hundred and twenty-five vascular plant species were found colonizing ten gravel sites examined on the Alaska North Slope (Appendix H). Some of the sites had been seeded with grasses: *Poa glauca*, *Festuca rubra*, and *Arctagrostis latifolia*. *Poa pratensis* was seeded on at least one of the gravel sites in NPRA, and perhaps all of the locations along the Trans-Alaska Pipeline. No one species occurred at all ten locations. *Arctagrostis latifolia*, *Poa glauca*, and *Festuca rubra* were the most widely distributed grasses among the locations. *Epilobium latifolium* was the most common forb. Families well-represented in this listing included: Gramineae, Cyperaceae, Salicaceae, Caryophyllaceae, Cruciferae, Leguminosae, and Compositae, as the genera appear in the flora by Hultén (1968). The largest number of colonizing species (58) was found on the Lisburne Test Wellsite No. 1 drilling pad in NPRA. The fewest colonizing vascular species were found on the Inigok Test Wellsite No. 1 drilling pad (four in 1984), also in NPRA, and on the Franklin Bluffs Camp pad (eight in 1987) in the Sagavanirktok River valley. Both of the NPRA sites were seeded and fertilized in 1980, and the Franklin Bluffs camp in 1984. Numbers of species increased on sites re-evaluated after six growing seasons had lapsed. In this survey, the numbers of family, genera, and species were similar between foothill and coastal plain locations. These were for foothill and coastal plain locations, respectively: 22 and 20 fami-

Table 8. Ratings and average maximum plant heights (cm) for species planted 27 June 1990 in the botanical garden at BP Put River No. 1 gravel pad. Plants were evaluated 29 August 1990 and 29 August 1991.

Row No.[1]	Species	Growth Form[2]	1990 Stand Rating[3]	1990 Mean Maximum Height	1991 Stand Rating[3]	1991 Mean Max-imum Height	Height Net Change[4]
1E	*Agropyron boreale* (Kuparuk River)	G	2	3.8	1	6.3	2.5
1W	*Agropyron boreale* (Put River)	G	4	4.0	2	7.7	3.7
2	*Alopecurus alpinus*	G	3	1.1	2	4.5	3.4
3	*Arctagrostis latifolia*	G	4	1.8	1E/2W	5.6	3.8
4	*Bromus pumpellianus*	G	5	1.5	2E/3W	5.1	3.6
5	*Deschampsia caespitosa*	G	2	1.5	1E/3W	9.0	7.5
6	*Dupontia fisheri*	G	5	1.0	4	3.0	2.0
7	*Elymus arenarius ssp. mollis*	G	2	3.8	1	10.8	7.0
8	*Festuca brachyphylla*	G	5	1.8	3E/4W	1.6	(0.2)
9	*Festuca ovina*	G	3	2.0	2E/3W	8.6	6.6
10	*Festuca vivipara*	G	3	1.3	3	7.6	6.3
11	*Poa arctica*	G	3	2.0	2E/3W	8.1	6.1
12E	*Poa glauca* (BP Plots)	G	2	1.4	1	15.8	14.4
12W	*Poa glauca* (1972 Haul Road)	G	2	1.4	1,2	16.9	15.5
13E	*Puccinellia langeana* (Put River)	G	1	1.5	3	2.0	0.5
13W	*Puccinellia langeana* (IBP Plots)	G	1	1.5	1	3.3	1.8
14	*Trisetum spicatum*	G	2	1.3	2	4.3	3.0
15E	*Festuca rubra* (Kuparuk River)	G	3	1.6	2	5.8	4.2
15W	*Festuca rubra* (IBP Plots)	G	2	1.5	1	9.2	7.7
16	*Carex maritima*	G	6	.	5	1.0	1.0
17	*Luzula arctica*	G	6	.	6	.	.
18E	*Armeria maritima* (Put River)	F	6	.	6	.	.
18W	*Armeria maritima* (ARCO State No. 1)	F	6	.	5	1.0	1.0
19	*Artemisia arctica*	F	2	0.6	2	1.5	0.9
20	*Artemisia borealis*	F	2	0.5	3	2.0	1.5
21	*Artemisia glomerata*	F	2	0.4	2E/3W	1.0	0.6
22	*Aster sibiricus*	F	6	.	6	.	.
23	*Braya pilosa/B. purpurascens*	F	6	.	3E/5W	0.2	0.2
24	*Cerastium beeringianum*	F	6	.	3E/5W	0.3	0.3
25E	*Descurainia sophioides*	F	6	.	2	13.3	13.3
25W	*Descurainia sophioides*	F	6	.	3	1.0	1.0
26	*Draba spp.*	F	6	.	5	0.5	0.5
27	*Epilobium latifolium*	F	4	0.3	6	0.0	(0.3)
28	*Eutrema edwardsii*	F	6	.	3E/4W	0.3	0.3
29	*Melandrium apetalum*	F	4	0.3	3E/4W	1.5	1.2
30	*Parrya nudicaulis*	F	6	.	3	1.0	1.0
31	*Sedum rosea*	F	4	0.2	2	0.2	0.0
32	*Senecio congestus*	F	6	.	3	1.5	1.5
33	*Silene acaulis*	F	6	.	3	0.2	0.2

[1] E and W refer to the east and west sections of the rows, respectively.
[2] G = graminoid; F = forb.
[3] 1 = very dense; 2 = dense; 3 = medium; 4 = thin; 5 = sparse, few plants; 6 = no plants.
[4] Height Net Change = (1991 average maximum height) - (1990 average maximum height).

Table 9. Ratings and average maximum plant heights (cm) for species planted 27 June 1991 in the botanical garden at BP Put River No. 1 gravel pad. Plants were evaluated 29 August 1991.

Row No.[1]	Species	Growth Form[2]	Stand Rating[3]	Mean Maximum Height (cm)
34E	*Arctophila fulva* (Lonnie Lake)	G	6	.
34W	*Arctophila fulva* (Pump Station No. 1)	G	6	.
35	*Elymus innovatus*	G	6	.
36E	*Festuca baffinensis* (72 Haul Road)	G	6	.
36W	*Festuca baffinensis* (Endicott Road)	G	6	.
37	*Carex ursina*	G	6	.
38E	*Androsace chamaejasme* (72 Haul Road)	F	6	.
38W	*Androsace chamaejasme* (E. Dock Dunes)	F	6	.
39	*Arabis arenicola*	F	6	.
40	*Astragalus aboriginum*	F	4	0.1
41	*Astragalus alpinus*	F	5	0.1
42	*Astragalus eucosmus*	F	5	0.1
43	*Astragalus nutzotinensis*	F	5	0.1
44	*Castilleja elegans*	F	6	.
45	*Tanacetum bipinnatum*	F	6	.
46	*Draba corymbosa*	F	6	.
47E	*Hedysarum mackenzii* (MP 369)	F	5	0.1
47W	*Hedysarum mackenzii* (MP 405)	F	5	0.1
48E	*Minuartia obtusiloba* (MP 354.5)	F	6	.
48W	*Minuartia obtusiloba* (MP365)	F	6	.
49E	*Oxytropis borealis* (8 Aug 1990)	F	5	0.1
49W	*Oxytropis borealis* (16 Aug 1990)	F	5	0.1
50	*Oxytropis nigrescens*	F	6	.
51	*Pedicularis capitata*	F	6	.
52	*Pedicularis labradorica*	F	6	.
53	*Pedicularis lanata*	F	6	.
54	*Polymonium boreale*	F	6	.
55	*Potentilla hookeriana*	F	6	.
56	*Saxifraga tricuspidata*	F	6	.
57	*Silene acaulis*	F	6	.
58	*Silene wahlbergella*	F	6	.
59	*Wilhelmisa physoides*	F	6	.
60E	*Dryas integrifolia* (E. Dock Dunes)	S	6	.
60W	*Dryas integrifolia* (Endicott Road)	S	6	.
61	*Dryas octopetala*	S	6	.
62E	*Salix arctica* (72 Haul Road)	S	6	.
62W	*Salix arctica* (Endicott Road)	S	6	.
63E	*Salix ovalifolia* (Endicott Road)	S	6	.
63W	*Salix ovalifolia* (E. Dock Dunes)	S	6	.

[1] E and W refer to the east and west sections of the row, respectively.
[2] G = graminoid; F = forb; S = shrub/woody.
[3] 1 = very dense; 2 = dense; 3 = medium; 5 = sparse, few plants; 6 = no plants.

lies, 53 and 53 genera, and 83 and 87 species (Appendix H).

DISCUSSION

Modifying Gravel Fill

The most significant changes measured on gravel fill thus far resulted from adding topsoil. By design, this nearly doubled the amount of fines in the surface portion of the gravel. That, in turn, lowered bulk density and increased the amount of soil moisture retained in the upper 10 cm of the gravel pad. Much of this moisture was presumed to be available for plants, but moisture desorption curves are required to actually evaluate the proportions of the water held at various tensions in the matrix. Because it was assumed there was a low amount of clay in the soil, much of the moisture was probably held at relatively low tensions and therefore available for plant uptake. Particle size analyses, in combination with analyses of cation exchange capacity and available nutrient, will assist in quantifying relative influences from this treatment.

Soil moisture was measured only once, and that was incidental to the bulk density sampling. It was expected that there would be less soil moisture in areas with greater plant cover, because use by plants should have reduced supplies in the soil. Just the opposite was found in the botanical garden. We found the highest soil moisture content in the vicinity of the largest plants. There are three possible reasons for this discrepancy. First, the sampling may have been inadequate to give a reliable estimate of the real soil moisture conditions. Second, the soil with the lowest moisture percentage was disturbed about eight weeks prior to sampling. In contrast, the soil with the highest moisture percentage had not been disturbed for approximately 18 months. Disturbance of soil encourages evaporation, which could have affected the results. And third, the plant biomass was relatively low; hence, soil moisture usage was probably also low. Further monitoring of that variable is considered important to this project.

Topsoil additions were associated with increased concentrations of nitrogen and calcium in plant tissues, according to preliminary data. These responses are only early indications from a limited number of samples, but the responses are reasonable. Cations of nitrogen and calcium are taken from the soil by plant roots. If the gravel had a low cation exchange capacity because of limited quantities of clay, silt, and organic matter, the addition of topsoil would enhance that capacity and provide a greater pool of available nutrients for plant uptake. Further monitoring of tissues and gravel chemistry may provide definitive information on this topic.

It was apparent that plants grown in gravel only (no topsoil) were probably deficient in nitrogen. Phosphorus concentration was low in these plant tissues, relative to concentrations typical of vigorously growing plants. However, guidelines for interpreting tissue mineral data with respect to plant vitality in the Arctic are scarce.

Tillage in the gravel plots appeared to reduce soil bulk densities and improve conditions for plant growth. Tillage may have improved either the uptake or availability of soil phosphorus, because plant tissues in tilled experimental units contained more phosphorus than those grown on untilled experimental units, according to preliminary data. If tillage caused a reduction in soil moisture, that could have, in turn, reduced plant growth relative to plants on untilled plots. Occasionally, there is a tendency for nutrient concentrations to be higher in plants experiencing drought stress, relative to plants not stressed by drought. Tillage may also have decreased the uptake and/or availability of sodium and magnesium, according to tissue analyses from samples taken in September, 1991. Plant cover produced from the 1990 seeding mixture increased with the tillage treatment.

From initial observations, it is clear that the fencing provided a significant trap for snow (Fig. 24). After even light snowfalls that were either accompanied with or followed by wind, snow cover in the fenced plots was markedly greater than in the non-fenced plots. This difference was apparent at both ends of the growing season. On 7 May 1991, we measured snow cover on these plots and found 1.09 m accumulated in the fenced area. This accumulation contained 42 cm of water. Snow cover on unfenced plots averaged between none and 25 cm, with the least accumulation on portions of the 1.5-m lifts. Maximum moisture accumulated on these unprotected plots was 3.8 cm and averaged less than 1.3 cm.

The plots in the treated area were still snow-covered until late in June, while the other portions of the experimental area were snow-free much earlier (Fig. 24). If too much snow cover is created, the length of the growing season may be reduced, thus affecting plant survival. It was noted that the snow fence treatment had no measurable effect on plant cover in the gravel vegetation plots after the first year. A longer observation period will be needed to measure the influences of snow fences on the formation of plant communities in these plots.

The tendency for plants to perform better at the east end of rows in the botanical garden compared to the west end may have been due to differential snow melting rates. Slowing the start of spring growth would be detrimental to plants in this region, where growing seasons are naturally brief. The later melting may have retarded initiation of plant growth at the west end of the rows because a snow fence at that end shaded that section during the warmest period of the day. Snow fencing at the east end of the rows may have provided a heat sink and radiation effect, which helped to melt snow at that end of the row. That is, late-afternoon solar radiation was striking the snow fence fabric and was either reradiated or otherwise reflected onto the snow immediately west of the fence.

Significant amounts of soil and plant particles carried by the wind were deposited in areas behind snow fences, coating the gravel surface after only one winter (Fig. 25). In the autumn of 1991, pans were placed in a snow-fenced block and on a block without snow fences to measure the fallout of soil and plant materials between treatments. Also, it has been noted that very small changes in elevation on the surface of the pad are important. Without snow fences to create drifts, the 8-cm lift of topsoil was often cleared of snow by wind while the adjacent gravel retained a slight snow covering.

At least three growing seasons are needed before seedlings in this region develop into mature plants. Therefore, the basal and canopy cover data obtained in 1991 are simply a preliminary measure to document canopy and basal cover after the second growing season. Repeating these measurements will become increasingly more useful after planted and volunteer stands of vegetation have had the opportunity to mature. These data will be helpful in projecting trends of seedings on actual rehabilitation projects.

Germination and subsequent plant growth in these first two plantings (1990 and 1991) on the gravel plots, as well as the botanical garden, were encouraging. A variety of plant species seemed to be germinating, and the potential for the formation of diverse communities was promising. However, long-term survival is most important.

The high seed application for 1990 was selected because the laboratory seed evaluations were not completed before spring planting. Had these laboratory data been available, we would have selected a lower application. Instead, we decided to use all the available seed minus amounts needed for the botanical garden, divided equally among the 144 plots to give maximum possible opportunity for seedling establishment from our collection efforts. The 1990 seed application of 9,469 PLS seed/m^2 is excessive and undoubtedly set up conditions for inter- and intraspecific plant competition. How this competition will eventually influence the species composition of the stands in these gravel plots remains to be seen.

We have observed naturally occurring dense stands of new seedlings on a disturbance 2.8 km northeast of the BP Put River No. 1 gravel pad (Mitchell and McKendrick 1975). These stands consisted of a single species, *Braya purpurascens*. As the dense stand aged, the competition not only reduced the density of the individuals, but also inhibited flowering and seed production. In 1991, after nearly 20 years, the stands have thinned considerably as the *Braya purpurascens* died and other species of grasses and forbs invaded the surface of this abandoned winter haul road. This road, coincidentally, was constructed to bring drilling equipment to the BP Put River No. 1 gravel pad. It is likely a similar pattern of thinning through competition will occur on the current experimental plots. The stand best adapted to the soil conditions will develop from among the seeded species and natural colonizers. Drought and other stresses, e.g., intense geese grazing, will hasten this realignment of plant densities and species composition.

To rank importance of species, point data should have been recorded by plant species. However, the plants were immature on the 1990 planting in 1991, and distinguishing among grass species was difficult. Canopy and basal cover categories were thus recorded either as grass or forb. Ultimately, the ranking of importance for individual species will be most valuable after plant communities have had an opportunity to mature and separate the survivors from those that could not compete.

Gravel thickness appeared to be affecting plant cover in the 1990 planting. Thicknesses greater than 0.6 m sustained less canopy cover than the 0.6-m thickness. Moisture available to plant roots may have been the major factor for this response. We observed that some experimental units on 0.6-m lifts appeared wetter than at other locations on the gravel pad, but our preliminary gravel moisture sampling did not include each thickness of gravel fill. Therefore, it was not possible to compare soil moisture percentages among lifts. It would be instructive to quantify the available soil moisture among gravel thicknesses and between snow-fenced and non-snow-fenced treatments.

At the time basal and canopy covers were measured (early September 1991), many of the plants had already senesced, and vegetative parts had begun to dry and shrivel. This probably lowered the canopy cover estimate with respect to that which would have been obtained had the sampling occurred at the peak of growth. Future cover sampling should be consistent among years, with respect to the phenological stage of the plants. Sampling during or soon after the first week in August is recommended, because it generally coincides with peak canopy development for the current growing season.

One aspect of the 1991 cover point data should be viewed with caution. The 1990 planting consisted overwhelmingly of graminoid species. Sixty-one percent of the cover data and 88% of the seeds planted were graminoids. The remaining 12% of seeds planted in 1990 were forbs. This, in association with the grass cover treatment, meant that graminoid species most likely suppressed the forb component in the 1990 seeding mixture. The 1991 seeding mixture was purposefully reversed, with forbs comprising the majority of the species (70% of all seeds planted). Grasses and shrubs each contributed 15% to the 1991 planting. Comparing these two plantings should prove interesting in future years.

The basal cover values of 10% or more, which were recorded in the 1990 seedings on the gravel plots, were quite high. This resulted primarily from sampling error, since live leaves at the surface of the ground were recorded as basal cover rather than canopy cover.

Comparing soil temperatures between the foothills site and the coastal plain was informative. The soil temperatures on the coastal site were consistently warmer than the soils in the foothills, and cumulatively higher temperatures were recorded at the coast. This difference was ascribed to variation of insulation at the soil surface. The coastal soil was nearly barren, while that in the foothills had a cover of tussock tundra vegetation and litter. During most of July and August, maximum and mean air temperatures were higher at the foothill site than on the coastal plain. Apparently, the insulating effects of the tussock tundra vegetation were great enough to prevent the soil in the foothills from warming, even though the heating of the air was obviously greater in the foothills than near the seacoast.

Variation in seed production among years and between the coastal and foothill locations appeared related to variations in air temperatures. Overall, better seed production consistently occurred in the location with the warmer air temperatures (foothills). Significant seed production on the coastal plain also coincided with the occurrence of warmer growing seasons. At the foothill location, *Arctophila fulva* consistently produced mature ovules among years, but mature seed was only abundantly produced on the coastal plain in 1989, which was an unusually warm growing season (McKendrick 1990). This affect was also recorded for *Bromus pumpellianus* seedlots collected from coastal and foothill locations in September 1990. Seed from two coastal plain sites, one near the coast at Big Skookum and the other about 10 miles inland (Kuparuk River Bridge), did not germinate (0%). In contrast, seed collected that same year from *Bromus pumpellianus* growing at a foothill location (MP 356 Dalton Highway) germinated with a maximum equal to 93%. The fact that collection from the foothill site was taken earlier in the season than on the coastal plain presumably should have placed the foothill seedlot at a disadvantage.

The differences in responses by vascular plants relative to air temperatures and soil temperatures between the coastal sites and the foothills suggested air temperature was probably more influential than soil temperature on plant growth and seed production in this region. Plants exposed to the lowest soil temperature and warmest air temperatures (foothills) outproduced those exposed to the coolest air temperatures and warmest soil temperatures (coastal). This was consistent with observations from agricultural and horticultural experiences in Alaska. Warm-season crop plants (corn, beans, tomatoes) introduced to Alaska from warmer climates generally respond favorably to treatments that warm the soil. In contrast, crop plants evolving in cold regions benefit less from such treatments.

Plant flowering in the area seemed to be above normal for many species in 1990. This was probably a carry-over effect from the 1989 growing season, when temperatures were unusually favorable. Abundant carbohydrate reserves were probably produced in 1989 and therefore were available for metabolism the following year. Also, floral parts undoubtedly differentiated in the 1989 growing season and developed into flowers during 1990, a normal pattern for bud and flower formation in the Arctic.

Identifying Plants to Colonize Gravel Fill

At least 125 vascular plant species were identified on the ten gravel sites examined in Phase III of this study. In addition to these plants, seed was identified and harvested from approximately 35 other species that were not recorded in that survey. Approximately 100 vascular plant species will be tested at the BP Put River No. 1 location during the course of this 10-year research project.

Considering the scope of this species list, it must be realized there is a substantial variety in the genetic array of plant materials in the Arctic. When major oil field production was starting at Prudhoe Bay, the arctic plant communities were considered to be under great threat, because they were believed to contain few species capable of colonizing disturbed sites. This was based partially on the lack of annual species, which normally quickly invade and colonize disturbed soils in temperate and warmer climates. That may be a mistaken notion. It is true there are few, if any, annuals in the Alaska Arctic. No annuals were found during this survey of plants occurring on gravel fill, and there were only two biennials, *Androsace septentrionalis* and *Descurainia sophioides*. All the rest were perennials. However, in spite of an absence of annuals in the indigenous plant communities, plant succession in the Arctic does exist, but it differs in aspect from that in warmer climates.

In the Arctic, the perennial plant species invade and initially form open and often inconspicuous communities. This is partially why the process seems to require more time in the Arctic, compared to temperate-zone plant succession. In warmer climates, canopy cover is quickly provided by annuals, which are absent in the Arctic. Temperate-zone perennials then invade, expand slowly, and simultaneously compete with annuals. The competition between annuals and perennials in stressful environments, such as the Arctic, would impede the succession process. Instead, succession by perennials occurs gradually, but steadily, over time in the absence of competition from aggressive annual vascular plant species. A dense seeding of grasses can give the impression of rapid recovery, but those very dense grass stands persist and undoubtedly present significant competition to the indigenous colonizers. There are, of course, management reasons for quickly establishing grass stands to protect soils, provide animal habitat, and improve aesthetics.

Currently, rehabilitation success of disturbed sites in the Alaska Arctic is evaluated primarily by measuring the canopy cover of vascular plants. Canopy cover is a feature selected for its simplicity to judge seeding success and may or may not relate to either the long-term stability of the vegetation community or to the aesthetic value of the stand. As the Trans-Alaska Pipeline was being completed in the late 1970's, the U.S. Department of the Interior's Alaska Pipeline Office introduced vascular plant canopy cover as the standard to be used with regard to revegetation. This method is now used routinely in judging rehabilitation success, despite its weaknesses in adequately predicting success on either gravel sites or rocky soils, which are inherently limited in their production potential.

It is important for land managers in the Arctic to recognize that differences exist in site *potential* for plant species composition as well as cover among various gravel fills. Such differences are governed by the local environmental conditions, i.e., proximity to the coast, elevation, regional climate, etc. Site potential is also governed by specific conditions of the gravel substrate itself. The amount of cobbles, sand, silt, and clay; organic matter; pH; available nutrients; depth of fill; and compaction (bulk density) of gravel fills vary from site to site. All sites cannot support the same kinds and amounts of vegetation. This was evident in this study, where no single species was found on all ten gravel fill locations examined.

Site *condition* is the present state of the vegetation (botanical composition and cover) in relation to the potential for that site. Cover and botanical composition characteristics may be rated excellent or good for one site, and those same values might be regarded as poor condition for another site which has a higher potential. As information is collected from numerous gravel fill sites, a database will emerge that can be used for determining site potential and rating vegetation condition of gravel fills in the Arctic. Currently, such information is unavailable. The third phase of this study is directed toward accumulating the necessary information to bring about a better understanding of site potential for various gravel fills in the Alaska Arctic.

Trend is a more sensitive indicator of change than condition and is probably more useful for rating both short- and long-term attributes of a site. Trend indicates the direction a community is proceeding with respect to the climax stage. Features such as the abundance of seedlings and young plants, presence of lichens and mosses as well as woody plants, amount of plant residues, plant vigor, species diversity, extent of bare ground, absence of soil erosion, and condition of the gravel surface should all be considered when evaluating trend. Trend is a tool that can be immediately utilized to determine whether a site is improving or deteriorating. Trend data should be obtained and used in conjunction with botanical composition and canopy cover for site evaluations.

The botanical species composition and hence aspect of communities forming on gravel pads will differ from that of the surrounding landscape whenever there are stark contrasts in the soil moisture and nutrient conditions between those two areas, i.e., differences in site potential. In other words, when the site potentials for the gravel fill and the adjacent landscape differ markedly, the resulting vegetation on the two sites will reflect that difference. As the soil environmental conditions become similar between gravel fill and the adjacent habitats (disturbed and undisturbed sites), the plant communities will also become similar. Therefore, it is necessary to consider the site *potential* when evaluating site *condition*, as opposed to using an arbitrary standard for gauging all rehabilitation projects. For evaluating the direction a community is moving, *trend* should be included in the assessment.

SUMMARY AND CONCLUSIONS

The major conclusions of the 1989 through 1991 field seasons of the Long-Term Gravel Vegetation Project are summarized below

- The amount of soil fines ≤2 mm improves soil bulk density, moisture content, and plant growth on gravel fill.
- Snow cover was significantly improved by the addition of snow fences. However, the snow cover remained late in spring and may have retarded growth of plants in snow-fenced areas.
- Over 125 vascular plant species have been found colonizing gravel fill in the Alaska Arctic. In terms of numbers of species colonizing gravel fill, the leading families of plants are: Gramineae, Compositae, Leguminosae, and Salicaceae. *Epilobium latifolium*, a member of the Onagraceae family, was found at more sites than any other species.
- Seed production by vascular plants in the Arctic was found to vary widely among years and locations and appears to be influenced mainly by air temperature. Cool temperatures coincided with poor seed production.
- One hundred and forty-four plots (experimental units) have been established on the BP Put River No. 1 gravel pad to evaluate influences of gravel thickness, topsoil addition, tilling, winter snow cover, and seeding *Poa glauca* lightly on plant colonization. Mixtures of indigenous plant seeds were applied to 1/5 of each plot in 1990 and 1991. The final planting is scheduled for 1993, because insufficient seed was obtained in the 1991 collections. Two subunits, each 1/5 of an experimental unit in size, will remain as unseeded control plots. This will result in a total of 720 subplots when the final planting occurs.
- Sixty-three species of indigenous vascular plants have been seeded in rows in the botanical garden on the BP Put River No. 1 gravel pad. Thirty-three were seeded in 1990, and 30 were seeded in 1991.
- Some plants appeared to be suffering from nutrient deficiencies after two growing seasons on the BP Put River No. 1 gravel pad, according to vigor and laboratory tests. Nitrogen appeared to be the most deficient macro-nutrient.
- Development of indigenous vascular plants in test plots and the botanical garden on the BP Put River No. 1 gravel pad was quite slow. Some species required more than one growing season to emerge. After emergence, top growth was slowly developing. At least three, and perhaps more, growing seasons are required before objective evaluations of indigenous colonizers are possible.
- Canopy cover averaged 47%, 34%, and 35%, respectively on gravel fill 0.6, 0.9, and 1.5 m in thickness after two growing seasons.
- Canopy cover averaged 51% and 32%, respectively, on test plots with and without 8 cm of topsoil after two growing seasons.
- Canopy cover averaged 46% and 26% on tilled and untilled test plots, respectively, after two growing seasons.

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Appendices

APPENDIX A

1990 GRAVEL COLLECTION DATA

Table A-1 presents the results of the sieve analyses for substrate samples collected from each of the 144 experimental plots at the BP Put River No. 1 gravel pad in 1990. Weights of each particle size are given to the nearest 0.0 g for each of three replicates sieved.

Table A-1. Sieve analysis of substrate samples taken from unplanted plots at the BP Put River No. 1 gravel pad in 1990

Block	Snow Fence	Poa Glauca	Repl	Height	Soil	Tilled	Percent												
							3.0"	2.5"	2.0"	1.5"	1.0"	3/4"	1/2"	3/8"	1/4"	#4	#10	Pan	Lost
1	1	1	1	5	0	1	0.0	0.0	0.0	0.0	6.3	10.0	14.4	15.7	13.0	6.9	9.9	23.8	0.1
1	1	1	1	5	0	0	0.0	0.0	0.0	1.1	6.1	6.1	13.3	12.5	15.3	7.6	11.3	26.5	0.1
1	1	1	1	5	1	1	0.0	0.0	0.0	0.0	4.5	4.5	6.6	8.4	8.3	4.7	7.2	55.4	0.3
1	1	1	1	5	1	0	0.0	0.0	0.0	2.3	0.5	4.1	6.5	6.8	6.8	3.9	6.1	62.7	0.3
1	1	1	1	3	0	1	0.0	0.0	0.0	0.0	4.6	5.8	13.4	14.9	15.0	8.4	11.4	26.6	0.0
1	1	1	1	3	0	0	0.0	0.0	0.0	1.0	4.3	8.0	14.0	12.3	14.4	7.7	11.3	27.1	0.0
1	1	1	1	3	1	1	0.0	0.0	0.0	1.3	3.6	3.0	7.9	7.0	7.5	4.1	6.3	59.0	0.2
1	1	1	1	3	1	0	0.0	0.0	0.0	0.0	0.4	1.7	4.4	5.3	6.7	3.9	5.7	71.5	0.4
1	1	1	1	2	0	1	0.0	0.0	0.0	0.0	5.4	8.6	17.8	13.9	14.4	7.3	10.1	22.4	0.0
1	1	1	1	2	0	0	0.0	0.0	0.0	3.5	5.0	9.0	13.9	13.1	14.1	7.3	10.5	23.6	0.0
1	1	1	1	2	1	1	0.0	0.0	0.0	0.0	5.3	3.6	8.9	7.4	7.7	4.2	6.1	56.7	0.2
1	1	1	1	2	1	0	0.0	0.0	0.0	0.0	3.8	1.3	5.2	4.9	6.1	3.6	5.2	69.6	0.3
1	1	1	2	5	0	1	0.0	0.0	0.0	0.0	4.6	9.8	16.0	14.2	13.6	7.4	10.0	24.2	0.1
1	1	1	2	5	0	0	0.0	0.0	0.0	2.2	3.1	6.6	15.3	13.0	15.1	7.7	11.1	25.8	0.0
1	1	1	2	5	1	1	0.0	0.0	0.0	0.0	2.5	5.1	9.9	9.4	8.3	4.6	7.1	52.9	0.2
1	1	1	2	5	1	0	0.0	0.0	0.0	0.0	2.4	3.1	8.3	6.7	7.7	4.4	6.6	60.5	0.2
1	1	1	2	3	0	1	0.0	0.0	0.0	0.0	4.1	7.8	14.9	14.9	15.8	7.7	10.6	24.3	0.0
1	1	1	2	3	0	0	0.0	0.0	3.1	0.0	6.1	5.6	14.6	13.0	13.0	7.2	11.1	26.2	0.1
1	1	1	2	3	1	1	0.0	0.0	0.0	0.0	2.4	6.3	10.6	8.3	9.5	5.0	7.7	50.0	0.2
1	1	1	2	3	1	0	0.0	0.0	0.0	0.0	0.0	0.9	5.4	6.3	6.4	3.6	5.9	71.4	0.1
1	1	1	2	2	0	1	0.0	0.0	0.0	0.0	7.0	9.6	17.7	14.3	14.4	6.2	9.1	21.6	0.0
1	1	1	2	2	0	0	0.0	0.0	0.0	0.0	7.8	6.4	16.1	12.9	12.9	7.2	10.8	26.0	0.0
1	1	1	2	2	1	1	0.0	0.0	0.0	0.0	1.7	3.8	4.9	6.4	6.7	3.9	5.4	66.8	0.2
1	1	1	2	2	1	0	0.0	0.0	0.0	0.0	1.3	2.1	3.7	3.6	5.0	3.1	4.6	76.4	0.2
1	1	1	3	5	0	1	0.0	0.0	0.0	0.0	6.0	9.4	15.7	12.6	14.6	7.3	10.1	24.3	0.0
1	1	1	3	5	0	0	0.0	0.0	0.0	2.5	7.6	8.6	13.0	12.3	14.3	6.9	10.5	24.3	0.1
1	1	1	3	5	1	1	0.0	0.0	0.0	4.3	2.1	5.5	8.9	7.0	7.9	4.1	6.5	53.4	0.2
1	1	1	3	5	1	0	0.0	0.0	0.0	0.0	2.8	2.8	5.5	5.9	6.4	3.8	5.9	66.8	0.3
1	1	1	3	3	0	1	0.0	0.0	0.0	0.0	6.1	7.8	15.6	13.2	14.4	7.3	10.8	24.6	0.1
1	1	1	3	3	0	0	0.0	0.0	2.7	1.8	7.1	6.1	14.3	10.0	12.3	7.2	11.3	27.2	0.1
1	1	1	3	3	1	1	0.0	0.0	0.0	0.0	4.4	4.4	8.2	7.5	7.7	4.4	6.2	57.2	0.1
1	1	1	3	3	1	0	0.0	0.0	0.0	2.7	1.1	1.1	4.2	6.0	6.5	3.6	5.8	68.7	0.3
1	1	1	3	2	0	1	0.0	0.0	0.0	0.0	3.9	9.5	16.6	12.5	13.9	7.2	10.6	25.7	0.1
1	1	1	3	2	0	0	0.0	0.0	0.0	0.0	9.7	7.9	12.4	12.4	13.4	7.3	10.9	26.0	0.1
1	1	1	3	2	1	1	0.0	0.0	0.0	2.3	0.9	3.7	9.0	7.7	8.0	4.0	6.0	58.2	0.2
1	1	1	3	2	1	0	0.0	0.0	0.0	0.0	1.1	2.6	3.9	4.8	6.0	3.5	5.1	72.7	0.2
2	0	1	1	5	0	1	0.0	0.0	0.0	1.1	15.6	12.2	15.3	11.4	10.3	4.8	7.2	21.8	0.1
2	0	1	1	5	0	0	0.0	0.0	0.0	3.8	9.3	8.9	17.7	11.4	11.3	5.5	7.7	24.5	0.1
2	0	1	1	5	1	1	0.0	0.0	0.0	0.0	3.0	4.7	7.2	6.6	7.3	4.0	5.6	61.5	0.2
2	0	1	1	5	1	0	0.0	0.0	0.0	0.0	2.9	3.6	5.3	6.0	6.5	4.2	6.1	65.3	0.2
2	0	1	1	3	0	1	0.0	0.0	0.0	3.7	11.2	13.3	16.0	11.4	10.7	5.0	7.0	21.7	0.1
2	0	1	1	3	0	0	0.0	0.0	0.0	0.0	7.7	11.7	15.8	12.9	12.8	5.8	9.1	24.1	0.1
2	0	1	1	3	1	1	0.0	0.0	0.0	0.0	2.2	4.4	10.5	7.2	7.4	4.5	6.1	57.5	0.2
2	0	1	1	3	1	0	0.0	0.0	0.0	0.0	1.5	1.5	4.9	4.4	5.9	3.1	5.1	73.4	0.2
2	0	1	1	2	0	1	0.0	0.0	0.0	1.5	13.7	10.4	15.8	11.0	11.0	5.2	7.2	24.1	0.1
2	0	1	1	2	0	0	0.0	0.0	0.0	0.0	8.3	9.0	17.3	11.5	12.4	5.6	8.4	27.5	0.0
2	0	1	1	2	1	1	0.0	0.0	0.0	0.0	1.8	3.4	8.6	6.0	6.9	3.8	5.7	63.6	0.2
2	0	1	1	2	1	0	0.0	0.0	0.0	0.0	0.4	1.2	5.0	4.0	6.3	3.2	5.1	74.8	0.2
2	0	1	2	5	0	1	0.0	0.0	0.0	2.1	9.6	11.3	17.2	11.7	11.0	5.5	7.7	23.8	0.1
2	0	1	2	5	0	0	0.0	0.0	3.4	4.0	7.9	7.6	12.6	11.2	11.7	6.4	8.8	26.3	0.1
2	0	1	2	5	1	1	0.0	0.0	5.2	0.0	4.1	5.9	7.3	6.8	6.5	3.6	5.2	55.2	0.2
2	0	1	2	5	1	0	0.0	0.0	0.0	0.0	0.4	2.9	5.5	5.9	7.3	3.9	5.7	68.1	0.3

Table A-1. (Cont.) Sieve analysis of substrate samples taken from unplanted plots at the BP Put River No. 1 gravel pad in 1990

							Percent												
Block	Snow Fence	Poa Glauca	Repl	Height	Soil	Tilled	3.0"	2.5"	2.0"	1.5"	1.0"	3/4"	1/2"	3/8"	1/4"	#4	#10	Pan	Lost
2	0	1	2	3	0	1	0.0	0.0	0.0	1.9	9.3	8.9	17.4	11.7	11.9	6.2	10.3	22.4	0.1
2	0	1	2	3	0	0	9.8	0.0	0.0	3.3	7.1	7.7	13.4	11.5	10.4	5.2	8.3	23.2	0.1
2	0	1	2	3	1	1	0.0	0.0	0.0	3.2	1.9	1.2	6.0	6.1	6.3	3.8	6.1	65.1	0.3
2	0	1	2	3	1	0	0.0	0.0	0.0	0.0	2.0	4.4	6.3	6.7	8.7	4.5	6.3	60.9	0.2
2	0	1	2	2	0	1	0.0	0.0	0.0	0.0	6.5	9.1	15.4	11.4	12.6	6.4	9.7	28.8	0.1
2	0	1	2	2	0	0	0.0	0.0	0.0	4.2	3.8	8.9	15.6	10.5	12.1	6.4	9.5	28.9	0.0
2	0	1	2	2	1	1	0.0	0.0	0.0	0.0	2.2	3.7	10.5	8.3	9.7	5.0	6.9	53.5	0.1
2	0	1	2	2	1	0	0.0	0.0	0.0	0.0	3.4	4.8	4.3	4.9	6.4	3.2	5.7	67.1	0.3
2	0	1	3	5	0	1	0.0	0.0	4.2	5.0	6.9	10.5	15.4	11.7	11.2	5.2	7.0	22.7	0.1
2	0	1	3	5	0	0	0.0	0.0	3.0	1.7	7.8	9.5	14.8	11.2	11.7	5.9	8.6	25.7	0.1
2	0	1	3	5	1	1	0.0	0.0	0.0	0.0	2.6	3.3	5.9	4.2	6.5	3.4	5.1	68.6	0.3
2	0	1	3	5	1	0	0.0	0.0	0.0	0.0	2.7	1.7	4.9	5.7	5.9	3.6	5.2	70.0	0.3
2	0	1	3	3	0	1	0.0	3.9	0.0	1.4	7.6	10.5	16.8	11.5	11.6	5.8	8.5	22.4	0.1
2	0	1	3	3	0	0	0.0	0.0	0.0	2.6	6.7	10.5	16.3	12.6	12.0	6.1	9.1	24.0	0.1
2	0	1	3	3	1	1	0.0	0.0	0.0	0.0	1.4	2.8	7.1	5.3	7.3	3.7	5.8	66.4	0.2
2	0	1	3	3	1	0	0.0	0.0	0.0	0.0	2.6	2.7	4.3	3.8	5.6	3.5	5.3	72.2	0.2
2	0	1	3	2	0	1	0.0	0.0	0.0	1.2	3.1	8.6	13.4	11.9	13.0	6.2	9.9	32.7	0.0
2	0	1	3	2	0	0	0.0	0.0	0.0	1.6	6.6	7.9	14.2	10.8	12.5	6.2	9.4	30.7	0.1
2	0	1	3	2	1	1	0.0	0.0	0.0	0.0	6.1	2.5	4.5	5.1	6.1	3.3	5.4	66.7	0.2
2	0	1	3	2	1	0	0.0	0.0	0.0	0.0	0.6	2.5	5.0	5.7	6.3	3.5	6.0	70.1	0.2
3	1	0	1	5	0	1	0.0	0.0	0.0	0.0	9.4	11.4	16.3	11.3	11.2	5.6	8.1	26.6	0.1
3	1	0	1	5	0	0	0.0	0.0	0.0	3.3	6.1	7.7	13.4	11.7	13.2	6.1	9.6	28.9	0.1
3	1	0	1	5	1	1	0.0	0.0	0.0	0.0	1.6	2.6	8.0	9.4	10.0	5.3	8.4	54.4	0.3
3	1	0	1	5	1	0	0.0	0.0	0.0	0.0	2.4	2.7	8.4	8.4	9.9	5.1	7.8	55.1	0.3
3	1	0	1	3	0	1	0.0	0.0	0.0	0.0	7.2	7.4	15.4	13.0	14.2	7.2	10.4	25.1	0.1
3	1	0	1	3	0	0	0.0	0.0	0.0	0.0	5.2	7.6	13.8	12.9	15.0	7.4	11.2	26.8	0.1
3	1	0	1	3	1	1	0.0	0.0	0.0	0.0	3.0	2.9	6.7	6.2	7.3	4.0	6.1	63.5	0.3
3	1	0	1	3	1	0	0.0	0.0	0.0	1.2	0.0	2.7	5.1	6.0	8.4	4.4	6.6	65.4	0.2
3	1	0	1	2	0	1	0.0	0.0	0.0	0.9	5.7	5.9	15.2	13.0	16.3	7.6	10.8	24.4	0.2
3	1	0	1	2	0	0	0.0	0.0	0.0	0.0	3.3	6.3	15.4	13.4	14.9	8.1	11.4	27.2	0.1
3	1	0	1	2	1	1	0.0	0.0	0.0	0.0	4.5	4.3	7.1	7.3	9.3	5.0	7.2	55.2	0.2
3	1	0	1	2	1	0	0.0	0.0	0.0	0.0	1.8	4.1	7.6	9.0	9.3	4.9	7.1	55.9	0.2
3	1	0	2	5	0	1	0.0	0.0	0.0	4.4	5.5	9.0	16.3	11.8	12.4	6.3	9.2	24.9	0.1
3	1	0	2	5	0	0	0.0	0.0	0.0	1.0	7.2	6.4	15.3	11.6	13.7	6.8	10.4	27.5	0.0
3	1	0	2	5	1	1	0.0	0.0	0.0	0.0	2.8	1.3	5.6	6.1	8.0	4.0	6.7	65.3	0.2
3	1	0	2	5	1	0	0.0	0.0	0.0	0.0	1.4	2.7	5.8	5.1	6.1	3.6	5.6	69.3	0.3
3	1	0	2	3	0	1	0.0	0.0	0.0	0.0	6.6	7.8	13.7	12.6	15.2	7.7	11.0	25.2	0.1
3	1	0	2	3	0	0	0.0	0.0	0.0	0.0	5.0	6.7	14.2	13.8	15.5	7.3	11.2	26.2	0.1
3	1	0	2	3	1	1	0.0	0.0	0.0	0.0	1.2	2.3	4.1	4.5	6.2	3.7	5.8	71.5	0.6
3	1	0	2	3	1	0	0.0	0.0	0.0	1.3	1.4	1.9	6.8	5.1	6.6	3.9	6.1	66.7	0.2
3	1	0	2	2	0	1	0.0	0.0	0.0	2.8	4.2	7.6	15.7	13.7	14.6	7.5	10.5	23.3	0.0
3	1	0	2	2	0	0	0.0	0.0	0.0	1.1	5.5	9.1	12.9	12.5	14.2	7.8	11.1	25.7	0.1
3	1	0	2	2	1	1	0.0	0.0	0.0	0.0	5.9	2.2	9.9	8.6	9.7	5.1	7.4	51.0	0.3
3	1	0	2	2	1	0	0.0	0.0	0.0	2.1	2.8	2.6	8.5	6.3	8.2	4.6	6.7	57.8	0.2
3	1	0	3	5	0	1	0.0	0.0	0.0	1.8	10.1	9.3	15.6	11.0	12.4	6.1	8.7	25.0	0.1
3	1	0	3	5	0	0	0.0	0.0	2.9	4.8	6.3	8.3	13.6	11.5	12.0	6.0	8.9	25.7	0.0
3	1	0	3	5	1	1	0.0	0.0	0.0	0.0	2.0	2.2	4.4	5.2	6.8	3.8	5.6	69.6	0.3
3	1	0	3	5	1	0	0.0	0.0	0.0	0.0	2.4	1.3	4.6	6.7	7.0	3.7	5.8	68.2	0.4
3	1	0	3	3	0	1	0.0	0.0	0.0	1.3	3.1	8.5	17.0	13.5	13.5	7.3	10.5	25.0	0.1
3	1	0	3	3	0	0	0.0	0.0	0.0	1.0	5.7	7.1	12.3	13.3	14.1	7.3	10.7	28.3	0.1
3	1	0	3	3	1	1	0.0	0.0	0.0	0.0	0.0	1.2	3.4	5.0	6.3	3.8	6.0	74.1	0.2
3	1	0	3	3	1	0	0.0	0.0	0.0	0.0	0.7	1.3	5.2	5.8	7.4	3.9	6.2	69.2	0.2

Table A-1. (Cont.) Sieve analysis of substrate samples taken from unplanted plots at the BP Put River No. 1 gravel pad in 1990

Block	Snow Fence	Poa Glauca	Repl	Height	Soil	Tilled	Percent												
							3.0"	2.5"	2.0"	1.5"	1.0"	3/4"	1/2"	3/8"	1/4"	#4	#10	Pan	Lost
3	1	0	3	2	0	1	0.0	0.0	0.0	2.0	6.1	8.8	14.3	14.4	14.6	7.1	10.0	22.7	0.1
3	1	0	3	2	0	0	0.0	0.0	0.0	1.6	2.9	5.8	14.2	14.7	15.7	7.9	11.4	25.6	0.2
3	1	0	3	2	1	1	0.0	0.0	0.0	2.2	2.2	4.9	8.7	7.8	9.2	4.9	6.9	53.0	0.3
3	1	0	3	2	1	0	0.0	0.0	0.0	0.0	1.2	6.2	5.9	7.1	8.9	4.7	6.5	59.1	0.3
4	0	0	1	5	0	1	0.0	0.0	2.5	5.0	15.7	10.6	14.2	10.6	9.9	4.7	7.0	19.6	0.2
4	0	0	1	5	0	0	0.0	0.0	0.0	8.1	7.6	9.6	13.9	11.3	12.0	5.7	8.4	23.4	0.1
4	0	0	1	5	1	1	0.0	0.0	0.0	0.0	4.7	2.7	7.5	6.9	7.3	3.7	6.1	60.7	0.3
4	0	0	1	5	1	0	0.0	0.0	5.5	0.0	2.9	2.2	5.9	6.0	6.7	3.8	5.6	61.1	0.3
4	0	0	1	3	0	1	0.0	0.0	0.0	3.7	10.2	9.0	15.9	11.5	11.7	5.6	7.9	24.4	0.0
4	0	0	1	3	0	0	0.0	0.0	4.8	0.0	8.0	10.9	15.0	10.9	11.3	5.2	8.3	25.5	0.1
4	0	0	1	3	1	1	0.0	0.0	0.0	0.0	5.3	5.8	9.6	5.0	8.3	4.7	6.2	55.0	0.1
4	0	0	1	3	1	0	0.0	0.0	0.0	3.6	1.7	3.2	5.6	5.9	6.2	4.1	5.7	63.7	0.2
4	0	0	1	2	0	1	0.0	0.0	0.0	0.0	11.0	11.1	18.8	12.3	12.3	5.5	8.0	21.0	0.0
4	0	0	1	2	0	0	0.0	0.0	0.0	1.8	7.1	12.2	16.9	12.7	12.6	5.9	8.9	21.8	0.1
4	0	0	1	2	1	1	0.0	0.0	0.0	0.0	4.0	4.4	7.5	5.8	7.2	3.7	6.2	60.9	0.3
4	0	0	1	2	1	0	0.0	0.0	0.0	0.0	1.7	3.6	4.9	5.5	6.2	3.7	6.3	67.9	0.3
4	0	0	2	5	0	1	0.0	0.0	0.0	2.3	8.9	11.8	17.0	11.0	12.1	5.5	8.1	23.3	0.1
4	0	0	2	5	0	0	0.0	0.0	0.0	2.1	6.0	8.1	16.9	12.3	12.5	6.1	9.0	26.9	0.1
4	0	0	2	5	1	1	0.0	0.0	0.0	0.0	3.8	3.2	8.7	7.0	8.4	4.1	6.4	58.0	0.3
4	0	0	2	5	1	0	0.0	0.0	0.0	0.0	1.5	2.7	5.9	5.9	7.3	4.0	6.1	66.5	0.2
4	0	0	2	3	0	1	0.0	0.0	0.0	0.0	9.7	9.0	16.8	12.4	12.6	5.8	8.2	25.5	0.0
4	0	0	2	3	0	0	0.0	0.0	0.0	4.5	7.3	6.5	14.8	11.8	12.8	5.3	9.6	27.4	0.0
4	0	0	2	3	1	1	0.0	0.0	0.0	2.4	3.8	5.2	9.3	7.1	7.8	3.8	5.5	55.1	0.0
4	0	0	2	3	1	0	0.0	0.0	0.0	0.0	2.2	1.1	4.3	5.1	6.5	3.9	5.5	71.1	0.2
4	0	0	2	2	0	1	0.0	0.0	0.0	3.4	12.9	14.7	16.3	10.5	10.0	4.5	6.7	21.0	0.1
4	0	0	2	2	0	0	0.0	0.0	0.0	3.6	7.4	13.6	14.0	11.4	12.4	5.8	8.8	22.9	0.0
4	0	0	2	2	1	1	0.0	0.0	0.0	0.0	3.2	3.7	4.4	6.4	7.0	3.8	5.9	65.4	0.4
4	0	0	2	2	1	0	0.0	0.0	0.0	0.0	1.4	1.8	5.8	4.2	6.7	3.6	6.0	70.2	0.3
4	0	0	3	5	0	1	0.0	0.0	0.0	0.0	6.1	8.7	14.5	12.6	13.7	6.8	9.8	27.6	0.2
4	0	0	3	5	0	0	0.0	0.0	0.0	1.6	5.8	6.7	13.6	12.5	13.2	6.7	10.2	29.5	0.1
4	0	0	3	5	1	1	0.0	0.0	0.0	0.0	5.2	3.2	5.9	7.2	8.2	4.5	6.8	58.8	0.2
4	0	0	3	5	1	0	0.0	0.0	0.0	1.9	3.0	0.9	5.5	5.5	6.7	3.7	6.4	66.0	0.3
4	0	0	3	3	0	1	0.0	0.0	0.0	1.0	6.4	10.8	13.3	13.5	13.5	6.7	9.3	25.6	0.0
4	0	0	3	3	0	0	0.0	0.0	0.0	1.5	8.7	10.1	13.6	12.5	12.5	6.1	8.8	26.2	0.0
4	0	0	3	3	1	1	0.0	0.0	0.0	0.0	1.5	3.2	7.0	6.7	7.9	3.9	5.8	63.8	0.2
4	0	0	3	3	1	0	0.0	0.0	0.0	3.5	0.0	2.9	5.5	5.6	6.5	3.8	5.7	66.2	0.2
4	0	0	3	2	0	1	0.0	0.0	0.0	7.7	9.7	12.8	15.9	11.3	10.3	4.8	6.8	20.6	0.0
4	0	0	3	2	0	0	0.0	0.0	0.0	2.5	8.8	10.1	16.7	12.6	12.0	6.0	8.9	22.3	0.0
4	0	0	3	2	1	1	0.0	0.0	0.0	3.9	1.8	5.8	6.5	6.9	7.6	4.4	6.6	56.4	0.1
4	0	0	3	2	1	0	0.0	0.0	0.0	0.0	3.4	2.2	6.6	6.4	7.0	3.8	6.5	63.8	0.4

Table A-2. Means of sieve analysis of substrate samples taken from unplanted plots at the BP Put River No. 1 gravel pad in 1990

						Percent												
Block	Snow Fence	Poa Glauca	Height	Soil	Tilled	3.0"	2.5"	2.0"	1.5"	1.0"	3/4"	1/2"	3.8"	1/4"	#4	#10	Pan	Lost
1	1	1	5	0	1	0.0	0.0	0.0	0.0	5.6	9.7	15.4	14.2	13.7	7.2	10.0	24.1	0.1
1	1	1	5	0	0	0.0	0.0	0.0	1.9	5.6	7.1	13.9	12.6	14.9	7.4	11.0	25.5	0.1
1	1	1	5	1	1	0.0	0.0	0.0	1.4	3.0	5.0	8.5	8.3	8.2	4.5	6.9	53.9	0.2
1	1	1	5	1	0	0.0	0.0	0.0	0.8	1.9	3.3	6.8	6.5	7.0	4.0	6.2	63.3	0.3
1	1	1	3	0	1	0.0	0.0	0.0	0.0	4.9	7.1	14.6	14.3	15.1	7.8	10.9	25.2	0.0
1	1	1	3	0	0	0.0	0.0	1.9	0.9	5.8	6.6	14.3	11.8	13.2	7.4	11.2	26.8	0.1
1	1	1	3	1	1	0.0	0.0	0.0	0.4	3.5	4.6	8.9	7.6	8.2	4.5	6.7	55.4	0.2
1	1	1	3	1	0	0.0	0.0	0.0	0.9	0.5	1.2	4.7	5.9	6.5	3:7	5.8	70.5	0.3
1	1	1	2	0	1	0.0	0.0	0.0	0.0	5.4	9.2	17.4	13.6	14.2	6.9	9.9	23.2	0.0
1	1	1	2	0	0	0.0	0.0	0.0	1.2	7.5	7.8	14.1	12.8	13.5	7.3	10.7	25.2	0.0
1	1	1	2	1	1	0.0	0.0	0.0	0.8	2.6	3.7	7.6	7.2	7.5	4.0	5.8	60.6	0.2
1	1	1	2	1	0	0.0	0.0	0.0	0.0	2.1	2.0	4.3	4.4	5.7	3.4	5.0	72.9	0.2
2	0	1	5	0	1	0.0	0.0	1.4	2.7	10.7	11.3	16.0	11.6	10.8	5.2	7.3	22.8	0.1
2	0	1	5	0	0	0.0	0.0	2.1	3.2	8.3	8.7	15.0	11.3	11.6	5.9	8.4	25.5	0.1
2	0	1	5	1	1	0.0	0.0	1.7	0.0	3.2	4.6	6.8	5.9	6.8	3.7	5.3	61.8	0.2
2	0	1	5	1	0	0.0	0.0	0.0	0.0	2.0	2.7	5.2	5.9	6.6	3.9	5.7	67.8	0.3
2	0	1	3	0	1	0.0	1.3	0.0	2.3	9.4	10.9	16.7	11.5	11.4	5.7	8.6	22.2	0.1
2	0	1	3	0	0	3.3	0.0	0.0	2.0	7.2	10.0	15.2	12.3	11.7	5.7	8.8	23.8	0.1
2	0	1	3	1	1	0.0	0.0	0.0	1.1	1.8	2.8	7.9	6.2	7.0	4.0	6.0	63.0	0.2
2	0	1	3	1	0	0.0	0.0	0.0	0.0	2.0	2.9	5.2	5.0	6.7	3.7	5.6	68.8	0.2
2	0	1	2	0	1	0.0	0.0	0.0	0.9	7.8	9.4	14.9	11.4	12.2	5.9	8.9	28.5	0.1
2	0	1	2	0	0	0.0	0.0	0.0	1.9	6.2	8.6	15.7	10.9	12.3	6.1	9.1	29.0	0.0
2	0	1	2	1	1	0.0	0.0	0.0	0.0	3.4	3.2	7.9	6.5	7.6	4.0	6.0	61.3	0.2
2	0	1	2	1	0	0.0	0.0	0.0	0.0	1.5	2.8	4.8	4.9	6.3	3.3	5.6	70.7	0.2
3	1	0	5	0	1	0.0	0.0	0.0	2.1	8.3	9.9	16.1	11.4	12.0	6.0	8.7	25.5	0.1
3	1	0	5	0	0	0.0	0.0	1.0	3.0	6.5	7.5	14.1	11.6	13.0	6.3	9.6	27.4	0.0
3	1	0	5	1	1	0.0	0.0	0.0	0.0	2.1	2.0	6.0	6.9	8.3	4.4	6.9	63.1	0.3
3	1	0	5	1	0	0.0	0.0	0.0	0.0	2.1	2.2	6.3	6.7	7.7	4.1	6.4	64.2	0.3
3	1	0	3	0	1	0.0	0.0	0.0	0.4	5.6	7.9	15.4	13.0	14.3	7.4	10.6	25.1	0.1
3	1	0	3	0	0	0.0	0.0	0.0	0.3	5.3	7.1	13.4	13.3	14.9	7.3	11.0	27.1	0.1
3	1	0	3	1	1	0.0	0.0	0.0	0.0	1.4	2.1	4.7	5.2	6.6	3.8.	6.0	69.7	0.4
3	1	0	3	1	0	0.0	0.0	0.0	0.8	0.7	2.0	5.7	5.6	7.5	4.1	6.3	67.1	0.2
3	1	0	2	0	1	0.0	0.0	0.0	1.9	5.3	7.4	15.1	13.7	15.2	7.4	10.4	23.5	0.1
3	1	0	2	0	0	0.0	0.0	0.0	0.9	3.9	7.1	14.2	13.5	14.9	7.9	11.3	26.2	0.1
3	1	0	2	1	1	0.0	0.0	0.0	0.7	4.2	3.8	8.6	7.9	9.4	5.0	7.2	53.1	0.3
3	1	0	2	1	0	0.0	0.0	0.0	0.7	1.9	4.3	7.3	7.5	8.8	4.7	6.8	57.6	0.2
4	0	0	5	0	1	0.0	0.0	0.8	2.4	10.2	10.4	15.2	11.4	11.9	5.7	8.3	23.5	0.2
4	0	0	5	0	0	0.0	0.0	0.0	3.9	6.5	8.1	14.8	12.0	12.6	6.2	9.2	26.6	0.1
4	0	0	5	1	1	0.0	0.0	0.0	0.0	4.6	3.0	7.4	7.0	8.0	4.1	6.4	59.2	0.3
4	0	0	5	1	0	0.0	0.0	1.8	0.6	2.5	1.9	5.8	5.8	6.9	3.8	6.0	64.5	0.3
4	0	0	3	0	1	0.0	0.0	0.0	1.6	8.8	9.6	15.3	12.5	12.6	6.0	8.5	25.2	0.0
4	0	0	3	0	0	0.0	0.0	1.6	2.0	8.0	9.2	14.5	11.7	12.2	5.5	8.9	26.4	0.0
4	0	0	3	1	1	0.0	0.0	0.0	0.8	3.5	4.7	8.6	6.3	8.0	4.1	5.8	58.0	0.1
4	0	0	3	1	0	0.0	0.0	0.0	2.4	1.3	2.4	5.1	5.5	6.4	3.9	5.6	67.0	0.2
4	0	0	2	0	1	0.0	0.0	0.0	3.7	11.2	12.9	17.0	11.4	10.9	4.9	7.2	20.9	0.0
4	0	0	2	0	0	0.0	0.0	0.0	2.6	7.8	12.0	15.9	12.2	12.3	5.9	8.9	22.3	0.0
4	0	0	2	1	1	0.0	0.0	0.0	1.3	3.0	4.6	6.1	6.4	7.3	4.0	6.2	60.9	0.3
4	0	0	2	1	0	0.0	0.0	0.0	0.0	2.2	2.5	5.8	5.4	6.6	3.7	6.3	67.3	0.3

Table A-3. Results of sieve analysis of substrate samples taken from unplanted plots at the BP Put River No. 1 gravel pad in 1990

Block	Snow Fence	Poa Glauca	Height	Soil	Tilled	Percent 3.0"	2.5"	2.0"	1.5"	1.0"	3/4"	1/2"	3.8"	1/4"	#4	#10	Pan	Lost
1	1	1				0.0	0.0	0.2	0.7	4.0	5.6	10.9	9.9	10.6	5.7	8.4	43.9	0.1
1	1	1	5			0.0	0.0	0.0	1.0	4.0	6.3	11.1	10.4	10.9	5.8	8.5	41.7	0.2
1	1	1	3			0.0	0.0	0.5	0.6	3.7	4.9	10.6	9.9	10.8	5.8	8.7	44.5	0.1
1	1	1	2			0.0	0.0	0.0	0.5	4.4	5.7	10.8	9.5	10.2	5.4	7.9	45.5	0.1
1	1	1		0		0.0	0.0	0.3	0.7	5.8	7.9	14.9	13.2	14.1	7.3	10.6	25.0	0.1
1	1	1		1		0.0	0.0	0.0	0.7	2.3	3.3	6.8	6.6	7.2	4.0	6.1	62.8	0.2
1	1	1			0	0.0	0.0	0.3	1.0	3.9	4.7	9.7	9.0	10.1	5.5	8.3	47.4	0.2
1	1	1			1	0.0	0.0	0.0	0.4	4.2	6.6	12.1	10.9	11.2	5.8	8.4	40.4	0.1
2	0	1				0.3	0.1	0.4	1.2	5.3	6.5	10.9	8.6	9.3	4.8	7.1	45.4	0.2
2	0	1	5			0.0	0.0	1.3	1.5	6.1	6.8	10.8	8.7	8.9	4.7	6.7	44.5	0.2
2	0	1	3			0.8	0.3	0.0	1.3	5.1	6.6	11.2	8.8	9.2	4.8	7.3	44.4	0.2
2	0	1	2			0.0	0.0	0.0	0.7	4.7	6.0	10.8	8.4	9.6	4.8	7.4	47.4	0.1
2	0	1		0		0.5	0.2	0.6	2.2	8.3	9.8	15.6	11.5	11.7	5.7	8.5	25.3	0.1
2	0	1		1		0.0	0.0	0.3	0.2	2.3	3.2	6.3	5.7	6.8	3.8	5.7	65.6	0.2
2	0	1			0	0.5	0.0	0.4	1.2	4.5	5.9	10.2	8.4	9.2	4.8	7.2	47.6	0.2
2	0	1			1	0.0	0.2	0.5	1.2	6.0	7.0	11.7	8.9	9.3	4.7	7.0	43.3	0.2
3	1	0				0.0	0.0	0.1	0.9	4.0	5.3	10.6	9.7	11.0	5.7	8.4	44.1	0.2
3	1	0	5			0.0	0.0	0.2	1.3	4.8	5.4	10.6	9.2	10.2	5.2	7.9	45.0	0.2
3	1	0	3			0.0	0.0	0.0	0.4	3.3	4.8	9.8	9.3	10.8	5.7	8.5	47.3	0.2
3	1	0	2			0.0	0.0	0.0	1.1	3.8	5.7	11.3	10.7	12.1	6.3	8.9	40.1	0.2
3	1	0		0		0.0	0.0	0.2	1.4	5.8	7.8	14.7	12.8	14.0	7.1	10.3	25.8	0.1
3	1	0		1		0.0	0.0	0.0	0.4	2.1	2.7	6.4	6.6	8.0	4.4	6.6	62.5	0.3
3	1	0			0	0.0	0.0	0.2	1.0	3.4	5.0	10.2	9.7	11.1	5.8	8.6	44.9	0.2
3	1	0			1	0.0	0.0	0.0	0.9	4.5	5.5	11.0	9.7	11.0	5.7	8.3	43.3	0.2
4	0	0				0.0	0.0	0.4	1.8	5.8	6.8	11.0	9.0	9.6	4.8	7.3	43.5	0.2
4	0	0	5			0.0	0.0	0.7	1.8	5.9	5.9	10.8	9.1	9.8	4.9	7.5	43.5	0.2
4	0	0	3			0.0	0.0	0.4	1.7	5.4	6.5	10.9	9.0	9.8	4.9	7.2	44.1	0.1
4	0	0	2			0.0	0.0	0.0	1.9	6.0	8.0	11.2	8.8	9.3	4.6	7.1	42.9	0.2
4	0	0		0		0.0	0.0	0.4	2.7	8.7	10.4	15.5	11.9	12.1	5.7	8.5	24.1	0.1
4	0	0		1		0.0	0.0	0.3	0.9	2.8	3.2	6.5	6.1	7.2	3.9	6.1	62.8	0.2
4	0	0			0	0.0	0.0	0.6	1.9	4.7	6.0	10.3	8.8	9.5	4.8	7.5	45.7	0.2
4	0	0			1	0.0	0.0	0.1	1.6	6.9	7.5	11.6	9.2	9.8	4.8	7.1	41.3	0.1

APPENDIX B

SEED COLLECTION AND PREPARATION DATA

Tables B-1 through B-3 list seed collected on the North Slope during 1989 through 1991, respectively. Table B-4 lists seed collected during 1991 in Russia. The tables include species collected, location, the collection date, grams of cleaned seedlot per collection and the estimated percent chaff still present in the cleaned seedlot. For the 1990 and 1991 collections, the relative size of the bulk field collection is also given (small bag, large bag, film canister, plus number of bags, canisters, etc.). The comments section provides insight on yield, effort required in cleaning seed, seed maturity, etc.

Table B-1. Species, locations, dates and data on threshing and cleaning of seed collected during 1989

Species	Collection Location	Collection Date	Grams Cleaned Seedlot	Est. % Chaff in Cleaned Seedlot*	Comments
GRASSES:					
Agropyron boreale	BP Put River No. 1	24 Aug 89	12.500		
Agropyron boreale	Kuparuk River Bridge	25 Aug 89	167.010		
Alopecurus alpinus	B.P. Put River No. 1	24 Sep 89	13.510	30	Very hard to clean seed
Alopecurus alpinus	Pump Station No. 1	27 Sep 89	1.703	30	Very hard to clean seed
Alopecurus alpinus	Van Cleave's Plots	26 Sep 89	10.435	30	Very hard to clean seed
Arctagrostis latifolia	M.P. 31 Dalton Highway	19 Sep 89	15.810		
Arctagrostis latifolia	Pump Station No. 1	27 Sep 89	5.960		
Arctagrostis latifolia	Sag. River E. of Airport	27/28 Sep 89	37.500		
Arctagrostis latifolia	IBP Plots	26 Aug 89	27.580		
Arctagrostis latifolia	72 Haul Road (introduced)	26 Sep 89	7.700		
Bromus pumpellianus	Kuparuk River Bridge	25 Aug 89	20.090		Seed 90% immature
Deschampsia beringensis	IBP Plots	26 Aug 89	0.000		Seeds are immature
Deschampsia caespitosa	1972 Haul Road	29 Aug 89	20.270		Fair yield
Deschampsia caespitosa	Kup. Haul Rd/N. ARCO Store Pad	29 Aug 89	34.600		
Deschampsia caespitosa	Kuparuk River Bridge	25 Aug 89	55.210		Fair yield
Deschampsia caespitosa	Sohio-Kuparuk Reserve Pit	29 Aug 89	20.080		
Dupontia fisheri	Pump Station No. 1	27 Sep 89	5.392		Poor yield
Elymus arenarius mollis	East Dock Dunes	25 Sep 89	122.900		
Festuca brachyphylla	Sohio-Kuparuk Reserve Pit	29 Aug 89	14.988		
Festuca brachyphylla	IBP Plots	26 Aug 89	22.420		
Festuca ovina	East Dock Dunes	25 Sep 89	10.050		
Festuca rubra	Kuparuk River Bridge	25 Aug 89	7.646		Poor yield, very few with any seed inside
Festuca rubra	IBP Plots	26 Aug 89	6.390		Poor yield, very few with any seed inside
Festuca 'vivipara'	B.P. Put River No. 1	24 Aug 89	26.220	90	
Poa arctica	East Dock Dunes	25 Sep 89	36.720		
Poa glauca	IBP Plots	26 Aug 89	63.800		
Poa glauca	72 Haul Road	29 Aug 89	176.400		
Poa pratensis	IBP Plots	26 Aug 89	34.860		
Puccinellia langeana	B.P. Put River No. 1	24 Aug 89	209.530		Good yield
Puccinellia langeana	IBP Plots	26 Aug 89	253.650		Good yield
Trisetum spicatum	B.P. Put River No. 1	24 Aug 89	60.290		Tough to thresh
Trisetum spicatum	IBP Plots	26 Aug 89	41.180		Tough to thresh

Table B-1. (Cont.) Species, locations, dates and data on threshing and cleaning of seed collected during 1989

Species	Collection Location	Collection Date	Grams Cleaned Seedlot	Est. % Chaff in Cleaned Seedlot*	Comments
GRASSLIKE:					
Carex maritima	Winter Haul Road, DS-2	31 Aug 89	8.278		
Carex maritima	B.P. Put River No. 1	27 Aug 89	2.037		
Carex maritima	Sohio-Kuparuk Reserve Pit	29 Aug 89	23.870		
Luzula arctica	Arco State #1	30 Aug 89	1.811		Some contamination
FORBS:					
Androsace chamaejasme	Winter Haul Road, DS-2	31 Aug 89	0.259		Very small sample
Armeria maritima	Arco Discovery Well Site	7 Sep 89	5.503		
Armeria maritima	Haul Road at Little Put River	31 Aug 89	0.829		Seed immature and very small
Artemisia arctica	Kuparuk River Bridge	25 Aug 89	14.946		
Artemisia arctica	M.P. 40 Dalton/Franklin Bluffs	19 Sep 89	14.100		
Artemisia borealis	Kuparuk River Bridge	25 Aug 89	6.061		
Artemisia glomerata	Kuparuk River Bridge	25 Aug 89	16.010		Good yield
Artemisia tilesi	Kuparuk River Bridge	25 Aug 89	0.256		Only a trace of seed
Aster sibericus	Sag. River E. of Airport	28 Sep 89	8.392		
Braya pilosa & purpurascens	Put R. #27 Gravel Pit	27 Aug 89	71.490		Topsoil stockpile, seed mixed
Cerastium beeringianum	72 Haul Road, DS-2	26 Sep 89	2.992		
Chrysanthemum bipinnatum	Kuparuk River Bridge	25 Aug 89	0.000		No apparent seed, but saved chaff
Descurainia sophioides	Sohio-Kuparuk Reserve Pit	29 Aug 89	18.800		
Draba spp.	B.P. Put River No. 1	27 Aug 89	11.444		White-flowered species
Epilobium latifolium	B.P. Put River No. 1	24 Aug 89	3.500		
Epilobium latifolium	Put River #27 Gravel Pit	27 Aug 89	7.540		
Eutrema edwardsii	Arco State No. 1	30 Aug 89	32.840		
Eutrema edwardsii	B.P. Put River No. 1	27 Aug 89	3.370		
Melandrium apetalum	Winter Haul Road, DS-2	31 Aug 89	11.250		
Parrya nudicaulis	Sag. River E. of Airport	27 Sep 89	0.989		
Pedicularis sudetica	Winter Haul Road, DS-2	31 Aug 89	0.219		
Polemonium boreale	BP Put River No. 1	24 Aug 89	0.691		

Table B-1. (Cont.) Species, locations, dates and data on threshing and cleaning of seed collected during 1989

Species	Collection Location	Collection Date	Grams Cleaned Seedlot	Est. % Chaff in Cleaned Seedlot*	Comments
FORBS (Cont.):					
Primula borealis	Winter Haul Road, DS-2	31 Aug 89	0.011		
Sedum rosea	Big Skookum	20 Sep 89	21.453		
Senecio congestus	M.P. 40 Dalton/Franklin Bluffs	19 Sep 89	4.390		
Silene acaulis	Arco State No. 1	30 Aug 89	20.103		
SHRUBS:					
Salix arctica	Winter Haul Road, DS-2	31 Aug 89	0.098		Very small sample

* In 1989, there was no concerted effort to estimate percent trash or purity of the seedlots.

Summary of North Slope Native Seed Collecion for 1989

Gramnoids	= 19 species in 37 bulk field collections
Forbs	= 23 species in 26 bulk field collections
Shrubs	= 1 species in 1 bulk field collection
Total	= 43 species in 64 bulk field collections

Table B-2. Species, locations, dates and data on threshing and cleaning of seed collected during 1990

Species	Collection Location	Collection Date	Bulk Field Collection	Grams Cleaned Seedlot	Est. % Chaff in Cleaned Seedlot	Comments
GRASSES:						**Seedlots placed in freezer 18 Jan 1991.**
Agropyron boreale	Kuparuk River Bridge	14 Sep 90	1 Lg. Bag	51.23	10%	No comments.
Alopecurus alpinus	1972 Haul Road	10 Sep 90	1 Sm. Bag	33.46	50%	Did not run through blower, too fuzzy and light.
Alopecurus alpinus	East Dock Dunes	8 Sep 90	1 Lg. Bag	29.10	50%	Did not run through blower, too fuzzy and light.
Arctagrostis latifolia	Kuparuk River Bridge	14 Sep 90	1 Lg. Bag	10.91	65%	Appears to have very few mature, viable seeds in relation to the number of seedheads.
Arctagrostis latifolia	Pump Station No. 1	11 Sep 90	1 Lg. Bag	13.59	35%	Appears to have small amount of mature seed.
Arctagrostis latifolia	Sag. River E. of Airport	18 Sep 90	2 Lg. Bags	28.74	15%	Fair percent of seed from sample.
Arctophila fulva	Lonnie Lake East	26 Sep 90	1 Lg. Bag	12.48	2%	Very high percent of seed retained in seedheads.
Arctophila fulva	Pump Station No. 1	11 Sep 90	1 Lg. Bag	11.19	5%	No comments.
Bromus pumpellianus	Endicott Rd-S. Big Skookum	13 Sep 90	1 Lg. Bag	0.00	100%	Found no mature seeds, all are in flower stage.
Bromus pumpellianus	Kuparuk River Bridge	14 Sep 90	1 Lg. Bag	19.53	99%	Appears to have very few mature seeds, perhaps one-dozen in the seedlot.
Bromus pumpellianus	M.P. 365 Dalton Highway	06 Aug 90	1 U.S. Bag	62.00	5%	Good yield, Seeds are shriveled - may be immature.
Calamagrostis inexpansa	Kuparuk River Bridge	14 Sep 90	Very Sm. Bag	1.35	98%	Appears to be no mature seed by visual examination.
Deschampsia caespitosa	1972 Haul Road	10 Sep 90	1 Lg. Bag	17.40	15%	Seed screened four times, then once through blower.
Deschampsia caespitosa	End. Rd-West Caribou Ramp	13 Sep 90	1 Lg. Bag	5.21	85%	Same treatment as above, poor seed yield.
Deschampsia caespitosa	Kuparuk River Bridge	14 Sep 90	2 Lg. Bags	32.73	20%	Seed screened four times, then once through blower.
Deschampsia caespitosa	Pump Station No. 1	11 Sep 90	2 Lg. Bags	15.62	35%	Seed screened four times, then once through blower.
Deschampsia caespitosa	Sag. River E. of Airport	18 Sep 90	2 Lg. Bags	27.88	5%	Seed screened four times, then once through blower. Good clean seed.
Dupontia fisheri	Pump Station No. 1	11 Sep 90	1 Lg. Bag	37.36	2%	Appears to be good clean seed.
Elymus arenarius mollis	East Dock Dunes	14 Jul 90	1 Sm. Bag	27.12	10%	1989 seedcrop, but collected in 1990. Good yield.
Elymus arenarius mollis	East Dock Dunes	07 Sep 90	2 Lg. Bags	248.00	10%	Good Yield, 2 large jars of seed.
Elymus innovatus	M.P. 365 Dalton Highway	06 Aug 90	1 U.S. Bag	32.49	10%	Poor yield, considerable immature seed blown away.
Festuca baffinensis	1972 Haul Road	10 Sep 90	1 Sm. Bag	12.65	15%	Good yield.
Festuca baffinensis	Endicott Road-S. of Big Skookum	13 Sep 90	1 Lg. Bag	25.32	15%	Fair yield.
Festuca ovina	East Dock Dunes	08 Sep 90	1 Lg. Bag	5.14	45%	Very poor yield.
Festuca rubra	Endicott Rd-S. Big Skookum	13 Sep 90	1 Lg. Bag	5.33	95%	Very poor yield.
Festuca rubra	Kuparuk River Bridge	14 Sep 90	1 Sm. Bag	6.19	98%	Very poor yield, found no seeds by inspection.
Festuca 'vivipara'	1972 Haul Road	10 Sep 90	1 Lg. Bag	22.38	95%	Unable to find any viable seed by inspection.
Festuca 'vivipara'	East Dock	29 Aug 90	1 Lg. Bag	30.90	95%	Unable to find any viable seed by inspection.
Poa arctica	East Dock Dunes	07 Sep 90	1 Lg. Bag	23.45	25%	Fuzzy seed, hard to clean.
Poa arctica	Endicott Rd-S. Big Skookum	13 Sep 90	1 Lg. Bag	6.61	45%	Fuzzy seed, hard to clean. Poor yield.

Table B-2. (Cont.) Species, locations, dates and data on threshing and cleaning of seeds collected during 1990

Species	Collection Location	Collection Date	Bulk Field Collection	Grams Cleaned Seedlot	Est. % Chaff in Cleaned Seedlot	Comments
GRASSES (Cont.):						**Seedlots placed in freezer 18 Jan 1991.**
Poa glauca	1972 Haul Road	10 Sep 90	2 Lg. Bags	11.34	90%	Very poor yield, observed only a few seeds.
Poa glauca	Endicott Road-1 mile W	13 Sep 90	2 Lg. Bags	43.98	25%	Fair yield.
"	of W Caribou Ramp					
Puccinellia langeana	East Dock	29 Sep 90	4 Lg. Bags	39.30	25%	Poor yield from large sample collected.
Poa pratensis	1972 Haul Road	10 Sep 90	1 Lg. Bag	20.64	90%	All seeds appear immature. Seed in two small jars.
" "						(Mitchell Introduction - Canada Bluegrass?)
Trisetum spicatum	1972 Haul Road	10 Sep 90	1 Lg. Bag	8.87	65%	Seed very light, unable to remove chaff
Trisetum spicatum	Kuparuk River Bridge	14 Sep 90	#8 P Sack	1.15	95%	Seed very light, unable to remove chaff
" "						saved entire sample.
Trisetum spicatum	M.P. 354.5 Dalton Hwy	16 Jul 90	1 Sm. Bag	0.84	80%	Lots of chaff, seeds larger and better filled
" "	M.P. 62 TAPS-dry ridge					than seed collected at Prudhoe.
GRASSLIKE:						
Carex maritima	East Dock	09 Sep 90	1 Lg. Bag	29.17	5%	Great yield.
Carex maritima	East Dock Dunes	08 Sep 90	1 Sm. Bag	24.78	5%	Great yield.
Carex ursina	East Dock	10 Sep 90	1 Sm. Bag	71.08	5%	Seed harvested with vacuum; Sample was a slurry of
" "				(2 jars)		mud, seed, and goose feces. Dried in oven at 30
						degrees C and screened. Some seed-size sand grains.
FORBS:						
Androsace chamaejasme	72 Haul Road	26 Aug 90	1 Sm. Bag	3.00	5%	Seed easy to clean.
Androsace chamaejasme	East Dock Dunes	09 Sep 90	1 Sm. Bag	3.50	1%	Seed easy to clean.
Androsace chamaejasme	M.P. 405 Dalton Hwy	05 Aug 90	#4 P Sack	1.49	10%	Seed easy to clean. Some dirt with seed.
Arabis arenicola	M.P. 405 Dalton Hwy	05 Aug 90	#4 P Sack	4.19	1%	No comments.
Armeria maritima	East Dock Dunes	09 Sep 90	1 Sm. Bag	5.14	15%	Seed light and fluffy, not sure of quality.
Armeria maritima	Kuparuk River Bridge	14 Sep 90	#8 P Sack	0.96	15%	Seed light and fluffy, not sure of quality.
Armeria maritima	M.P. 405 Dalton Hwy	05 Aug 90	#4 P Sack	18.87	15%	Seed light and fluffy, not sure of quality.
Armeria maritima	Sag. R. E. of Airport	18 Sep 90	1 Sm. Bag	3.54	15%	Seed light and fluffy, not sure of quality.
Artemisia arctica	East Dock Dunes	09 Sep 90	1 Sm. Bag	7.00	1%	Seed cleans up well.
Artemisia arctica	Kuparuk River Bridge	14 Sep 90	#8 P Sack	0.41	1%	Seed cleans up well, small sample.
Artemisia arctica	M.P. 377.5 Dalton Hwy	17 Sep 90	1 Lg. Bag	28.23	1%	Seed cleans up well.
" "	Franklin Bluffs Camp					
Artemisia borealis	Kuparuk River Bridge	14 Sep 90	#8 P Sack	0.31	5%	Small sample.
Artemisia borealis	Put #23 Gravel Mine Pit	19 Sep 90	1 Sm. Bag	0.23	5%	Poor yield of seed, most blown away before harvest.
Artemisia glomerata	Kuparuk River Bridge	14 Sep 90	1 Sm. Bag	5.46	15%	Poor yield; Collection extremely dusty and dirty,
" "						some dirt still in seed.
Artemisia glomerata	M.P. 405 Dalton Hwy	05 Aug 90	#8 P Sack	1.97	1%	Fair yield.

Table B-2. (Cont.) Species, locations, dates and data on threshing and cleaning of seeds collected during 1990

Species	Collection Location	Collection Date	Bulk Field Collection	Grams Cleaned Seedlot	Est. % Chaff in Cleaned Seedlot	Comments
FORBS (Cont.):						Seedlots placed in freezer 18 Jan 1991.
Artemisia tilesii	Kuparuk River Bridge	14 Sep 90	#8 P Sack	0.15	1%	A very small sample, only a few seeds.
Aster sibericus	Sag. R.-E. of Airport	18 Sep 90	Very Sm. Bag	0.84	2%	Small sample.
Astragalus aboriginum	M.P. 399 Dalton Hwy	05 Aug 90	#8 P Sack	3.85	0%	Small amount of seed.
Astragalus alpinus	M.P. 405 Dalton Hwy	05 Aug 90	1 Lg. Bag	37.44	1%	Seeds green in color, good amount.
Astragalus alpinus	M.P. 405 Dalton Hwy	16 Aug 90	1 Sm. Bag	25.61	0%	Seeds green in color, good amount.
Astragalus alpinus	M.P. 399 Dalton Hwy	05 Aug 90	#8 P Sack	5.23	0%	Seed greenish in color and larger than A. eucosmus.
" "						(Seed was initially mixed with A. eucosmus below,
" "						but seeds are different, allowing for separation.)
Astragalus eucosmus	M.P. 399 Dalton Hwy	05 Aug 90	#8 P Sack	17.34	0%	Seed brownish and smaller than A. alpinus above.
Astragalus nutzotinensis	M.P. 395.9 Dalton Hwy	17 Aug 90	1 Lg. Bag	13.86	0%	No comments.
Astragalus nutzotinensis	M.P. 405 Dalton Hwy	05 Aug 90	#2 P Sack	2.76	0%	Seeds from both 5, 8 August collections combined
Astragalus nutzotinensis	M.P. 405 Dalton Hwy	08 Aug 90	#2 P Sack			into one seedlot
Castilleja elegans	M.P. 395.9 Dalton Hwy	17 Aug 90	1 Sm. Bag	3.85	5%	Seeds need scrubbing 2-3 times to remove from white
" "	M.P. 21.5 TAPS-Spur Dike					tissue.
Castilleja elegans	M.P. 405 Dalton Hwy	05 Aug 90	#8 P Sack	0.15	5%	Seeds need scrubbing 2-3 times to remove from white
" "						tissue. Seeds may be immature, still green.
Cerastium beeringianum	72 Haul Road	10 Sep 90	1 Lg. Bag	9.33	5%	Tiny seeds.
Chrysanthemum bipinnatum	Kuparuk River Bridge	14 Sep 90	1 Lg. Bag	23.00	90%	Seeds do not appear to be mature.
Descurainia sophioides	M.P. 398.7 Dalton Hwy	17 Aug 90	1 Sm. Bag	170.30	2%	Combined both into 1 seedlot, lg. bag not threshed.
Descurainia sophioides	M.P. 398.7 Dalton Hwy	17 Aug 90	1 Lg. Bag	"	"	Static electricity is problem in cleaning seedlot.
Draba corymbosa	72 Haul Road	26 Aug 90	Very Sm. Bag	0.52	1%	Small sample.
Epilobium latifolium	M.P. 395.9 Dalton Hwy	17 Aug 90	2 lg. Bags	17.59	10%	Problem cleaning, saved fluff.
" "	M.P. 21.5 TAPS-Spur Dike					
Epilobium latifolium	M.P. 405 Dalton Hwy	05 Aug 90	1 Lg. Bag	19.93	10%	Problem cleaning, saved fluff.
Epilobium latifolium	Dalton Hwy-395.9 & 405			2.95	5%	Fluff from both seedlots above combined and run
" "						through Fuzzbuster (delinter).
Eutrema edwardsii	72 Haul Road	26 Aug 90	Very Sm. Bag	5.06	1%	Good yield for small sample.
Hedysarum mackenzii	M.P. 369.25 Dalton Hwy	06 Aug 90	3 U.S. Bags	467.20	2%	Seeds still in pods, stored in U.S. Bag
" "	"	"	"	14.46	5%	Naked Seeds, stored in small jar.
Hedysarum mackenzii	M.P. 405 Dalton Hwy	06 Aug 90	1 U.S. Bag	127.57	2%	Seeds still in pods, stored in quart jar.
" "	"	"	"	3.14	5%	Naked Seeds, stored in small jar.
Hedysarum mackenzii	M.P. 405 Dalton Hwy	16 Aug 90	1 Lg. Bag	73.65	2%	Seeds still in pods, stored in quart jar.
" "	"	"	"	2.46	2%	Naked Seeds, stored in small jar.
Minuartia arctica	Arco State No. 1	15 Sep 90	Very Sm. Bag	0.05	1%	Maybe 20 seeds total

Table B-2. (Cont.) Species, locations, dates and data on threshing and cleaning of seeds collected during 1990

Species	Collection Location	Collection Date	Bulk Field Collection	Grams Cleaned Seedlot	Est. % Chaff in Cleaned Seedlot	Comments
FORBS (Cont.):						**Seedlots placed in freezer 18 Jan 1991.**
Minuartia obtusiloba " "	M.P. 354.5 Dalton Hwy- M.P. 62 TAPS-Dry Ridge	17 Sep 90	1 Sm. Bag	0.37	20%	Very tiny seeds.
Minuartia obtusiloba	M.P. 365 Dalton Hwy	06 Aug 90	#4 P Sack	0.71	30%	Very tiny seeds.
Oxytropis borealis	M.P. 405 Dalton Hwy	08 Aug 90	1 Lg. Bag	132.48	5%	Seed stored in 2 Jars.
Oxytropis borealis	M.P. 405 Dalton Hwy	16 Aug 90	1 Lg. Bag	68.45	2%	Seed cleans well.
Oxytropis nigrescens " "	Dunes between Endicott Pipeline and E-2 Pond	07 Aug 90	1 Sm. Bag	19.90	0%	Seed cleans well.
Oxytropis nigrescens " "	Dunes between Endicott Pipeline and E-2 Pond	09 Aug 90	1 U.S. Bag	75.61	0%	Seed cleans well.
Oxytropis nigrescens	Dunes West of E-2 Pond	09 Aug 90	3 U.S. Bags	209.03	0%	Seed cleans well.
Oxytropis nigrescens	Dunes West of E-2 Pond	22 Aug 90	1 Sm. Bag	8.39	0%	Seed cleans well.
Oxytropis nigrescens " "	Dunes E. Endicott Pipe -2nd Caribou Ramp	08 Aug 90	1 Sm. Bag	9.04	0%	Seed cleans well.
Pedicularis capitata	M.P. 405 Dalton Hwy	05 Aug 90	#2 P Sack	0.80	15%	Seeds appear shrivelled.
Pedicularis labradorica	M.P. 405 Dalton Hwy	05 Aug 90	#8 P Sack	1.41	15%	No comments.
Pedicularis lanata kanei	M.P. 405 Dalton Hwy	05 Aug 90	Large P Sack	30.60	10%	About half the seeds have pods still around them.
Polymonium boreale	East Dock Dunes	08 Aug 90	Very Sm. bag	4.00	2%	No comments.
Potentilla hookeriana	Big Skookum	13 Sep 90	1 Lg. Bag	3.99	1%	Very tiny seeds; poor yield for size of collection.
Primula borealis	Endicott Coastal	03 Aug 90	Letter Envelope	0.23	40%	Difficult to determine if seed is mature.
Saxifraga oppositifolia	Arco State No. 1	15 Sep 90	#4 P Sack	0.16	40%	No comments.
Saxifraga oppositifolia	Haul Road SE D.S. #5	19 Sep 90	Very Sm. Bag	0.18	40%	No comments.
Saxifraga tricuspidata " "	M.P. 354.5 Dalton Hwy M.P. 62 TAPS-Dry Ridge	17 Sep 90	1 Sm. Bag	1.91	5%	Very, very tiny seeds.
Sedum rosea	East Dock	09 Sep 90	1 Lg. Bag	15.28	1%	Good yield.
Sedum rosea	Big Skookum	13 Sep 90	2 Lg. Bags	8.92	20%	Fair yield.
Senecio congestus " "	M.P. 377.5 Dalton Hwy Franklin Bluffs Camp	17 Sep 90	1 Lg. Bag	12.15	50%	Difficult to determine between seed and chaff.
Silene acaulis	Arco State No. 1	15 Sep 90	1 Sm. Bag	3.88	15%	No comments.
Silene wahlbergella	1972 Haul Road	26 Aug 90	1 Sm. Bag	4.03	5%	No comments.
Wilhelmsia physoides	M.P. 401/405 Dalton Hwy.	05 Aug 90	#4 P Sack	0.91	5%	No comments.

Table B-2. (Cont.) Species, locations, dates and data on threshing and cleaning of seeds collected during 1990

Species	Collection Location	Collection Date	Bulk Field Collection	Grams Cleaned Seedlot	Est. % Chaff in Cleaned Seedlot	Comments
SHRUBS:						**Seedlots placed in freezer 28 Jan 1991**
Dryas integrifolia " "	East Dock Dunes	09 Sep 90	1 Lg. Bag	16.63	40%	Difficult to separate seed from fluff; used Fuzzbuster (delinter).
Dryas integrifolia " "	Endicott Road- Mid Caribou Ramp	21 Aug 90	1 Sm. Bag	1.71	40%	Difficult to separate seed from fluff; used Fuzzbuster.
Dryas integrifolia " "	Endicott Road- Mid Caribou Ramp	13 Sep 90	2 Lg. Bags	33.17	40%	Difficult to separate seed from fluff; Fuzzbuster utilized. Salix arctica seed accidently mixed in seedlot and then screened out, a few seeds may
Dryas octopetala " "	M.P. 354.5 Dalton Hwy M.P. 62 TAPS-Dry Ridge	17 Sep 90	Very Sm. Bag	1.67	100%	No viable seed detected.
Salix arctica " "	1972 Haul Road	10 Sep 90	1 Sm. Bag	1.36	35%	Difficult to separate seed from fluff; used Fuzzbuster.
Salix arctica " "	Endicott Road at West Caribou Ramp (End Terr)	13 Sep 90	1 Lg. Bag	2.78	5%	Seedlot accidently mixed with Dryas integrifolia. Screened to seperate seeds, a few Dryas seeds are still mixed with this seedlot. Used Fuzzbuster.
Salix ovalifolia " "	Dunes West of E-2 Pond	22 Aug 90	#12 P Sack	5.82	35%	Difficult to separate seed from fluff; used Fuzzbuster.
Salix ovalifolia " "	East Dock Dunes	08 Sep 90	1 Sm. Bag	2.78	45%	Extremely difficult to separate seed from fluff; maybe 50% removed. Used Fuzzbuster.
Salix ovalifolia " "	M.P. 405 Dalton Hwy	05 Aug 90	#4 P Sack	4.03	10%	Difficult to separate seed from fluff; used Fuzzbuster (delinter).

Summary of North Slope Native Seed Collection in 1990

Graminoids	= 21 species in 40 bulk field collections
Forbs	= 37 species in 62 bulk field collections
Shrubs	= 4 species in 9 bulk field collections
Totals	= 62 species in 111 bulk field collections

Table B-3. Species, locations, dates and data on threshing and cleaning of seed collected during 1991

Species	Collection Location	Collection 4/6/92	Bulk Field Collection	Grams Cleaned Seedlot	Est. % Chaff in Cleaned Seedlot	Comments
GRASSES:						
Agropyron boreale	Lisburne - NPRA	7/23/91	1 Sm. Bag	64.540	15%	Good yield
Agropyron boreale	M.P. 334.4 Dalton Highway	8/11/91	1/3 Lg. Bag	18.790	15%	Good yield
" "	Happy Valley Airstrip					
Agropyron boreale	Kuparuk River Bridge	9/3/91	1/2 Lg. Bag	3.907	90%	Very poor yield, 10% seed
Alopecurus alpinus	BP Put River No. 1	9/3/91	1 Sm. Bag	11.700	50%	Estimated 50% seed
Arctagrostis latifolia	Sag. River E. of Airport	9/15/91	2 Lg. Bags	1.596	50%	Few mature seeds, est. 90% chaff was blown off.
" "				0.632	?	Separate jar of enlarged seeds, possibly with
" "						Ergot kept with screened off trash.
Bromus pumpellianus	M.P. 334.4 Dalton Highway	8/11/91	1/10 Sm. Bag	0.000	100%	Immature, no seed in this seedlot
" "	-Happy Valley Airstrip					
Bromus pumpellianus	Mix from: M.P. 354.4	8/31/91	1/10 Sm. Bag	0.678	10%	Very few seeds, 90% pure
" "	(m.p. 62) & M.P. 324.6	9/1/91				
" "	(ice cut) Dalton Highway					
Bromus pumpellianus	Kuparuk River Bridge	9/3/91	1/3 Sm. Bag	0.000	100%	Immature, no seed at all - examined throughly
Calamagrostis canadensis	M.P. 334.4 Dalton Highway	8/11/91	1/10 Sm. Bag	0.000	100%	Immature, no seed
" "	-Happy Valley Airstrip					
Calamagrostis lapponica	M.P. 354.4 (m.p 62) and	8/31/91	1 Lg. Bag	9.750	100%	No seed found, appears to be trash. Saved chaff
" "	M.P. 352.8 (m.p. 64) D.H.					that was not blown off.
Calamagrostis purpurascens	M.P. 354.4 Dalton Highway	8/31/91	1/2 Sm. Bag	3.398	80%	Poor yield, appears to have approximately 20%
" "						viable seed.
Calamagrostis purpurascens	Mixed from: M.P. 354.4	8/31/91	1/10 Sm. Bag	0.664	75%	Very small sample, mostly immature
and lapponica	Dalton Highway					
Deschampsia caespitosa	Kuparuk River Bridge	9/3/91	2 Lg. Bags	14.280	100%	All is immature, 100% trash
Deschampsia caespitosa	M.P. 405 Dalton Highway	9/5/91	1 Lg. Bag	6.840	95%	Mostly trash, few seeds found by visual inspection
Elymus arenarius mollis	East Dock Dunes	9/15/91	1/3 Lg. Bag	11.190	90%	Most of seedlot is immature
Elymus innovatus	Franklin Bluffs on	8/10/91	1/3 Lg. Bag	2.392	100%	No seed but saved chaff sample
" "	squirrel mound					
Elymus innovatus	M.P. 365 Dalton Highway	8/30/91	2/3 Lg. Bag	9.900	100%	No seed but saved chaff sample
" "	on squirrel mound					
Elymus innovatus	M.P. 324.6 Dalton Highway	9/1/91	1/2 Lg. Bag	50.070	10%	Good yield, appears to be good quality seed
" "	(Turnoff at Ice Cut Sign)					
Elymus innovatus	M.P. 334.4 Dalton Highway	9/1/91	1 Sm. Bag	24.880	20%	Good yield, appears to be good quality seed
" "	Happy Valley Airstrip					
Festuca altaica	M.P. 334.4 Dalton Highway	8/11/91	1/10 Sm. Bag	1.531	10%	Fair yield, appears mature
" "	Happy Valley Gravelbar					
Festuca altaica	M.P. 324.6 Dalton Highway	9/1/91	1/3 Sm. Bag	1.928	10%	Fair yield, appears mature
" "	(Turnoff at Ice Cut Sign)					
Festuca baffinensis	BP Put River No. 1	9/3/91	1 Sm. Bag	7.423	30%	30% Trash or immature seed

Table B-3. (Cont.) Species, locations, dates and data on threshing and cleaning of seed collected during 1991

Species	Collection Location	Collection 4/6/92	Bulk Field Collection	Grams Cleaned Seedlot	Est. % Chaff in Cleaned Seedlot	Comments
GRASSES (Cont.):						
Festuca ovina	East Dock Dunes	9/4/91	1 Sm. Bag	1.848	95%	2 mature seeds found in visual inspection of 40
Festuca rubra	M.P. 334.4 Dalton Highway	8/11/91	1/3 Lg. Bag	6.567	40%	Some seeds appear green and shriveled, immature
" "	Happy Valley Gravelbar					
Festuca rubra	M.P. 334.4 Dalton Highway	9/1/91	1/3 Sm. Bag	5.591	10%	Good yield, appears to be mature seed
" "	Happy Valley Gravelbar					
Festuca rubra	Kuparuk River Bridge	9/3/91	1 Sm. Bag	1.093	75%	Mostly immature seed
Festuca 'vivipara'	BP Put River No. 1	9/3/91	2 Lg. Bags	43.320	50%	Impossible to visually determine quality of seed
Hierochloe alpina	Franklin Bluffs	8/10/91	1/10 Sm. Bag	0.074	20%	Very small sample, only a few seeds, appears mature
Hierochloe alpina	M.P. 354.4 (m.p 62) and	8/31/91	1/2 Lg. Bag	5.540	20%	Poor yield, mostly shattered prior to harvest
" "	M.P. 352.8 (m.p. 64) D.H.					
Poa alpigena	Kuparuk River Bridge	9/3/91	1/2 Sm. Bag	4.920	100%	No seed, all appears immature
Poa arctica	East Dock Dunes	9/4/91	1 Lg. Bag	6.466	100%	No seed, all appears immature
Poa glauca	Franklin Bluffs	8/10/91	2/3 Lg. Bag	4.116	100%	No seed, all appears immature
" "	on squirrel mounds					
Poa glauca	M.P. 354.4 Dalton Highway	8/31/91	1/2 Lg. Bag	6.831	5%	Poor yield, appears mature and of good quality
Poa glauca	BP Put River No. 1	9/3/91	1 Sm. Bag	2.100	99%	No seed, appears immature
Poa glauca	Kuparuk River Bridge	9/3/91	1 Sm. Bag	2.496	100%	No seed, appears immature
Poa glauca	Endicott Road - 1/2 mile	9/4/91	1 Lg. Bag	13.340	95%	Unable to identify any mature or viable seed
" "	East of Duck Island Gravel					
" "	Pit on squirrel mounds					
Puccinellia langeana	BP Put River No. 1	9/3/91	2 Lg. Bags	50.190	20%	Fair yield, maturity varies, some seed is small
Trisetum spicatum	Franklin Bluffs	8/10/91	1/10 Sm. Bag	1.437	50%	Some seed is green, may be immature
Trisetum spicatum	M.P. 352.8 Dalton Highway	8/31/91	1/10 Sm. Bag	0.633	25%	Appears mature
" "	(Rocky Ridge at m.p. 64)					
Trisetum spicatum	BP Put River No. 1	9/3/91	1/2 Lg. Bag	6.720	50%	Poor yield, mostly immature
FORBS:						
Arnica alpina	Franklin Bluffs	8/10/91	1/10 Sm. Bag	0.024		42 seeds total
Artemisia arctica	M.P. 346.4 Dalton Highway	9/1/91	1 Sm. Bag	17.932	2%	Fair yield, seed appears mature
" "	collection site N. 1.2 mi.					
" "	along pipeline to Sag. R.					
Artemisia arctica	Between E2-NA Pond and	9/4/91	1 Sm. Bag	1.281	30%	Very poor yield, mostly immature
" "	Endicott Road					
Artemisia arctica	M.P. 405 Dalton Highway	9/5/91	1/2 Lg. Bag	7.225	100%	Poor yield
Artemisia arctica	M.P. 377.5 Dalton Highway	9/11/91	1/3 Lg. Bag	11.373	1%	Fair yield
" "	Franklin Bluffs Camp					
Artemisia borealis	Put #23 Gravel Mine Pit	9/4/91	2 Lg. Bags	83.810	1%	Good yield
Artemisia borealis	M.P. 405 Dalton Highway	9/5/91	1/2 Lg. Bag	11.265	25%	Fair yield

Table B-3. (Cont.) Species, locations, dates and data on threshing and cleaning of seed collected during 1991

Species	Collection Location	Collection 4/6/92	Bulk Field Collection	Grams Cleaned Seedlot	Est. % Chaff in Cleaned Seedlot	Comments
FORBS (Cont.):						
Artemisia glomerata	Kuparuk River Bridge	9/3/91	1 Sm. Bag	2.712	5%	Poor yield, some dirt in seed sample
Artemisia tilesii " "	M.P. 334.4 Dalton Highway Happy Valley Gravel Bar	9/1/91	1/10 Sm. Bag	0.370	99%	20-30 seeds found, may be immature
Artemisia tilesii	Kuparuk River Bridge	9/3/91	1/10 Sm. Bag	0.000		No seed, no sample saved
Aster sibericus " " " "	M.P. 346.4 Dalton Highway collection site N. 1.2 mi. along pipeline to Sag. R.	9/1/91	1/2 Sm. Bag	6.956	60%	Difficult to clean, somewhat immature
Aster sibericus " "	M.P. 334.4 Dalton Highway Happy Valley gravel bar	8/11/91	1/10 Sm. Bag	1.418	70%	Seed appears mostly immature
Astragalus aboriginum " "	M.P. 395.9 Dalton Highway (M.P. 21.5 TAPS Spur Dike)	8/9/91	1 Sm. Bag	7.564	2%	Green seeds, appear immature
Astragalus alpinus " "	M.P. 395.9 Dalton Highway (M.P. 21.5 TAPS Spur Dike)	8/9/91	1/3 Sm. Bag	5.415	40%	Green seeds, poor yield
Astragalus alpinus " "	M.P. 395.9 Dalton Highway (M.P. 21.5 TAPS Spur Dike)	9/5/91	1/4 Sm. Bag	5.115	20%	Green seeds, poor yield
Astragalus nutzotinensis " "	M.P. 395.9 Dalton Highway (M.P. 21.5 TAPS Spur Dike)	8/9/91	1/3 Sm. Bag	6.839	15%	Seed not uniform, odd shapes and sizes
Astragalus nutzotinensis " "	M.P. 395.9 Dalton Highway (M.P. 21.5 TAPS Spur Dike)	9/5/91	1/4 Sm. Bag	6.709	15%	Odd shapes, sizes, and color of seed. Some sand.
Castilleja elegans " "	M.P. 334.4 Dalton Highway Happy Valley Gravel Bar	9/1/91	1 Sm. Bag (full)	14.900	50%	Hard to clean out trash
Cerastium beeringianum	BP Put River No. 1	9/3/91	1/2 Sm. Bag	1.682	1%	Appears to be good seed
Epilobium latifolium " "	M.P. 334.4 Dalton Highway Happy Valley Gravel Bar	8/11/91	1 Lg. Bag (full)	12.808	2%	Apears good, fair yield
Eriophorum scheuchzeri	BP Put River No. 1	9/3/91	1 Lg. Bag	10.455	10%	Appears mature, fair yield
Geum glaciale	Franklin Bluffs	8/10/91	1/2 Sm. Bag	1.161	100%	No seed
Hedysarum mackenzii " "	M.P. 334.4 Dalton Highway Happy Valley Gravel Bar	8/11/91	1/2 Lg. Bag	11.611	23%	Appears mature, green seed
Hedysarum mackenzii " "	M.P. 334.4 Dalton Highway Happy Valley Gravel Bar	9/1/91	1/3 Sm. Bag	9.343	5%	Appears mature, fair yield. Seed stripped from plants
Lagotis glauca	Franklin Bluffs	8/10/91	1/10 Sm. Bag	0.617	90%	Very few seeds, perhaps a dozen
Lupinus arcticus	Franklin Bluffs	8/10/91	1/10 Sm. Bag	0.119	0%	12-15 seedpods, 20 seeds
Minuartia obtusiloba	Franklin Bluffs	8/10/91	1/10 Sm. Bag	0.253	100%	No seed
Minuartia obtusiloba " "	M.P. 354.5 Dalton Highway Dry Tundra Ridge	8/31/91	1/3 Sm. Bag	0.901	20%	Poor yield, may have shattered prior to collection

Table B-3. (Cont.) Species, locations, dates and data on threshing and cleaning of seed collected during 1991

Species	Collection Location	Collection 4/6/92	Bulk Field Collection	Grams Cleaned Seedlot	Est. % Chaff in Cleaned Seedlot	Comments
FORBS (Cont.):						
Oxytropis borealis	M.P. 405 Dalton Highway	9/5/91	1 Sm. Bag	9.160	43%	Poor yield, lots of trash and dirt
Oxytropis campestris	M.P. 324.6 Dalton Highway	9/1/91	1 Sm. Bag	16.069	1%	Fairly pure seed, fair yield
" "	(Turnoff at Ice Cut Sign)					
Pedicularis capitata	M.P. 405 Dalton Highway	8/9/91	1/10 Sm. Bag	4.043	40%	May be immature
Pedicularis verticillata	M.P. 324.6 Dalton Highway	9/1/91	1 Sm. Bag	10.416	5%	Seed appears mature, good yield
" "	(Turnoff at Ice Cut Sign)					
Polygonum bistorta	M.P. 354.5 Dalton Highway	8/30/91	1/3 Sm. Bag	8.937	7%	Seed appears mature good yield
Polygonum bistorta	Along low bluff between	8/30/91	1/3 Sm. Bag	10.382	9%	Seed appears mature good yield
" "	M.P. 364.7 & 365 Dalton Hwy.					
Potentilla biflora	Franklin Bluffs	8/10/91	1/10 Sm. Bag	0.314	0%	Only a few green colored seeds
Saussurea angustifolia	Along low bluff between	8/30/91	1 Lg. Bag	25.500	40%	Very difficult to clean, some seeds appear to be broken by use of the fuzzbuster
" "	M.P. 364.7 & 365 Dalton Hwy.					
Saxifraga bronchialis	Franklin Bluffs	8/10/91	1/3 Sm. Bag	0.305	80%	Very tiny green seed, all appear to be immature
Saxifraga tricuspidata	M.P. 354.5 Dalton Highway	8/31/91	1/2 Sm. Bag	1.469	20%	Very small seeds
" "	Dry Tundra Ridge					
Senecio congestus	M.P. 377.5 Dalton Highway	9/11/91	1/2 Lg. Bag	8.413	43%	Hard to clean, appears mature
" "	Franklin Bluffs Camp					
Zygadenus elegans	M.P. 324.6 Dalton Highway	9/1/91	1/3 Lg. Bag	12.720	5%	Appears mature
" "	(Turnoff at Ice Cut Sign)					
SHRUBS:						
Cassiope tetragona	Franklin Bluffs	8/10/91	1/3 Sm. Bag	0.000		No seed, sample saved
Dryas octopetala	Franklin Bluffs	8/10/91	1/2 Sm. Bag	4.688	30%	Seed appears mature
Empetrum nigram (in Bear Feces)	M.P. 324.6 Dalton Highway (Turnoff at Ice Cut Sign)	9/11/91	1 Lg. Bag (frozen)	1.930	2%	Contained some hulless Sheperdia seed, below
Salix glauca	M.P. 334.4 Dalton Highway	8/11/91	1 Sm. Bag	14.320	5%	Seed well-formed and ppears mature
" "	Happy Valley Gravel Bar					
Salix ovalifolia	East Dock Dunes	9/4/91	1/4 Sm. Bag	1.141	35%	Seed appears mature
Salix ovalifolia	M.P. 405 Dalton Highway	9/5/91	1/2 Sm. Bag	4.588	20%	Good seed
Salix pulchra	Inigok TW #1 - NPRA	7/18/91	1/3 Sm. Bag	0.674	5%	Small sample

Table B-3. (Cont.) Species, locations, dates and data on threshing and cleaning of seed collected during 1991

Species	Collection Location	Collection 4/6/92	Bulk Field Collection	Grams Cleaned Seedlot	Est. % Chaff in Cleaned Seedlot	Comments
SHRUBS (Cont.):						
Shepherdia canadensis " "	M.P. 324.6 Dalton Highway (Turnoff at Ice Cut Sign)	9/11/91	1/10 Sm. Bag	4.122	0%	Recovered all seed
Shepherdia canadensis (in Bear Feces)	M.P. 324.6 Dalton Highway (Turnoff at Ice Cut Sign)	9/11/91	1 Lg. Bag (frozen)	150.960	0%	Seed appears good, mixed with Empetrum seed, above

Summary of North Slope Native Seed Collection for 1991

Grasses	=	21 species in 40 bulk field collections
Forbs	=	29 species in 40 bulk field collections
Shrubs	=	7 species in 9 bulk field collections
Total	=	57 species in 89 bulk field collections

Table B-4. Species, location, date, and data on threshing and cleaning of seed collected in Russia during 1991

Species	Collection Location	Collection Date	Bulk Field Collection	Grams Cleaned Seedlot	Est. % Chaff in Cleaned Seedlot	Comments
GRASSES:						
Alopecurus	Yamal Peninsula	8/20/91	Full film Canister	4.290	0%	Species not designated.
Deschampsia	Yamburg	8/24/91	Small sample	4.210	0%	Species not designated; mixed with Pubescent Red Fescue from Navy Post Plots.
Festuca rubra?	Yamburg	8/19/91	Full film canister	2.461	5%	Not sure of species.
Festuca (Pubescent Red Fescue)	Navy Post Plots	8/20/91	Small sample	1.440	0%	Species not designated; mixed with Deschampsia from Yamburg.
FORBS:						
Artemisia tilesii	Yamburg	8/24/91	Small sample	13.332	1%	Good yield, a few Senecio seed mixed in, left
Hedysarum alpinum	Yamburg	8/17/91	1/4 Film Canister	0.581	1%	Probably immature.
" "						
Hedysarum alpinum	Yamburg	8/18/91	Medium Glass Jar	4.640	1%	
Senecio congestus	Yamburg	8/24/91	Small sample			A few seed mixed with Artemisia tilesii sample
Tanacetum bipinnatum	Yamburg	8/19/91	Medium Glass Jar	7.470	35%	Same plant as Chrysanthemum bipinnatum (Welsh p. 170)
Tripleurospermum phaeocephalum	Nadym	8/15/91	1/2 Film Canister	1.222	20%	Wild Camomile

Summary of native seeds collected in Russia during 1991

Grasses = 4 species in 4 field collections
Forbs = 5 species in 6 field collections

Total = 9 species in 10 field collections

APPENDIX C

GERMINATION DATA

Tables C-1 and C-2 list the results of germination tests for seed collected in 1989 and 1990, respectively. By counting out a specific number of seeds (300 in 1989 and 320 in 1990) and weighing them, then dividing the number by the weight, the number of seeds per gram was determined. The germination rate was derived from the mean of the three replicates (100 seeds tested per replicate). The seedlots consist of species by collection location and date since both can effect the viability of seeds. Harvested seed was placed in the deep freeze for at least 2 weeks after being threshed and cleaned. Seeds selected for germination trials were treated with clorox bleach for 5 minutes, rinsed with water and placed in a refrigerator for 6 days prior to being put in the germinator. Seeds were watered with a captan solution (1/2 g per quart) to control molds. The germinator was set for 16 hours of light at a temperature of 20 °C and 8 hours of darkness at a temperature of 13 °C. Seeds were monitored daily during the germination trials so rate of germination could be determined. Germination tests were also run on different sized seeds from selected species/collections and for different seed treatments.

Table C-1. Germination record for North Slope native seeds collected in 1989

Species	Collection Location	Collection Date	Seeds/ Germ. Test	Grams/ Germ. Test	No. Seeds/ Gram	Date in Refrig.	Monitoring Dates in Germinator	No. Seeds Germinated REP I	REP II	REP III	Average Percent Germ.
GRASSES:											
Agropyron boreale	B.P. Put River No. 1	8/24/89	300	1.259	238	5/21/90	5/28 - 6/14	98	96	92	95.3
Agropyron boreale	Kuparuk River Bridge	8/25/89	300	1.068	281	5/21/90	5/28 - 6/14	99	99	99	99.0
Alopecurus alpinus	B.P. Put River No. 1	8/24/89	300	0.258	1163	5/16/90	5/22 - 6/14	95	92	92	93.0
Alopecurus alpinus	Pump Station No. 1	9/27/89	300	0.1	2083	5/31/90	6/6 - 6/19	30	23	32	28.3
Alopecurus alpinus	IBP Plots	8/26/89	300	0.258	1163	5/3/90	5/9 - 5/29	88	89	93	90.0
Arctagrostis latifolia	M.P. 31 Dalton Highway	9/19/89	300	0.081	3704	5/11/90	5/17 - 5/30	79	80	81	80.0
Arctagrostis latifolia	Pump Station No. 1	9/27/89	300	0.075	4000	5/7/90	5/13 - 5/26	73	64	69	68.7
Arctagrostis latifolia	Sag. River E. of Airport	9/27/89	300	0.092	3261	5/3/90	5/9 - 5/23	99	97	98	98.0
Arctagrostis latifolia	IBP Plots	8/26/89	300	0.071	4225	5/3/90	5/9 - 5/23	60	50	55	55.0
Arctagrostis latifolia	72 Haul Road-introduced	9/26/89	300	0.082	3659	5/7/90	5/13 - 5/30	89	86	90	88.3
Bromus pumpellianus	Kuparuk River Bridge	8/25/89	300	1.149	261	5/3/90	5/9 - 5/29	91	93	91	91.7
Deschampsia beringensis	IBP Plots-introduced	8/26/89	300	0.064	4688	6/11/90	6/17 - 7/16	2	1	0	1.0
Deschampsia caespitosa	1972 Haul Road	8/29/89	300	0.098	3061	5/7/90	5/13 - 5/26	93	96	97	95.3
Deschampsia caespitosa	Kuparuk Haul Road North	8/29/89	300	0.096	3125	5/11/90	5/17 - 5/30	96	89	91	92.0
" "	of Arco Storage Pad										
Deschampsia caespitosa	Kuparuk River Bridge	8/25/89	300	0.098	3061	5/11/90	5/17 - 5/30	95	96	91	94.0
Deschampsia caespitosa	Sohio-Kuparuk Reserve Pit	8/29/89	300	0.100	3000	5/3/90	5/9 - 5/23	97	92	95	94.7
Dupontia fisheri	Pump Station No. 1	9/27/89	300	0.274	1095	5/16/90	5/22 - 6/14	87	84	92	87.7
Elymus arenarius mollis	East Dock Dunes	9/25/89	300	1.824	164	5/31/90	6/6 - 6/19	100	99	93	97.3
Festuca brachyphylla	Sohio-Kuparuk Reserve Pit	8/29/89	300	0.169	1775	5/3/90	5/9 - 5/28	89	89	89	89.0
Festuca brachyphylla	IBP Plots	8/26/89	300	0.180	1667	5/16/90	5/22 - 6/14	83	91	92	88.7
Festuca ovina	East Dock Dunes	9/25/89	300	0.287	1045	5/16/90	5/22 - 6/12	87	87	86	86.7
Festuca rubra	Kuparuk River Bridge	8/25/89	300	0.2	1370	5/21/90	5/28 - 6/19	57	73	55	61.7
Festuca rubra	IBP Plots-introduced	8/26/89	300	0.2	1546	5/21/90	5/28 - 6/19	57	60	66	61.0
Festuca 'vivipara'	B.P. Put River No. 1	8/24/89	300	1.004	299	5/11/90	5/17 - 6/8	72	81	83	78.7
Poa arctica	East Dock Dunes	9/25/89	300	0.138	2174	5/7/90	5/13 - 5/29	86	88	87	87.0
Poa glauca	1972 Haul Road	8/29/89	300	0.106	2830	5/11/90	5/17 - 5/31	94	97	97	96.0
Poa glauca	IBP Plots	8/26/89	300	0.098	3061	5/11/90	5/17 - 5/30	93	88	94	91.7
Poa pratensis	IBP Plots-introduced	8/26/89	300	0.107	2804	5/7/90	5/13 - 6/2	95	92	86	91.0
Puccinellia langeana	B.P. Put River No. 1	8/24/89	300	0.045	6667	5/3/90	5/9 - 5/23	97	96	97	96.7
Puccinellia langeana	IBP Plots	8/26/89	300	0.045	6667	5/7/90	5/13 - 5/24	96	98	98	97.3

Table C-1. (Cont.) Germination record for North Slope native seeds collected in 1989

Species	Collection Location	Collection Date	No. Seed in Germ. Test	Grams/ Germ. Test	No. Seeds/ Gram	Date in Refrig.	Monitoring Dates in Germinator	No. Seeds Germinated REP I	REP II	REP III	Average Percent Germ.
GRASSES (Cont.):											
Trisetum spicatum *1	B.P. Put River No. 1	8/24/89	300	0.100	3000	5/3/90	5/9 - 5/29	84	84	96	88.0
Trisetum spicatum	IBP Plots	8/26/89									
GRASSLIKE:											
Carex maritima	72 Haul Road	8/31/89	300	0.270	1111	5/7/90	5/13 - 6/7	94	93	98	95.0
Carex maritima	B.P. Put River No. 1	8/27/89	300	0.203	1478	5/21/90	5/28 - 6/19	96	96	96	96.0
Carex maritima	Sohio-Kuparuk Reserve Pit	8/29/89	300	0.236	1271	5/31/90	6/6 - 7/6	95	96	92	94.3
Luzula arctica	Arco State No. 1	8/30/89	150	0.033	4545	6/11/90	6/17 - 7/16	1	5	1	4.7
FORBS:											
Androsace chamaejasme	72 Haul Road	8/31/89	150	0.099	1515	6/11/90	6/17 - 7/16	0	0	0	0.0
Armeria maritima	Arco Discovery Well Site	9/7/89	300	0.388	773	5/16/90	5/22 - 6/11	57	67	55	59.7
Armeria maritima	72 Haul Road and L Put R.	8/31/89	150	0.191	785	5/21/90	5/28 - 6/14	40	44	49	88.7
Artemisia arctica	Kuparuk River Bridge	8/25/89	300	0.157	1911	5/31/90	6/6 - 6/12	99	100	100	99.7
Artemisia arctica	M.P. 40 Dalton Highway	9/19/89	300	0.136	2206	5/31/90	6/6 - 6/19	77	81	80	79.3
Artemisia borealis	Kuparuk River Bridge	8/25/89	300	0.149	2013	5/31/90	6/6 - 6/13	99	96	97	97.3
Artemisia glomerata	Kuparuk River Bridge	8/25/89	300	0.121	2479	5/16/90	5/22 - 6/7	93	95	100	96.0
Artemisia tilesii	Kuparuk River Bridge	8/25/89	150	0.051	2941	6/11/90	6/17 - 7/6	41	40	38	79.3
Aster sibericus	Sag. River E. of Airport	9/28/89	300	0.084	3571	5/16/90	5/22 - 7/6	43	42	57	47.3
Braya pilosa & purpurascens	Put R. #27 Gravel Pit	8/27/89	300	0.039	7692	5/7/90	5/13 - 6/7	6	12	14	10.7
Braya pilosa & purpurascens	72 Haul Road	8/28/72	300	0.063	4762	6/11/90	6/17 - 7/30	23	24	21	22.7
Cerastium beeringianum	72 Haul Road	9/26/89	300	0.037	8108	6/11/90	6/17 - 7/2	95	93	94	94.0
Chrysanthemum bipinnatum *2	Kuparuk River Bridge	8/25/89	300			6/11/90	6/17 - 7/16	0	3	2	1.7
Descurainia sophioides	Sohio-Kuparuk Reserve Pit	8/29/89	300	0.021	14286	5/31/90	6/6 - 6/19	45	73	83	67.0
Draba spp. (White-Flowered)	B.P. Put River No. 1	8/27/89	300	0.046	6522	5/31/90	6/6 - 6/19	11	5	11	9.0
Epilobium latifolium	B.P. Put River No. 1	8/27/89	300	0.042	7143	5/21/90	5/28 - 6/14	91	91	91	91.0
Epilobium latifolium	Put River #27 Gravel Pit	8/27/89	300	0.043	6977	5/31/90	6/6 - 6/19	87	91	86	88.0

*1 Trisetum seedlots were mixed together because of their close proximity and similar harvest dates.
*2 Seeds were immature, lots were not weighed

Table C-1. (Cont.) Germination record for North Slope native seeds collected in 1989

Species	Collection Location	Collection Date	No. Seed in Germ. Test	Grams/ Germ. Test	No. Seeds/ Gram	Date in Refrig.	Monitoring Dates in Germinator	No. Seeds Germinated REP I	REP II	REP III	Average Percent Germ.
FORBS (Cont.):											
Eutrema edwardsii	Arco State No. 1	8/30/89	300	0.150	2000	5/21/90	5/28 - 6/16	23	41	32	32.0
Eutrema edwardsii	B.P. Put River No. 1	8/27/89	300	0.184	1630	5/16/90	5/22 - 6/12	0	0	0	0.0
Melandrium apetalum	72 Haul Road	8/31/89	300	0.097	3093	5/3/90	5/9 - 5/29	3	3	4	3.3
Parrya nudicaulis	Sag. River E. of Airport	9/27/89	300	0.989	303	5/11/90	5/17 - 6/8	0	2	3	1.7
Pedicularis sudetica	72 Haul Road	8/31/89	150	0.117	1282	6/11/90	6/17 - 7/16	0	2	1	2.0
Polymonium boreale	B.P. Put River No. 1	8/24/89	150	0.320	469	6/11/90	6/17 - 7/30	38	26	23	58.0
Sedum rosea	Big Skookum	9/20/89	300	0.045	6667	5/11/90	5/17 - 5/30	77	84	80	80.3
Senecio congestus	M.P. 40 Dalton Highway	9/19/89	300	0.046	6522	5/21/90	5/28 - 6/14	68	71	71	70.0
Silene acaulis	Arco State No. 1	8/30/89	300	0.135	2222	5/7/90	5/13 - 6/7	1	0	4	1.7

Summary of germination tests on seeds collected in 1989

Graminoids	=	19 species in 36 seedlots
Forbs	=	22 species in 26 seedlots
Totals	=	41 species in 66 seedlots

Average Germ. Gramnoids	81.5
Average Germ. Forbs	49.2

Table C-2. North Slope native seed germination record for seeds collected during 1990

Species	Collection Location	Collection Date	No. Seeds in Test	Grams/ 320 Seeds	Seeds/ Gram Tested	Date in Refrig.	Monitoring Dates in Germinator	No. Seeds Germinated Rep I	Rep II	Rep III	Average Percent Germ.
GRASSES:											
Agropyron boreale	Kuparuk River Bridge	14 Sep 90	320	0.679	471	14 Feb 91	02/20 - 03/16	59	55	57	57.0%
Alopecurus alpinus	1972 Haul Road	10 Sep 90	320	0.054	5926	14 Feb 91	02/20 - 03/06	5	2	9	5.3%
Alopecurus alpinus	East Dock Dunes	08 Sep 90	320	0.119	2689	14 Feb 91	02/20 - 03/07	22	27	23	24.0%
Arctagrostis latifolia	Kuparuk River Bridge	14 Sep 90	320	0.060	5333	14 Feb 91	02/20 - 03/07	22	24	18	21.3%
Arctagrostis latifolia	Pump Station No. 1	11 Sep 90	320	0.057	5614	14 Feb 91	02/20 - 03/09	47	41	52	46.7%
Arctagrostis latifolia	Sag. River E. of Airport	18 Sep 90	320	0.070	4571	14 Feb 91	02/20 - 03/09	73	78	83	78.0%
Arctophila fulva	Lonnie Lake East	26 Sep 90	320	0.086	3721	14 Feb 91	02/20 - 03/06	95	89	95	93.0%
Arctophila fulva	Pump Station No. 1	11 Sep 90	320	0.088	3636	14 Feb 91	02/20 - 03/06	68	70	63	67.0%
Bromus pumpellianus	End Rd-S. of B.S.	13 Sep 90	320	0.434	737	14 Feb 91	02/20 - 03/04	0	0	0	0.0%
Bromus pumpellianus	Kuparuk River Bridge	14 Sep 90	320	0.625	512	14 Feb 91	02/20 - 03/04	0	0	0	0.0%
Bromus pumpellianus	M.P. 365 Dalton Highway	06 Aug 90	320	1.160	276	14 Feb 91	02/20 - 03/04	93	93	93	93.0%
Calamagrostis inexpansa	Kuparuk River Bridge	14 Sep 90	320	0.042	7619	14 Feb 91	02/20 - 03/04	0	0	0	0.0%
Deschampsia caespitosa	1972 Haul Road	10 Sep 90	320	0.062	5161	23 Feb 91	03/01 - 03/16	43	38	49	43.3%
Deschampsia caespitosa	End. Rd-W. Caribou Ramp	13 Sep 90	320	0.042	7619	23 Feb 91	03/01 - 03/16	5	2	8	5.0%
Deschampsia caespitosa	Kuparuk River Bridge	14 Sep 90	320	0.060	5333	23 Feb 91	03/01 - 03/16	41	45	43	43.0%
Deschampsia caespitosa	Pump Station No. 1	11 Sep 90	320	0.072	4444	23 Feb 91	03/01 - 03/16	60	54	61	58.3%
Deschampsia caespitosa	Sag. River E. of Airport	18 Sep 90	320	0.073	4384	23 Feb 91	03/01 - 03/16	87	91	87	88.3%
Dupontia fisheri	Pump Station No. 1	11 Sep 90	320	0.200	1600	23 Feb 91	03/01 - 03/16	87	87	78	84.0%
Elymus arenarius mollis *1	East Dock Dunes	14 Jul 90	320	2.010	159	23 Feb 91	03/01 - 03/16	85	90	82	85.7%
Elymus arenarius mollis	East Dock Dunes	07 Sep 90	320	2.032	157	23 Feb 91	03/01 - 03/25	79	76	75	76.7%
Elymus innovatus	M.P. 365 Dalton Highway	06 Aug 90	320	1.467	218	23 Feb 91	03/01 - 03/25	74	82	75	77.0%
Festuca baffinensis	1972 Haul Road	10 Sep 90	320	0.186	1720	23 Feb 91	03/01 - 03/29	86	69	77	77.3%
Festuca baffinensis	End Rd-S. of B.S.	13 Sep 90	320	0.132	2424	23 Feb 91	03/01 - 04/03	24	42	24	30.0%
Festuca ovina	East Dock Dunes	08 Sep 90	320	0.176	1818	23 Feb 91	03/01 - 03/29	10	6	13	9.7%
Festuca rubra	End Rd-S. of B.S.	13 Sep 90	320	0.142	2254	23 Feb 91	03/01 - 03/27	1	2	1	1.3%
Festuca rubra	Kuparuk River Bridge	14 Sep 90	320	0.156	2051	23 Feb 91	03/01 - 03/27	1	0	0	0.3%
Festuca 'vivipara'	1972 Haul Road	10 Sep 90	320	0.139	2302	01 Mar 91	03/07 - 04/03	8	14	11	11.0%
Festuca 'vivipara'	East Dock	29 Aug 90	320	0.158	2025	01 Mar 91	03/07 - 04/03	14	7	7	9.3%
Poa arctica	East Dock Dunes	07 Sep 90	320	0.126	2540	01 Mar 91	03/07 - 04/01	61	58	41	53.3%
Poa arctica	End Rd-S. of B.S.	13 Sep 90	320	0.076	4211	01 Mar 91	03/07 - 03/27	20	25	13	19.3%

*1 1989 seedcrop collected in 1990

Table C-2. (Cont.) North Slope native seed germination record for seeds collected during 1990

Species	Collection Location	Collection Date	No. Seeds in Test	Grams/ 320 Seeds	Seeds/ Gram Tested	Date in Refrig.	Monitoring Dates in Germinator	No. Seeds Germinated Rep I	Rep II	Rep III	Average Percent Germ.
GRASSES (Cont.):											
Poa glauca	1972 Haul Road	10 Sep 90	320	0.078	4103	01 Mar 91	03/07 - 03/27	3	0	3	2.0%
Poa glauca	1 mile W-W Caribou Ramp	13 Sep 90	320	0.063	5079	01 Mar 91	03/07 - 04/01	56	50	61	55.7%
Poa pratensis	1972 Haul Road-introduced	10 Sep 90	320	0.057	5614	20 Mar 91	03/26 - 04/12	4	5	2	3.7%
Puccinellia langeana	East Dock	29 Sep 90	320	0.061	5246	01 Mar 91	03/07 - 04/01	48	50	55	51.0%
Trisetum spicatum	1972 Haul Road	10 Sep 90	320	0.079	4051	01 Mar 91	03/07 - 04/10	53	59	56	56.0%
Trisetum spicatum	Kuparuk River Bridge	14 Sep 90	320	0.104	3077	20 Mar 91	03/26 - 05/02	54	49	53	52.0%
Trisetum spicatum *2	M.P. 62 TAPS-dry ridge	16 Jul 90	118	0.073	1616	20 Mar 91	03/26 - 04/24	30			25.4%
GRASSLIKE:											
Carex maritima	East Dock	09 Sep 90	320	0.200	1600	20 Mar 91	03/26 - 05/06	26	22	23	23.7%
Carex maritima	East Dock Dunes	08 Sep 90	320	0.214	1495	20 Mar 91	03/26 - 05/04	89	83	87	86.3%
Carex ursina	East Dock	10 Sep 90	320	0.141	2270	20 Mar 91	03/26 - 05/29	79	72	59	70.0%
FORBS:											
Androsace chamaejasme	72 Haul Road	26 Aug 90	320	0.180	1778	20 Mar 91	03/26 - 04/17	1	0	0	0.3%
Androsace chamaejasme	East Dock Dunes	09 Sep 90	320	0.110	2909	20 Mar 91	03/26 - 04/17	0	0	0	0.0%
Androsace chamaejasme	M.P. 405 Dalton Hwy	05 Aug 90	320	0.151	2119	20 Mar 91	03/26 - 04/17	1	1	3	1.7%
Arabis arenicola	M.P. 405 Dalton Hwy	05 Aug 90	320	0.027	11852	20 Mar 91	03/26 - 04/06	53	61	61	58.3%
Armeria maritima	East Dock Dunes	09 Sep 90	320	0.287	1115	20 Mar 91	03/26 - 04/06	22	23	18	21.0%
Armeria maritima	Kuparuk River Bridge	14 Sep 90	320	0.315	1016	20 Mar 91	03/26 - 04/06	59	58	57	58.0%
Armeria maritima	M.P. 405 Dalton Hwy	05 Aug 90	320	0.328	976	20 Mar 91	03/26 - 04/06	36	50	46	44.0%
Armeria maritima	Sag. R. E. of Airport	18 Sep 90	320	0.332	964	20 Mar 91	03/26 - 04/06	72	66	66	68.0%
Artemisia arctica	East Dock Dunes	09 Sep 90	320	0.109	2936	20 Mar 91	03/26 - 04/05	96	97	99	97.3%
Artemisia arctica	Kuparuk River Bridge	14 Sep 90	320	0.121	2645	20 Mar 91	03/26 - 04/04	100	100	98	99.3%
Artemisia arctica	Franklin Bluffs Camp	17 Sep 90	320	0.122	2623	20 Mar 91	03/26 - 04/04	99	97	100	98.7%
Artemisia borealis *2	Kuparuk River Bridge	14 Sep 90	60	0.023	2609	29 Mar 91	04/04 - 04/10	56			93.3%
Artemisia borealis	Put #23 Gravel Mine Pit	19 Sep 90	150	0.063	2381	29 Mar 91	04/04 - 04/10	38	42	37	78.0%
Artemisia glomerata	Kuparuk River Bridge	14 Sep 90	320	0.131	2443	29 Mar 91	04/04 - 04/17	94	96	90	93.3%
Artemisia glomerata	M.P. 405 Dalton Hwy	05 Aug 90	320	0.135	2370	29 Mar 91	04/04 - 04/24	96	98	93	95.7%
Artemisia tilesii *3	Kuparuk River Bridge	14 Sep 90	320	0.045	7111	29 Mar 91	04/04 - 04/12	0	0	0	0.0%

*2 Only enough seed for 1 replicate
*3 Seeds molded

Table C-2. (Cont.) North Slope native seed germination record for seeds collected during 1990

Species	Collection Location	Collection Date	No. Seeds in Test	Grams/ 320 Seeds	Seeds/ Gram Tested	Date in Refrig.	Monitoring Dates in Germinator	No. Seeds Germinated Rep I	Rep II	Rep III	Average Percent Germ.
FORBS (Cont.):											
Aster sibericus	Sag. R.-E. of Airport	18 Sep 90	320	0.075	4267	29 Mar 91	04/04 - 05/06	18	22	13	17.7%
Astragalus aboriginum	M.P. 399 Dalton Hwy	05 Aug 90	320	1.066	300	29 Mar 91	04/04 - 05/11	7	3	9	6.3%
Astragalus alpinus	M.P. 405 Dalton Hwy	05 Aug 90	320	0.556	576	29 Mar 91	04/04 - 04/14	19	25	17	20.3%
Astragalus alpinus	M.P. 405 Dalton Hwy	16 Aug 90	320	0.601	532	29 Mar 91	04/04 - 04/14	17	23	19	19.7%
Astragalus alpinus	M.P. 399 Dalton Hwy	05 Aug 90	320	0.540	593	29 Mar 91	04/04 - 04/14	22	25	28	25.0%
Astragalus eucosmus	M.P. 399 Dalton Hwy	05 Aug 90	320	0.343	933	29 Mar 91	04/04 - 04/29	5	4	3	4.0%
Astragalus nutzotinensis	M.P. 395.9 Dalton Hwy	17 Aug 90	320	0.762	420	29 Mar 91	04/04 - 04/29	4	7	6	5.7%
Astragalus nutzotinensis	M.P. 405 Dalton Hwy	5,8 Aug 90	150	0.378	397	29 Mar 91	04/04 - 04/29	6	2	2	6.7%
Castilleja elegans	M.P. 395.9 Dalton Hwy	17 Aug 90	320	0.043	7442	29 Mar 91	04/04 - 04/22	32	28	34	31.3%
Castilleja elegans	M.P. 405 Dalton Hwy	05 Aug 90	150	0.026	5769	29 Mar 91	04/04 - 04/22	22	19	18	39.3%
Cerastium beeringianum	72 Haul Road	10 Sep 90	320	0.036	8889	4/11/91	04/17 - 05/04	87	86	75	82.7%
Chrysanthemum bipinnatum	Kuparuk River Bridge	14 Sep 90	320	0.080	4000	4/11/91	04/17 - 04/29	0	0	0	0.0%
Descurainia sophioides *4	M.P. 398.7 Dalton Hwy	17 Aug 90	320	0.039	8205	4/11/91	04/17 - 05/06	67	60	76	67.7%
Descurainia sophioides *5	M.P. 398.7 Dalton Hwy	17 Aug 90	320	0.039	8205	4/11/91	04/17 - 04/29	92	86	91	89.7%
Draba corymbosa	72 Haul Road	26 Aug 90	320	0.046	6957	4/11/91	04/17 - 05/11	0	3	2	1.7%
Epilobium latifolium	M.P. 21.5 TAPS-Spur Dike	17 Aug 90	320	0.050	6400	4/11/91	04/17 - 05/06	81	78	82	80.3%
Epilobium latifolium	M.P. 405 Dalton Hwy	05 Aug 90	320	0.045	7111	4/11/91	04/17 - 05/06	69	69	83	73.7%
Eutrema edwardsii *6	72 Haul Road	26 Aug 90	320	0.038	8421	4/11/91	04/17 - 05/11	40	32	38	36.7%
Eutrema edwardsii *7	72 Haul Road	26 Aug 90	150	0.070	2143	4/11/91	04/17 - 05/11	6	8	11	16.7%
Hedysarum mackenzii *8	M.P. 369.25 Dalton Hwy	06 Aug 90	320	0.536	597	4/11/91	04/17 - 05/11	7	5	6	6.0%
Hedysarum mackenzii *9	M.P. 369.25 Dalton Hwy	06 Aug 90	320	1.745	183	4/11/91	04/17 - 05/06	5	3	7	5.0%
Hedysarum mackenzii *8	M.P. 405 Dalton Hwy	05 Aug 90	320	0.350	914	4/11/91	04/17 - 05/06	2	2	1	1.7%
Hedysarum mackenzii *9	M.P. 405 Dalton Hwy	05 Aug 90	320	1.700	188	4/11/91	04/17 - 05/06	3	0	2	1.7%
Hedysarum mackenzii *8	M.P. 405 Dalton Hwy	16 Aug 90	320	0.429	746	4/11/91	04/17 - 05/14	14	8	10	10.7%
Hedysarum mackenzii *9	M.P. 405 Dalton Hwy	16 Aug 90	320	1.533	209	4/11/91	04/17 - 05/14	9	7	16	10.7%
Minuartia obtusiloba	M.P. 62 TAPS	17 Sep 90	320	0.062	5161	4/11/91	04/17 - 05/11	76	80	78	78.0%
Minuartia obtusiloba	M.P. 365 Dalton Hwy	06 Aug 90	320	0.087	3678	4/11/91	04/17 - 05/11	13	12	16	13.7%
Oxytropis borealis	M.P. 405 Dalton Hwy	08 Aug 90	320	0.350	914	4/11/91	04/17 - 05/14	14	23	19	18.7%
Oxytropis borealis	M.P. 405 Dalton Hwy	16 Aug 90	320	0.469	682	4/11/91	04/17 - 05/14	28	23	21	24.0%

*4 Chlorox treatment
*5 No treatment
*6 Small seeds
*7 Large seeds
*8 Hull removed from seeds
*9 Hull still on seed

Table C-2. (Cont.) North Slope native seed germination record for seeds collected during 1990

Species	Collection Location	Collection Date	No. Seeds in Test	Grams/ 320 Seeds	Seeds/ Gram Tested	Date in Refrig.	Monitoring Dates in Germinator	No. Seeds Germinated Rep I	Rep II	Rep III	Average Percent Germ.
FORBS (Cont.):											
Oxytropis nigrescens	Dunes-Pipeline and E-2	07 Aug 90	320	0.915	350	5/6/91	05/11 - 05/29	15	24	14	17.7%
Oxytropis nigrescens	Dunes-Pipeline and E-2	09 Aug 90	320	0.882	363	5/6/91	05/11 - 05/29	21	28	24	24.3%
Oxytropis nigrescens	Dunes West of E-2 Pond	09 Aug 90	320	0.940	340	5/6/91	05/11 - 05/29	22	14	30	22.0%
Oxytropis nigrescens	Dunes West of E-2 Pond	22 Aug 90	320	0.948	338	5/6/91	05/11 - 05/29	12	13	15	13.3%
Oxytropis nigrescens	Dunes-Mid Caribou Ramp End.	08 Aug 90	320	0.765	418	5/6/91	05/11 - 05/29	9	11	6	8.7%
Pedicularis capitata	M.P. 405 Dalton Hwy	05 Aug 90	320	0.181	1768	5/6/91	05/11 - 05/29	0	0	0	0.0%
Pedicularis labradorica	M.P. 405 Dalton Hwy	05 Aug 90	320	0.113	2832	5/6/91	05/11 - 05/29	0	0	2	0.7%
Pedicularis lanata	M.P. 405 Dalton Hwy	05 Aug 90	320	0.130	2462	5/6/91	05/11 - 05/29	8	10	16	11.3%
Polymonium boreale	East Dock Dunes	08 Sep 90	320	0.486	658	5/6/91	05/11 - 06/10	48	58	48	51.3%
Potentilla hookeriana	Big Skookum	13 Sep 90	320	0.041	7805	5/6/91	05/11 - 06/06	20	17	28	21.7%
Primula borealis *2	Endicott Coastal	03 Aug 90	30	0.018	1667	5/6/91	05/11 - 05/22	0			0.0%
Saxifraga oppositifolia *2	Arco State No. 1	15 Sep 90	60	0.009	6667	5/6/91	05/11 - 05/22	0			0.0%
Saxifraga oppositifolia	Haul Road SE of D.S.-5	19 Sep 90	320	0.036	8889	5/6/91	05/11 - 05/29	0	0	0	0.0%
Saxifraga tricuspidata	M.P. 62 TAPS-Dry Ridge	17 Sep 90	320	0.011	29091	5/6/91	05/11 - 05/29	0	0	0	0.0%
Sedum rosea	East Dock	09 Sep 90	320	0.045	7111	5/6/91	05/11 - 05/22	92	84	84	86.7%
Sedum rosea	Big Skookum	13 Sep 90	320	0.035	9143	5/6/91	05/11 - 05/22	45	32	58	45.0%
Senecio congestus	Franklin Bluffs Camp	17 Sep 90	320	0.024	13333	5/6/91	05/11 - 05/29	7	7	16	10.0%
Silene acaulis	Arco State No. 1	15 Sep 90	320	0.096	3333	5/6/91	05/11 - 05/29	9	6	9	8.0%
Silene wahlbergella	1972 Haul Road	26 Aug 90	320	0.105	3048	5/6/91	05/11 - 05/29	61	72	50	61.0%
Wilhelmsia physoides	M.P. 401/405 Dalton Hwy.	05 Aug 90	320	0.147	2177	5/6/91	05/11 - 05/29	58	62	67	62.3%
SHRUBS:											
Dryas integrifolia	East Dock Dunes	09 Sep 90	320	0.082	3902	5/16/91	05/23 - 06/06	36	34	32	34.0%
Dryas integrifolia	End. Mid Caribou Ramp	21 Aug 90	320	0.082	3902	5/16/91	05/23 - 06/06	35	37	32	34.7%
Dryas integrifolia	End. Mid Caribou Ramp	13 Sep 90	320	0.065	4923	5/16/91	05/23 - 06/06	16	11	14	13.7%
Dryas octopetala	M.P. 62 TAPS-Dry Ridge	17 Sep 90	320	0.011	29091	5/16/91	05/23 - 06/03	0	0	0	0.0%
Salix arctica	1972 Haul Road	10 Sep 90	320	0.061	5246	5/16/91	05/23 - 06/03	96	98	100	98.0%
Salix arctica	End. West Caribou Ramp	13 Sep 90	320	0.064	5000	5/16/91	05/23 - 06/03	97	94	96	95.7%

*2 Only enough seed for 1 replicate

Table C-2. (Cont.) North Slope native seed germination record for seeds collected during 1990

Species	Collection Location	Collection Date	No. Seeds in Test	Grams/ 320 Seeds	Seeds/ Gram Tested	Date in Refrig.	Monitoring Dates in Germinator	No. Seeds Germinated Rep I	Rep II	Rep III	Average Percent Germ.
SHRUBS (Cont.):											
Salix ovalifolia	Dunes West of E-2 Pond	22 Aug 90	320	0.059	5424	5/16/91	05/23 - 06/06	62	57	66	61.7%
Salix ovalifolia	East Dock Dunes	08 Sep 90	320	0.069	4638	5/16/91	05/23 - 06/06	92	94	91	92.3%
Salix ovalifolia	M.P. 405 Dalton Hwy	05 Aug 90	320	0.053	6038	5/16/91	05/23 - 06/06	36	39	35	36.7%

Summary of germination tests on seeds collected in 1990

Graminoids	=	21 species in 40 seedlots
Forbs	=	36 species in 60 seedlots
Shrubs	=	4 species in 9 seedlots
Totals	=	61 species in 109 seedlots

1990 Gramnoid mean germination rate	42.1
1990 Forb mean germination rate	33.0
1990 Shrub mean germination rate	51.9

APPENDIX D

BOTANICAL GARDEN PLANTINGS

Tables D-1 and D-2 list the species planted in the Botanical Garden at the BP Put River No. 1 gravel pad in 1990 and 1991, respectively. The row number, species, collection location and collection date are given. For 1991, the planting rates were determined and are listed.

Table D-1. Species planted at the BP Put River No. 1 gravel pad, 27 June 1990

Row No.*	Species	Location	Collection Date
GRASSES:			
1E	Agropyron boreale	Kuparuk River Bridge	8/25/89
1W	Agropyron boreale	BP Put River No. 1	8/24/89
2	Alopecurus alpinus **	BP Put River No. 1	8/24/89
	Alopecurus alpinus	Pump Station No. 1	9/27/89
	Alopecurus alpinus	IBP Plots	8/26/89
3	Arctagrostis latifolia **	1972 Haul Road	9/26/89
	Arctagrostis latifolia	M.P. 31 Dalton Highway	9/19/89
	Arctagrostis latifolia	Pump Station No. 1	9/27/89
	Arctagrostis latifolia	Sag. River E. of Airport	9/27/89
	Arctagrostis latifolia	IBP Plots	8/26/89
4	Bromus pumpellianus	Kuparuk River Bridge	8/25/89
5	Deschampsia caespitosa **	1972 Haul Road	8/29/89
	Deschampsia caespitosa	Kuparuk Haul Road	8/29/89
	Deschampsia caespitosa	Kuparuk River Bridge	8/25/89
	Deschampsia caespitosa	Sohio-Kuparuk Reserve Pit	8/29/89
6	Dupontia fischeri	Pump Station No. 1	9/27/89
7	Elymus arenarius mollis	East Dock Dunes	9/25/89
8	Festuca brachyphylla **	Sohio-Kuparuk Reserve Pit	8/29/89
	Festuca brachyphylla	IBP Plots	8/26/89
9	Festuca ovina	East Dock Dunes	9/25/89
10	Festuca 'vivipara'	BP Put River No. 1	8/24/89
11	Poa arctica	East Dock Dunes	9/25/89
12E	Poa glauca	IBP Plots	8/26/89
12W	Poa glauca	1972 Haul Road	8/29/89
13E	Puccinellia langeana	BP Put River No. 1	8/24/89
13W	Puccinellia langeana	IBP Plots	8/26/89
14	Trisetum spicatum **	BP Put River No. 1	8/24/89
	Trisetum spicatum	IBP Plots	8/26/89
15E	Festuca rubra	Kuparuk River Bridge	8/25/89
15W	Festuca rubra	IBP Plots	8/26/89

Table D-1. (Cont.) Species planted at the BP Put River No. 1 gravel pad, 27 June 1990

Row No.*	Species	Location	Collection Date
GRASSLIKE:			
16	Carex maritima **	1972 Haul Road	8/31/89
	Carex maritima	BP Put River No. 1	8/27/89
	Carex maritima	Sohio-Kuparuk Reserve Pit	8/29/89
17	Luzula arctica	Arco State No. 1	8/30/89
FORBS:			
18E	Armeria maritima **	Little Put R. & 72 Haul Rd.	8/31/89
18W	Armeria maritima	Arco State No. 1	9/7/89
19	Artemisia arctica **	Kuparuk River Bridge	8/25/89
	Artemisia arctica	M.P. 40 Dalton Highway	9/19/89
20	Artemisia borealis	Kuparuk River Bridge	8/25/89
21	Artemisia glomerata	Kuparuk River Bridge	8/25/89
22	Aster sibericus	Sag. River E. of Airport	9/28/89
23	Braya pilosa & purpurascens	Put R. No. 27 Gravel Pit	8/27/89
24	Cerastium beeringianum	1972 Haul Road	9/26/89
25	Descurainia sophioides	Sohio-Kuparuk Reserve Pit	8/29/89
26	Draba spp. (white-flowered)	BP Put River No. 1	8/27/89
27	Epilobium latifolium **	BP Put River No. 1	8/27/89
	Epilobium latifolium	Put River No. 27 Gravel Pit	8/27/89
28	Eutrema edwardsii **	Arco State No. 1	8/30/89
	Eutrema edwardsii	BP Put River No. 1	8/27/89
29	Melandrium apetalum	1972 Haul Road	8/31/89
30	Parrya nudicaulis	Sag. River E. of Airport	9/27/89
31	Sedum rosea	Big Skookum - Endicott	9/20/89
32	Senecio congestus	M.P. 40 Dalton Highway	9/19/89
33	Silene acaulis	Arco State No. 1	8/30/89

* Nursery Rows are 31 feet long - Row 1 is in Southeast corner

** Seeds from different locations were mixed before planting

Table D-2. Species planted at the BP Put River No. 1 gravel pad botanical garden on 27 June 1991

Row No.	Species	Location	Collection Date	Length (Feet)	Purity	Germ.	Wt. 320 Seeds	Required Number PLS *1	Required Number Seeds	Required G Seed	G Seed Used *2
GRASSES:											
34E	Arctophila fulva	Lonnie Lake East	9/26/90	15.5	0.98	0.930	0.086	744	816.3	0.219	
34W	Arctophila fulva	Pump Station No 1	9/11/90	15.5	0.95	0.670	0.088	744	1168.9	0.321	
35W	Elymus innovatus	M.P. 365 Dalton Highway	8/6/90	15.5	0.90	0.770	1.467	744	1073.6	4.922	0.647
36E	Festuca baffinensis	1972 Haul Road	9/10/90	15.5	0.85	0.733	0.186	744	1194.1	0.694	
36W	Festuca baffinensis	Endicott Rd.-S. Big Skookum	9/13/90	15.5	0.85	0.700	0.132	744	1250.4	0.516	
GRASSLIKE:											
37	Carex ursina	East Dock	9/10/90	31.0	0.95	0.700	0.141	1488	2237.6	0.986	
FORBS:											
38E	Androsace chamaejasme *3	1972 Haul Road	8/26/90	15.5	0.95	0.003	0.180	744	261052.6	146.842	0.328
38W	Androsace chamaejasme *3	East Dock Dunes	9/9/90	15.5	0.99	0.000	0.110	744			0.378
39	Arabis arenicola	M.P. 405 Dalton Highway	8/5/90	31.0	0.99	0.583	0.027	1488	2578.1	0.218	
40	Astragalus aboriginum *3	M.P. 399 Dalton Highway	8/5/90	31.0	1.00	0.063	1.066	1488	23619.0	78.681	2.000
41	Astragalus alpinus	M.P. 399 Dalton Highway	8/5/90	31.0	1.00	0.250	0.540	1488	5952.0	10.044	3.750
42	Astragalus eucosmus	M.P. 399 Dalton Highway	8/5/90	31.0	1.00	0.790	0.343	1488	1883.5	2.019	0.838
43	Astragalus Nutzotinensis	M.P. 405 Dalton Highway	5,8 Aug 90	31.0	1.00	0.067	0.756	1488	22209.0	52.469	1.150
44	Castilleja elegans	M.P. 395.9 Dalton Highway	8/17/90	31.0	0.95	0.313	0.043	1488	5004.2	0.672	
45	Chrysanthemum bipinnatum	Kuparuk River Bridge	9/14/90	31.0	0.90	0.000	0.080	1488			1.000
46	Draba corymbosa	1972 Haul Road	8/26/90	31.0	0.99	0.017	0.046	1488	88413.5	12.709	0.350
47E	Hedysarum Mackenzii	M.P. 369 Dalton Highway	8/6/90	15.5	0.95	0.060	0.536	744	13052.6	21.863	8.000
47W	Hedysarum Mackenzii	M.P. 405 Dalton Highway	8/16/90	15.5	0.98	0.107	0.429	744	7095.2	9.512	1.300
48E	Minuartia obtusiloba	M.P. 354.5 Dalton Highway	9/17/90	15.5	0.80	0.780	0.062	744	1192.3	0.231	
48W	Minuartia obtusiloba	M.P. 365 Dalton Highway	8/6/90	15.5	0.70	0.137	0.087	744	7758.1	2.109	0.550
49E	Oxytropis borealis	M.P. 405 Dalton Highway	8/8/90	15.0	0.95	0.187	0.350	720	4052.9	4.433	
49W	Oxytropis borealis	M.P. 405 Dalton Highway	8/16/90	15.0	0.98	0.240	0.469	720	3061.2	4.487	
50	Oxytropis nigrescens	Mix from Dunes near E-2	8/9/90	30.0	1.00	0.225	0.927	1440	6400.0	18.540	

*1 PLS = Pure Live Seed reflects the percentage of pure seed that has the ability to germinate = % Germination x % Purity
*2 Attempted to apply seed at rate of 1 PLS per 1/4" of row (48 PLS/Ft.), when less seed was available, this amount was used.
*3 Seed lot mechanically scarified to try improving germination.

Table D-2. (Cont.) Species planted at the BP Put River No. 1 gravel pad botanical garden on 27 June 1991

Row No.	Species	Location	Collection Date	Length (Feet)	Purity	Germ.	Wt. 320 Seeds	Required Number PLS *1	Required Number Seeds	Required G Seed	G Seed Used *2
FORBS (Cont.):											
51	*Pedicularis capitata*	M.P. 405 Dalton Highway	8/5/90	30.0	0.85	0.000	0.181	1440			0.366
52	*Pedicularis labradorica*	M.P. 405 Dalton Highway	8/5/90	30.0	0.85	0.007	0.113	1440	242016.8	85.462	1.000
53	*Pedicularis lanata*	M.P. 405 Dalton Highway	8/5/90	30.0	0.90	0.113	0.130	1440	14159.3	5.752	2.250
54	*Polymonium boreale*	East Dock Dunes	9/8/90	30.0	0.98	0.513	0.486	1440	2864.3	4.350	3.000
55	*Potentilla Hookeriana*	Big Skookum	9/13/90	30.0	0.99	0.217	0.041	1440	6703.0	0.859	0.300
56	*Saxifraga tricuspidata*	M.P. 354.5 Dalton Highway	9/17/90	30.0	0.95	0.000	0.011	1440			1.600
57	*Silene acaulis*	Arco State No 1	9/15/90	30.0	0.85	0.080	0.096	1440	21176.5	6.353	3.000
58	*Silene Wahlbergella*	1972 Haul Road	8/26/90	30.0	0.95	0.610	0.105	1440	2484.9	0.815	0.150
59	*Wilhelmsia physoides*	M.P. 401 & 405 Dalton Highway	8/5/90	30.0	0.95	0.623	0.147	1440	2433.0	1.118	0.400
SHRUBS:											
60E	*Dryas integrifolia*	East Dock Dunes	9/9/90	15.0	0.60	0.340	0.082	720	3529.4	0.904	
60W	*Dryas integrifolia*	Endicott Rd-mid Caribou Ramp	9/13/90	15.0	0.60	0.137	0.065	720	8759.1	1.779	
61	*Dryas octopetala*	M.P. 354.5 Dalton Highway	9/17/90	30.0	1.00	0.000	0.011	1440			1.300
62E	*Salix arctica*	1972 Haul Road	9/10/90	15.0	0.65	0.980	0.061	720	1130.3	0.215	0.208
62W	*Salix arctica*	Endicott Rd-W Caribou Ramp	9/13/90	15.0	0.95	0.956	0.064	720	792.8	0.159	
63E	*Salix ovalifolia*	Dunes West of E-2 Pond	8/22/90	15.0	0.65	0.617	0.059	720	1795.3	0.331	
63W	*Salix ovalifolia*	East Dock Dunes	9/8/90	15.0	0.55	0.923	0.069	720	1418.3	0.306	

*1 PLS = Pure Live Seed reflects the percentage of pure seed that has the ability to germinate = % Germination x % Purity
*2 Attempted to apply seed at rate of 1 PLS per 1/4" of row (48 PLS/Ft.), when less seed was available, this amount was used.

Summary of seeds planted in the botanical garden on 27 June 1991

Graminoids	=	4 species in 6 seedlots
Forbs	=	22 species in 26 seedlotds
Shrubs	=	3 species in 7 seedlots
Totals	=	29 species in 39 seedlots

APPENDIX E

PLOT PLANTINGS

Tables E-1 and E-2 list the species/collections planted in the 144 experimental plots at the BP Put River No. 1 gravel pad in 1990 and 1991, respectively. The seedlot germination rate and purity are used to derive the seeding rate which is given as grams seed per plot, grams seed per sq. foot, PLS (Pure Live Seed) per sq. foot, and lbs. PLS per acre.

Table E-1. Record of species and amount of seed planted in each of 144 plots at the BP Put River No. 1 gravel pad during 21-27 June 1990

Species	Collection Location	Number Seeds/g	Germ.	Purity	Number PLS/g *1	SEEDING RATE Grams per Plot *2	Grams/sq. Foot	# PLS/sq. Foot *1	Lbs. PLS/ Acre *1
GRASSES:									
Agropyron boreale	Kuparuk River Bridge	281	99.0%	99%	275	1.000	0.031	8.6	3.00
Alopecurus alpinus	B.P. Put River No. 1	1163	93.0%	70%	757	0.063	0.002	1.5	0.19
Alopecurus alpinus	Pump Station No. 1	2083	28.3%	70%	413	0.005	0.000	0.1	0.02
Alopecurus alpinus	IBP Plots	1163	90.0%	70%	733	0.057	0.002	1.3	0.17
Arctagrostis latifolia	M.P. 31 Dalton Highway	3704	80.0%	99%	2934	0.087	0.003	8.0	0.26
Arctagrostis latifolia	Pump Station No, 1	4000	68.7%	99%	2721	0.030	0.001	2.5	0.09
Arctagrostis latifolia	Sag. River E. of Airport	3261	98.0%	99%	3164	0.196	0.006	19.4	0.59
Arctagrostis latifolia	IBP Plots	4225	55.0%	99%	2301	0.147	0.005	10.6	0.44
Arctagrostis latifolia	72 Haul Road (introduced)	3659	88.3%	99%	3199	0.039	0.001	3.9	0.12
Bromus pumpellianus	Kuparuk River Bridge	261	91.7%	99%	237	0.100	0.003	0.7	0.30
Deschampsia caespitosa	1972 Haul Road	3061	95.3%	99%	2888	0.106	0.003	9.5	0.32
Deschampsia caespitosa	Kuparuk Haul Road	3125	92.0%	99%	2846	0.203	0.006	18.1	0.61
Deschampsia caespitosa	Kuparuk River Bridge	3061	94.0%	99%	2849	0.338	0.011	30.1	1.01
Deschampsia caespitosa	Sohio-Kuparuk Reserve Pit	3000	94.7%	99%	2813	0.122	0.004	10.7	0.37
Elymus arenarius mollis	East Dock Dunes	164	97.3%	99%	158	0.736	0.023	3.6	2.21
Festuca brachyphylla	Sohio-Kuparuk Reserve Pit	1775	89.0%	99%	1564	0.087	0.003	4.2	0.26
Festuca brachyphylla	IBP Plots	1667	88.7%	99%	1464	0.133	0.004	6.1	0.40
Festuca ovina	East Dock Dunes	1045	86.7%	99%	897	0.055	0.002	1.5	0.16
Festuca rubra	Kuparuk River Bridge	1370	61.7%	99%	837	0.043	0.001	1.1	0.13
Festuca 'vivipara'	B.P. Put River No. 1	299	78.7%	10%	24	0.140	0.004	0.1	0.42
Poa arctica	East Dock Dunes	2174	87.0%	99%	1872	0.225	0.007	13.2	0.67
Puccinellia langeana	B.P. Put River No. 1	6667	96.7%	99%	6383	1.319	0.041	263.1	3.95
Puccinellia langeana	IBP Plots	6667	97.3%	99%	6422	1.493	0.047	299.6	4.48
Trisetum spicatum *3	B.P. Put River No. 1	3000	88.0%	99%	2614	0.625	0.020	51.0	1.87
Trisetum spicatum *3	IBP Plots								
GRASSLIKE:									
Carex maritima	72 Haul Road	1111	95.0%	99%	1045	0.046	0.001	1.5	0.14
Carex maritima	B.P. Put River No. 1	1478	96.0%	99%	1405	0.004	0.000	0.2	0.01
Carex maritima	Sohio-Kuparuk Reserve Pit	1271	94.3%	99%	1187	0.120	0.004	4.4	0.36
						TOTAL GRAMINOID SEEDS =		774.9	

*1 Pure Live Seed (PLS) reflects the percentage of pure seed that has the ability to germinate; PLS = % Germination X % Purity
*2 Seed was weighed into 144 equal lots (one for each test plot) for each of the 30 species planted.
*3 Trisetum seedlots were mixed together because of their close proximity and similar harvest dates.

Table E-1. (Cont.) Record of species and amount of seed planted in each of 144 plots at the BP Put River No.1 gravel pad during 21-27 June 1990

Species	Collection Location	Number Seeds/g	Germ.	Purity	Number PLS/g *1	SEEDING RATE: Grams per Plot *2	SEEDING RATE: Grams/sq. Foot	SEEDING RATE: # PLS/sq. Foot *1	SEEDING RATE: Lbs. PLS/Acre *1
FORBS:									
Armeria maritima	Arco Discovery Well Site	773	59.7%	99%	457	0.025	0.001	0.4	0.07
Artemisia arctica	Kuparuk River Bridge	1911	99.7%	99%	1886	0.077	0.002	4.5	0.23
Artemisia arctica	M.P. 40 Dalton Highway	2206	79.3%	99%	1732	0.073	0.002	4.0	0.22
Artemisia borealis	Kuparuk River Bridge	2013	97.3%	99%	1939	0.030	0.001	1.8	0.09
Artemisia glomerata	Kuparuk River Bridge	2479	96.3%	99%	2363	0.083	0.003	6.1	0.25
Aster sibericus	Sag. River E. of Airport	3571	47.3%	99%	1672	0.050	0.002	2.6	0.15
Braya pilosa & purpurascens	Put R. #27 Gravel Pit	7692	10.7%	99%	815	0.450	0.014	11.5	1.35
Cerastium beeringianum	72 Haul Road	8108	94.0%	99%	7545	0.015	0.000	3.5	0.04
Descurainia sophioides	Sohio-Kuparuk Reserve Pit	14286	67.0%	99%	9476	0.100	0.003	29.6	0.30
Draba spp. (white-flowered)	B.P. Put River No. 1	6522	9.0%	99%	581	0.060	0.002	1.1	0.18
Epilobium latifolium	B.P. Put River No. 1	7143	91.0%	99%	6435	0.017	0.001	3.5	0.05
Epilobium latifolium	Put River #27 Gravel Pit	6977	88.0%	99%	6078	0.045	0.001	8.5	0.13
Eutrema edwardsii	Arco State No. 1	2000	32.0%	99%	634	0.180	0.006	3.6	0.54
Eutrema edwardsii	B.P. Put River No. 1	1630	0.0%	99%	0	0.010	0.000	0.0	0.03
Melandrium apetalum	72 Haul Road	3093	3.3%	99%	101	0.062	0.002	0.2	0.19
Parrya nudicaulis	Sag. River E. of Airport	303	1.7%	99%	5	0.160	0.005	0.0	0.48
Sedum rosea	Big Skookum	6667	80.3%	99%	5300	0.125	0.004	20.7	0.37
Senecio congestus	M.P. 40 Dalton Highway	6522	70.0%	99%	4520	0.021	0.001	3.0	0.06
Silene acaulis	Arco State No. 1	2222	1.7%	99%	37	0.100	0.003	0.1	0.30
						TOTAL FORB SEEDS =		104.6	
TOTAL AMOUNT OF SEED FOR 31 SPECIES PLANTED IN EACH OF 144 TEST PLOT						9.203	0.288	879.5	27.59

Summary of seeds planted at the BP Put River No. 1 gravel plot in 1990

Graminoids	=	14 species in 28 seedlots
Forbs	=	17 species in 19 seedlots
Totals	=	31 species in 47 seedlots

Table E-2. Record of species and amount of seeds planted in each of 144 plots at the BP Put River No. 1 gravel pad during 25-27 June 1991 */1

Species	Collection Location	Wt 320 Seeds	Grams PLS Required per Plot *2	Total Grams PLS Required	Purity	Germ.	Total Gms. Seed Required	Seeding Rate *3: Gms. per Plot *1	Seeding Rate *3: # PLS/sq. Ft. *3	Seeding Rate *3: Lbs. PLS/ Acre *2
GRASSES:										
Elymus innovatus	M.P. 365 Dalton Hwy	1.467	0.1467	21.125	0.90	0.770	30.483	0.212	1.00	0.440
Poa glauca	Endicott Road - 1 mile West of W Caribou Ramp	0.076	0.0456	6.566	0.75	0.557	15.718	0.109	6.00	0.137
GRASSLIKE:										
Carex ursina	East Dock	0.141	0.0846	12.182	0.95	0.700	18.319	0.127	6.00	0.254
							TOTAL GRAMINOID SEEDS =		13.00	
FORBS:										
Androsace chamaejasme	72 Haul Road *4 East Dock Dunes	0.142			0.92	0.012	5.500	0.038		
Arabis arenicola	M.P. 405 Dalton Hwy	0.025	0.0150	2.160	0.99	0.583	3.742	0.026	6.00	0.045
Armeria maritima Armeria maritima Armeria maritima Armeria maritima	East Dock Dunes *4 Kuparuk River Bridge M.P. 405 Dalton Hwy Sag River East of Airport	0.321	0.0642	9.245	0.85	0.433	25.118	0.174	2.00	0.192
Artemisia arctica	M.P. 377.5 Dalton Hwy	0.122	0.0732	10.541	0.99	0.987	10.788	0.075	6.00	0.219
Artemisia glomerata Artemisia glomerata	Kuparuk River Bridge *4 M.P. 405 Dalton Hwy	0.132	0.0396	5.702	0.89	0.939	6.846	0.048	3.00	0.119
Astragalus alpinus	M.P. 405 Dalton Hwy	0.574	0.0861	12.398	0.99	0.201	62.431	0.434	1.50	0.258
Astragalus eucosmus	M.P. 399 Dalton Hwy	0.343			1.00	0.040	14.400	0.100		
Astragalus nutzotinensis Astragalus nutzotinensis	M.P. 395.9 Dalton Hwy 84 *4 M.P. 405 Dalton Hwy	0.761			1.00	0.059	14.400	0.100		
Castilleja elegans	M.P. 395.9 Dalton Hwy	0.043	0.0065	0.929	0.95	0.313	3.124	0.022	1.50	0.019
Cerastium beeringianum	72 Haul Road	0.036	0.0216	3.110	0.95	0.825	3.969	0.028	6.00	0.065
Chrysanthemum bipinnatum	Kuparuk River Bridge	0.080			0.10	0.000	21.600	0.150		
Descurainia sophioides	M.P. 398.7 Dalton Hwy	0.039	0.0234	3.370	0.98	0.897	3.833	0.027	6.00	0.070
Epilobium latifolium	M.P. 405 Dalton Hwy	0.045	0.0270	3.888	0.90	0.737	5.862	0.041	6.00	0.081

*1 Seed was weighed into 144 equal lots (one for each test plot) for each of 28 species planted.
*2 Pure Live Seed (PLS) reflects the amount of seed that has the ability to germinate; PLS = % Germination X % Purity.
*3 Planting 6 PLS per sq. ft. for each species was the goal, where germination and quantity of seed allowed.
*4 Seed weight, purity, and germination prorated by percent of seed lot used

Table E-2. (Cont.) Record of species and amount of seeds planted in each of 144 plots at the BP Put River No. 1 gravel pad during 25-27 June 1991 *1

Species	Collection Location	Wt 320 Seeds	Grams PLS Required per Plot *2	Total Grams PLS Required	Purity	Germ.	Total Gms. Seed Required	Seeding Rate *3: Gms. per Plot *1	Seeding Rate *3: # PLS/sq. Ft. *3	Seeding Rate *3: Lbs. PLS/ Acre *2
FORBS (Cont.):										
Eutrema edwardsii	72 Haul Road	0.038	0.0114	1.642	0.99	0.367	4.518	0.031	3.00	0.034
Hedysarum mackenzii	M.P. 369.5 Dalton Hwy *4	1.719	0.1719	24.754	0.98	0.057	443.136	3.077	1.00	0.515
Hedysarum mackenzii	M.P. 405 Dalton Hwy									
Oxytropis borealis	M.P. 405 Dalton Hwy	0.400	0.1600	23.040	0.96	0.209	114.534	0.795	4.00	0.480
Oxytropis nigrescens	E-2 Dunes *4	0.927	0.3708	53.395	1.00	0.225	236.996	1.646	4.00	1.112
Oxytropis nigrescens	E-2 Pond/Pipeline									
Pedicularis lanata subsp. kanei	M.P. 405 Dalton Hwy	0.130	0.0195	2.808	0.90	0.113	27.611	0.192	1.50	0.058
Potentilla hookeriana	Big Skookum	0.041	0.0051	0.738	0.99	0.217	3.435	0.024	1.25	0.015
Sedum rosea	East Dock	0.045	0.0270	3.888	0.99	0.867	4.530	0.031	6.00	0.081
Senecio congestus	M.P. 377.5 Dalton Hwy	0.024	0.0036	0.518	0.50	0.100	10.368	0.072	1.50	0.011
Silene wahlbergella	72 Haul Road	0.105	0.0158	2.268	0.95	0.610	3.914	0.027	1.50	0.047
							TOTAL FORB SEEDS =		61.75	
SHRUBS:										
Dryas integrifolia	East Dock Dunes *4	0.070	0.0368	5.292	0.60	0.202	43.663	0.303	5.25	0.110
Dryas integrifolia	Endicott-mid Caribou Ramp									
Salix arctica	1972 Haul Road *4	0.063	0.0189	2.722	0.86	0.963	3.279	0.023	3.00	0.057
Salix arctica	Endicott-N Caribou Ramp									
Salix ovalifolia	E-2 Dunes *4	0.059	0.0295	4.248	0.71	0.592	10.050	0.070	5.00	0.088
Salix ovalifolia	East Dock Dunes									
Salix ovalifolia	M.P. 405 Dalton Hwy									
							TOTAL SHRUB SEEDS =		13.25	
	TOTAL AMOUNT OF SEED FOR 28 SPECIES PLANTED IN EACH OF 144 TEST PLOTS:						1152.17	8.001	88.00	4.509

*1 Seed was weighed into 144 equal lots (one for each test plot) for each of 28 species planted.
*2 Pure Live Seed (PLS) reflects the amount of seed that has the ability to germinate; PLS = % Germination X % Purity.
*3 Planting 6 PLS per sq. ft. for each species was the goal, where germination and quantity of seed allowed.
*4 Seed weight, purity, and germination prorated by percent of seed lot used

Summary of seeds planted at BP Put River No. 1 gravel pad in 1991

Graminoids	= 3 species in 3 seedlots
Forbs	= 22 species in 30 seedlots
Shrubs	= 3 species in 7 seedlots
Totals	= 28 species in 40 seedlots

APPENDIX F

COVER POINT FRAME DATA AND ANALYSES

The point hit cover data sampled at the BP Put River No. 1 gravel pad during 2-4 September 1991 are listed and converted to percent cover (number of hits/30 hits total) in Tables F-1 through F-5. Tables F-1 through 4 (a,b) present data from the 1990 planted plots, Tables F-5 and F-5a present data from the unplanted plots located between the center 1990 planting and the eastern 1991 planting plots. The means of the three 1990 planting replicates are presented in Tables F-1a through F-4a. Finally, the means of the various treatments (block, gravel thickness, presence or absence of topsoil, and whether or not the substrate was tilled) are presented in Tables F-1b through F-4b and F-5a.

Table F-1. 1991 point frame hits and percent cover for plots planted in 1990 in Block 1 at the BP Put River No. 1 gravel pad, n=30

							Aerial Cover				Ground Cover													
Block	Snow Fence	Poa Glauca	Repl	Gravel Thick.	Soil	Tilled	Grass	%	Forb	%	Plant	%	Moss	%	Rock	%	Barren	%	Mulch	%	Wood	%	Feces	%
1	1	1	1	5	0	1	14	46.7	2	6.7	1	3.3	0.0	0.0	29	96.7	0	0.0	0	0.0	0	0.0	0	0.0
1	1	1	1	5	0	0	11	36.7	1	3.3	2	6.7	0.0	0.0	24	80.0	4	13.3	0	0.0	0	0.0	0	0.0
1	1	1	1	5	1	1	19	63.3	3	10.0	8	26.7	0.0	0.0	7	23.3	15	50.0	0	0.0	0	0.0	0	0.0
1	1	1	1	5	1	0	15	50.0	2	6.7	6	20.0	0.0	0.0	3	10.0	21	70.0	0	0.0	0	0.0	0	0.0
1	1	1	1	3	0	1	6	20.0	0	0.0	0	0.0	0.0	0.0	26	86.7	4	13.3	0	0.0	0	0.0	0	0.0
1	1	1	1	3	0	0	9	30.0	0	0.0	0	0.0	0.0	0.0	24	80.0	6	20.0	0	0.0	0	0.0	0	0.0
1	1	1	1	3	1	1	15	50.0	3	10.0	1	3.3	0.0	0.0	3	10.0	26	86.7	0	0.0	0	0.0	0	0.0
1	1	1	1	3	1	0	8	26.7	1	3.3	0	0.0	0.0	0.0	1	3.3	29	96.7	0	0.0	0	0.0	0	0.0
1	1	1	1	2	0	1	14	46.7	1	3.3	2	6.7	0.0	0.0	24	80.0	3	10.0	1	3.3	0	0.0	0	0.0
1	1	1	1	2	0	0	15	50.0	2	6.7	1	3.3	0.0	0.0	29	96.7	0	0.0	0	0.0	0	0.0	0	0.0
1	1	1	1	2	1	1	26	86.7	0	0.0	8	26.7	0.0	0.0	2	6.7	20	66.7	0	0.0	0	0.0	0	0.0
1	1	1	1	2	1	0	20	66.7	0	0.0	4	13.3	0.0	0.0	2	6.7	24	80.0	0	0.0	0	0.0	0	0.0
1	1	1	2	5	0	1	6	20.0	1	3.3	0	0.0	0.0	0.0	27	90.0	1	3.3	2	6.7	0	0.0	0	0.0
1	1	1	2	5	0	0	3	10.0	1	3.3	0	0.0	0.0	0.0	26	86.7	4	13.3	0	0.0	0	0.0	0	0.0
1	1	1	2	5	1	1	13	43.3	2	6.7	0	0.0	0.0	0.0	13	43.3	17	56.7	0	0.0	0	0.0	0	0.0
1	1	1	2	5	1	0	21	70.0	3	10.0	7	23.3	0.0	0.0	5	16.7	18	60.0	0	0.0	0	0.0	0	0.0
1	1	1	2	3	0	1	6	20.0	0	0.0	0	0.0	0.0	0.0	22	73.3	5	16.7	3	10.0	0	0.0	0	0.0
1	1	1	2	3	0	0	9	30.0	0	0.0	0	0.0	0.0	0.0	27	90.0	3	10.0	0	0.0	0	0.0	0	0.0
1	1	1	2	3	1	1	17	56.7	1	3.3	1	3.3	0.0	0.0	14	46.7	15	50.0	0	0.0	0	0.0	0	0.0
1	1	1	2	3	1	0	21	70.0	2	6.7	4	13.3	0.0	0.0	1	3.3	25	83.3	0	0.0	0	0.0	0	0.0
1	1	1	2	2	0	1	16	53.3	0	0.0	1	3.3	0.0	0.0	28	93.3	1	3.3	0	0.0	0	0.0	0	0.0
1	1	1	2	2	0	0	6	20.0	1	3.3	0	0.0	0.0	0.0	26	86.7	4	13.3	0	0.0	0	0.0	0	0.0
1	1	1	2	2	1	1	13	43.3	0	0.0	0	0.0	0.0	0.0	4	13.3	26	86.7	0	0.0	0	0.0	0	0.0
1	1	1	2	2	1	0	14	46.7	1	3.3	1	3.3	0.0	0.0	2	6.7	27	90.0	0	0.0	0	0.0	0	0.0
1	1	1	3	5	0	1	5	16.7	1	3.3	0	0.0	0.0	0.0	24	80.0	6	20.0	0	0.0	0	0.0	0	0.0
1	1	1	3	5	0	0	13	43.3	2	6.7	1	3.3	0.0	0.0	26	86.7	3	10.0	0	0.0	0	0.0	0	0.0
1	1	1	3	5	1	1	27	90.0	0	0.0	10	33.3	0.0	0.0	3	10.0	17	56.7	0	0.0	0	0.0	0	0.0
1	1	1	3	5	1	0	15	50.0	1	3.3	3	10.0	0.0	0.0	5	16.7	22	73.3	0	0.0	0	0.0	0	0.0
1	1	1	3	3	0	1	16	53.3	4	13.3	0	0.0	0.0	0.0	27	90.0	3	10.0	0	0.0	0	0.0	0	0.0
1	1	1	3	3	0	0	10	33.3	1	3.3	0	0.0	0.0	0.0	28	93.3	2	6.7	0	0.0	0	0.0	0	0.0
1	1	1	3	3	1	1	17	56.7	1	3.3	2	6.7	0.0	0.0	10	33.3	17	56.7	1	3.3	0	0.0	0	0.0
1	1	1	3	3	1	0	10	33.3	1	3.3	2	6.7	0.0	0.0	5	16.7	23	76.7	0	0.0	0	0.0	0	0.0
1	1	1	3	2	0	1	19	63.3	1	3.3	4	13.3	0.0	0.0	23	76.7	2	6.7	0	0.0	1	3.3	0	0.0
1	1	1	3	2	0	0	14	46.7	0	0.0	3	10.0	0.0	0.0	22	73.3	5	16.7	0	0.0	0	0.0	0	0.0
1	1	1	3	2	1	1	23	76.7	2	6.7	15	50.0	8.0	26.7	2	6.7	5	16.7	0	0.0	0	0.0	0	0.0
1	1	1	3	2	1	0	24	80.0	1	3.3	16	53.3	4.0	13.3	2	6.7	8	26.7	0	0.0	0	0.0	0	0.0

Table F-1a. Means for 1991 point frame hits and percent cover for three replicates at each 1990 planted plot in Block 1 at the BP Put River No. 1 gravel pad

						Aerial Cover				Ground Cover													
Block	Snow Fence	Poa Glauca	Gravel Thick.	Soil	Tilled	Grass	%	Forb	%	Plant	%	Moss	%	Rock	%	Barren	%	Mulch	%	Wood	%	Feces	%
1	1	1	5	0	1	8.3	27.8	1.3	4.4	0.3	1.1	0.0	0.0	26.7	88.9	2.3	7.8	0.7	2.2	0.0	0.0	0.0	0.0
1	1	1	5	0	0	9.0	30.0	1.3	4.4	1.0	3.3	0.0	0.0	25.3	84.4	3.7	12.2	0.0	0.0	0.0	0.0	0.0	0.0
1	1	1	5	1	1	19.7	65.6	1.7	5.6	6.0	20.0	0.0	0.0	7.7	25.6	16.3	54.4	0.0	0.0	0.0	0.0	0.0	0.0
1	1	1	5	1	0	17.0	56.7	2.0	6.7	5.3	17.8	0.0	0.0	4.3	14.4	20.3	67.8	0.0	0.0	0.0	0.0	0.0	0.0
1	1	1	3	0	1	9.3	31.1	1.3	4.4	0.0	0.0	0.0	0.0	25.0	83.3	4.0	13.3	1.0	3.3	0.0	0.0	0.0	0.0
1	1	1	3	0	0	9.3	31.1	0.3	1.1	0.0	0.0	0.0	0.0	26.3	87.8	3.7	12.2	0.0	0.0	0.0	0.0	0.0	0.0
1	1	1	3	1	1	16.3	54.4	1.7	5.6	1.3	4.4	0.0	0.0	9.0	30.0	19.3	64.4	0.3	1.1	0.0	0.0	0.0	0.0
1	1	1	3	1	0	13.0	43.3	1.3	4.4	2.0	6.7	0.0	0.0	2.3	7.8	25.7	85.6	0.0	0.0	0.0	0.0	0.0	0.0
1	1	1	2	0	1	16.3	54.4	0.7	2.2	2.3	7.8	0.0	0.0	25.0	83.3	2.0	6.7	0.3	1.1	0.3	1.1	0.0	0.0
1	1	1	2	0	0	11.7	38.9	1.0	3.3	1.3	4.4	0.0	0.0	25.7	85.6	3.0	10.0	0.0	0.0	0.0	0.0	0.0	0.0
1	1	1	2	1	1	20.7	68.9	0.7	2.2	7.7	25.6	2.7	8.9	2.7	8.9	17.0	56.7	0.0	0.0	0.0	0.0	0.0	0.0
1	1	1	2	1	0	19.3	64.4	0.7	2.2	7.0	23.3	1.3	4.4	2.0	6.7	19.7	65.6	0.0	0.0	0.0	0.0	0.0	0.0

Table F-1b. 1991 treatment means for point frame hits and percent cover at 1990 planted plots in Block 1, BP Put River No. 1 gravel pad

						Aerial Cover				Ground Cover													
Block	Snow Fence	Poa Glauca	Gravel Thick.	Soil	Tilled	Grass	%	Forb	%	Plant	%	Moss	%	Rock	%	Barren	%	Mulch	%	Wood	%	Feces	%
1	1	1				14.2	47.2	1.2	3.9	2.9	9.5	0.3	1.1	15.2	50.6	11.4	38.1	0.2	0.6	0.0	0.1	0.0	0.0
1	1	1	5			13.5	45.0	1.6	5.3	3.2	10.6	0.0	0.0	16.0	53.3	10.7	35.6	0.2	0.6	0.0	0.0	0.0	0.0
1	1	1	3			12.0	40.0	1.2	3.9	0.8	2.8	0.0	0.0	15.7	52.2	13.2	43.9	0.3	1.1	0.0	0.0	0.0	0.0
1	1	1	2			17.0	56.7	0.8	2.5	4.6	15.3	1.0	3.3	13.8	46.1	10.4	34.7	0.1	0.3	0.1	0.3	0.0	0.0
1	1	1		0		10.7	35.6	1.0	3.3	0.8	2.8	0.0	0.0	25.7	85.6	3.1	10.4	0.3	1.1	0.1	0.2	0.0	0.0
1	1	1		1		17.7	58.9	1.3	4.4	4.9	16.3	0.7	2.2	4.7	15.6	19.7	65.7	0.1	0.2	0.0	0.0	0.0	0.0
1	1	1			0	13.2	44.1	1.1	3.7	2.8	9.3	0.2	0.7	14.3	47.8	12.7	42.2	0.0	0.0	0.0	0.0	0.0	0.0
1	1	1			1	15.1	50.4	1.2	4.1	2.9	9.8	0.4	1.5	16.0	53.3	10.2	33.9	0.4	1.3	0.1	0.2	0.0	0.0

Table F-2. 1991 point frame hits (n=30) and percent cover for plots planted in 1990 in Block 2 at the BP Put River No. 1 gravel pad

							Aerial Cover				Ground Cover													
Block	Snow Fence	Poa Glauca	Repl	Gravel Thick.	Soil	Tilled	Grass	%	Forb	%	Plant	%	Moss	%	Rock	%	Barren	%	Mulch	%	Wood	%	Feces	%
2	0	1	1	5	0	1	7	23.3	4	13.3	0	0.0	0	0.0	28	93.3	1	3.3	1	3.3	0	0.0	0	0.0
2	0	1	1	5	0	0	3	10.0	0	0.0	0	0.0	0	0.0	20	66.7	10	33.3	0	0.0	0	0.0	0	0.0
2	0	1	1	5	1	1	12	40.0	1	3.3	1	3.3	0	0.0	3	10.0	26	86.7	0	0.0	0	0.0	0	0.0
2	0	1	1	5	1	0	10	33.3	0	0.0	1	3.3	0	0.0	3	10.0	26	86.7	0	0.0	0	0.0	0	0.0
2	0	1	1	3	0	1	11	36.7	4	13.3	0	0.0	0	0.0	22	73.3	4	13.3	3	10.0	1	3.3	0	0.0
2	0	1	1	3	0	0	10	33.3	0	0.0	0	0.0	0	0.0	21	70.0	9	30.0	0	0.0	0	0.0	0	0.0
2	0	1	1	3	1	1	23	76.7	5	16.7	6	20.0	0	0.0	9	30.0	15	50.0	0	0.0	0	0.0	0	0.0
2	0	1	1	3	1	0	21	70.0	0	0.0	8	26.7	0	0.0	5	16.7	17	56.7	0	0.0	0	0.0	0	0.0
2	0	1	1	2	0	1	17	56.7	0	0.0	4	13.3	0	0.0	21	70.0	5	16.7	0	0.0	0	0.0	0	0.0
2	0	1	1	2	0	0	8	26.7	1	3.3	0	0.0	0	0.0	22	73.3	8	26.7	0	0.0	0	0.0	0	0.0
2	0	1	1	2	1	1	24	80.0	0	0.0	10	33.3	0	0.0	2	6.7	18	60.0	0	0.0	0	0.0	0	0.0
2	0	1	1	2	1	0	22	73.3	2	6.7	8	26.7	0	0.0	0	0.0	22	73.3	0	0.0	0	0.0	0	0.0
2	0	1	2	5	0	1	3	10.0	1	3.3	0	0.0	0	0.0	27	90.0	3	10.0	0	0.0	0	0.0	0	0.0
2	0	1	2	5	0	0	9	30.0	1	3.3	0	0.0	0	0.0	22	73.3	8	26.7	0	0.0	0	0.0	0	0.0
2	0	1	2	5	1	1	15	50.0	0	0.0	3	10.0	0	0.0	2	6.7	25	83.3	0	0.0	0	0.0	0	0.0
2	0	1	2	5	1	0	2	6.7	0	0.0	0	0.0	0	0.0	6	20.0	24	80.0	0	0.0	0	0.0	0	0.0
2	0	1	2	3	0	1	9	30.0	1	3.3	0	0.0	0	0.0	27	90.0	3	10.0	0	0.0	0	0.0	0	0.0
2	0	1	2	3	0	0	8	26.7	1	3.3	0	0.0	0	0.0	25	83.3	5	16.7	0	0.0	0	0.0	0	0.0
2	0	1	2	3	1	1	18	60.0	0	0.0	4	13.3	0	0.0	8	26.7	18	60.0	0	0.0	0	0.0	0	0.0
2	0	1	2	3	1	0	12	40.0	0	0.0	0	0.0	0	0.0	7	23.3	23	76.7	0	0.0	0	0.0	0	0.0
2	0	1	2	2	0	1	9	30.0	0	0.0	0	0.0	0	0.0	26	86.7	4	13.3	0	0.0	0	0.0	0	0.0
2	0	1	2	2	0	0	12	40.0	0	0.0	2	6.7	0	0.0	24	80.0	4	13.3	0	0.0	0	0.0	0	0.0
2	0	1	2	2	1	1	30	100.0	0	0.0	23	76.7	0	0.0	1	3.3	6	20.0	0	0.0	0	0.0	0	0.0
2	0	1	2	2	1	0	26	86.7	2	6.7	14	46.7	0	0.0	4	13.3	11	36.7	0	0.0	0	0.0	1	3.3
2	0	1	3	5	0	1	8	26.7	0	0.0	0	0.0	0	0.0	24	80.0	5	16.7	1	3.3	0	0.0	0	0.0
2	0	1	3	5	0	0	4	13.3	0	0.0	0	0.0	0	0.0	20	66.7	10	33.3	0	0.0	0	0.0	0	0.0
2	0	1	3	5	1	1	7	23.3	0	0.0	1	3.3	0	0.0	8	26.7	20	66.7	0	0.0	0	0.0	1	3.3
2	0	1	3	5	1	0	5	16.7	0	0.0	0	0.0	0	0.0	7	23.3	23	76.7	0	0.0	0	0.0	0	0.0
2	0	1	3	3	0	1	4	13.3	1	3.3	0	0.0	0	0.0	27	90.0	3	10.0	0	0.0	0	0.0	0	0.0
2	0	1	3	3	0	0	10	33.3	1	3.3	0	0.0	0	0.0	25	83.3	5	16.7	0	0.0	0	0.0	0	0.0
2	0	1	3	3	1	1	14	46.7	0	0.0	2	6.7	0	0.0	2	6.7	26	86.7	0	0.0	0	0.0	0	0.0
2	0	1	3	3	1	0	11	36.7	4	13.3	1	3.3	0	0.0	2	6.7	27	90.0	0	0.0	0	0.0	0	0.0
2	0	1	3	2	0	1	23	76.7	0	0.0	6	20.0	0	0.0	17	56.7	7	23.3	0	0.0	0	0.0	0	0.0
2	0	1	3	2	0	0	15	50.0	0	0.0	1	3.3	0	0.0	24	80.0	5	16.7	0	0.0	0	0.0	0	0.0
2	0	1	3	2	1	1	28	93.3	0	0.0	8	26.7	0	0.0	4	13.3	18	60.0	0	0.0	0	0.0	0	0.0
2	0	1	3	2	1	0	9	30.0	0	0.0	1	3.3	0	0.0	5	16.7	24	80.0	0	0.0	0	0.0	0	0.0

Table F-2a. Means for 1991 point frame hits and percent cover for three replicates at each 1990 planted plot in Block 2 at the BP Put River No. 1 gravel pad

Block	Snow Fence	Poa Glauca	Gravel Thick.	Soil	Tilled	Aerial Cover: Grass	%	Forb	%	Ground Cover: Plant	%	Moss	%	Rock	%	Barren	%	Mulch	%	Wood	%	Feces	%
2	0	1	5	0	1	6.0	6.0	1.7	1.7	0.0	0.0	0.0	0.0	26.3	26.3	3.0	3.0	0.7	0.7	0.0	0.0	0.0	0.0
2	0	1	5	0	0	5.3	5.3	0.3	0.3	0.0	0.0	0.0	0.0	20.7	20.7	9.3	9.3	0.0	0.0	0.0	0.0	0.0	0.0
2	0	1	5	1	1	11.3	11.3	0.3	0.3	1.7	1.7	0.0	0.0	4.3	4.3	23.7	23.7	0.0	0.0	0.0	0.0	0.3	0.3
2	0	1	5	1	0	5.7	5.7	0.0	0.0	0.3	0.3	0.0	0.0	5.3	5.3	24.3	24.3	0.0	0.0	0.0	0.0	0.0	0.0
2	0	1	3	0	1	8.0	8.0	2.0	2.0	0.0	0.0	0.0	0.0	25.3	25.3	3.3	3.3	1.0	1.0	0.3	0.3	0.0	0.0
2	0	1	3	0	0	9.3	9.3	0.7	0.7	0.0	0.0	0.0	0.0	23.7	23.7	6.3	6.3	0.0	0.0	0.0	0.0	0.0	0.0
2	0	1	3	1	1	18.3	18.3	1.7	1.7	4.0	4.0	0.0	0.0	6.3	6.3	19.7	19.7	0.0	0.0	0.0	0.0	0.0	0.0
2	0	1	3	1	0	14.7	14.7	1.3	1.3	3.0	3.0	0.0	0.0	4.7	4.7	22.3	22.3	0.0	0.0	0.0	0.0	0.0	0.0
2	0	1	2	0	1	16.3	16.3	0.0	0.0	3.3	3.3	0.0	0.0	21.3	21.3	5.3	5.3	0.0	0.0	0.0	0.0	0.0	0.0
2	0	1	2	0	0	11.7	11.7	0.3	0.3	1.0	1.0	0.0	0.0	23.3	23.3	5.7	5.7	0.0	0.0	0.0	0.0	0.0	0.0
2	0	1	2	1	1	27.3	27.3	0.0	0.0	13.7	13.7	0.0	0.0	2.3	2.3	14.0	14.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0	1	2	1	0	19.0	19.0	1.3	1.3	7.7	7.7	0.0	0.0	3.0	3.0	19.0	19.0	0.0	0.0	0.0	0.0	0.3	0.3

Table F-2b. 1991 treatment means for point frame hits and percent cover at 1990 planted plots in Block 2, BP Put River No. 1 gravel pad

Block	Snow Fence	Poa Glauca	Gravel Thick.	Soil	Tilled	Aerial Cover: Grass	%	Forb	%	Ground Cover: Plant	%	Moss	%	Rock	%	Barren	%	Mulch	%	Wood	%	Feces	%
2	0	1				12.8	42.5	0.8	2.7	2.9	9.6	0.0	0.0	13.9	46.3	13.0	43.3	0.1	0.5	0.0	0.1	0.1	0.2
2	0	1	5			7.1	23.6	0.6	1.9	0.5	1.7	0.0	0.0	14.2	47.2	15.1	50.3	0.2	0.6	0.0	0.0	0.1	0.3
2	0	1	3			12.6	41.9	1.4	4.7	1.8	5.8	0.0	0.0	15.0	50.0	12.9	43.1	0.3	0.8	0.1	0.3	0.0	0.0
2	0	1	2			18.6	61.9	0.4	1.4	6.4	21.4	0.0	0.0	12.5	41.7	11.0	36.7	0.0	0.0	0.0	0.0	0.1	0.3
2	0	1		0		9.4	31.5	0.8	2.8	0.7	2.4	0.0	0.0	23.4	78.1	5.5	18.3	0.3	0.9	0.1	0.2	0.0	0.0
2	0	1		1		16.1	53.5	0.8	2.6	5.1	16.9	0.0	0.0	4.3	14.4	20.5	68.3	0.0	0.0	0.0	0.0	0.1	0.4
2	0	1			0	10.9	36.5	0.7	2.2	2.0	6.7	0.0	0.0	13.4	44.8	14.5	48.3	0.0	0.0	0.0	0.0	0.1	0.2
2	0	1			1	14.6	48.5	0.9	3.1	3.8	12.6	0.0	0.0	14.3	47.8	11.5	38.3	0.3	0.9	0.1	0.2	0.1	0.2

Table F-3. 1991 point frame hits (n=30) and percent cover for plots planted in 1990 in Block 3 at the BP Put River No. 1 gravel pad

							Aerial Cover				Ground Cover													
Block	Snow Fence	Poa Glauca	Repl	Gravel Thick.	Soil	Tilled	Grass	%	Forb	%	Plant	%	Moss	%	Rock	%	Barren	%	Mulch	%	Wood	%	Feces	%
3	1	0	1	5	0	1	16	53.3	2	6.7	0	0.0	0	0.0	24	80.0	6	20.0	0	0.0	0	0.0	0	0.0
3	1	0	1	5	0	0	6	20.0	0	0.0	0	0.0	0	0.0	23	76.7	7	23.3	0	0.0	0	0.0	0	0.0
3	1	0	1	5	1	1	13	43.3	0	0.0	0	0.0	0	0.0	6	20.0	24	80.0	0	0.0	0	0.0	0	0.0
3	1	0	1	5	1	0	13	43.3	1	3.3	0	0.0	0	0.0	14	46.7	16	53.3	0	0.0	0	0.0	0	0.0
3	1	0	1	3	0	1	12	40.0	1	3.3	0	0.0	0	0.0	28	93.3	2	6.7	0	0.0	0	0.0	0	0.0
3	1	0	1	3	0	0	10	33.3	2	6.7	1	3.3	0	0.0	27	90.0	2	6.7	0	0.0	0	0.0	0	0.0
3	1	0	1	3	1	1	10	33.3	1	3.3	0	0.0	0	0.0	3	10.0	27	90.0	0	0.0	0	0.0	0	0.0
3	1	0	1	3	1	0	12	40.0	1	3.3	4	13.3	0	0.0	5	16.7	21	70.0	0	0.0	0	0.0	0	0.0
3	1	0	1	2	0	1	14	46.7	5	16.7	1	3.3	0	0.0	20	66.7	9	30.0	0	0.0	0	0.0	0	0.0
3	1	0	1	2	0	0	5	16.7	1	3.3	0	0.0	0	0.0	26	86.7	4	13.3	0	0.0	0	0.0	0	0.0
3	1	0	1	2	1	1	6	20.0	0	0.0	0	0.0	0	0.0	17	56.7	13	43.3	0	0.0	0	0.0	0	0.0
3	1	0	1	2	1	0	12	40.0	2	6.7	4	13.3	0	0.0	7	23.3	19	63.3	0	0.0	0	0.0	0	0.0
3	1	0	2	5	0	1	6	20.0	0	0.0	0	0.0	0	0.0	28	93.3	2	6.7	0	0.0	0	0.0	0	0.0
3	1	0	2	5	0	0	8	26.7	0	0.0	0	0.0	0	0.0	22	73.3	8	26.7	0	0.0	0	0.0	0	0.0
3	1	0	2	5	1	1	19	63.3	1	3.3	15	50.0	0	0.0	4	13.3	11	36.7	0	0.0	0	0.0	0	0.0
3	1	0	2	5	1	0	5	16.7	0	0.0	3	10.0	0	0.0	9	30.0	18	60.0	0	0.0	0	0.0	0	0.0
3	1	0	2	3	0	1	2	6.7	0	0.0	0	0.0	0	0.0	23	76.7	7	23.3	0	0.0	0	0.0	0	0.0
3	1	0	2	3	0	0	7	23.3	1	3.3	0	0.0	0	0.0	24	80.0	6	20.0	0	0.0	0	0.0	0	0.0
3	1	0	2	3	1	1	10	33.3	0	0.0	3	10.0	0	0.0	7	23.3	20	66.7	0	0.0	0	0.0	0	0.0
3	1	0	2	3	1	0	20	66.7	0	0.0	11	36.7	0	0.0	4	13.3	15	50.0	0	0.0	0	0.0	0	0.0
3	1	0	2	2	0	1	5	16.7	0	0.0	0	0.0	0	0.0	28	93.3	2	6.7	0	0.0	0	0.0	0	0.0
3	1	0	2	2	0	0	8	26.7	1	3.3	0	0.0	0	0.0	29	96.7	1	3.3	0	0.0	0	0.0	0	0.0
3	1	0	2	2	1	1	10	33.3	0	0.0	1	3.3	0	0.0	8	26.7	21	70.0	0	0.0	0	0.0	0	0.0
3	1	0	2	2	1	0	3	10.0	0	0.0	0	0.0	0	0.0	5	16.7	25	83.3	0	0.0	0	0.0	0	0.0
3	1	0	3	5	0	1	10	33.3	0	0.0	1	3.3	0	0.0	26	86.7	3	10.0	0	0.0	0	0.0	0	0.0
3	1	0	3	5	0	0	4	13.3	0	0.0	1	3.3	0	0.0	19	63.3	10	33.3	0	0.0	0	0.0	0	0.0
3	1	0	3	5	1	1	13	43.3	2	6.7	5	16.7	0	0.0	7	23.3	18	60.0	0	0.0	0	0.0	0	0.0
3	1	0	3	5	1	0	15	50.0	0	0.0	3	10.0	0	0.0	9	30.0	18	60.0	0	0.0	0	0.0	0	0.0
3	1	0	3	3	0	1	8	26.7	1	3.3	0	0.0	0	0.0	27	90.0	3	10.0	0	0.0	0	0.0	0	0.0
3	1	0	3	3	0	0	5	16.7	2	6.7	0	0.0	0	0.0	25	83.3	5	16.7	0	0.0	0	0.0	0	0.0
3	1	0	3	3	1	1	17	56.7	0	0.0	5	16.7	0	0.0	1	3.3	24	80.0	0	0.0	0	0.0	0	0.0
3	1	0	3	3	1	0	14	46.7	1	3.3	3	10.0	0	0.0	6	20.0	21	70.0	0	0.0	0	0.0	0	0.0
3	1	0	3	2	0	1	10	33.3	2	6.7	0	0.0	0	0.0	28	93.3	2	6.7	0	0.0	0	0.0	0	0.0
3	1	0	3	2	0	0	7	23.3	1	3.3	0	0.0	0	0.0	26	86.7	4	13.3	0	0.0	0	0.0	0	0.0
3	1	0	3	2	1	1	11	36.7	0	0.0	1	3.3	0	0.0	8	26.7	21	70.0	0	0.0	0	0.0	0	0.0
3	1	0	3	2	1	0	14	46.7	1	3.3	2	6.7	0	0.0	4	13.3	24	80.0	0	0.0	0	0.0	0	0.0

Table F-3a. Means for 1991 point frame hits and percent cover for three replicates at each 1990 planted plot in Block 3 at the BP Put River No. 1 gravel pad

						Aerial Cover				Ground Cover													
Block	Snow Fence	Poa Glauca	Gravel Thick.	Soil	Tilled	Grass	%	Forb	%	Plant	%	Moss	%	Rock	%	Barren	%	Mulch	%	Wood	%	Feces	%
3	1	0	5	0	1	10.7	35.6	0.7	2.2	0.3	1.1	0.0	0.0	26.0	86.7	3.7	12.2	0.0	0.0	0.0	0.0	0.0	0.0
3	1	0	5	0	0	6.0	20.0	0.0	0.0	0.3	1.1	0.0	0.0	21.3	71.1	8.3	27.8	0.0	0.0	0.0	0.0	0.0	0.0
3	1	0	5	1	1	15.0	50.0	1.0	3.3	6.7	22.2	0.0	0.0	5.7	18.9	17.7	58.9	0.0	0.0	0.0	0.0	0.0	0.0
3	1	0	5	1	0	11.0	36.7	0.3	1.1	2.0	6.7	0.0	0.0	10.7	35.6	17.3	57.8	0.0	0.0	0.0	0.0	0.0	0.0
3	1	0	3	0	1	7.3	24.4	0.7	2.2	0.0	0.0	0.0	0.0	26.0	86.7	4.0	13.3	0.0	0.0	0.0	0.0	0.0	0.0
3	1	0	3	0	0	7.3	24.4	1.7	5.6	0.3	1.1	0.0	0.0	25.3	84.4	4.3	14.4	0.0	0.0	0.0	0.0	0.0	0.0
3	1	0	3	1	1	12.3	41.1	0.3	1.1	2.7	8.9	0.0	0.0	3.7	12.2	23.7	78.9	0.0	0.0	0.0	0.0	0.0	0.0
3	1	0	3	1	0	15.3	51.1	0.7	2.2	6.0	20.0	0.0	0.0	5.0	16.7	19.0	63.3	0.0	0.0	0.0	0.0	0.0	0.0
3	1	0	2	0	1	9.7	32.2	2.3	7.8	0.3	1.1	0.0	0.0	25.3	84.4	4.3	14.4	0.0	0.0	0.0	0.0	0.0	0.0
3	1	0	2	0	0	6.7	22.2	1.0	3.3	0.0	0.0	0.0	0.0	27.0	90.0	3.0	10.0	0.0	0.0	0.0	0.0	0.0	0.0
3	1	0	2	1	1	9.0	30.0	0.0	0.0	0.7	2.2	0.0	0.0	11.0	36.7	18.3	61.1	0.0	0.0	0.0	0.0	0.0	0.0
3	1	0	2	1	0	9.7	32.2	1.0	3.3	2.0	6.7	0.0	0.0	5.3	17.8	22.7	75.6	0.0	0.0	0.0	0.0	0.0	0.0

Table F-3b. 1991 treatment means for point frame hits and percent cover at 1990 planted plot in Block 3, BP Put River No. 1 gravel pad

						Aerial Cover				Ground Cover													
Block	Snow Fence	Poa Glauca	Gravel Thick.	Soil	Tilled	Grass	%	Forb	%	Plant	%	Moss	%	Rock	%	Barren	%	Mulch	%	Wood	%	Feces	%
3	1	0				10.0	33.3	0.8	2.7	1.8	5.9	0.0	0.0	16.0	53.4	12.2	40.6	0.0	0.0	0.0	0.0	0.0	0.0
3	1	0	5			10.7	35.6	0.5	1.7	2.3	7.8	0.0	0.0	15.9	53.1	11.8	39.2	0.0	0.0	0.0	0.0	0.0	0.0
3	1	0	3			10.6	35.3	0.8	2.8	2.3	7.5	0.0	0.0	15.0	50.0	12.8	42.5	0.0	0.0	0.0	0.0	0.0	0.0
3	1	0	2			8.8	29.2	1.1	3.6	0.8	2.5	0.0	0.0	17.2	57.2	12.1	40.3	0.0	0.0	0.0	0.0	0.0	0.0
3	1	0		0		7.9	26.5	1.1	3.5	0.2	0.7	0.0	0.0	25.2	83.9	4.6	15.4	0.0	0.0	0.0	0.0	0.0	0.0
3	1	0		1		12.1	40.2	0.6	1.9	3.3	11.1	0.0	0.0	6.9	23.0	19.8	65.9	0.0	0.0	0.0	0.0	0.0	0.0
3	1	0			0	9.3	31.1	0.8	2.6	1.8	5.9	0.0	0.0	15.8	52.6	12.4	41.5	0.0	0.0	0.0	0.0	0.0	0.0
3	1	0			1	10.7	35.6	0.8	2.8	1.8	5.9	0.0	0.0	16.3	54.3	11.9	39.8	0.0	0.0	0.0	0.0	0.0	0.0

Table F-4. 1991 point frame hits and percent cover for plots planted in 1990 in Block 4 at the BP Put River No. 1 gravel pad, n=30

							Aerial Cover				Ground Cover													
Block	Snow Fence	Poa Glauca	Repl	Gravel Thick.	Soil	Tilled	Grass	%	Forb	%	Plant	%	Moss	%	Rock	%	Barren	%	Mulch	%	Wood	%	Feces	%
4	0	0	1	5	0	1	3	10.0	0	0.0	0	0.0	0	0.0	28	93.3	2	6.7	0	0.0	0	0.0	0	0.0
4	0	0	1	5	0	0	4	13.3	0	0.0	0	0.0	0	0.0	22	73.3	8	26.7	0	0.0	0	0.0	0	0.0
4	0	0	1	5	1	1	14	46.7	1	3.3	4	13.3	0	0.0	8	26.7	18	60.0	0	0.0	0	0.0	0	0.0
4	0	0	1	5	1	0	6	20.0	0	0.0	0	0.0	0	0.0	8	26.7	22	73.3	0	0.0	0	0.0	0	0.0
4	0	0	1	3	0	1	8	26.7	0	0.0	0	0.0	0	0.0	30	100.0	0	0.0	0	0.0	0	0.0	0	0.0
4	0	0	1	3	0	0	7	23.3	1	3.3	0	0.0	0	0.0	25	83.3	5	16.7	0	0.0	0	0.0	0	0.0
4	0	0	1	3	1	1	16	53.3	0	0.0	3	10.0	0	0.0	10	33.3	16	53.3	0	0.0	0	0.0	1	3.3
4	0	0	1	3	1	0	10	33.3	0	0.0	2	6.7	0	0.0	9	30.0	19	63.3	0	0.0	0	0.0	0	0.0
4	0	0	1	2	0	1	10	33.3	0	0.0	0	0.0	0	0.0	29	96.7	1	3.3	0	0.0	0	0.0	0	0.0
4	0	0	1	2	0	0	6	20.0	0	0.0	0	0.0	0	0.0	25	83.3	5	16.7	0	0.0	0	0.0	0	0.0
4	0	0	1	2	1	1	7	23.3	0	0.0	0	0.0	0	0.0	9	30.0	21	70.0	0	0.0	0	0.0	0	0.0
4	0	0	1	2	1	0	6	20.0	1	3.3	2	6.7	0	0.0	9	30.0	19	63.3	0	0.0	0	0.0	0	0.0
4	0	0	2	5	0	1	1	3.3	0	0.0	0	0.0	0	0.0	22	73.3	8	26.7	0	0.0	0	0.0	0	0.0
4	0	0	2	5	0	0	8	26.7	0	0.0	1	3.3	0	0.0	21	70.0	8	26.7	0	0.0	0	0.0	0	0.0
4	0	0	2	5	1	1	13	43.3	0	0.0	2	6.7	0	0.0	7	23.3	21	70.0	0	0.0	0	0.0	0	0.0
4	0	0	2	5	1	0	1	3.3	0	0.0	0	0.0	0	0.0	10	33.3	20	66.7	0	0.0	0	0.0	0	0.0
4	0	0	2	3	0	1	9	30.0	0	0.0	1	3.3	0	0.0	21	70.0	8	26.7	0	0.0	0	0.0	0	0.0
4	0	0	2	3	0	0	9	30.0	0	0.0	0	0.0	0	0.0	25	83.3	5	16.7	0	0.0	0	0.0	0	0.0
4	0	0	2	3	1	1	22	73.3	0	0.0	7	23.3	0	0.0	8	26.7	15	50.0	0	0.0	0	0.0	0	0.0
4	0	0	2	3	1	0	11	36.7	1	3.3	4	13.3	0	0.0	6	20.0	20	66.7	0	0.0	0	0.0	0	0.0
4	0	0	2	2	0	1	10	33.3	1	3.3	1	3.3	0	0.0	25	83.3	4	13.3	0	0.0	0	0.0	0	0.0
4	0	0	2	2	0	0	4	13.3	0	0.0	0	0.0	0	0.0	26	86.7	4	13.3	0	0.0	0	0.0	0	0.0
4	0	0	2	2	1	1	12	40.0	1	3.3	2	6.7	0	0.0	12	40.0	16	53.3	0	0.0	0	0.0	0	0.0
4	0	0	2	2	1	0	15	50.0	2	6.7	1	3.3	0	0.0	8	26.7	21	70.0	0	0.0	0	0.0	0	0.0
4	0	0	3	5	0	1	11	36.7	0	0.0	1	3.3	0	0.0	24	80.0	5	16.7	0	0.0	0	0.0	0	0.0
4	0	0	3	5	0	0	6	20.0	0	0.0	0	0.0	0	0.0	22	73.3	8	26.7	0	0.0	0	0.0	0	0.0
4	0	0	3	5	1	1	13	43.3	0	0.0	0	0.0	0	0.0	8	26.7	22	73.3	0	0.0	0	0.0	0	0.0
4	0	0	3	5	1	0	7	23.3	0	0.0	2	6.7	0	0.0	9	30.0	19	63.3	0	0.0	0	0.0	0	0.0
4	0	0	3	3	0	1	12	40.0	2	6.7	2	6.7	0	0.0	25	83.3	3	10.0	0	0.0	0	0.0	0	0.0
4	0	0	3	3	0	0	5	16.7	0	0.0	0	0.0	0	0.0	23	76.7	7	23.3	0	0.0	0	0.0	0	0.0
4	0	0	3	3	1	1	24	80.0	0	0.0	5	16.7	0	0.0	3	10.0	22	73.3	0	0.0	0	0.0	0	0.0
4	0	0	3	3	1	0	18	60.0	2	6.7	2	6.7	0	0.0	7	23.3	21	70.0	0	0.0	0	0.0	0	0.0
4	0	0	3	2	0	1	8	26.7	2	6.7	1	3.3	0	0.0	27	90.0	2	6.7	0	0.0	0	0.0	0	0.0
4	0	0	3	2	0	0	1	3.3	0	0.0	0	0.0	0	0.0	25	83.3	5	16.7	0	0.0	0	0.0	0	0.0
4	0	0	3	2	1	1	10	33.3	0	0.0	5	16.7	0	0.0	8	26.7	17	56.7	0	0.0	0	0.0	0	0.0
4	0	0	3	2	1	0	15	50.0	0	0.0	0	0.0	0	0.0	7	23.3	23	76.7	0	0.0	0	0.0	0	0.0

Table F-4a. Means for 1991 point frame hits and percent cover for three replicates at each 1990 planted plot in Block 4 at the BP Put River No. 1 gravel pad

						Aerial Cover				Ground Cover													
Block	Snow Fence	Poa Glauca	Gravel Thick.	Soil	Tilled	Grass	%	Forb	%	Plant	%	Moss	%	Rock	%	Barren	%	Mulch	%	Wood	%	Feces	%
4	0	0	5	0	1	5.0	16.7	0.0	0.0	0.3	1.1	0.0	0.0	24.7	82.2	5.0	16.7	0.0	0.0	0.0	0.0	0.0	0.0
4	0	0	5	0	0	6.0	20.0	0.0	0.0	0.3	1.1	0.0	0.0	21.7	72.2	8.0	26.7	0.0	0.0	0.0	0.0	0.0	0.0
4	0	0	5	1	1	13.3	44.4	0.3	1.1	2.0	6.7	0.0	0.0	7.7	25.6	20.3	67.8	0.0	0.0	0.0	0.0	0.0	0.0
4	0	0	5	1	0	4.7	15.6	0.0	0.0	0.7	2.2	0.0	0.0	9.0	30.0	20.3	67.8	0.0	0.0	0.0	0.0	0.0	0.0
4	0	0	3	0	1	9.7	32.2	0.7	2.2	1.0	3.3	0.0	0.0	25.3	84.4	3.7	12.2	0.0	0.0	0.0	0.0	0.0	0.0
4	0	0	3	0	0	7.0	23.3	0.3	1.1	0.0	0.0	0.0	0.0	24.3	81.1	5.7	18.9	0.0	0.0	0.0	0.0	0.0	0.0
4	0	0	3	1	1	20.7	68.9	0.0	0.0	5.0	16.7	0.0	0.0	7.0	23.3	17.7	58.9	0.0	0.0	0.0	0.0	0.3	1.1
4	0	0	3	1	0	13.0	43.3	1.0	3.3	2.7	8.9	0.0	0.0	7.3	24.4	20.0	66.7	0.0	0.0	0.0	0.0	0.0	0.0
4	0	0	2	0	1	9.3	31.1	1.0	3.3	0.7	2.2	0.0	0.0	27.0	90.0	2.3	7.8	0.0	0.0	0.0	0.0	0.0	0.0
4	0	0	2	0	0	3.7	12.2	0.0	0.0	0.0	0.0	0.0	0.0	25.3	84.4	4.7	15.6	0.0	0.0	0.0	0.0	0.0	0.0
4	0	0	2	1	1	9.7	32.2	0.3	1.1	2.3	7.8	0.0	0.0	9.7	32.2	18.0	60.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0	0	2	1	0	12.0	40.0	1.0	3.3	1.0	3.3	0.0	0.0	8.0	26.7	21.0	70.0	0.0	0.0	0.0	0.0	0.0	0.0

Table F-4b. 1991 treatment means for point frame hits and percent cover at 1990 planted plots in Block 4, BP Put River No. 1 gravel pad .

						Aerial Cover				Ground Cover													
Block	Snow Fence	Poa Glauca	Gravel Thick.	Soil	Tilled	Grass	%	Forb	%	Plant	%	Moss	%	Rock	%	Barren	%	Mulch	%	Wood	%	Feces	%
4	0	0				9.5	31.7	0.4	1.3	1.3	4.4	0.0	0.0	16.4	54.7	12.2	40.7	0.0	0.0	0.0	0.0	0.0	0.1
4	0	0	5			7.3	24.2	0.1	0.3	0.8	2.8	0.0	0.0	15.8	52.5	13.4	44.7	0.0	0.0	0.0	0.0	0.0	0.0
4	0	0	3			12.6	41.9	0.5	1.7	2.2	7.2	0.0	0.0	16.0	53.3	11.8	39.2	0.0	0.0	0.0	0.0	0.1	0.3
4	0	0	2			8.7	28.9	0.6	1.9	1.0	3.3	0.0	0.0	17.5	58.3	11.5	38.3	0.0	0.0	0.0	0.0	0.0	0.0
4	0	0		0		6.8	22.6	0.3	1.1	0.4	1.3	0.0	0.0	24.7	82.4	4.9	16.3	0.0	0.0	0.0	0.0	0.0	0.0
4	0	0		1		12.2	40.7	0.4	1.5	2.3	7.6	0.0	0.0	8.1	27.0	19.6	65.2	0.0	0.0	0.0	0.0	0.1	0.2
4	0	0			0	7.7	25.7	0.4	1.3	0.8	2.6	0.0	0.0	15.9	53.1	13.3	44.3	0.0	0.0	0.0	0.0	0.0	0.0
4	0	0			1	11.3	37.6	0.4	1.3	1.9	6.3	0.0	0.0	16.9	56.3	11.2	37.2	0.0	0.0	0.0	0.0	0.1	0.2

Table F-5. 1991 point frame hits (n=30) and percent cover from Replicate 2 unplanted plots at the BP Put River No. 1 gravel pad

Block	Snow Fence	Poa Glauca	Repl	Gravel Thick.	Soil	Tilled	Aerial Cover: Grass	%	Forb	%	Plant	%	Ground Cover: Moss	%	Rock	%	Barren	%	Mulch	%	Wood	%	Feces	%
1	1	1	2	5	0	1	0	0.0	0	0.0	0	0.0	0	0.0	26	86.7	2	6.7	2	6.7	0	0.0	0	0.0
1	1	1	2	5	0	0	0	0.0	0	0.0	0	0.0	0	0.0	27	90.0	3	10.0	0	0.0	0	0.0	0	0.0
1	1	1	2	5	1	1	0	0.0	0	0.0	0	0.0	0	0.0	15	50.0	15	50.0	0	0.0	0	0.0	0	0.0
1	1	1	2	5	1	0	0	0.0	0	0.0	0	0.0	0	0.0	2	6.7	24	80.0	4	13.3	0	0.0	0	0.0
1	1	1	2	3	0	1	0	0.0	0	0.0	0	0.0	0	0.0	29	96.7	0	0.0	1	3.3	0	0.0	0	0.0
1	1	1	2	3	0	0	0	0.0	0	0.0	0	0.0	0	0.0	23	76.7	7	23.3	0	0.0	0	0.0	0	0.0
1	1	1	2	3	1	1	0	0.0	0	0.0	0	0.0	0	0.0	16	53.3	14	46.7	0	0.0	0	0.0	0	0.0
1	1	1	2	3	1	0	0	0.0	0	0.0	0	0.0	0	0.0	8	26.7	22	73.3	0	0.0	0	0.0	0	0.0
1	1	1	2	2	0	1	0	0.0	1	3.3	1	3.3	1	3.3	24	80.0	3	10.0	1	3.3	0	0.0	0	0.0
1	1	1	2	2	0	0	7	23.3	0	0.0	0	0.0	0	0.0	28	93.3	2	6.7	0	0.0	0	0.0	0	0.0
1	1	1	2	2	1	1	4	13.3	0	0.0	0	0.0	0	0.0	6	20.0	24	80.0	0	0.0	0	0.0	0	0.0
1	1	1	2	2	1	0	4	13.3	1	3.3	0	0.0	0	0.0	8	26.7	21	70.0	0	0.0	0	0.0	1	3.3
2	0	1	2	5	0	1	0	0.0	0	0.0	0	0.0	4	13.3	23	76.7	3	10.0	0	0.0	0	0.0	0	0.0
2	0	1	2	5	0	0	0	0.0	0	0.0	0	0.0	0	0.0	22	73.3	8	26.7	0	0.0	0	0.0	0	0.0
2	0	1	2	5	1	1	0	0.0	0	0.0	0	0.0	0	0.0	7	23.3	23	76.7	0	0.0	0	0.0	0	0.0
2	0	1	2	5	1	0	0	0.0	0	0.0	0	0.0	0	0.0	6	20.0	24	80.0	0	0.0	0	0.0	0	0.0
2	0	1	2	3	0	1	0	0.0	0	0.0	0	0.0	0	0.0	28	93.3	2	6.7	0	0.0	0	0.0	0	0.0
2	0	1	2	3	0	0	0	0.0	0	0.0	0	0.0	0	0.0	24	80.0	6	20.0	0	0.0	0	0.0	0	0.0
2	0	1	2	3	1	1	1	3.3	0	0.0	0	0.0	0	0.0	11	36.7	19	63.3	0	0.0	0	0.0	0	0.0
2	0	1	2	3	1	0	0	0.0	0	0.0	0	0.0	0	0.0	13	43.3	17	56.7	0	0.0	0	0.0	0	0.0
2	0	1	2	2	0	1	0	0.0	0	0.0	0	0.0	0	0.0	26	86.7	4	13.3	0	0.0	0	0.0	0	0.0
2	0	1	2	2	0	0	1	3.3	0	0.0	0	0.0	0	0.0	19	63.3	11	36.7	0	0.0	0	0.0	0	0.0
2	0	1	2	2	1	1	0	0.0	0	0.0	0	0.0	0	0.0	14	46.7	16	53.3	0	0.0	0	0.0	0	0.0
2	0	1	2	2	1	0	1	3.3	0	0.0	0	0.0	0	0.0	4	13.3	26	86.7	0	0.0	0	0.0	0	0.0
3	1	0	2	5	0	1	0	0.0	0	0.0	0	0.0	0	0.0	20	66.7	10	33.3	0	0.0	0	0.0	0	0.0
3	1	0	2	5	0	0	0	0.0	0	0.0	0	0.0	0	0.0	22	73.3	8	26.7	0	0.0	0	0.0	0	0.0
3	1	0	2	5	1	1	0	0.0	0	0.0	0	0.0	0	0.0	8	26.7	22	73.3	0	0.0	0	0.0	0	0.0
3	1	0	2	5	1	0	0	0.0	0	0.0	0	0.0	0	0.0	16	53.3	14	46.7	0	0.0	0	0.0	0	0.0
3	1	0	2	3	0	1	0	0.0	0	0.0	0	0.0	0	0.0	25	83.3	5	16.7	0	0.0	0	0.0	0	0.0
3	1	0	2	3	0	0	0	0.0	0	0.0	0	0.0	0	0.0	22	73.3	8	26.7	0	0.0	0	0.0	0	0.0
3	1	0	2	3	1	1	0	0.0	0	0.0	1	3.3	0	0.0	12	40.0	17	56.7	0	0.0	0	0.0	0	0.0
3	1	0	2	3	1	0	0	0.0	0	0.0	0	0.0	0	0.0	17	56.7	13	43.3	0	0.0	0	0.0	0	0.0
3	1	0	2	2	0	1	0	0.0	0	0.0	0	0.0	0	0.0	24	80.0	6	20.0	0	0.0	0	0.0	0	0.0
3	1	0	2	2	0	0	0	0.0	0	0.0	0	0.0	0	0.0	25	83.3	5	16.7	0	0.0	0	0.0	0	0.0
3	1	0	2	2	1	1	0	0.0	0	0.0	0	0.0	0	0.0	11	36.7	19	63.3	0	0.0	0	0.0	0	0.0
3	1	0	2	2	1	0	0	0.0	0	0.0	0	0.0	0	0.0	13	43.3	17	56.7	0	0.0	0	0.0	0	0.0
4	0	0	2	5	0	1	0	0.0	2	6.7	0	0.0	0	0.0	28	93.3	2	6.7	0	0.0	0	0.0	0	0.0
4	0	0	2	5	0	0	0	0.0	0	0.0	0	0.0	0	0.0	26	86.7	4	13.3	0	0.0	0	0.0	0	0.0
4	0	0	2	5	1	1	0	0.0	0	0.0	0	0.0	0	0.0	16	53.3	14	46.7	0	0.0	0	0.0	0	0.0
4	0	0	2	5	1	0	0	0.0	0	0.0	0	0.0	0	0.0	12	40.0	18	60.0	0	0.0	0	0.0	0	0.0
4	0	0	2	3	0	1	0	0.0	0	0.0	0	0.0	0	0.0	29	96.7	1	3.3	0	0.0	0	0.0	0	0.0
4	0	0	2	3	0	0	0	0.0	0	0.0	0	0.0	0	0.0	27	90.0	3	10.0	0	0.0	0	0.0	0	0.0
4	0	0	2	3	1	1	0	0.0	0	0.0	0	0.0	0	0.0	17	56.7	13	43.3	0	0.0	0	0.0	0	0.0
4	0	0	2	3	1	0	1	3.3	0	0.0	0	0.0	0	0.0	7	23.3	23	76.7	0	0.0	0	0.0	0	0.0
4	0	0	2	2	0	1	0	0.0	0	0.0	0	0.0	0	0.0	27	90.0	3	10.0	0	0.0	0	0.0	0	0.0
4	0	0	2	2	0	0	0	0.0	0	0.0	0	0.0	0	0.0	25	83.3	5	16.7	0	0.0	0	0.0	0	0.0
4	0	0	2	2	1	1	0	0.0	0	0.0	0	0.0	0	0.0	11	36.7	19	63.3	0	0.0	0	0.0	0	0.0
4	0	0	2	2	1	0	0	0.0	0	0.0	0	0.0	0	0.0	13	43.3	17	56.7	0	0.0	0	0.0	0	0.0

Table F-5a. 1991 treatment means for point frame hits and percent cover for Replicate 2 unplanted plots at the BP Put River No. 1 gravel pad

						Aerial Cover				Ground Cover													
Block	Snow Fence	Poa Glauca	Gravel Thick.	Soil	Tilled	Grass	%	Forb	%	Plant	%	Moss	%	Rock	%	Barren	%	Mulch	%	Wood	%	Feces	%
1	1	1				1.3	4.2	0.2	0.6	0.1	0.3	0.1	0.3	17.7	58.9	11.4	38.1	0.7	2.2	0.0	0.0	0.1	0.3
1	1	1	5			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	17.5	58.3	11.0	36.7	1.5	5.0	0.0	0.0	0.0	0.0
1	1	1	3			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	19.0	63.3	10.8	35.8	0.3	0.8	0.0	0.0	0.0	0.0
1	1	1	2			3.8	12.5	0.5	1.7	0.3	0.8	0.3	0.8	16.5	55.0	12.5	41.7	0.3	0.8	0.0	0.0	0.3	0.8
1	1	1		0		1.2	3.9	0.2	0.6	0.2	0.6	0.2	0.6	26.2	87.2	2.8	9.4	0.7	2.2	0.0	0.0	0.0	0.0
1	1	1		1		1.3	4.4	0.2	0.6	0.0	0.0	0.0	0.0	9.2	30.6	20.0	66.7	0.7	2.2	0.0	0.0	0.2	0.6
1	1	1			0	0.7	2.2	0.2	0.6	0.2	0.6	0.2	0.6	19.3	64.4	9.7	32.2	0.7	2.2	0.0	0.0	0.0	0.0
1	1	1			1	1.8	6.1	0.2	0.6	0.0	0.0	0.0	0.0	16.0	53.3	13.2	43.9	0.7	2.2	0.0	0.0	0.2	0.6
2	0	1				0.3	0.8	0.0	0.0	0.0	0.0	0.3	1.1	16.4	54.7	13.3	44.2	0.0	0.0	0.0	0.0	0.0	0.0
2	0	1	5			0.0	0.0	0.0	0.0	0.0	0.0	1.0	3.3	14.5	48.3	14.5	48.3	0.0	0.0	0.0	0.0	0.0	0.0
2	0	1	3			0.3	0.8	0.0	0.0	0.0	0.0	0.0	0.0	19.0	63.3	11.0	36.7	0.0	0.0	0.0	0.0	0.0	0.0
2	0	1	2			0.5	1.7	0.0	0.0	0.0	0.0	0.0	0.0	15.8	52.5	14.3	47.5	0.0	0.0	0.0	0.0	0.0	0.0
2	0	1		0		0.2	0.6	0.0	0.0	0.0	0.0	0.7	2.2	23.7	78.9	5.7	18.9	0.0	0.0	0.0	0.0	0.0	0.0
2	0	1		1		0.3	1.1	0.0	0.0	0.0	0.0	0.0	0.0	9.2	30.6	20.8	69.4	0.0	0.0	0.0	0.0	0.0	0.0
2	0	1			0	0.2	0.6	0.0	0.0	0.0	0.0	0.7	2.2	18.2	60.6	11.2	37.2	0.0	0.0	0.0	0.0	0.0	0.0
2	0	1			1	0.3	1.1	0.0	0.0	0.0	0.0	0.0	0.0	14.7	48.9	15.3	51.1	0.0	0.0	0.0	0.0	0.0	0.0
3	1	0				0.0	0.0	0.0	0.0	0.1	0.3	0.0	0.0	17.9	59.7	12.0	40.0	0.0	0.0	0.0	0.0	0.0	0.0
3	1	0	5			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	16.5	55.0	13.5	45.0	0.0	0.0	0.0	0.0	0.0	0.0
3	1	0	3			0.0	0.0	0.0	0.0	0.3	0.8	0.0	0.0	19.0	63.3	10.8	35.8	0.0	0.0	0.0	0.0	0.0	0.0
3	1	0	2			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	18.3	60.8	11.8	39.2	0.0	0.0	0.0	0.0	0.0	0.0
3	1	0		0		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	23.0	76.7	7.0	23.3	0.0	0.0	0.0	0.0	0.0	0.0
3	1	0		1		0.0	0.0	0.0	0.0	0.2	0.6	0.0	0.0	12.8	42.8	17.0	56.7	0.0	0.0	0.0	0.0	0.0	0.0
3	1	0			0	0.0	0.0	0.0	0.0	0.2	0.6	0.0	0.0	16.7	55.6	13.2	43.9	0.0	0.0	0.0	0.0	0.0	0.0
3	1	0			1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	19.2	63.9	10.8	36.1	0.0	0.0	0.0	0.0	0.0	0.0
4	0	0				0.1	0.3	0.2	0.6	0.0	0.0	0.0	0.0	19.8	66.1	10.2	33.9	0.0	0.0	0.0	0.0	0.0	0.0
4	0	0	5			0.0	0.0	0.5	1.7	0.0	0.0	0.0	0.0	20.5	68.3	9.5	31.7	0.0	0.0	0.0	0.0	0.0	0.0
4	0	0	3			0.3	0.8	0.0	0.0	0.0	0.0	0.0	0.0	20.0	66.7	10.0	33.3	0.0	0.0	0.0	0.0	0.0	0.0
4	0	0	2			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	19.0	63.3	11.0	36.7	0.0	0.0	0.0	0.0	0.0	0.0
4	0	0		0		0.0	0.0	0.3	1.1	0.0	0.0	0.0	0.0	27.0	90.0	3.0	10.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0	0		1		0.2	0.6	0.0	0.0	0.0	0.0	0.0	0.0	12.7	42.2	17.3	57.8	0.0	0.0	0.0	0.0	0.0	0.0
4	0	0			0	0.0	0.0	0.3	1.1	0.0	0.0	0.0	0.0	21.3	71.1	8.7	28.9	0.0	0.0	0.0	0.0	0.0	0.0
4	0	0			1	0.2	0.6	0.0	0.0	0.0	0.0	0.0	0.0	18.3	61.1	11.7	38.9	0.0	0.0	0.0	0.0	0.0	0.0
	0					0.2	0.6	0.1	0.3	0.0	0.0	0.2	0.6	18.1	60.4	11.7	39.0	0.0	0.0	0.0	0.0	0.0	0.0
	1					0.6	2.1	0.1	0.3	0.1	0.3	0.0	0.1	17.8	59.3	11.7	39.0	0.3	1.1	0.0	0.0	0.0	0.1
		0				0.0	0.1	0.1	0.3	0.0	0.1	0.0	0.0	18.9	62.9	11.1	36.9	0.0	0.0	0.0	0.0	0.0	0.0
		1				0.8	2.5	0.1	0.3	0.0	0.1	0.2	0.7	17.0	56.8	12.3	41.1	0.3	1.1	0.0	0.0	0.0	0.1
			5			0.0	0.0	0.1	0.4	0.0	0.0	0.3	0.8	17.3	57.5	12.1	40.4	0.4	1.3	0.0	0.0	0.0	0.0
			3			0.1	0.4	0.0	0.0	0.1	0.2	0.0	0.0	19.3	64.2	10.6	35.4	0.1	0.2	0.0	0.0	0.0	0.0
			2			1.1	3.5	0.1	0.4	0.1	0.2	0.1	0.2	17.4	57.9	12.4	41.3	0.1	0.2	0.0	0.0	0.1	0.2
				0		0.3	1.1	0.1	0.4	0.0	0.1	0.2	0.7	25.0	83.2	4.6	15.4	0.2	0.6	0.0	0.0	0.0	0.0
				1		0.5	1.5	0.0	0.1	0.0	0.1	0.0	0.0	11.0	36.5	18.8	62.6	0.2	0.6	0.0	0.0	0.0	0.1
					0	0.2	0.7	0.1	0.4	0.1	0.3	0.2	0.7	19.0	63.2	10.6	35.3	0.2	0.6	0.0	0.0	0.0	0.0
					1	0.6	1.9	0.0	0.1	0.0	0.0	0.0	0.0	16.5	55.0	12.0	40.1	0.2	0.6	0.0	0.0	0.0	0.1

APPENDIX G

TEMPERATURE DATA

Cumulative positive (>0 degrees) and negative (≤0 degrees) degree hours are listed for the months of June, July and August for 1988 through 1991 for a coastal (Big Skookum) and foothill (M.P. 62) site on the North Slope, Alaska.

Table G-1. Summaries of postitive (>0) and negative (= or <0) degree hours during July through September for four years (1988 -1991) at coastal (Big Skookum) and foothill (M.P. 62) sites

		Degree Hours							
		July		August		September		Cumulative	
Site	Year	Positive	Negative	Positive	Negative	Positive	Negative	Positive	Negative
Coastal									
Air									
	1988	4513	15	3652	181	457	1106	8622	1302
	1989	7971	2	6802	0	1743	380	16516	382
	1990	5548	0	3067	22	703	545	9318	567
	1991	2236	133	1578	215	324	895	4138	1243
Soil									
	1988	5011	0	3657	13	300	188	8968	201
	1989	7299	0	6337	0	1538	138	15174	138
	1990	5719	0	3483	0	593	132	9795	132
	1991	4445	0	2672	0	369	165	7486	165
Foothill									
Air									
	1988	9927	12	5489	225	1471	1296	16887	1533
	1989	10834	2	9251	3	2848	1220	22933	1225
	1990	10399	22	6154	81	1013	1372	17566	1475
	1991	6277	64	3941	372	1770	1564	11988	2000
Soil									
	1988	1550	0	2117	0	261	149	3928	149
	1989	4027	0	5815	0	1652	82	11494	82
	1990	3473	0	2119	0	233	118	5825	118
	1991	2657	0	1794	0	424	119	4875	119

APPENDIX H

LISTING OF VASCULAR PLANT SPECIES OCCURRING ON TEN GRAVEL SITES ON THE ALASKA NORTH SLOPE, 1984 AND 1991

Appendix H. 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 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								•						•
Silene acaulis		•												
Stellaria edwardsii	•											•		
Stellaria humifusa								•						
Stellaria longipes						•			•			•		•
Stellaria sp. (laeta?)														•
COMPOSITAE:														
Achillea borealis						•								
Antennaria friesiana		•												
Arnica lessingii		•												
Artemisia alaskana						•			•	•	•	•		
Artemisia arctica					•				•	•	•	•	•	
Artemisia glomerata										•	•			
Artemisia tilesii	•	•		•		•	•	•						
Aster sibercus	•	•			•				•	•		•	•	
Chrysanthemum integrifolium									•					
Crepis nana var. nana		•							•	•	•	•		
Erigeron spp.		•												
Petasites frigidus		•												

Appendix H. 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 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
Saussurea angustifolia		•												
Senecio atropurpureus		•							•			•		
Senecio congestus				•	•	•	•	•						
Tanacetum bipinnatum				•										
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:														

Appendix H. 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 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
Equisetum arvense	•	•		•		•								
Equisetum scirpoides														•
Equisetum variegatum									•				•	
GENTIANACEAE:														
Gentiana propinqua												•		
GRAMINEAE:														
Agropyron boreale ssp. alaskanum	•	•												
Agropyron macrourum						•			•	•	•	•	•	
Agropyron violaceum		•												
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 andersonii	•	•				•	•	•			•			
Poa glauca	•	•	•	•		•	•	•	•	•		•		
Poa pratensis var. "Nugget"					•			•	•	•		•	•	
Puccinellia arctica	•			•										
Puccinellia langeana														•
Trisetum spicatum	•	•							•	•	•			•

Appendix H. 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 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
HALORAGACEAE:														
Hippuris vulgaris								•						
JUNCACEAE:														
Juncus arcticus				•										
Juncus castaneus subsp. castaneus	•	•										•		
Juncus triglumis									•					
Luzula arcuata subsp. unalaschensis	•													
Luzula confusa								•						
Luzula wahlenbergii subsp. wahlenbergii							•							
LEGUMINOSAE:														
Astragalus alpinus subsp. alpinus	•	•		•		•			•			•	•	•
Astragalus alpinus subsp. arcticus	•													
Astragalus nutzotinensis									•	•	•			
Hedysarum alpinum		•											•	
Hedysarum hedysaroides												•		
Hedysarum mackenzii											•	•	•	
Oxytropis borealis									•	•	•	•		•
Oxytropis campestris subsp. gracilis	•												•	
Oxytropis deflexa var. foliolosa		•												
Oxytropis nigrescens											•			
Oxytropis viscida	•	•												
ONAGRACEAE:														
Epilobium angustifolium		•					•	•		•				
Epilobium latifolium	•	•		•	•	•			•		•	•	•	•
PAPAVERACEAE:														
Papaver lapponicum subsp. porsildii	•	•												
Papaver macounii		•							•					

Appendix H. 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 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
PLUMBAGINACEAE:														
Armeria maritima				•							•			
POLEMONIACEAE:														
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		•							•					•
Dryas octopetala		•												
Potentilla fruiticosa		•												
SALICACEAE:														
Salix alaxensis var. alaxensis	•	•		•		•					•			
Salix arctica		•							•					•
Salix brachycarpa ssp. niphoclada				•		•		•				•		
Salix glauca		•		•				•						
Salix lanata ssp. richardsonii													•	
Salix ovalifolia								•	•					•

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Physiographic Location	Foothills						Coastal Plain							
FAMILY 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
Salix planifolia ssp. pulchra var. pulchra	•	•		•		•		•						
Salix reticulata									•					
SAXIFRAGACEAE:														
Chrysosplenium tetrandrum	•													
Parnassia palustris												•		
Saxifraga cernua	•													
Saxifraga hirculus									•					
Saxifraga oppositifolia									•			•		
Saxifraga punctata var. nelsoniana		•												
Saxifraga tricuspidata		•												
SCROPHULARIACEAE:														
Castilleja caudata												•		
Castilleja elegans		•												
Pedicularis verticilliata												•	•	•
VIOLACEAE:														
Viola epipsila		•												
TOTAL FAMILIES / TOTAL Genera / TOTAL species — Physiographic Location	22 53 82						20 53 87							
TOTAL FAMILIES (25)	16	20	2	12	5	9	6	10	13	5	8	10	9	10
TOTAL Genera (70)	26	41	4	19	8	16	14	22	27	15	16	21	16	23
TOTAL species (125)	31	58	4	23	8	20	15	28	33	18	19	25	17	28