Arctic Gas

BIOLOGICAL REPORT SERIES
VOLUME TWO

PIPELINE REVEGETATION

DON L. DABBS, WILHELM FRIESEN, SHANE MITCHELL

Prepared by
NORTHERN ENGINEERING SERVICES COMPANY LIMITED

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CANADIAN ARCTIC GAS STUDY LIMITED

ALASKAN ARCTIC GAS STUDY COMPANY

PIPELINE REVEGETATION

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1.1 PURPOSE

Development in northern Canada and Alaska has brought with it sophisticated technology, particularly within the petroleum industry. This industry has developed and changed quickly over the past several years in response to climatic and terrain restrictions imposed on it in Arctic and sub-Arctic regions. Part of this developing northern technology includes the design of a proposed large diameter pipeline for the transport of natural gas from Prudhoe Bay and the Mackenzie Delta region to markets in southern Canada and the United States. A pipeline of this length would traverse many hundreds of miles of terrain which would be subject to potential soil and thermal erosion when the existing plant and organic cover is removed. The purpose of this research project has been to develop data relevant to the revegetation of land surfaces disturbed by pipeline construction and operation, to prevent such erosion.

1.2 SCOPE

This paper reports only on the research which has been conducted at the Sans Sault test facility on the Mackenzie River (Figure 1). Hernandez (1973) has provided an excellent review of the revegetation research conducted by others in Canada and Alaska.

The location of the Sans Sault test facility is shown in Figure I. This site is located within Rowe's (1959) "Lower Mackenzie Section of the Boreal Forest". The site is situated on a high terrace above the river. The vegetation around the site is an open, stunted black spruce/lichen forest.

2.0 OBJECTIVES

The objectives of this research project has been to determine the suitability of twenty-three different plant species, mostly grasses, for use in revegetating disturbed land surfaces in the northern boreal forest.

The various species used have been evaluated on the basis of:

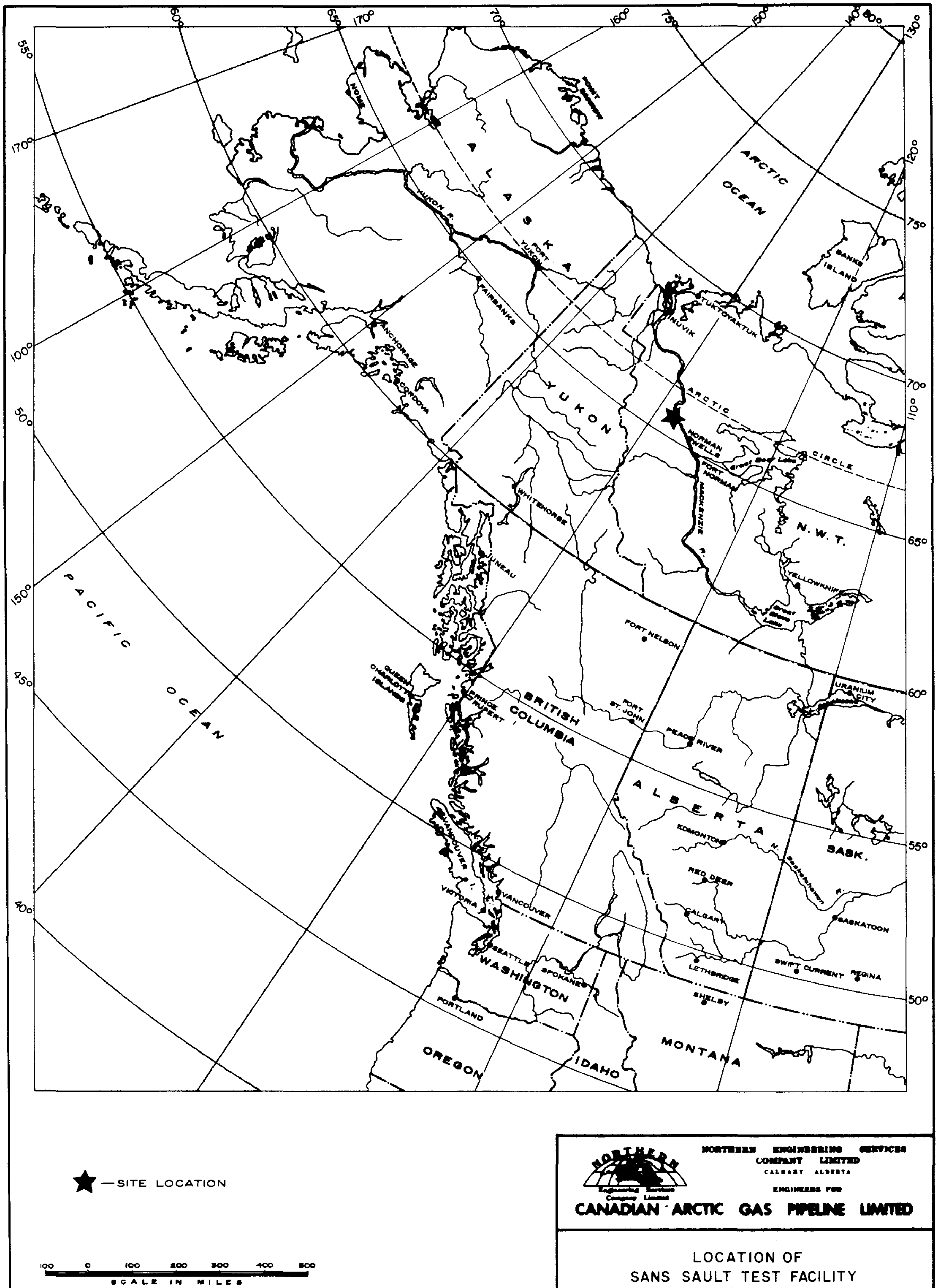
- Rate of growth
- Ground covered by shoot
- Biomass production
- Rate and depth of rooting
- Litter accumulation
- Winter survival
- Nutrient requirement for establishment and continued growth
- Insulative value and effect on soil energy budget.

Evaluation of these plots has also included a measurement of the rate and character of invasion by native plant species.

As seeding of grasses alone may not be adequate in some areas, the feasibility of hand planting shrub cuttings to prevent soil erosion on side slopes and approaches to rivers and streams has been examined.

Results reported by other researchers indicate that the growth and biomass production of seeded grasses in tundra areas has been much less than trials conducted in forested regions. The potential of stripping and replacing the surface tundra mat to the backfill as an additional restoration measure to seeding has been studied in the northern Yukon.

The effects of habitat alteration and cropping of grasses by small mammals was studied in detail.



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LOCATION OF
SANS SAULT TEST FACILITY
(65° 40' N, 128° 49' W.)

FIGURE 1

3.1 ARCTIC TEST FACILITY

The experiments designed to evaluate and select the plant species best suited to restore a plant cover following construction in northern latitudes, was implemented in the spring of 1971 at the Arctic Test Facility (65° 40' N 128° 49' W). The site is situated at the confluence of the Mountain and Mackenzie Rivers (Figure 1).

3.1.1 Construction of Test Site and Seeding of Plots

During the winter of 1970/71, four experimental test sections of 48" pipe were installed for the purpose of testing the engineering concept of a winter constructed, buried, chilled natural gas pipeline.

It is important to understand the techniques used in constructing the pipeline because the amount and type of disturbance for which restoration programs must be developed, depends entirely on the engineering and construction methods employed.

The first stage was to hand-clear all trees and shrubs over two feet high, piling the slash in a windrow at the periphery of the clearing. Gravel was back-loaded onto the windrow of trees to build a narrow roadway.

All pipeline ditching and construction activities took place on top of packed snow in December, January and February. The material taken from the ditch was dumped on the snow, pipe installed and the backfill returned to the ditch. Due to the bulking up of the soil, when removed from the ditch in a frozen state, and the fact that a four foot diameter pipe had been placed in the ditch, a mound or berm of material was left over the line. With subsequent thawing and compaction of the top layers, the berm receded to less than two feet above grade. The net result of this construction technique was that the low shrubs, moss and ground litter was left undisturbed except for the actual backfill mound and part of the spoil not returned to the ditch.

On June 19th and 20th, 1971 test sections I, II, III and IV were seeded (Fig. II). Each 500 foot buried test section was marked off into 20 equal plots measuring 25 X 80 feet with the pipeline running through the centre of the plot (Figure III). The central 18 plots (outside plots seeded to a guard mix) were each subdivided into "a" and "b" subplots.

The grasses seeded were selected by an agricultural consultant retained by ARCO Chemical Company of Fairbanks, Alaska. The common and scientific names of these 18 grasses and the rates at which they were seeded (pounds/acre) is given in Table I.

The seed was pre-weighed (plot size 0.046 of an acre), and applied evenly over the entire plot using a hand-operated broadcast spreader. The fertilizer was spread after the seed was sown, using the same technique. Subplot "a" received fertilizer at a rate equivalent to 700 pounds per acre and subplot "b" at the rate equivalent to 350 pounds per acre of the formulation 10-19-19. See Table II for the analysis of this fertilizer and the weight in pounds of nutrients added.

To simulate construction conditions, no seedbed preparations were made and no post-seeding treatments were applied. The seed and fertilizer were broadcast on the ground surface and allowed to lie, subject to predation and adverse climatic conditions.

3.1.2 Second Season Evaluation

.1 Plot Plan, Operating Test Sections - Figure II shows the layout of the Arctic Test Facility. Test section I, II, III, and IV were over the buried pipe sections through which chilled air had been circulated for two years.

The placement of each plot and initial rate of fertilization for each operating test section is given in Figure III.

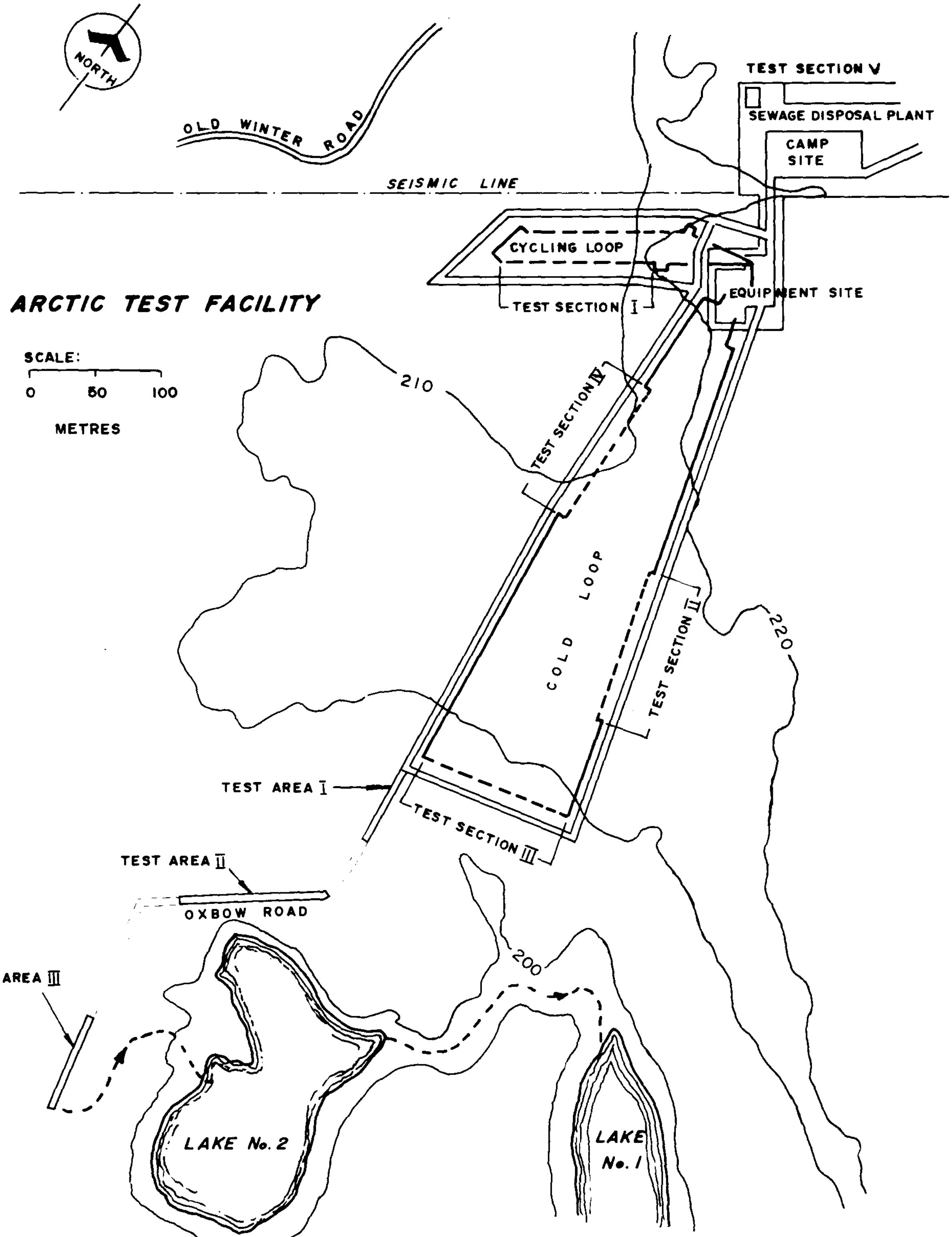
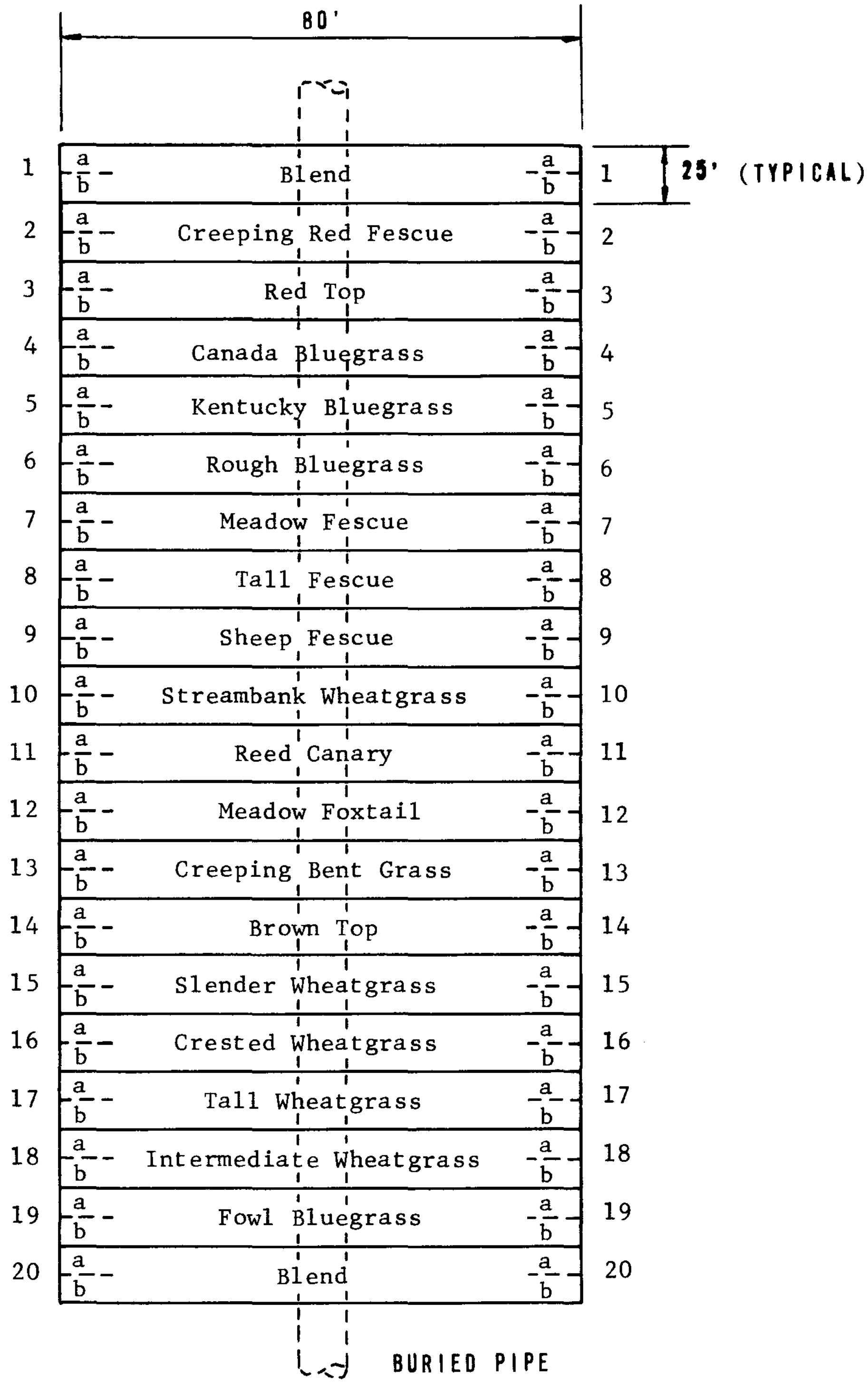


FIGURE 11

DESIGNED BY:	NORTHERN ENGINEERING SERVICES LIMITED CALGARY ALBERTA ENGINEERS FOR CANADIAN ARCTIC GAS STUDY LTD.	
DRAWN BY: W. W.		
CHECKED BY:		SCALE:
ENGINEERS APP:	LOCATION OF TEST PLOTS AT THE SANS SAULT ARCTIC TEST FACILITY	DATE:
PROJECT MANAGER:		PROJECT No.
		DRAWING No. - A	REV.



Fertilization Rates: a - 700#/Acre
10-19-19 b - 350#/Acre

Figure III

DESIGNED BY:	NORTHERN ENGINEERING SERVICES LIMITED CALGARY ALBERTA ENGINEERS FOR CANADIAN ARCTIC GAS STUDY LTD.	
DRAWN BY:		
CHECKED BY:		SCALE:
ENGINEERS APP:	TYPICAL SEEDING PLOT PLAN BURIED PIPE SECTIONS	DATE:
		PROJECT No.
PROJECT MANAGER:		DRAWING No. - A / REV.

TABLE I

Grasses Seeded in the Experimental

Test Plots at the

Arctic Test Facility

Common Name	Botanical Name	Rate/Acre (#)
Brown Top	Agrostis tenius	10
Creeping Bent	A. palustris	10
Red Top	A. alba	40
Canada Bluegrass	Poa compressa	50
Fowl Bluegrass	P. palustris	30
Kentucky Bluegrass	P. pratensis	30
Rough Bluegrass	P. trivialis	30
Creeping Red Fescue	Festuca rubra	50
Meadow Fescue	F. elatior	30
Reed Fescue, Alta Fescue	F. arundinacea	30
Sheep Fescue	F. ovina	50
Meadow Foxtail	Alopecurus pratensis	30
Reed Canary Grass	Phalaris arundinacea	30
Crested Wheatgrass	Agropyron cristatum	30
Intermediate Wheatgrass	A. intermedium	30
Slender Wheatgrass	A. trachycaulum	30
Streambank Wheatgrass	A. riparium	30
Tall Wheatgrass	A. elongatum	30

TABLE II

Pounds, on a per acre basis,

of nutrient applied in the 1971 fertilizer trials

Fertilizer 10 - 19 - 19

Components	Percent	700 lb/acre	350 lb/acre
Total Nitrogen (N)	10.0	70.0	35.0
Available phosphoric acid ($P_2 0_5$)	19.0	133.0	66.5
Soluable potash ($K_2 0$)	19.0	133.0	66.5
Sulfur (S)	2.6	18.2	9.1
Boron (B)	0.2	1.4	0.7
Copper (Cu)	0.3	2.1	1.05
Manganese (Mn)	0.9	6.3	3.15
Molybdenum (Mo)	0.0005	0.0035	0.00175
Zinc (Zn)	0.2	1.4	0.7
Bulk	47.8	334.6	167.3

.2 Plot Sampling - The amount of ground cover by standing dead biomass, "litter", and standing living biomass, "plant tops", was determined by estimating the amount of ground covered in five, 1/4 m^2 quadrats placed in each subplot. Cover classes for each seeded and native species were recorded using a modified Braun-Blanquet scale (from Knapp, 1958).

Cover Class	Range of Cover Per Cent	Mid-Point Per Cent
+	Present But Rare	0.25
1	1 - 5	2.5
2	6 - 25	15.0
3	26 - 50	37.5
4	51 - 75	62.5
5	76 - 100	87.5

Using the mid-point percentage, an estimate of the amount of ground surface covered by top growth and litter was computed.

The amount of surface litter laid down by each species, after one year of growth, was determined in the second growing season. This was determined prior to the initiation of growth in order to avoid confusion with the second year production.

The percent survival was determined by counting the number of new shoots in twenty, 1/16 m^2 quadrats per subplot, compared to the number of seeds sown in the equivalent area of plot in 1971.

Ground cover of both seeded grasses and native species was determined at the end of the growing season, August 28th to September 15th.

.3 Instrumentation -

Soil Temperatures

As part of the initial instrumentation of the test site, silicone diode sensors were installed above, below and beside the pipe sections, in twelve locations (three per operating pipe test section). Soil temperatures were automatically read and recorded twice daily. These data were used to compare 1971 and 1972 near surface soil temperatures under several plots at different pipe operating temperatures.

Soil Heat Flux Measurement

To determine the heat flux at the soil surface under different plots, heat flux plates were installed in mid-July.

Six revegetated plots were instrumented with three plates in each plot. The plates were placed in a horizontal plain 5 - 10 cm beneath the surface, arranged roughly in a three foot triangle. The plates in each plot were wired in series, to integrate the readings, and connected to a continuous recorder. Two control plots, a denuded mineral backfill mound and undisturbed open black spruce-lichen forest, were similarly instrumented. The plots instrumented with heat flux plates were:

Test Section I

Plot 5	*Poa pratensis*
Plot 12	*Alopecurus pratensis*
Plot 16	*Agropyron cristatum*

Test Section III

Plot 2	*Festuca rubra*
Plot 7	*Festuca elatior*
Plot 10	*Agropyron riparium*

The data, by hour, have been averaged over one month periods and expressed graphically on a 24 hour time scale. The data were registered in terms of millivolts on a strip chart recorder. The millivolt equivalents in BTU/ft^2/hr. and cal./cm^{2}min. have been calculated and plotted against the time scale to show the daily average heat energy flux in the plots.

.4 Measurement of Active Layer - The seasonal recession of the permafrost table above and beside the test sections of pipeline was monitored by means of repeated probing of permanently marked transects. A portable Yellowsprings Model 42 telethermometer, equipped with a graduated one metre stainless steel insert probe, was used in probing to determine the permafrost (0°C) level at measured intervals along the transect lines.

One transect line was directly down the centre line of the pipe with two lines parallelling the pipe, five metres to either side. The two parallel lines were within the right-of-way clearing. Depth to permafrost was determined at intervals of five metres along the longitudinal transects. Three lines were probed at one metre intervals, perpendicular to the ditchline. Starting from the edge of the clearing adjacent to the roadway, they extended across the pipeline and into the undisturbed black spruce forest.

Level surveys were run on all transects probed. The surface grade was plotted and the maximum depth of thaw (determined September 22nd) drawn in relationship to grade.

.5 <u>Winter Road Seeding</u> - Plots were established on a roadway which runs from the south end of the cold loop to a small oxbow lake, near the Carcajou River, on June 15th, 1972 (Figure IV). This road had been used during the early operation of the test facility. The vegetation had been destroyed due to use of the road by tracked vehicles during the growing season.

To determine the effect of varying the rate of fertilization, a single mix of seed was applied uniformly to three test areas on the winter road. All areas, except replications 'a' and 'h' in test area II, were seeded with a mix containing equal portions of Frontier Reed Canary Grass, Climax Timothy, Fall Rye, Common Bromegrass, Boreal Creeping Red Fescue, Red Top, Alsike Clover, and Alfalfa applied at a rate of 30 kilograms/hectare. Fertilizer was applied to plots 1.5 X 20 metres long at 0, 100, 200 and 300 kilograms/hectare.

The fertilizer formulae contained 24% total nitrogen and 24% available phosphoric acid (P_2O_5). The fertilizer applications were replicated four times in test areas I, eight times in test area II, and four times in test area III. Fertilizer treatments were randomized throughout the three test areas.

Two, 1 m^2 quadrats were used to determine the percent ground cover in each plot. Ground covered by both the seeded vascular plants and mosses was determined at the end of the growing season, September 20th, 1972.

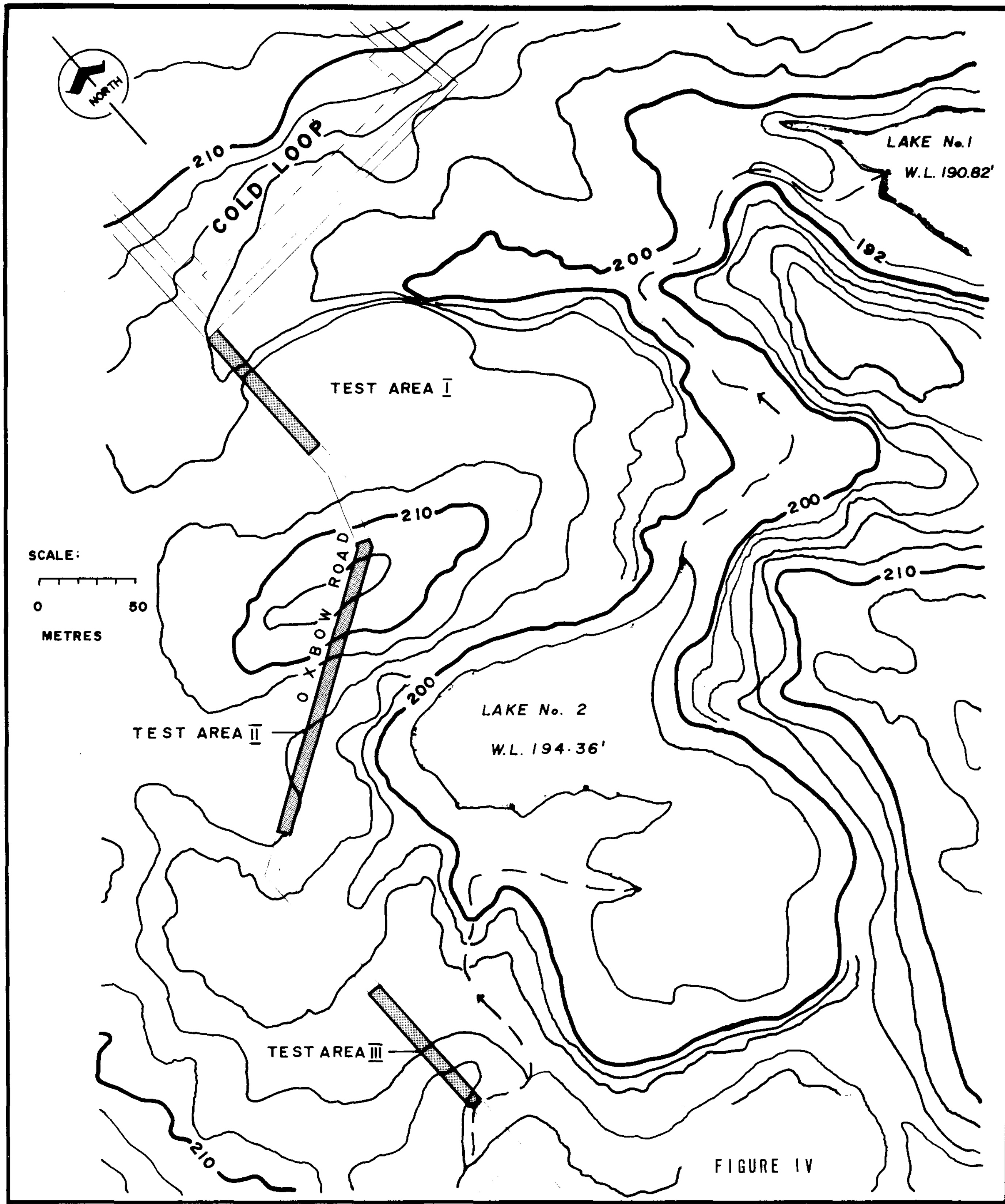


FIGURE IV

DESIGNED BY:	NORTHERN ENGINEERING SERVICES LIMITED CALGARY ALBERTA ENGINEERS FOR CANADIAN ARCTIC GAS STUDY LTD.	
DRAWN BY:		
CHECKED BY:		SCALE:
ENGINEERS APP:	LOCATION OF TEST AREAS ON THE OXBOW WINTER ROAD	DATE:
PROJECT MANAGER:		PROJECT No.
		DRAWING No. - A	REV.

.6 Second Fertilization - The plots on the active pipeline test sections were fertilized at the time of seeding in June of 1971 with as much as 70 kilograms/hectare nitrogen. By late July 1972, many varieties showed signs of chlorosis. To determine if it was a nutrient deficiency, and identify the deficiency, fertilizer was applied to 1 m^2 subplots within the major plot. The formulations 34-0-0 and 11-48-0 were applied at the equivalent of 400 kg/ha on July 25th, 1972 in the following plots:

Test Section No. 1
Plots 2,3,4,5,7,10,
11,15,17,19.

Test Section No. II
Plots 2,3,7,11,12,
15,17,19.

Test Section No. III
Plots 3,7,11,15.

Test Section No. IV
Plots 2,3,5,10,11,12,
15,19.

On August 25th, 1972, additional fertilizer trials were established. Within randomly located 1 m^2 quadrats, the following fertilizer formulations and rates were applied in the plots listed below:

34-0-0	@	200	Kilograms/hectare	
46-0-0	@	310	"	"
11-51-0	@	200	"	"
0-0-62	@	200	"	"

Test Section No. I
Plots 2,3,4,5,7,10,
11,15,17,19.

Test Section No. II
Plots 2,3,7,11,12,15,
17,19.

Test Section No. IV
Plots 2,3,5,7, (no 0-0-62).

One year after initial fertilization, soil samples were taken for laboratory analysis. Composite samples from the top 30 cm in 16 plots were analyzed for: texture, loss on ignition, carbonates, available phosphorous, total nitrogen, nitrates, and total cation exchange. All analyses followed Harowitz (1970).

.7 Biomass Determination - Biomass production, determined by clipping, was used to evaluate the increase in productivity resulting from the fertilization of plots on July 25th, 1972.

Plant biomass was determined for all plots on test sections I and II plus those plots on sections III and IV that were fertilized in July, between August 19th and 25th.

Four to ten (depending on density and uniformity) 1/16 m^2 quadrats were clipped and sorted into:

1) current years productions
2) standing dead biomass

A minimum of four quadrats were randomly placed over the backfill mound or mineral spoil bank. One, 1/16 m^2 quadrat was clipped in the centre of each 1 m^2 fertilized plot.

The quadrats were placed in the plot to provide the best measure of the net primary production of the seeded species and a measure of the annual increment of litter accumulation.

The samples were oven dried at 60°C for 18 to 24 hours. The results are expressed as dry matter in grams/metre square.

.8 Shrub Plantings - The evaluation of planting shrub cuttings to stabilize sideslopes and river banks was started in September 1971. Several hundred cuttings of willow (*Salix*), alder (*Alnus*), birch (*Betula*), and dogwood (*Cornus*) were hand-planted on the side of an unstable, water-saturated, gravelly sideslope on a seismic line near camp.

The above ground portions of the stems were cut back to:

- 5 centimetres above ground (or not less than the second stem axis).
- 20 centimetres above ground.
- 30-45 centimetres.

The purpose of cutting the stems back was to avoid desiccation of tips exposed above the snow surface.

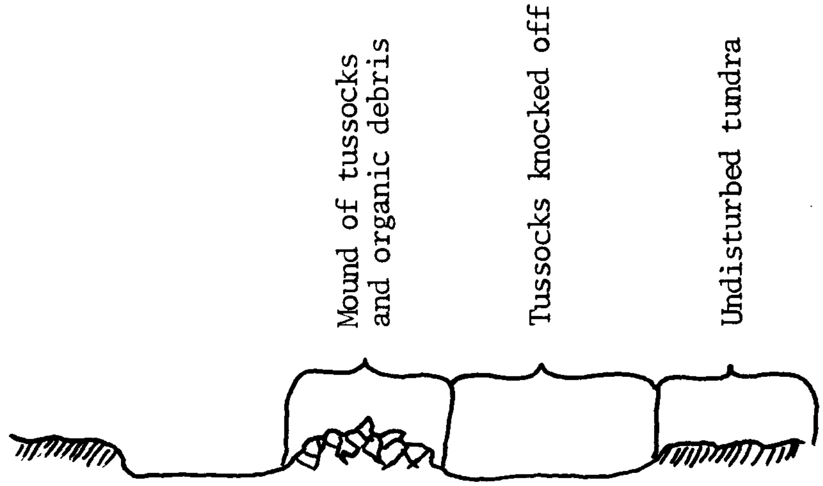
To evaluate spring planting of shrub cuttings and to determine the number of man hours required to plant a unit area of sideslope, three additional locations were planted in June of 1972.

1) Inactive pipe test no. 2, on the banks of the Mountain River. An area of 180 m^2.
2) Test area I on the Oxbow Winter Road, 60 m^2.
3) Test area III on the Oxbow Winter Road, 75 m^2.

The percent survival of shrub plantings was determined in late summer by laying out a series of 1 m^2 quadrats, counting the living and dead shrubs, by species, per quadrat.

.9 Tundra Restoration - The restoration of plant cover in tundra regions has been shown in other studies (Hernandez 1973) to be much more difficult than within the northern boreal forest. A technique which included stripping the tundra mat and replacing it plus seeding and fertilizing was tried on a location on the coastal plateau of the northern Yukon. A seismic line located at 69°15'N., 139°05'W., at an elevation of 136 m above sea level over a low ridge in the Buckland Hills was selected for this study.

The seismic line was put in during the winter of 1971/72, making 1972 the first growing season after disturbance. The bulldozer blade was set not to strip the vegetation off completely, but had the effect of knocking off the *Eriophorum* tussocks in a path about two metres wide along both sides of the line with the effect that the tussocks were piled in a low mound down the centre line.



Cross sectional profile of line on June 13th, 1972.

Approximately 400 metres of line was seeded on June 13th, 1972. One hundred metre plots were seeded to *Festuca rubra* (Boreal Creeping Red Fescue), *Phalaris arundinacea* (Frontier Reed Canary Grass), *Phleum pratense* (Climax Timothy), plus a mix of all three. They were seeded at a rate of approximtely 15 kg/ha. About 40 metres of each strip plot (5 m wide) was fertilized, at an approximate rate of 800 kg/ha with the formulation 26-24-24.

Growth of all tundra species had just been initiated at the time of seeding. The tussocks of *Eriophorum* were loosely scattered on the surface and could be easily kicked around as they were not rooted, though they contained viable green plants.

4.1 SUMMARY OF FIRST YEARS FINDINGS

The following briefly summarizes the findings of the first growing season (1971), of plots established on the four active test pipe sections at the Sans Sault test facility:

- All species of grass seeded in June successfully germinated and produced good stands.
- Ten of the eighteen species attained a 50% ground cover on at least one of the four test sections.
- Several species had an average rate of root growth in excess of 2.0 mm/day.
- Two species successfully germinated and grew in both organic and mineral soils.
- Transpiration cooling of the soil may be an important mechanism by which reseeded plants aid in the restoration of the predisturbance soil thermal balance.
- Restored plant cover on the ditchline is not expected to have a marked effect on the depth of thaw in the active layer during the first season.
- One-third of the species under study require a comparatively high level of fertilization for maximum growth.
- A total of 35 native plant species were found to recolonize the mineral spoil bank in the first season after construction.

4.2 SECOND YEAR EVALUATION OF PLOTS

Evaluation of plots at the end of the first growing season emphasized germination, initial establishment and growth. Second season sampling included measurements of factors related to longer term objectives such as surface litter accumulation, winter survival and continued growth.

Table III (a,b,c & d) summarizes the data collected in 1972 in the plots established on the four active pipeline test sections.

4.2.1 Ground Litter Cover

The restoration of the soil energy budget in disturbed areas is dependent on both accumulation of an organic layer on the soil and growth of actively transpiring plants.

The litter (standing dead biomass) of plant tops laid down in each plot at the end of one full year was determined and is expressed in the table in percent ground cover (for the mineral backfill only).

To determine the effect of the initial fertilization rates on the amount of litter accumulated, the cover data in subplot 'a' was compared with subplot 'b' for each variety, by means of a paired t-test.

Photos 1 and 3 show the surface litter in the plots on test sections I and II. These pictures were taken before the initiation of new growth.

4.2.2 Percent Survival

The winter survival of the grasses planted is an absolute requirement for a successful revegetation program. Though all species germinated and grew well during the first season, they did not all survive the first winter equally well. Photo 2 shows two plots in which the grass did not survive the first winter.

As there are two distinct rooting media, organic mat (natural ground cover) and mineral backfill, the data were collected and are presented to show the difference between the two.

Growth and Development of Grasses
Seeded at the Arctic Test Facility

Test Section I

Table III (a)

Species	Plot No.	Litter Cover (%)	Initial Fertility Comp.	% Survival Organic	Initial Fertility Comp.	% Survival Mineral	Initial Fertility Comp.	Substrate Comparison	% Grd. Cover Organic	Initial Fertility Comp.	% Grd. Cover Mineral	Initial Fertility Comp.	Substrate Comparison	Rate of Growth (mm/day) Shoot	Rate of Growth (mm/day) Root
Festuca rubra	2a	7.0 ± 1.9		8.5 ± 1.9		21.0 ± 3.4		**	11.8 ± 5.9		38.8 ± 13.7			3.5	2.5
	2b	21.5 ± 6.9		9.5 ± 3.4		33.9 ± 3.7	*	**	5.9 ± 2.9		75.0 ± 7.2		**		
Agrostis alba	3a	87.5 ∓ 0.0		2.3 ∓ 0.6		0.8 ∓ 0.3			25.9 ∓ 14.0		8.8 ∓ 3.6			2.4	2.1
	3b	77.5 ± 6.1		3.5 ± 0.9		1.8 ± 0.4	*		15.5 ± 7.3		20.0 ± 10.1				
Poa compressa	4a	55.5 ± 14.1		6.6 ± 2.0		10.2 ± 2.2			11.4 ± 6.0		23.1 ± 8.7			2.4	2.0
	4b	53.0 ± 12.4		3.1 ± 0.9		10.0 ± 2.1		**	7.5 ± 6.0		17.5 ± 7.3				
Poa pratensis	5a	14.5 ± 6.4		5.1 ± 1.0		12.5 ± 1.3		**	12.1 ± 5.7		38.1 ± 9.7			2.1	1.7
	5b	14.5 ± 6.4		5.9 ± 1.9		10.5 ± 0.9			15.5 ± 7.3		31.9 ± 5.6				
Poa trivialis	6a	87.5 ± 0.0		4.2 ± 1.4		5.8 ± 1.7			15.5 ± 7.3		4.5 ± 3.6			0.9	1.5
	6b	77.5 ± 6.1		4.3 ± 2.1		6.3 ± 2.8			25.5 ± 16.0		7.6 ± 4.3				
Festuca elatior	7a	14.5 ± 6.4		24.8 ± 7.2		56.6 ± 5.7		**	5.5 ± 3.0		11.9 ± 3.1			7.9	2.8
	7b	36.0 ± 12.2		27.0 ± 10.0		55.7 ± 7.8			13.0 ± 10.2		29.4 ± 13.2				
Festuca arundinacea	8a	57.5 ± 9.4		7.0 ± 2.5		1.7 ± 0.8	*		9.6 ± 6.0		1.3 ± 0.7			6.5	2.5
	8b	48.0 ± 9.6		7.5 ± 3.9		7.1 ± 2.0			0.5 ± 0.4		1.4 ± 0.7				
Festuca ovina	9a	77.5 ± 6.1		19.4 ± 4.9		12.4 ± 5.4			3.8 ± 2.3		2.5 ± 0.0			1.3	2.4
	9b	77.5 ± 6.1		11.2 ± 4.1		14.5 ± 4.8			1.4 ± 0.5		5.6 ± 3.1				
Agropyron riparium	10a	17.0 ± 5.7	*	17.4 ± 4.7		52.3 ± 6.8	*	**	1.0 ± 0.5		8.8 ± 3.6		*	4.2	2.7
	10b	1.1 ± 0.6		16.0 ± 3.7		29.5 ± 5.3			3.1 ± 2.4		5.1 ± 3.4				
Phalaris arundinacea	11a	62.5 ± 7.9		5.2 ± 2.3		16.0 ± 2.6		*	9.2 ± 6.1		32.5 ± 11.3			8.9	3.0
	11b	67.5 ± 9.4		4.5 ± 1.8		15.9 ± 1.7		**	1.0 ± 0.5		15.0 ± 0.0		**		
Alopecurus pratensis	12a	43.5 ± 14.1		19.8 ± 6.6		38.4 ± 5.3			9.6 ± 6.0		81.3 ± 6.2		**	6.3	2.5
	12b	57.5 ± 12.2		14.0 ± 4.0		36.8 ± 8.6			3.5 ± 2.4		81.3 ± 6.2		**		
Agrostis palustris	13a	63.0 ± 15.4		15.6 ± 1.5		3.1 ± 0.9			9.7 ± 6.0		43.8 ± 6.2		**	3.2	2.8
	13b	87.5 ± 0.0		1.5 ± 0.5		4.3 ± 0.9		*	7.2 ± 6.1		62.5 ± 10.2		**		
Agrostis tenuis	14a	82.5 ± 5.0		3.5 ± 1.3		1.7 ± 0.8			1.3 ± 0.5		8.8 ± 3.6	*		1.4	2.6
	14b	72.5 ± 10.0		6.0 ± 3.7		4.4 ± 2.0			3.4 ± 2.4		26.3 ± 6.5		**		
Agropyron trachycaulum	15a	7.5 ± 3.1		29.5 ± 8.4		35.8 ± 3.3	*		0.6 ± 0.4		8.8 ± 3.6		*	6.5	2.7
	15b	17.0 ± 5.7		23.4 ± 6.5		54.5 ± 8.4		*	0.6 ± 0.4		20.6 ± 5.6		**		
Agropyron cristatum	16a	10.0 ± 3.1		15.9 ± 5.2		17.0 ± 3.9			0.5 ± 0.4		2.0 ± 0.6			4.3	3.0
	16b	12.5 ± 2.5		16.4 ± 4.4		12.1 ± 2.0			0.2 ± 0.0		2.0 ± 0.6		*		
Agropyron elongatum	17a	14.5 ± 6.4		22.7 ± 8.8		39.7 ± 9.1			0.6 ± 0.4		5.6 ± 3.1			10.9	2.7
	17b	5.0 ± 2.5		14.4 ± 4.3		33.7 ± 6.3		*	0.6 ± 0.4		5.6 ± 3.1				
Agropyron intermedium	18a	7.0 ± 3.3		24.4 ± 5.0		32.2 ± 9.6			1.4 ± 0.5		4.5 ± 3.5			8.5	2.8
	18b	7.5 ± 3.1		33.6 ± 9.4		48.5 ± 6.2			1.0 ± 0.5		11.3 ± 8.8				
Poa palustris	19a	67.5 ± 12.2		7.3 ± 2.5		12.1 ± 1.9			8.0 ± 3.2		50.0 ± 7.2		**	6.3	2.7
	19b	52.5 ± 6.1		4.2 ± 1.5		17.4 ± 2.8		**	11.4 ± 6.0		43.8 ± 6.2		*		

* - Significant at the 95% level
** - Significant at the 99% level

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Test Section II

Table III (b)

Species	Subplot	% Litter	% Survival Organic	% Survival Mineral	Sig.	% Grd. Cover Organic	% Grd. Cover Mineral	Sig.	Rate of Growth (mm/day) Shoot	Rate of Growth (mm/day) Root
Festuca rubra	2a	34.2 ± 17.4	18.2 ± 4.2 *	46.6 ± 46.6 * *	* *	50.0	62.5		2.4	1.6
	2b	1.7 ± 0.8	8.3 ± 1.7	18.7 ± 3.4	*	15.0	37.5			
Agrostis alba	3a	38.3 ± 13.7	1.9 ± 0.7	2.3 ± 1.0		7.6	15.0		4.2	2.2
	3b	54.2 ± 8.3	3.0 ± 0.7	3.0 ± 1.7		37.5	15.0			
Poa compressa	4a	30.0 ± 7.5	8.0 ± 1.6	13.8 ± 1.9 *		37.5	37.5		2.3	1.8
	4b	26.7 ± 18.3	4.8 ± 1.3	7.1 ± 2.3		38.8	37.5			
P. pratensis	5a	6.7 ± 4.2	7.5 ± 1.5 *	11.1 ± 2.9		62.5	62.5		4.3	2.0
	5b	0.2 ± 0.0	4.2 ± 0.5	9.7 ± 2.6		15.0	37.5			
P. trivialis	6a	87.5 ± 0.0	9.2 ± 3.0	10.7 ± 3.9		15.0	37.5		1.0	2.3
	6b	62.5 ± 14.4	7.4 ± 1.9	13.2 ± 2.7		26.2	37.5			
Festuca elatior	7a	15.0 ± 0.0	45.4 ± 7.0	53.7 ± 4.4		75.0	62.5		8.4	2.6
	7b	22.5 ± 7.5	48.7 ± 7.5	68.6 ± 8.4		38.8	81.5			
F. arundinacea	8a	54.2 ± 8.3 *	26.9 ± 5.4	13.4 ± 6.3		26.3	15.0		4.0	2.9
	8b	22.5 ± 7.5	24.5 ± 4.4	21.0 ± 5.7		26.2	15.0			
F. ovina	9a	87.5 ± 0.0	16.6 ± 3.9	26.3 ± 10.4		37.5	37.5		1.3	2.2
	9b	46.7 ± 21.4	23.1 ± 5.4	30.1 ± 8.1		50.0	62.5			
Agropyron riparium	10a	22.5 ± 7.5	52.2 ± 8.7	58.8 ± 13.1		62.5	62.5		6.0	3.7
	10b	6.7 ± 4.2	37.0 ± 8.1	62.8 ± 12.2		8.8	37.5			
Phalaris arundinacea	11a	62.5 ± 14.4	9.8 ± 2.2	10.8 ± 2.7		50.0	62.5		5.3	3.1
	11b	30.8 ± 15.8	16.6 ± 4.0	11.6 ± 1.3		51.2	62.5			
Alopecurus pratensis	12a	45.8 ± 8.3 *	27.3 ± 5.0 * *	32.0 ± 7.1		50.0	87.5		3.3	2.0
	12b	6.7 ± 4.2	8.4 ± 2.1	26.2 ± 7.6	*	32.5	87.5			
Agrostis palustris	13a	37.5 ± 0.0	6.4 ± 2.1	5.0 ± 1.9		50.0	62.5		4.0	2.0
	13b	62.5 ± 14.4	7.1 ± 1.9	6.7 ± 1.7		50.0	62.5			
A. tenuis	14a	46.7 ± 15.8	4.0 ± 1.6	1.9 ± 0.9		38.8	62.5		2.0	2.0
	14b	79.2 ± 8.3	2.8 ± 1.4	4.1 ± 0.8		37.5	62.5			
Agropyron trachycaulum	15a	62.5 ± 14.4 * *	32.2 ± 7.7	47.0 ± 9.4		37.5	37.5		6.1	2.1
	15b	10.8 ± 4.2	31.5 ± 8.3	67.4 ± 11.6	*	26.2	62.5			
A. cristatum	16a	2.5 ± 0.0	16.1 ± 3.3 *	23.9 ± 4.5 *		8.8	15.0		7.2	2.0
	16b	2.5 ± 0.0	34.1 ± 6.5	60.3 ± 12.0		20.0	15.0			
A. elongatum	17a	2.5 ± 0.0	31.9 ± 8.2	56.4 ± 16.0		26.2	15.0		9.9	2.2
	17b	15.0 ± 0.0	32.3 ± 9.2	71.2 ± 9.2	*	8.8	37.5			
A. intermedium	18a	2.5 ± 0.0	31.5 ± 6.6	60.4 ± 11.1	*	8.8	37.5		10.5	2.0
	18b	2.5 ± 0.0	29.0 ± 6.0	67.6 ± 8.4	* *	8.8	15.0			
Poa palustris	19a	54.2 ± 8.3	10.0 ± 1.6	12.8 ± 1.8		51.3	87.5		5.3	1.7
	19b	54.2 ± 8.3	12.5 ± 1.6	9.9 ± 1.8		62.5	62.5			

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Test Section III

Table III (c)

Species	Subplot	% Litter	% Survival Organic	% Survival Mineral	Sig.	% Grd. Cover Organic	% Grd. Cover Mineral	Sig.	Rate of Growth (mm/day) Shoot	Rate of Growth (mm/day) Root
Festuca rubra	2a	70.8 ± 8.3	3.1 ± 1.1	57.7 ± 9.4 * *	* *	11.3	81.3			3.0
	2b	54.2 ± 8.3	1.5 ± 0.8	15.8 ± 6.9	* *	0.5	87.5			
Agrostis alba	3a	62.5 ± 14.4	0.2 ± 0.1	2.6 ± 1.0	* *	2.5	31.9		5.4	2.5
	3b	54.2 ± 16.7	0.1 ± 0.0	0.6 ± 0.4		0.9	43.8			
Poa compressa	4a	70.8 ± 16.7	0.8 ± 0.6	3.1 ± 1.0						3.0
	4b	70.8 ± 8.3	0.3 ± 0.2	5.8 ± 1.7	* *					
P. pratensis	5a	18.3 ± 10.2	2.8 ± 1.4	16.7 ± 6.7	* *					3.0
	5b	30.8 ± 15.8	1.3 ± 0.5	8.2 ± 3.1	* *					
P. trivialis	6a	62.5 ± 14.4	2.1 ± 1.4	2.0 ± 0.6						2.8
	6b	55.0 ± 21.3	3.5 ± 1.9	4.1 ± 2.6						
Festuca elatior	7a	10.8 ± 4.2	33.7 ± 6.5	79.0 ± 13.0	* *	20.0	87.5		11.5	3.0
	7b	30.0 ± 7.5	50.0 ± 7.9	56.5 ± 7.1		38.8	62.5			
F. arundinacea	8a	45.8 ± 8.3 * *	21.7 ± 4.6	19.1 ± 8.1						3.2
	8b	10.8 ± 4.2	22.0 ± 5.2	34.0 ± 8.3						
F. ovina	9a	70.8 ± 8.3	34.7 ± 6.7	5.8 ± 1.3	*					2.7
	9b	62.5 ± 14.4	29.7 ± 6.7	24.5 ± 12.9						
Agropyron riparium	10a	5.9 ± 4.6	66.0 ± 7.0 *	63.9 ± 13.7		50.0	37.5			3.0
	10b	2.5 ± 0.0	39.8 ± 7.8	44.6 ± 7.2		26.3	2.5			
Phalaris arundinacea	11a	15.0 ± 0.0 * *	19.4 ± 3.6	21.0 ± 3.0					3.9	3.5
	11b	2.5 ± 0.0	18.4 ± 3.7	20.5 ± 4.9						
Alopecurus pratensis	12a	6.7 ± 4.2	36.2 ± 5.6 * *	26.0 ± 9.0						3.0
	12b	6.7 ± 4.2	12.1 ± 3.2	23.3 ± 4.7						
Agrostis palustris	13a	59.2 ± 28.3	4.6 ± 1.3	6.9 ± 2.2						2.0
	13b	14.2 ± 11.7	4.0 ± 1.6	11.2 ± 4.0						
A. tenuis	14a	38.3 ± 13.7 *	5.0 ± 1.9	1.0 ± 0.3						2.0
	14b	1.7 ± 0.8	2.5 ± 0.6	4.5 ± 2.0						
Agropyron trachycaulum	15a	5.9 ± 4.6	28.3 ± 5.6	45.9 ± 9.7					4.6	3.0
	15b	6.7 ± 4.2	36.0 ± 7.9	59.8 ± 6.5						
A. cristatum	16a	1.7 ± 0.8	19.3 ± 3.6	19.6 ± 5.0						2.4
	16b	1.0 ± 0.8	28.1 ± 4.8	33.0 ± 7.2						
A. elongatum	17a	2.5 ± 0.0	50.0 ± 7.6 *	52.7 ± 9.6 *						3.0
	17b	1.7 ± 0.8	30.6 ± 5.7	26.3 ± 6.9						
A. intermedium	18a	1.7 ± 0.8	29.1 ± 6.7	18.8 ± 11.5						2.5
	18b	0.2 ± 0.0	24.1 ± 6.6	10.1 ± 8.0						
Poa palustris	19a	79.2 ± 8.3 * *	2.6 ± 1.0	5.5 ± 1.8						2.0
	19b	1.7 ± 0.8	1.7 ± 0.8	7.6 ± 3.2	*					

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Test Section IV

Table III (d)

Species	Subplot	% Litter	% Survival Organic	% Survival Mineral	Sig.	% Grd. Cover Organic	% Grd. Cover Mineral	Sig.	Rate of Growth (mm/day) Shoot	Rate of Growth (mm/day) Root
Festuca rubra	2a	6.7 ± 4.2	13.8 ± 3.1	29.7 ± 3.1	* *	30.8 ± 11.9	62.5 ± 10.2		3.1	3.0
	2b	1.7 ± 0.8	15.0 ± 4.4	30.7 ± 3.0	*	18.8 ± 9.1	43.8 ± 6.2			
Agrostis alba	3a	6.7 ± 4.2	0.6 ± 0.4	2.9 ± 1.4		26.3 ± 11.7	8.2 ± 4.0		5.6	2.5
	3b	46.7 ± 21.4	0.1 ± 0.0	4.1 ± 1.6	*	15.1 ± 14.5	18.9 ± 10.8			
Poa compressa	4a	30.8 ± 15.8	1.9 ± 0.6	9.7 ± 2.7	* *	17.5 ± 10.8	8.8 ± 3.6		4.5	2.5
	4b	18.3 ± 10.2	1.3 ± 0.4	9.9 ± 3.0	* *	7.2 ± 6.1	14.4 ± 8.2			
P. pratensis	5a	22.5 ± 20.0	3.4 ± 1.4	12.2 ± 2.1 *	* *	15.5 ± 7.3	31.9 ± 5.6 *		3.4	2.4
	5b	2.5 ± 0.0	2.1 ± 0.4	6.4 ± 1.5	* *	6.8 ± 6.1	11.9 ± 3.1			
P. trivialis	6a	79.2 ± 8.3	3.9 ± 1.3	7.4 ± 2.4		9.6 ± 6.0	7.6 ± 4.3			2.6
	6b	70.8 ± 8.3	3.4 ± 1.6	9.2 ± 3.2		5.2 ± 3.1	4.5 ± 3.6			
Festuca elatior	7a	45.8 ± 8.3	32.8 ± 6.8	58.5 ± 6.4	*	18.3 ± 6.5	38.1 ± 9.7		3.5	3.0
	7b	37.5 ± 0.0	18.3 ± 5.6	40.3 ± 4.5	*	5.9 ± 2.9	50.0 ± 7.2	* *		
F. arundinacea	8a	10.8 ± 4.2	12.6 ± 2.8	18.7 ± 7.4		1.3 ± 0.5	4.5 ± 3.5			3.5
	8b	54.2 ± 8.3	15.7 ± 7.5	20.8 ± 6.6		5.9 ± 2.9	0.8 ± 0.6			
F. ovina	9a	62.5 ± 14.4	25.7 ± 4.9 * *	23.7 ± 11.6		16.9 ± 4.6	2.5 ± 0.0	*		2.0
	9b	62.5 ± 14.4	10.8 ± 2.5	22.7 ± 5.2		6.3 ± 2.8	5.1 ± 3.4			
Agropyron riparium	10a	38.3 ± 13.7	39.1 ± 10.5	24.8 ± 9.8		3.5 ± 2.4	16.9 ± 7.7		4.0	3.0
	10b	26.7 ± 18.3	48.4 ± 7.7	23.8 ± 5.2		1.4 ± 0.5	17.5 ± 7.3	*		
Phalaris arundinacea	11a	38.3 ± 13.7	7.1 ± 2.6	6.1 ± 1.4		8.0 ± 3.2	29.4 ± 13.2		7.5	2.3
	11b	54.2 ± 16.7	6.8 ± 2.1	4.9 ± 1.8		8.8 ± 2.8	23.1 ± 8.7			
Alopecurus pratensis	12a	38.3 ± 13.7	18.9 ± 5.4	32.0 ± 7.5		32.5 ± 10.6	68.8 ± 6.2	*	9.0	3.2
	12b	38.3 ± 13.7	17.4 ± 3.6	17.1 ± 6.1		20.8 ± 13.6	62.5 ± 0.0			
Agrostis palustris	13a	79.2 ± 8.3	4.9 ± 2.1	1.9 ± 1.5		5.5 ± 3.0	35.6 ± 15.7		3.0	3.6
	13b	79.2 ± 8.3	2.9 ± 2.4	0.6 ± 0.3		19.6 ± 10.4	44.4 ± 11.4			
A. tenuis	14a	87.5 ± 0.0	1.1 ± 0.7	0.1 ± 0.1		0.6 ± 0.4	1.3 ± 0.7			1.5
	14b	87.5 ± 0.0	0.4 ± 0.2	0.2 ± 0.1		0.9 ± 0.5	2.0 ± 0.6			
Agropyron trachycaulum	15a	37.5 ± 0.0	17.5 ± 7.0	9.7 ± 4.8		3.4 ± 2.4	11.9 ± 3.1		5.0	1.9
	15b	22.5 ± 7.5	24.2 ± 7.8	10.2 ± 5.2		1.8 ± 0.5	8.8 ± 3.6			
A. cristatum	16a	10.8 ± 4.2	12.8 ± 6.2	8.0 ± 3.1		0.1 ± 0.0	1.9 ± 0.6	* *		1.5
	16b	6.7 ± 4.2	6.6 ± 3.0	3.9 ± 2.3		0.1 ± 0.0	0.8 ± 0.6			
A. elongatum	17a	18.3 ± 10.2	18.4 ± 7.7	18.5 ± 7.3		1.0 ± 0.5	1.9 ± 0.6		10.0	2.0
	17b	10.8 ± 4.2	14.1 ± 4.9	14.5 ± 5.5		2.5 ± 0.0	2.5 ± 0.0	* *		
A. intermedium	18a	0.2 ± 0.0	40.4 ± 9.6	27.4 ± 7.6		0.6 ± 0.4	5.6 ± 3.1 *		9.5	3.5
	18b	2.5 ± 0.0 * *	29.3 ± 6.5	36.8 ± 7.0		1.0 ± 0.5	15.0 ± 0.0	* *		
Poa palustris	19a	79.2 ± 8.3	5.6 ± 1.7	14.7 ± 4.0	*	14.2 ± 5.4	8.8 ± 3.6		5.0	3.0
	19b	79.2 ± 8.3	4.9 ± 1.5	7.6 ± 2.2		6.3 ± 2.8	20.6 ± 5.6			

PHOTO 1: View from the west end of test section I in the spring of the second growing season (June 8, 1972).

PHOTO 2: Test section I on July 2, 1972. Note that some plots were very slow to initiate growth the second year. Notice the growth of willow and birch from root stocks.

PHOTO 3: The north end of test section II on June 7, 1972. The "mineral backfill" discussed in the text is the 12 - 15' wide strip over the pipeline. The "organic substrate" is shown to the right of the pipeline where the trees and shrubs have been removed.

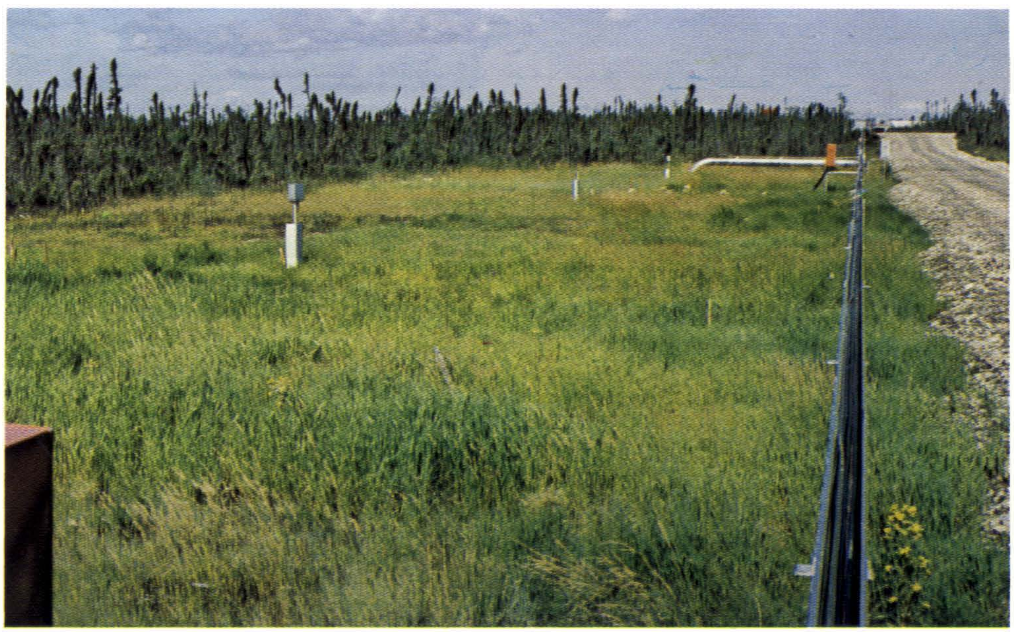

PHOTO 4: The north end of test section II on August 9, 1972. Note the amount of cover provided by native species such as *Arctagrostis latifolia* and *Carex aquatilis*.

The data presented are a measure of the net survival of seeds in each plot. The figure is the percentage of seeds sown in 1971 which germinated, established and survived the first winter.

A t-test was used to compare the survival, on both substrates (organic and mineral), and between the two initial rates of fertilization.

4.2.3 Percent Ground Cover

The amount of ground covered by plant tops, of the seeded varieties, is expressed as a percentage for the two habitat types. Here also, the two initial rates of fertilization and substrates have been compared in terms of the top production (ground cover) after two growing seasons.

4.2.4 Rate of Growth

An average rate of growth in millimetres per day of both shoot and root is given for each species of grass, for each test plot. This was computed on the basis of length of growth of representative specimens divided by 100 (a growing season of 100 days).

Photos 1 to 4 provide a visual assessment of the rate of growth during the second summer on two different test sections.

4.3 REINVASION OF BACKFILL BY NATIVE SPECIES

The seeding of grasses, or other plant types, on disturbed land surfaces is intended to provide a quick cover to control erosion for the first few years. It is important, for the maintenance of a stabilized area, that native species invade and establish a stable plant community on the disturbed soils.

As part of this study, the process of succession on the backfill mound, or exposed mineral soil, has been monitored. Table IV (a, b, c and d) summarizes the data collected in the second year after construction. Due to the importance of mosses in maintaining ground temperatures, the bryophytes and vascular plants are shown separately. The percent ground cover for each species, for each subplot, is given together with the percent frequency as a measure of the relative importance of each.

The species list and ground cover data for the portion of the right-of-way in which only trees and shrubs were removed (organic mat) is given in appendix "A".

4.4 FERTILITY REQUIREMENTS

The very low fertility levels of arctic soils require that fertilizer be used when growing agronomic forage grasses in the north. In a trial to determine fertilizer requirements to maintain the established grasses in a vigorous and healthy condition, two formulations (34-0-0 and 11-48-0) were applied to a number of small subplots within the major trial plots. Table V summarizes the results of this test. The effects of fertilization was measured in terms of gms/m^2 production of shoot biomass, one month after the fertilizer was applied.

REINVASION OF PLOTS BY NATIVE SPECIES Table IV (a)

TEST SECTION: I SUBSTRATE: MINERAL

PLOT	2		3		4		5		6		7		8		9		10		11		12		13		14		15		16		17		18		19		%
SPECIES SUBPLOT	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	Freq.
Bryophyta																																					
Ceratodon purpureus	5.1	23.1	1.4	3.8	16.9	5.6	14.4	5.6	23.8	2.5					.2	.1	4.4	1.4		.7		.6		+	+	.8	5.1	1.4	1.4	8.8	5.6	1.9	5.0	5.6	+	1.9	66.0
Leptobryum pyriforme											1.9	11.2	1.3	1.9	2.5	1.9	5.1	4.5	.8	1.4	.2	.2	.2	.8	1.4	1.4	1.9	1.9	5.1	5.6	17.5	8.8	15.0	8.8	1.3	5.6	67.4
Splachnum sterile											.8	5.6	1.3	+	1.4	1.9	5.2	.2	1.4	1.9	.8	.1	.2	.2	.2	.8	1.4	1.9	.8	.8	5.6	5.6	8.2	13.8	.8	5.6	61.1
Funaria hygrometrica	.2	.8		.6	.8	.8	1.3	.8			.2	1.4	.2	1.9	.2	.2	1.4	1.4	.1	.1					+	.8	4.5	.8	.2	1.4	1.9	1.3	5.0	17.5	.1	1.4	69.4
Moss 214											.2						.6	+	4.4	1.9	3.8	.1	.7	1.4	1.4	1.9	1.3	.6	3.8	+	.2	.7	.6		4.4	4.4	34.0
Marchantia polymorpha	.2	.2	+	+	.7	+	.2	+	1.3	.1	.1	.1	1.9	.2	+	.2	14.4	2.5	1.4	1.4	+	.1	.8	.8	5.1	2.5	26.2	26.2	20.6	.43.8	26.2	31.9	10.7	5.6	.1	.2	68.0
Bryum pseudotriquetrum												.1					.8		.2	.8	.1	+	+	.2	.1	.2	.2	.2	.2	+	.2	.2	.2	.2	.2	.2	42.4
Aulacomnium acuminatum	+	+					+	.1			.2	.2	.1	.2		+	.2	.2				+		+	+	.+	.1	.2	.2	.2	.2	.2	.2	.2	.1	.2	35.4
Hylocomium splendens													+	+				+				+	+				+		+	.1		+				.1	7.6
Tomenthypnum nitens																.1		.1										+		+						+	6.2
Polytrichum juniperinum																		+									.1			.1	.1						4.9
Cinclidium stygium					+		.2																														2.8
Sphagnum spp.																+							+														1.4
Vascular Plants																																					
Epilobium angustifolium									1.2	+			.6				.1						+		.6		.2		.8	.7	.2	+	+				15.3
Equisetum arvense	+							+									+	.7									.1		.7	.1	+	.1	.1	1.3			11.8
Potentilla spp.																																			.8	1.4	5.6
Carex aquatilis	.7	+			+											+	1.2	+																			5.6
Salix spp.	+							+									.1	.1								.1	.6	+	.2	+	+	+	.1	.2		.1	14.6
Arctagrostis latifolia					+			+						+			+							+					.6	.7					+		6.9
Epilobium spp.			+	+									.1				.1	+					+					.2				+	.8	.2			15.3
Equisetum scirpoides										+			+	+				+						+			+			+	+	+	.6	+		.2	9.7
Rubus chamaemorus						+	+								.6	+	+		+																		4.9
Rosa acicularis			+					.1									.6																				0.7
Senecio congestus														+																.6			+				2.1
Equisetum palustre	.1	+		.2	.1	.1							+																								10.4

Figures Represent Percent Ground Cover

\+ - Species is present

REINVASION OF PLOTS BY NATIVE SPECIES

Table IV (a) cont.

TEST SECTION: I

SUBSTRATE: MINERAL

PLOT	2		3		4		5		6		7		8		9		10		11		12		13		14		15		16		17		18		19		%
SPECIES SUBPLOT	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	Freq.
Salix alaxensis		+				.1							+	.1			+	+								.1	+			+				+			9.0
Salix planifolia									+																												0.7
Vaccinium uliginosum						.6				+	+																									.7	3.5
Carex spp.							+						+				+																				1.4
Eriophorum spp.				+													+																				0.7
Populus tremuloides																										+			+					+			1.4
Andromeda polifolia						+	+						+																								2.1
Achillea borealis			+	.1																																.1	3.5
Stellaria spp.						+																					+										0.7
Trifolium spp.																														+				+			2.1
Betula glandulosa		+																																			0.7
Picea mariana			+																																		0.7
Chamaedaphne calyculata						+																															0.7
Oxycoccus microcarpus		+																																			0.7
Arctostaphylos rubra																																				+	0.7
Poa palustris																															+	+	.7				3.5
Agrostis alba																		.6						+													5.6
Hordeum jubatum																	.6	+									+										2.1
Phalaris arundinacea																		+											+								0.7
Poa pratensis																																-					0.7

REINVASION OF PLOTS BY NATIVE SPECIES — Table IV (b)

TEST SECTION: II — SUBSTRATE: MINERAL

SPECIES PLOT	2		3		4		5		6		7		8		9		10		11		12		13		14		15		16		17		18		19		%
SUBPLOT	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	Freq.
Bryophyta																																					
Marchantia polymorpha			.2				.2	.2			2.5	.2	15.0	15.0	15.0	2.5	15.0	2.5	37.5	2.5	2.5	.2	15.0	2.5	37.5	15.0	37.5	37.5	62.5	37.5	37.5	15.0	37.5	15.0	.2	.2	83.3
Ceratodon purpureus	2.5	.2	.2			.2	.2	.2			2.5	2.5	2.5	.2	.2	.2	.2	.2		2.5	2.5	.2	2.5		.2	2.5	.2	15.0	15.0	37.5	37.5	37.5	37.5	62.5	.2	2.5	86.1
Leptobryum pyriforme	15.0	15.0	15.0	2.5	2.5		.2	2.5		.2	.2	2.5	15.0	15.0	2.5		15.0	15.0		.2	.2	2.5	.2	.2	2.5	.2	15.0	15.0	15.0	15.0	2.5	2.5	2.5	2.5	.2	7.5	88.9
Moss 214	.2	.2	2.5	.2	2.5	.2	.2	.2	.2	2.5	.2	2.5	.2	.2	2.5	2.5	.2	.2	15.0	15.0	.2	2.5	2.5	16.0	2.5	.2	2.5	.2	.2	.2	.2	2.5	.2	.2	2.5	15.0	100.0
Splachnum sterile	15.0	2.5	2.5	.2	.2	.2	2.5	15.0	.2	2.5	2.5	2.5	.2	.2	.2			.2	2.5	.2	.2					.2			.2	.2	.2	.2		.2	.2	.2	77.8
Funaria hygrometrica	2.5	.2	.2	2.5	.2	.2	2.5	2.5				.2	.2	.2	.2	.2	.2									.2		2.5	.2	.2	.2	.2		.2			66.7
Aulacomnium acuminatum	.2	.2	.2	.2	.2	.2	.2	.2			.2	.2			.2	.2		.2		.2		.2		.2		.2	.2	.2	.2	.2	.2	.2	.2	2.5	.2	.2	75.0
Polytrichum juniperinum																.2				.2			.2	.2	.2	.2	.2	2.5	.2	.2	.2	.2	.2	.2		.2	41.7
Bryum pseudotriquetrum	.2						.2	.2			.2	.2			.2	.2				.2	.2	.2	.2	.2	.2	.2		.2	.2	.2	.2	.2	.2	.2		.2	63.9
Hylocomium splendens	.2	.2	.2			.2	.2	.2	.2																										.2	.2	27.8
Tomenthypnum nitens																.2														.2			.2		.2	.2	13.9
Pleurozium schreberi				.2																																	2.8
Sphagnum spp																														.2							2.8
Vascular Plants																																					
Epilobium angustifolium			.2										.2	1.2	2.5	2.5	2.5	.2																			16.7
Arctagrostis latifolia			.2										7.5																					.2	.2	.2	8.3
Salix alaxensis							.2																					.2	2.5					.2			13.9
CRUCIFERAE																.2													.2	2.5				.2			8.3
Epilobium spp																				.2			.2		.2	.2	.2		.2	.2	.2	.2	.2	.2			22.2
Salix spp.		.2			.2			.2																					.2	.2	.2						16.7
Equisetum scirpoides				.2										.2																				.2			11.1
Potentilla spp.																										.2									.2	.2	8.3
Picea mariana					.2																												.2				8.3
Plantago major																															.2				.2		5.6
Vaccinium uliginosum			.2																																		2.8
Achillea borealis			.2																																		2.8
Ranunculus lapponicus			.2																																		2.8
R. gmelinii																															.2						2.8
Smilacina spp											.2																										2.8
Poa trivialis													7.5	.2																2.5							5.6
Poa palustris																													2.5	2.5	2.5			2.5			8.3

REINVASION OF PLOTS BY NATIVE SPECIES Table IV (b) cont.

TEST SECTION: II SUBSTRATE: MINERAL

PLOT	2		3		4		5		6		7		8		9		10		11		12		13		14		15		16		17		18		19		%
SPECIES SUBPLOT	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	Freq.
Agrostis tenuis																											2.5	.2	2.5			.2			.2		5.6
Festuca ovina																		2.5																			2.8
Agrostis alba																.2		.2												.2							8.3
Poa pratensis																.2														.2	.2						8.3
Alopecurus pratensis													.2				.2																				5.6
Phleum spp.															.2																					.2	5.6
Bromus secalinus																													.2								2.8
Bromus tectorum																													.2								2.8
Hordeum jubatum																											.2										2.8
Agropyron trachycaulum																										.2											2.8

REINVASION OF PLOTS BY NATIVE SPECIES Table IV (c)

TEST SECTION: III SUBSTRATE: MINERAL

PLOT	2		3		4		5		6		7		8		9		10		11		12		13		14		15		16		17		18		19		%
SPECIES SUBPLOT	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	Freq.
Bryophyta																																					
Funaria hygrometrica			.2	.2								37.5					2.5	2.5																			46.9
Leptobryum pyriforme	.7	.8	2.5	5.1								15.0					2.5	15.0																			78.1
Splachnum sterile	1.4	.2	.8	4.5								15.0					15.0	2.5																			62.5
Marchantia polymorpha	+	.2	.8	1.4								.2					.2																				46.9
Moss 214	.2	.2	.8	1.4								.2																									62.5
Aulacomnium acuminatum			.2	.2								.2					.2																				34.4
Bryum pseudotriquetrum		+	.2	.2								.2																									34.4
Tomenthypnum nitens			+	.2														.2																			25.0
Ceratodon purpureus			+									.2																									15.6
Vascular Plants																																					
Equisetum arvense			+	1.2																																	21.9
Arctagrostis latifolia	+	+																																			3.1
Achillea borealis			.1	.1																																	12.5
Salix spp.				+																																	3.1
Epilobium angustifolium				+																																	3.1

REINVASION OF PLOTS BY NATIVE SPECIES Table IV (d)

TEST SECTION: IV SUBSTRATE: MINERAL

PLOT	2		3		4		5		6		7		8		9		10		11		12		13		14		15		16		17		18		19		%
SPECIES SUBPLOT	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	Freq.
Bryophyta																																					
Leptobryum pyriforme	.1	.8	.1	3.9	32.5	26.9	29.4	16.9	1.9	1.9	5.1	11.9	17.5	8.8	11.9	1.9	8.8	2.5	5.1	5.6	.2	.8	.8	1.4	.2	5.6	1.9	5.6	14.4	8.8	11.9	11.9	11.9	5.6	1.9	1.3	93.8
Splachnum sterile	+	.1		+	1.3	1.4	1.4	.8	1.4	.8	4.4	5.1	8.8	11.7	5.6	2.5	17.5	23.1	14.4	8.8	1.4	8.8	1.4	5.6	.1	.7	20.6	20.6	11.3	11.9	11.9	11.9	8.8	8.8	5.1	1.4	86.8
Funaria hygrometrica		+		.6	.1	1.3	1.4	6.0	+	.1	.8	.8	11.3	8.2	.2	.2	8.8	2.5	3.9	.2	.1	1.4	+	.2		.1	11.9	8.2	8.2	5.6	8.2	15.0	5.1	8.8	1.9	+	72.9
Marchantia polymorpha			+	+	.2	.7	1.9	.8	.5	.2	5.6	1.4	5.1	2.5	1.9	1.4	14.4	5.6	2.5	2.5	.1	.9	.8	2.5	.8	1.9	11.9	14.4	2.5	1.9	1.9	5.6	.8	1.9	.8		81.9
Moss 214	.1	+			.7	+	.8	.1	.8	2.5	1.9	1.9	.8	.1	.8	1.9	.8	.8	1.4	.8	.2	.2	1.9	.8	.8	1.9	.2	.8	1.4	1.4	.8	.7	.1		1.4	1.4	78.5
Ceratodon purpureus	.2	.8	.2	.7	.1	.2	.2	.2		+	.2	.2	.2	.2	.2	.1	.8	.8	.8	.2	.1	.2	+	.1	+	.1	.1	.2	1.4	.8	.8	.1	.7	1.4	.2	.8	66.0
Bryum pseudotriquetrum	.1	+	+	.1	.1	.2	.1	+	.2	.8	.2	.2	.8	.7	.1	.1	.2	.8	.2	.2		.2	.1	.2	.1	.1	1.4	.8	1.4	1.4	.8	.2	+	.1	+	.1	63.2
Aulacomnium acuminatum		+	+	.1			.2	.1	.1	.2	.2	.2	.2	.2	.2	.1	.2	.8	.2	.2		+	+		+	.8	.2	.8	.8	.8	.2	.8	.2	.2	.8	.8	64.6
Hylocomium splendens			+		.1	.1	+	.1		+	.1	.2	+					+								+		.2	.1	+	+	.1		.1	+	.2	24.3
Tomenthypnum nitens														+												+		+		.6	+	.1			+	+	6.3
Polytrichum juniperinum																+						+												+			2.1
Sphagnum spp.																										+										+	1.4
Vascular Plants																																					
Equisetum arvense													.7	1.4			.7	.8	.1	+		+	+			.7	1.3	4.5	10.6	18.9			.2	.1			31.9
Arctagrostis latifolia								+					.8	.8	.2		+	.1										+	.7	.2		.6	.6		+	.6	16.7
Equisetum scirpoides				+		+	.1	.6	.1		.2	+	.8	.7		+	+	+	+		+		+				+	+	.1	+	.7	.6	.4	.1	.1	+	25.7
Equisetum silvaticum														+			.6	+	.6				.6	+		+	+	+		.2	+	+	1.2	.1	.1	.2	16.0
CRUCIFERAE													.2	.8	.1	.2	+	.1	+	.2			+	1.3	+		.6	+		+	+		+		.2	+	19.4
Potentilla spp.																																			1.4	1.9	5.6
Salix spp.		+				+							+				.1	.1	.1						+	.1		.1	.8	.2	.2	.2	.7	.1			20.1
Eriophorum spp.																			+					.6				.6	.6	+		.6		+			4.9
Epilobium angustifolium			+	+					+	+				.1	.8	.2	.7	.1								.1					+						14.6
Salix alaxensis		+						+					+				.1								+			.6	.7	+	.1	+		.1	+	+	10.4
Epilobium spp.					+						+		.1	.1						.2			.1	+					.1		+		+	.2			13.2
Achillea borealis															.6																				.1	+	2.8
Carex spp.																													.6								0.7

REINVASION OF PLOTS BY NATIVE SPECIES Table IV (d) cont.

TEST SECTION: IV SUBSTRATE: MINERAL

PLOT	2		3		4		5		6		7		8		9		10		11		12		13		14		15		16		17		18		19		%
SPECIES SUBPLOT	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	Freq.
Calamagrostis lapponica																																	.6				0.7
Rubus chamaemorus																															.6					+	1.4
Betula papyrifera						+							+	+									+						+	+							4.9
Picea mariana						+							+																			+					3.5
Salix glauca								+																													0.7
Vaccinium vitis-idaea																																+					0.7
Stellaria spp.					+																																0.7
Alopecurus pratensis																	.6	.6												1.2							3.5
Poa pratensis															1.4	.1																					4.2
Festuca rubra			.6	+																															1.2	.1	4.2
Agrostis alba															.1	.8																					3.5
Agropyron trachycaulum																													.8								1.4
Agrostis tenuis																											+	+		.6							2.1
Poa palustris																															+						0.7
Phalaris arundinacea																												+									0.7
Hordeum jubatum																											+										0.7
Phleum spp.																+																					0.7

Response To Second Fertilization

Table V

Sec. No.	Plot No.	Biomass gm/m^2	Litter gm/m^2	Height (cm.)	Sec. No.	Plot No.	Biomass gm/m^2	Litter gm/m^2	Height (cm.)	Sec. No.	Plot No.	Biomass gm/m^2	Litter gm/m^2	Height (cm.)
I	P-2	307.6	40.8	24 - 28	I	P-18	122.0	10.4	80 - 90	II	P-17	187.6	86.8	90 - 100
"	P-2, 34-0-0	403.2		38 - 42	"	P-19	168.4	54.0	60 - 70	"	P-17, 34-0-0	219.2		90 - 100
"	P-2, 11-48-0	344.0		34 - 38	"	P-19, 34-0-0	316.8		60 - 70	"	P-17, 11-48-0	156.8		90 - 100
"	P-3	33.0	140.6	18 - 24	"	P-19, 11-48-0	161.6		60 - 70	"	P-18	283.2	33.2	100 - 110
"	P-3, 34-0-0	163.2		26 - 30	"	P-20	116.8	2.8	20 - 30	"	P-19	185.2	118.0	50 - 55
"	P-3, 11-48-0	108.8		22 - 26						"	P-19, 34-0-0	292.8		55 - 60
"	P-4	137.2	114.4	12 - 18	II	P-1	123.2	4.4		"	P-19,11-48-0	172.8		45 - 50
"	P-4, 34-0-0	131.2		18 - 24	"	P-2	231.2	8.8	18 - 25	"	P-20	213.2	102.4	
"	P-4, 11-48-0	102.4		20 - 26	"	P-2, 34-0-0	209.6		25 - 30					
"	P-5	105.2	9.2	14 - 18	"	P-2, 11-48-0	160.0		20 - 25	III	P-1	179.6	86.0	30 - 35
"	P-5, 34-0-0	273.6		36 - 40	"	P-3	92.0	128.8	35 - 40	"	P-2	514.4	40.8	
"	P-5, 11-48-0	163.2		16 - 20	"	P-3, 34-0-0	222.4		40 - 50	"	P-3	182.8	95.6	50 - 55
"	P-6	30.0	170.0	4 - 8	"	P-3, 11-48-0	156.8		40 - 45	"	P-3, 34-0-0	315.2		50 - 55
"	P-7	159.2	11.6	75 - 80	"	P-4	93.2	71.2	15 - 20	"	P-3, 11-48-0	344.0		55 - 60
"	P-7, 34-0-0	348.8		80 - 90	"	P-5	179.6	40.0	40 - 45	"	P-7	448.4	25.6	110 - 120
"	P-7, 11-48-0	254.4		75 - 80	"	P-6	58.0	140.0	5 - 10	"	P-7, 34-0-0	180.8		110 - 120
"	P-8	21.4	69.6	60 - 65	"	P-7	232.8	38.8	80 - 85	"	P-7, 11-48-0	305.6		110 - 120
"	P-9	70.4	60.8	10 - 14	"	P-7, 34-0-0	476.8		80 - 85	"	P-11	122.0	85.6	35 - 40
"	P-10	189.2	33.6	36 - 40	"	P-7, 11-48-0	379.2			"	P-11, 34-0-0	273.6		40 - 45
"	P-10, 34-0-0	204.8		40 - 44	"	P-8	135.6	103.2	35 - 40	"	P-11, 11-48-0	144.0		35 - 40
"	P-10, 11-48-0	313.6		36 - 40	"	P-9	128.8	107.6	10 - 15	"	P-15	130.4	36.4	40 - 50
"	P-11	648.7	230.8	80 - 100	"	P-10	214.8	49.2	55 - 60	"	P-15, 34-0-0	235.2		45 - 50
"	P-11, 34-0-0	532.8		80 - 100	"	P-11	253.2	111.2	40 - 70	"	P-15, 11-48-0	150.4		40 - 50
"	P-11, 11-48-0	308.8		80 - 100	"	P-11, 34-0-0	278.4		40 - 45					
"	P-12	377.6	70.4	55 - 60	"	P-11, 11-48-0	188.8			IV	P-1	93.2	27.2	
"	P-13	234.0	250.8	25 - 30	"	P-12	208.0	66.8	35 - 45	"	P-2	422.2	9.6	25 - 30
"	P-14	136.4	137.2	12 - 16	"	P-12, 34-0-0	158.4		35 - 40	"	P-2, 34-0-0	384.0		34 - 40
"	P-15	233.2	16.4	60 - 70	"	P-12, 11-48-0	94.4		20 - 25	"	P-2, 11-48-0	363.2		25 - 30
"	P-15, 34-0-0	212.8		60 - 65	"	P-13	186.0	175.6	35 - 40	"	P-3	295.2	13.6	55 - 60
"	P-15, 11-48-0	275.2		60 - 70	"	P-14	114.8	88.4	15 - 20	"	P-3, 34-0-0	401.6		55 - 60
"	P-16	50.0	73.2	40 - 45	"	P-15	217.2	85.2	60 - 70	"	P-3, 11-48-0	472.0		55 - 60
"	P-17	151.2	22.4	100 - 110	"	P-15, 34-0-0	302.4		55 - 60	"	P-5	165.2	46.4	25 - 30
"	P-17, 34-0-0	177.6		100 - 110	"	P-15, 11-48-0	534.4		55 - 60	"	P-5, 34-0-0	217.6		40 - 45
"	P-17, 11-48-0	233.6		100 - 110	"	P-16	160.0	54.8	75 - 80	"	P-5, 11-48-0	161.6		25 - 30
										"	P-7	272.0	76.4	30 - 40

The visual results of the second fertilizer application are shown in photo 5. This picture shows both fertilizer formulations (34-0-0 in foreground and 11-48-0 in background) in a plot of Creeping Red Fescue (Plot 2, Sec. II).

In a test to determine the nutrient levels in the plots one year after initial fertilization of the mineral backfill mound, samples were collected and analysed by Chemical and Geological Labs in Edmonton. The results of these analyses are shown in Table VI. Note the extremely low nitrate and phosphate levels.

4.5 SEEDING OF WINTER ROAD

As plots on the active test sections did not include a zero control and a range of fertilizer levels, the major objective of the winter road seeding project was to determine the response of a standard seed mix to a range of fertilizer levels. Table VII presents the results of this test.

Due to time limitations when sampling, the data are shown according to a simple distinction; vascular plants and mosses. The mean cover values indicate the response of these plants to the four levels of fertilization.

A Duncan's Multiple Range Test was used to determine significance of effects between rates of fertilization. There is a significant difference in response of both vasculars and bryophytes between the 0 and 100 kg/ha rate of fertilization. There is no significant difference, in either case, between the 100 and 200 kg/ha rates. There is however, a significant difference between 300 kg/ha and either 100 or 200 kg/ha in the case of both vasculars and bryophytes. Due to the highly significant difference between replications, the magnitude of difference caused by different fertilizer rates cannot be accurately determined.

4.6 PLANT COVER EFFECTS ON SOIL ENERGY BUDGET AND PERMAFROST RECESSION

The results obtained from the heat flux plate installations are shown in Figures V to XIV. These provide a visual assessment of the month to month (July to November) average hourly heat flux in six revegetated plots, a denuded mineral backfill site and an undisturbed stand of black spruce forest. The units of heat energy are expressed both in BTU's per square foot per hour and calories per square centimetre per minute.

From this data the mean hourly heat flow was calculated for each month at each instrumented site. Twenty monthly averages were computed for the undisturbed and backfill site data (these were installed in August 1971) and eight monthly averages were used from the data for each revegetated plot.

A best fit sine curve was calculated for each plot, using the least squares method, and these curves were plotted over graphs of the original points for each site. Mean values of the sine curves show that there was a net heat flow into the ground, at each site, for the period studied. Table VIII presents the results of this analysis.

In a study to determine the effect on near surface ground temperatures caused by the chilled gas pipeline, a comparison of temperatures recorded in 1971 and 1972 was made. Table IX presents a comparison of only four plots, as the same pattern of results was evident in all instrumented sites.

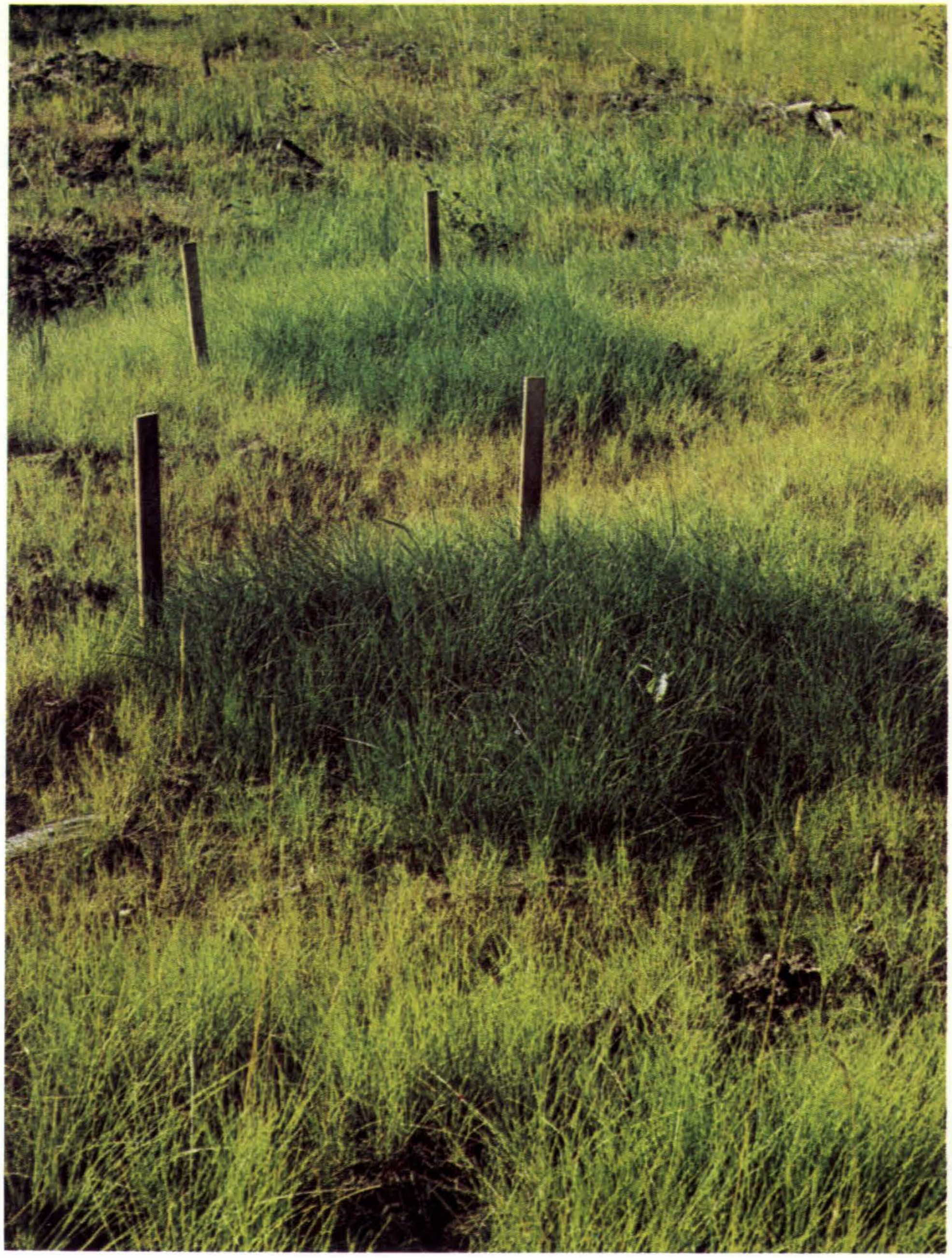

PHOTO 5: Plot of Creeping Red Fescue established in 1971. Two small plots fertilized July 25, 1972, photo taken August 20, 1972. Subplot in foreground was fertilized with 34-0-0 @ rate of 400 kg/ha, background with 11-48-0 at the same rate.

SOIL ANALYSIS, ONE YEAR
AFTER FERTILIZATION

Table VI
Sampled July 1, 1972

Sample Number	Plot	Rate of Fertilizer (lbs/acre) (10-19-19)	Textural Classification	Loss on Ignition (%wt.)	Carbonates (%/wt.)	Available Phosphates (ppm.)	Total nitrogen (%/wt.)	Total Cation Exchange Meg./100 gm	Nitrates (ppm).
F1	1,5b	350	Fine silty clay loam	9.30	6.99	1.8	.24	11.1	2.0
F2	I,7a	700	Fine silty clay loam	7.35	8.63	3.2	.21	20.3	.4
F3	I,17b	350	Medium clay loam	18.15	.51	1.8	.44	58.0	1.1
F4	I,19a	700	Medium sandy clay loam	22.40	1.43	14.8	.61	38.88	.3
F5	II,2b	350	Medium clay loam	6.64	8.00	1.1	.18	17.5	1.0
F6	II,5a	700	Fine silty clay loam	7.75	9.14	2.6	.20	19.3	.3
F7	II,17b	350	Medium clay loam	35.65	.84	2.6	.79	64.7	.3
F8	II,19a	700	Medium clay loam	24.87	.59	2.2	.56	59.6	1.4
F9	III,2b	350	Medium clay loam	12.04	7.54	1.5	.29	20.27	.2
F10	III,4a	700	Medium clay loam	11.50	6.56	1.8	.27	23.89	1.3
F11	III,17b	350	Medium loam	6.04	8.45	1.7	.17	14.38	.5
F12	III,19a	700	Fine silt loam	4.82	9.46	1.7	.11	11.78	.3
F13	IV,2a	350	Coarse sandy loam	1.75	4.85	7.0	.08	3.22	.5
F14	IV,4b	700	Coarse sandy loam	4.10	2.20	7.4	.12	12.70	.5
F15	IV,17b	350	Fine silty clay loam	14.47	14.17	2.9	.37	21.97	.4
F16	IV,19a	700	Medium clay loam	15.16	3.49	2.2	.36	27.72	.3

Ground Cover; Oxbow Lake Winter Road Table VII

Test Area	Replication	Vasculars 0	Vasculars 1	Vasculars 2	Vasculars 3*	Bryophyta 0	Bryophyta 1	Bryophyta 2	Bryophyta 3*
I	a	2.5	37.5	20.0	62.5	0.2	8.0	7.5	20.0
	b	26.2	8.8	8.8	75.0	8.8	0.2	0.2	8.8
	c	2.5	37.5	50.0	38.8	1.4	8.8	15.0	37.5
	d	2.5	2.5	2.5	15.0	0.2	8.8	8.8	37.5
II	a	0.0	1.2	1.2	1.4	1.4	38.8	26.2	50.0
	b	37.5	62.5	37.5	62.5	7.6	37.5	26.2	26.2
	c	50.0	37.5	37.5	87.5	15.0	15.0	15.0	37.5
	d	2.5	62.5	37.5	50.0	2.5	26.2	26.2	62.5
	e	26.5	62.5	26.5	26.5	20.0	50.0	37.5	50.0
	f	32.5	8.8	50.0	26.5	8.8	20.0	50.0	37.5
	g	2.5	26.5	37.5	62.5	1.4	15.0	37.5	37.5
	h	0.2	1.4	0.2	1.2	1.4	0.2	15.0	50.0
III	a	15.0	26.2	26.2	50.0	1.4	15.0	26.2	62.5
	b	7.6	20.0	20.0	50.0	0.2	1.4	8.8	32.5
	c	2.5	7.6	38.0	50.0	0.2	1.4	8.8	32.5
	d	18.9	37.5	62.5	50.0	0.2	8.8	18.8	15.0
Mean		16.4	31.9	32.5	50.5	4.4	15.9	17.4	37.3
Standard Error		4.1	5.4	4.2	5.0	1.5	3.6	3.2	3.7

Figures represent percent ground cover. All areas, except replications "a" and "h" in Test Area II, were seeded with a mixture of six graminoids (Reed Canary, Climax Timothy, Fall Rye, Common Bromegrass, Creeping Red Fescue, and Red Top) and two legumes (Alsike Clover and Alfalfa). The mixture was spread at a rate of 30 kilograms per hectare with each species comprising 12.5% (3.75 kgm) of the mixture.

*Numbers 0, 1, 2, 3 indicate fertilizer rates in hundreds of kilograms per hectare. The fertilizer formula contains 24% total nitrogen and 24% available phosphoric acid (P_2O_5).

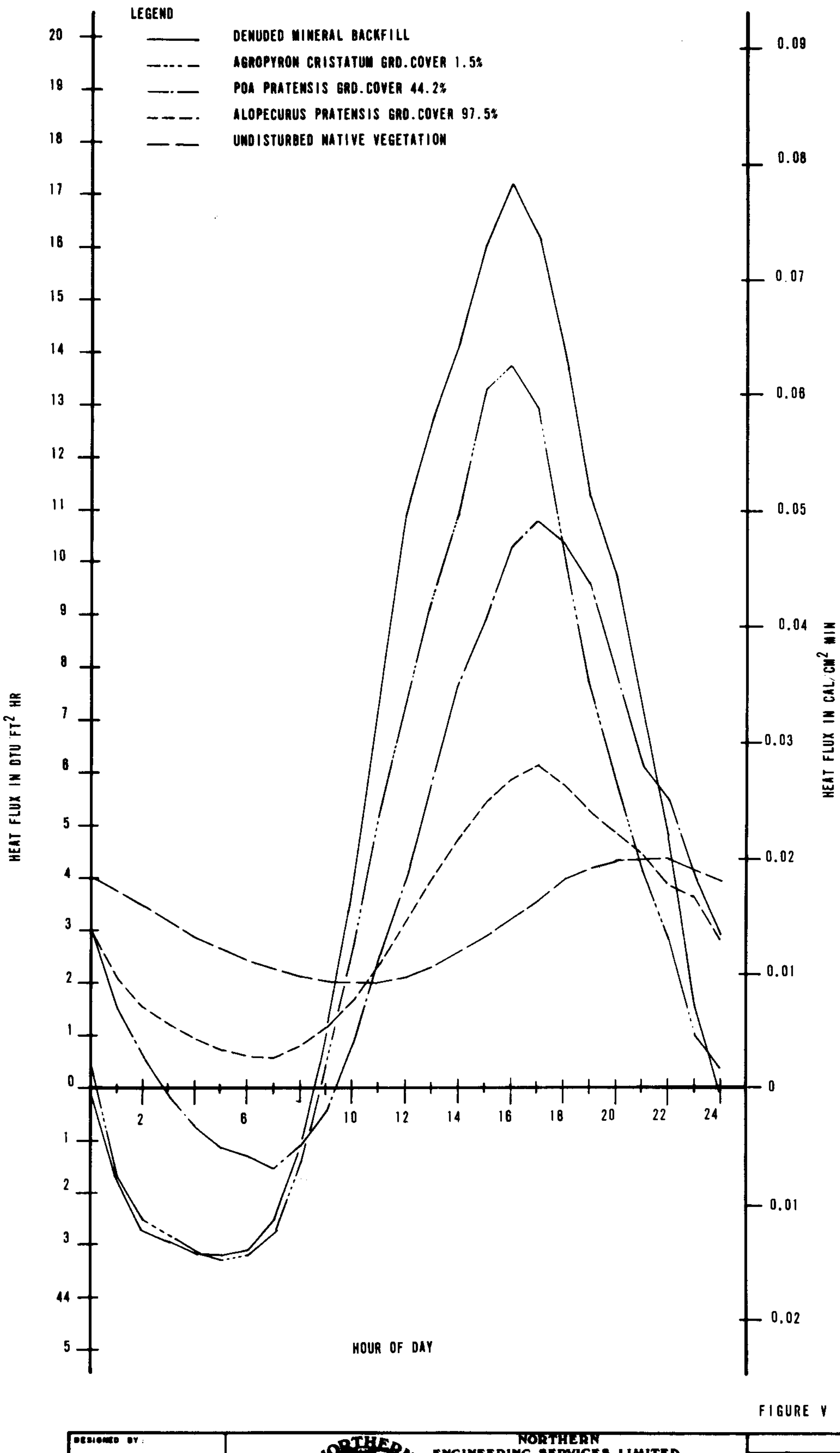

FIGURE V

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DRAWN BY:		
CHECKED BY:		SCALE:
ENGINEERS APP:	AVERAGE HOURLY HEAT FLUX IN TWO CONTROL PLOTS AND THREE PLOTS OVER TEST SECTION 1 JULY 17-31, 1972	DATE:
PROJECT MANAGER		PROJECT No.
		DRAWING No. -B REV.

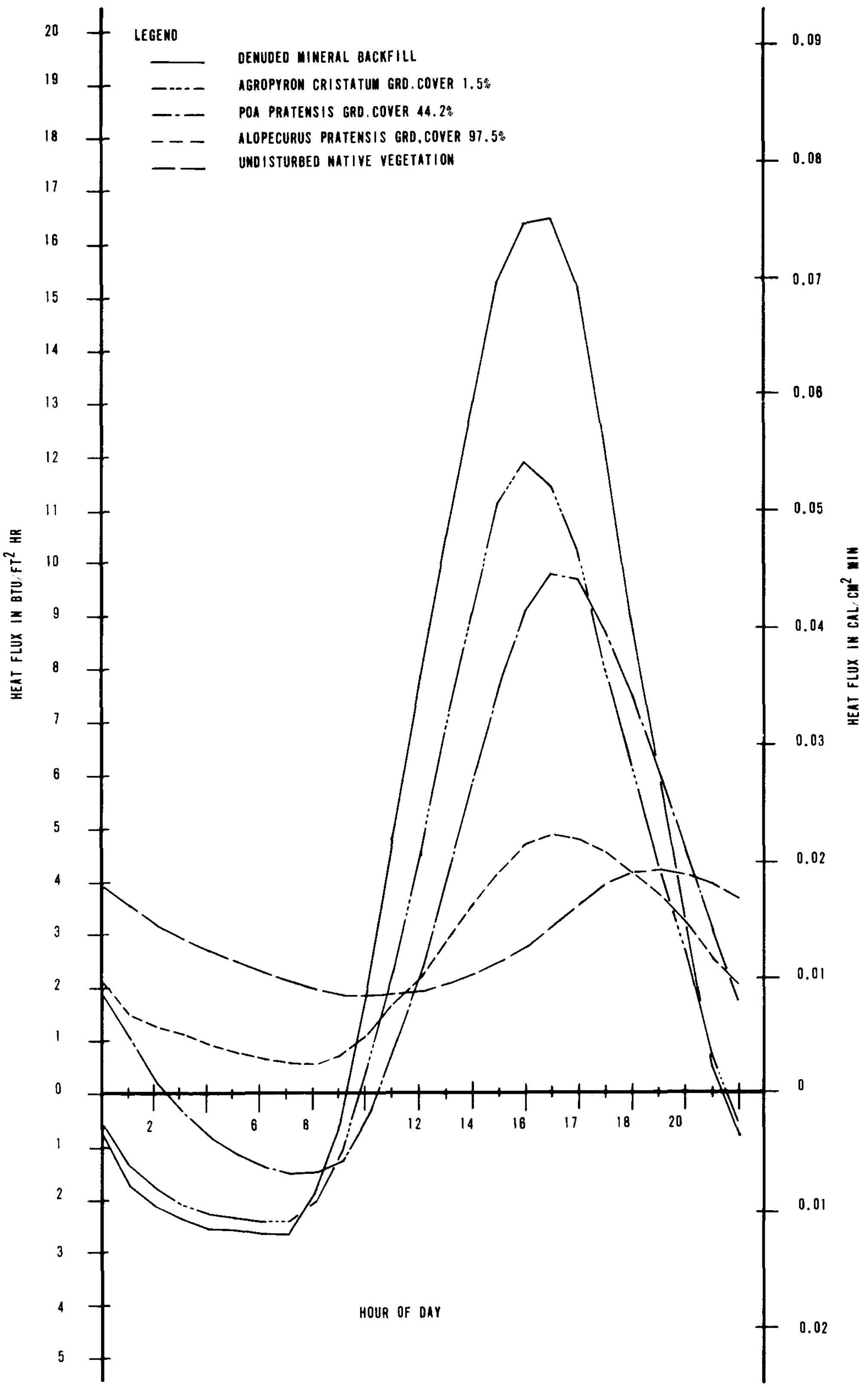

FIGURE VI

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DRAWN BY:		
CHECKED BY:		SCALE:
ENGINEERS APP:	AVERAGE HOURLY HEAT FLUX IN TWO CONTROL PLOTS AND THREE PLOTS OVER TEST SECTION 1 AUGUST 1-31,1972	DATE:
PROJECT MANAGER		PROJECT No.
		DRAWING No. -B REV.

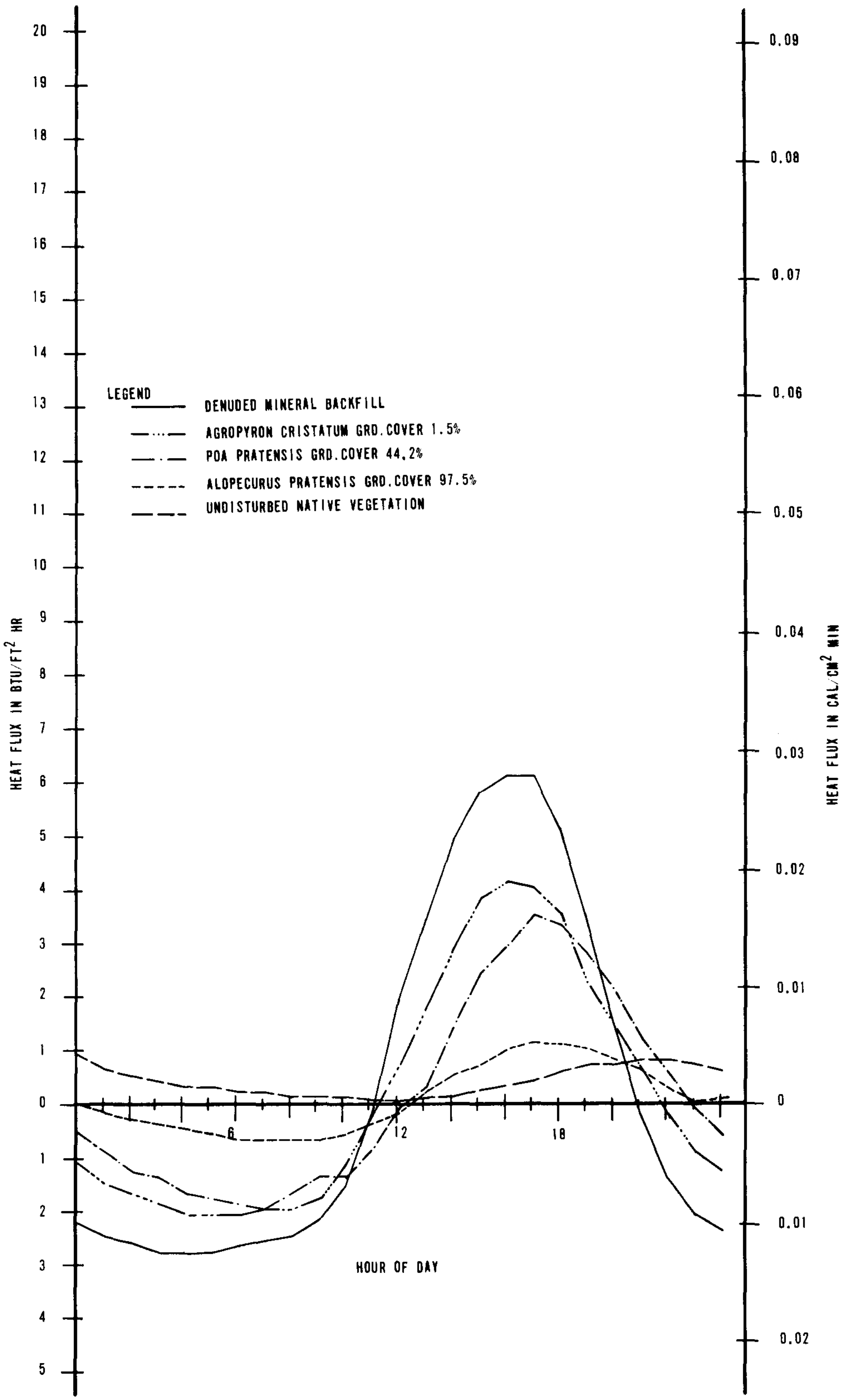

FIGURE VII

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DRAWN BY:		
CHECKED BY:		SCALE:
ENGINEERS APP:	AVERAGE HOURLY HEAT FLUX IN TWO CONTROL PLOTS AND THREE PLOTS OVER TEST SECTION 1 SEPTEMBER 1-30,1972	DATE:
PROJECT MANAGER:		PROJECT No.
		DRAWING No. -B REV.

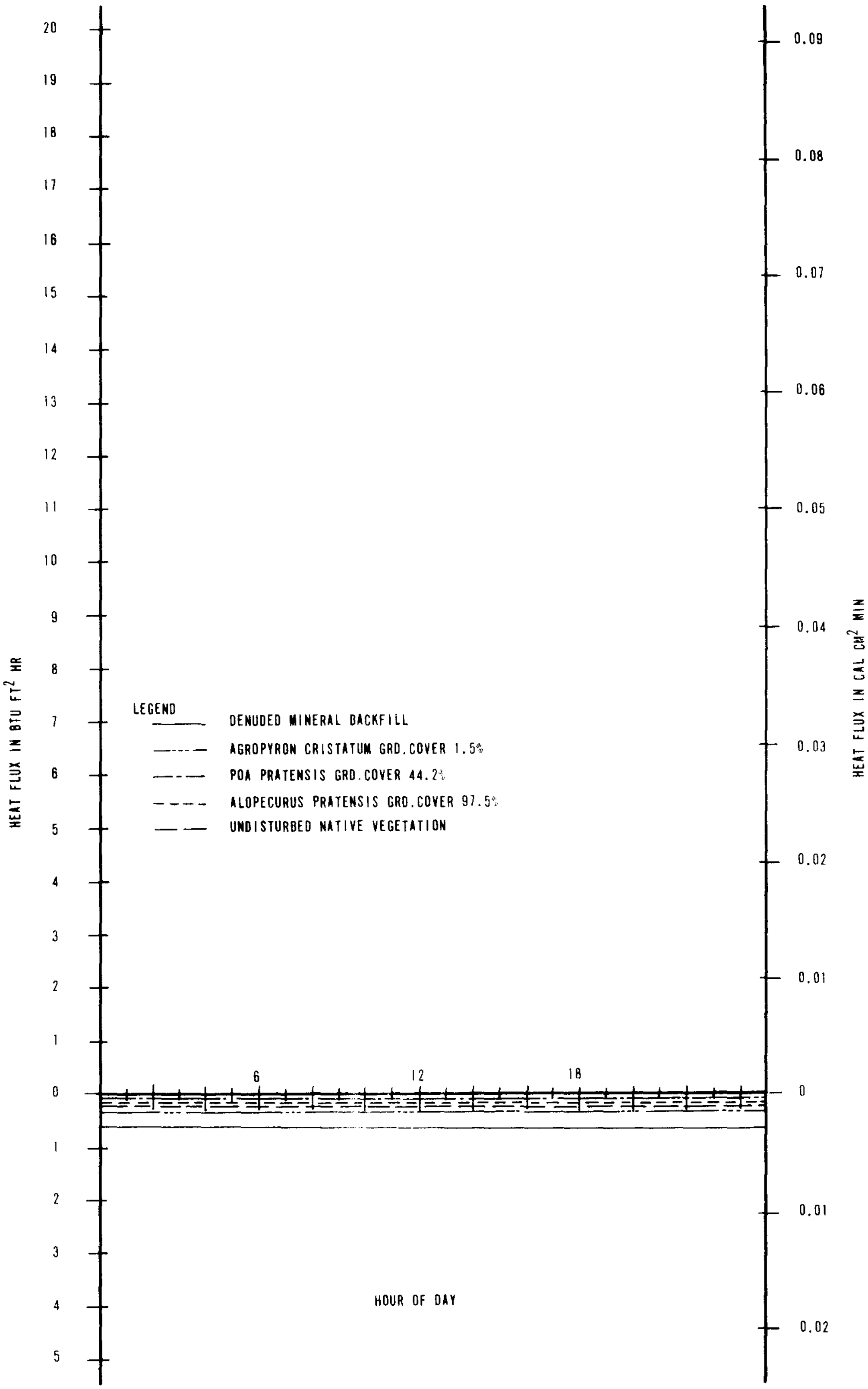

FIGURE VIII

DESIGNED BY	NORTHERN ENGINEERING SERVICES LIMITED CALGARY ALBERTA ENGINEERS FOR CANADIAN ARCTIC GAS STUDY LTD.	SCALE
DRAWN BY		DATE
CHECKED BY		PROJECT No.
ENGINEERS APP.	AVERAGE HOURLY HEAT FLUX IN TWO CONTROL PLOTS AND THREE PLOTS OVER TEST SECTION 1 OCTOBER 1972	DRAWING No. -8
PROJECT MANAGER		REV

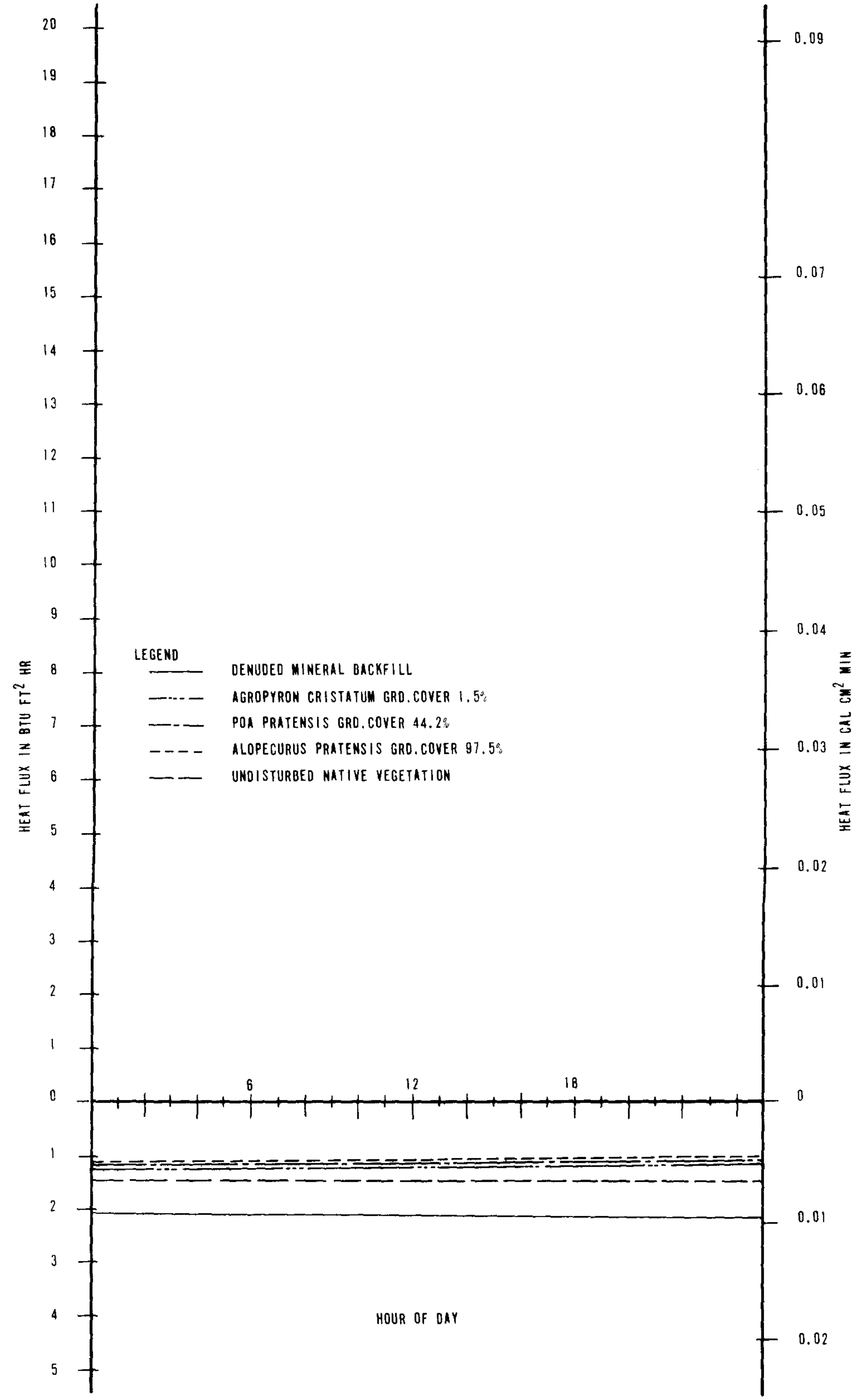

FIGURE IX

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DRAWN BY:		
CHECKED BY:		SCALE:
ENGINEERS APP:	AVERAGE HOURLY HEAT FLUX IN TWO CONTROL PLOTS AND THREE PLOTS OVER TEST SECTION1 NOVEMBER 1972	DATE:
		PROJECT No.
PROJECT MANAGER		DRAWING No. -B / REV

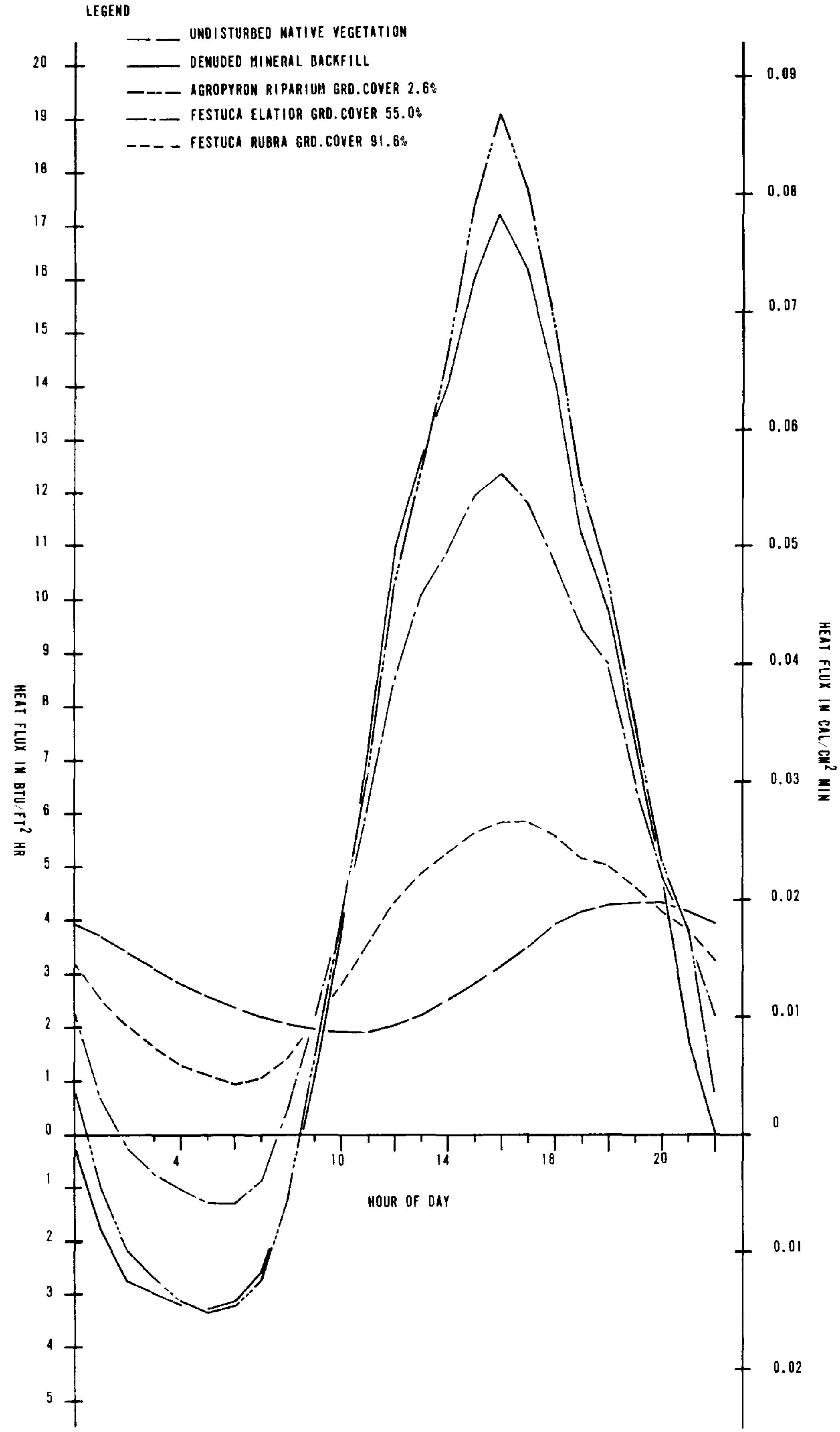

FIGURE X

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DRAWN BY:		
CHECKED BY:		SCALE:
ENGINEERS APP.	AVERAGE HOURLY HEAT FLUX IN TWO CONTROL PLOTS AND THREE PLOTS OVER TEST SECTION 3 JULY 17-31, 1972	DATE:
PROJECT MANAGER		PROJECT No.
		DRAWING No. -B REV.

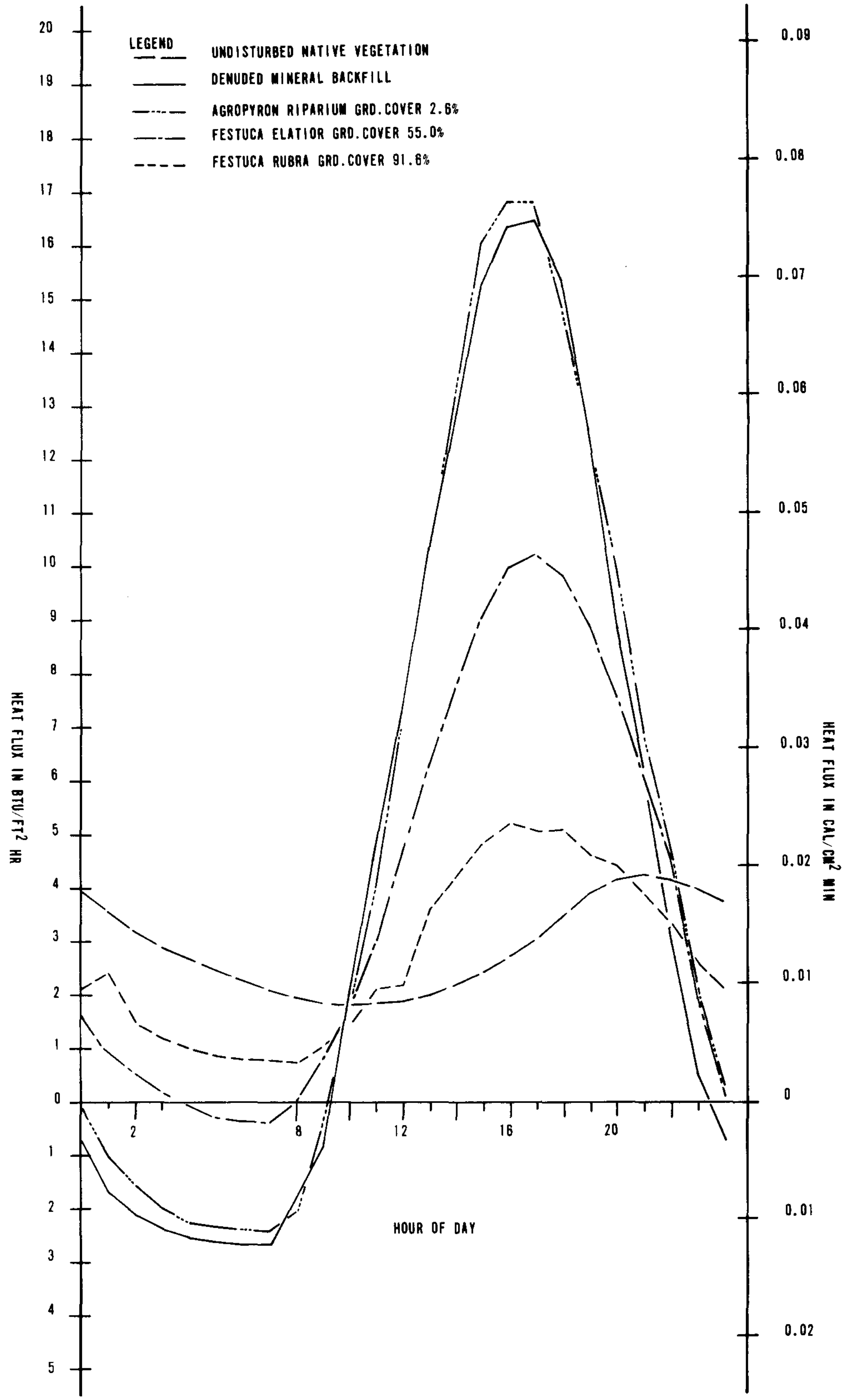

FIGURE XI

DESIGNED BY	NORTHERN ENGINEERING SERVICES LIMITED CALGARY ALBERTA ENGINEERS FOR CANADIAN ARCTIC GAS STUDY LTD.	
DRAWN BY		
CHECKED BY		SCALE
ENGINEERS APP	AVERAGE HOURLY HEAT FLUX IN TWO CONTROL PLOTS AND THREE PLOTS OVER SECTION 3 AUGUST 1-31, 1972	DATE
		PROJECT No.
PROJECT MANAGER		DRAWING No. -8 REV

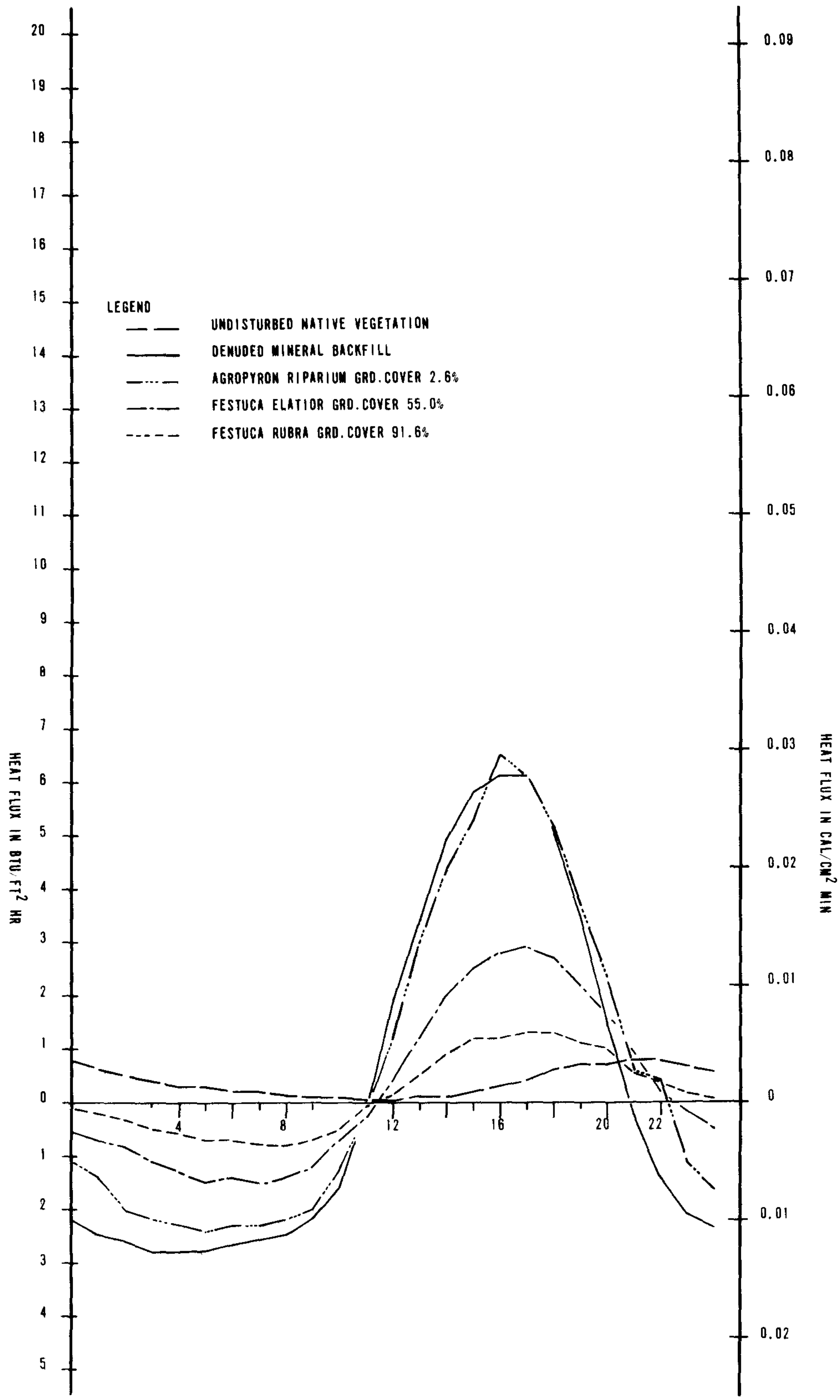

FIGURE XII

DESIGNED BY	NORTHERN ENGINEERING SERVICES LIMITED CALGARY ALBERTA ENGINEERS FOR CANADIAN ARCTIC GAS STUDY LTD.	
DRAWN BY		
CHECKED BY		SCALE
ENGINEERS APP	AVERAGE HOURLY HEAT FLUX IN TWO CONTROL PLOTS AND THREE PLOTS OVER TEST SECTION 3 SEPTEMBER 1-30, 1972	DATE
		PROJECT No.
PROJECT MANAGER		DRAWING No. - B REV

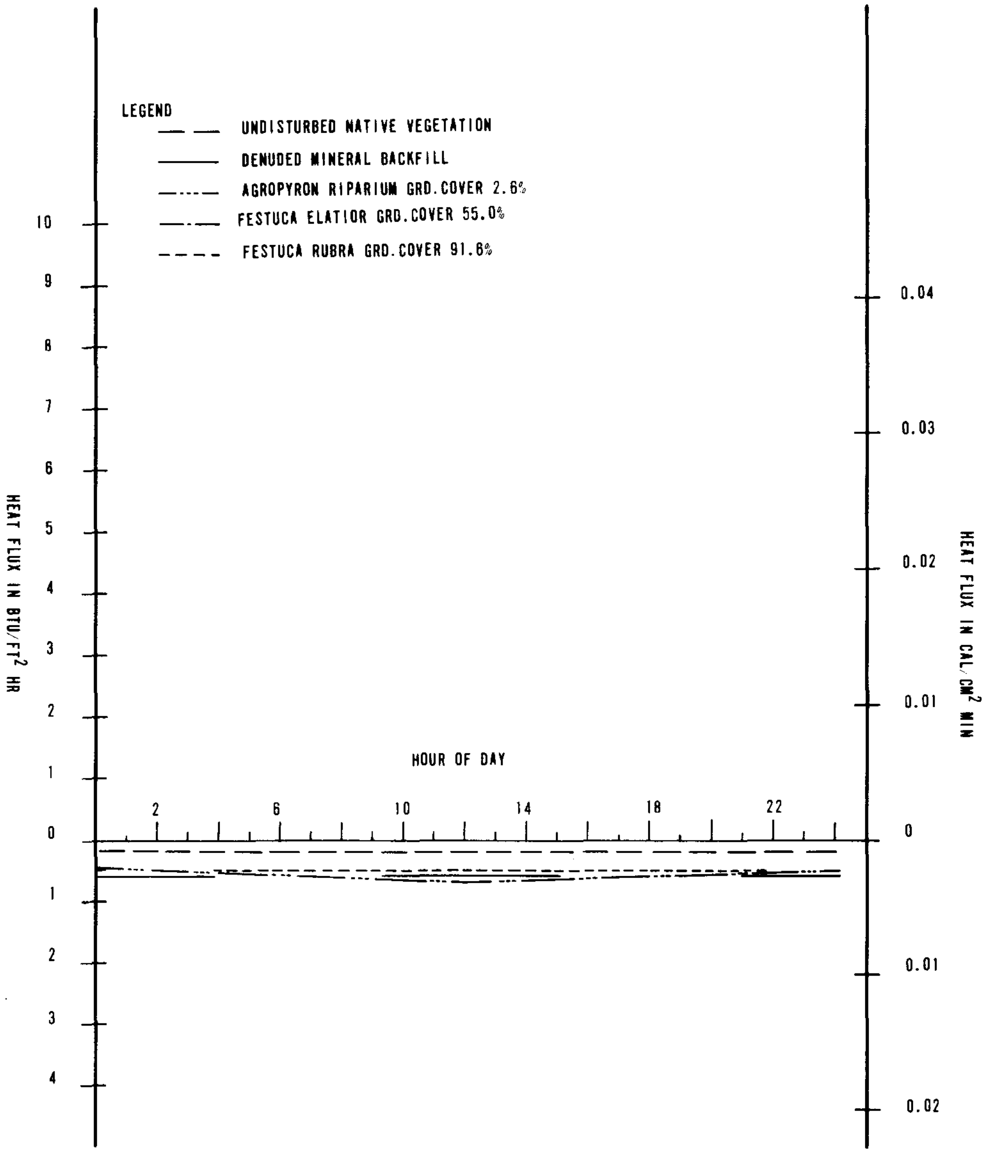

FIGURE XIII

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DRAWN BY:		
CHECKED BY:		SCALE:
ENGINEERS APP:	AVERAGE HOURLY HEAT FLUX IN TWO CONTROL PLOTS AND THREE PLOTS OVER TEST SECTION 3 OCTOBER 1972	DATE
PROJECT MANAGER		PROJECT No.
		DRAWING No. -B REV.

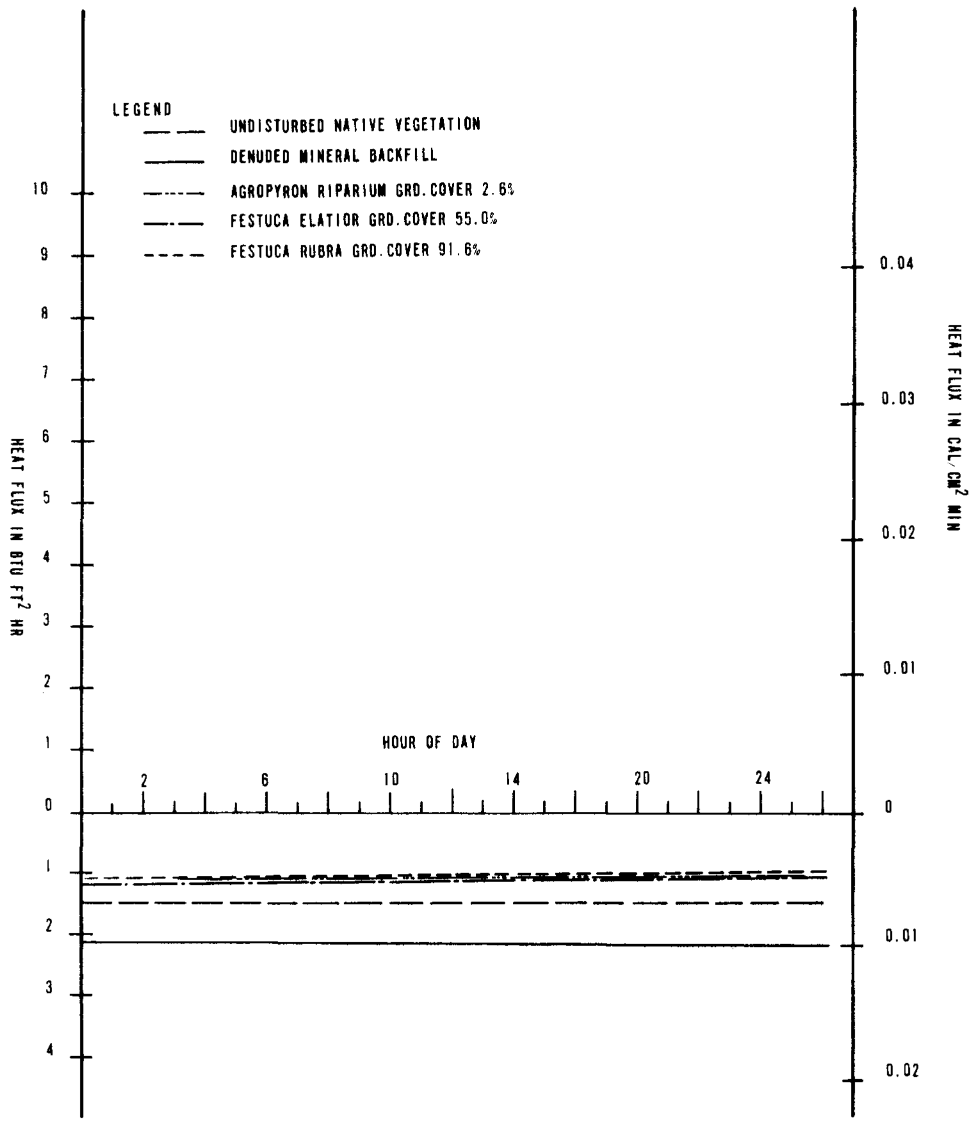


FIGURE XIV

DESIGNED BY	NORTHERN ENGINEERING SERVICES LIMITED CALGARY ALBERTA ENGINEERS FOR CANADIAN ARCTIC GAS STUDY LTD.	
DRAWN BY		
CHECKED BY		SCALE
ENGINEERS APP	AVERAGE HOURLY HEAT FLUX IN TWO CONTROL PLOTS AND THREE PLOTS OVER TEST SECTION 3 NOVEMBER 1972	DATE
PROJECT MANAGER		PROJECT No.
		DRAWING No. -B REV.

Influence Of Restored Plant Cover
On The Soil Energy Budget

Table VIII

Instrumented Plot	Percent Ground Cover	Heat In L[1]	Heat Out L[1]	Net L[1] L4	Ratio to Undisturbed Plot	One Year Average Heat Flow (From Sine Curve Fitted To Data) cal./cm^2 min	BTU/ft^2 hr.
Undisturbed	100	0.0503	0.0274	0.0229	1.00	+ 0.0019	+ 0.421
Meadow Foxtail (Plot #12)	97.5	0.0723	0.0164	0.0559	2.45	+ 0.0047	+ 1.03
Creeping Red Fescue (Plot #2)	91.6	0.0843	0.0148	0.0695	3.04	+ 0.0058	+ 1.28
Crested Wheatgrass L[2] (Plot #16)	1.5	0.0884	0.0184	0.0700	3.07	+ 0.0058	+ 1.29
Kentucky Bluegrass (Plot #5)	44.2	0.0909	0.0171	0.0738	3.23	+ 0.0062	+ 1.36
Meadow Fescue (Plot #7)	55.0	0.1200	0.0181	0.1019	4.47	+ 0.0085	+ 1.88
Streambank Wheatgrass L[3] (Plot #10)	2.6	0.1428	0.0180	0.0248	5.47	+ 0.0104	+ 2.30

L[1] Units = cal. mo/cm^2 yr

$$1 \frac{\text{cal}}{\text{cm}^2\text{yr}} \cdot \frac{\text{mo}}{\text{min}} = 43,200 \text{ cal/cm}^2 \text{ yr}$$

L[2] 63% bryophyt cover

L[3] Virtually no plant cover over plates

L[4] This figure does not take into account the effects of mass transportation.

TABLE IX

Comparison of Soil Temperatures, 1971 &

1972, to a Maximum Depth of 50 cm

Plot	Date	Temperature °C				Plot	Date	Temperature °C			
		6.5 cm	21.5 cm	37.0 cm	x			19.5 cm	34.5 cm	50.0 cm	x
	1/7/71	5.3	2.5	0.8	2.9		1/7/71	6.6	4.5	2.2	4.4
Intermediate	1/7/72	12.1	7.5	3.9	7.8	Canada	1/7/72	10.3	7.6	4.6	7.5
Wheatgrass						Bluegrass					
	17/7/71	10.9	4.9	0.4	5.4		17/7/71	12.3	7.7	4.1	8.0
	16/7/72	18.4	14.7	8.1	13.7		16/7/72	-	-	-	-
18a						4b					
Sec. 1	1/8/71	11.8	7.8	2.6	7.4	Sec. 11	1/8/71	12.3	10.0	6.8	9.7
4% cover	1/8/72	13.8	12.7	9.3	11.9	38% cover	1/8/72	13.7	11.6	8.6	11.3
	16/8/71	10.0	6.1	2.8	6.3		16/8/71	9.4	6.9	4.2	6.8
	16/8/72	17.1	18.6	13.7	16.5		16/8/72	17.4	16.5	10.6	14.8
		12.0 cm	27.5 cm	42.5 cm				19.0 cm	34.5 cm	49.5 cm	
	1/7/71	7.9	5.3	1.9	4.3		1/7/71	3.0	1.4	1.3	1.9
Intermediate	1/7/72	11.1	6.6	3.3	7.0	Streambank	1/7/72	6.0	2.2	-1.2	2.3
Wheatgrass						Wheatgrass					
	17/7/71	17.3	9.3	4.5	10.4		17/7/71	8.9	3.6	0.6	4.4
18b	16/7/72	19.9	14.6	7.1	13.9	10a	16/7/72	14.5	6.0	-0.6	6.6
Sec. IV						Sec. 11					
15% cover	1/8/71	15.9	10.8	7.8	11.5	62% cover	1/8/71	11.9	8.0	2.8	7.6
	1/8/72	13.4	11.4	7.3	10.7		1/8/72	11.0	6.6	0.7	6.1
	16/8/71	6.4	7.9	4.8	6.4		16/8/71	8.6	5.4	2.8	5.6
	16/8/72	17.2	14.7	8.4	13.4		16/8/72	14.2	7.3	1.1	7.5

Test section I was operated at -3.9°C (25°F) during both years. Test section II was operated at -2.2°C (28°F) during the 1971 growing season and at -12.8°C (9°F) during 1972. Test section IV was operated at -6.7°C (20°F) during 1971 and -15.0°C (5°F) during 1972.

A brief summary of climatic records during these periods follows:

		1971	1972
	Mean Temperature (°F)	58.7	60.7
JUNE	Mean sunshine hours	98.7	104.0
	Total precipitation	0.28	1.63
	Mean Temperature	62.9	62.0
JULY	Mean sunshine hours	83.5	86.0
	Total precipitation	2.21	0.77
	Mean temperature	53.1	61.2
AUGUST	Mean sunshine hours	48.3	64.3
	Total precipitation	5.08	1.81

The three dimensional permafrost profiles given in appendix 'B' provide an assessment of the effects of the plant cover and operating chilled gas pipeline on the depth of thaw in the active layer during the second operating season at Sans Sault.

4.7 SLOPE STABILIZATION

On August 25th, 1972, the survival of shrub cuttings planted on sideslopes and roadways was determined.

The survival of cuttings planted on the seismic line in the fall of 1971 was:

Salix alaxensis	94%
Salix arbusculoides	83%
Salix planifolia	22%
Alnus incana	60%
Alnus crispa	100%
Cornus stolonifera	0%
Betula papyrifera	0%

The grass seeded in the late fall of 1971 on this slope germinated and grew well. The result of the combined treatments was that the slope was completely stabilized.

The survival success of cuttings planted in the two plots on the winter road in June of 1972 was as follows:

Test Area I	
Salix alaxensis	96%
Alnus crispa	100%
Alnus incana	67%

Test Area III	
Alnus crispa	78%
Alnus incana	75%
Larix laricina	10%
Salix spp.	83%
Betula papyrifera	0%
Shepherdia canadensis	100%

The time required to hand plant shrub cuttings on three areas was determined. The total area planted was 315 m^2 at a density of 10.3 cuttings per square metre. This planting program required 52 man hours. These figures convert to 1650 man hr/hectare or 660 man hr/acre. With more experience and improved efficiency, plus a lower density, this could be reduced to 1500 man hr/hectare or about 600 man hr/acre.

4.8 TUNDRA RESTORATION

The plots established on a seismic line between the Firth and Babbage rivers on the Yukon north slope were revisited on August 29th, 1972.

The four seeding trials showed similar growth responses in this habitat. Fertilizer is an absolute requirement for the growth of all grasses seeded. The establishment in the fertilized plots was patchy, as only Creeping Red Fescue was able to grow in the depressions between tussocks and organic debris. Generally the seeded grasses established only where mineral soil was exposed at the surface, such as frost boils or seismic drill holes. In these areas, however, the seedlings had attained a height of only 10-12 centermetres.

The fertilizer stimulated the growth of native species, particularly *Arctagrostis latifolia*.

Many of the *Eriphorum* (cottongrass) tussocks that were knocked loose by the bulldozer operation successfully re-established themselves during the summer. Approximately 35 to 45 percent of the cottongrass tussocks were estimated to have rooted and successfully continued to grow in unfertilized plots. Fertilization appeared to improve the establishment success to 65-75%.

Photo 6 shows a tussock of *Eriophorum* which had been knocked loose and thrown up on the pile of organic debris in the centre of the seismic line. Note that, to some degree, other species such as willow are also tolerant to this stripping treatment. Photo 7 shows the root system of the tussock. This one had been completely loose when first visited in June.

The influence on the depth of thaw in the active layer of leaving the stripped organic debris and cottongrass tussocks is shown in Figure XV.

PHOTO 6: A tussock of cottongrass (*Eriophorum vaginatum* var. *vaginatum*) that had been knocked loose by seismic activity in the winter.

PHOTO 7: The root systems developed in one season by a cottongrass tussock that had been sitting loose on the surface in June. Photo taken August 29, 1972.

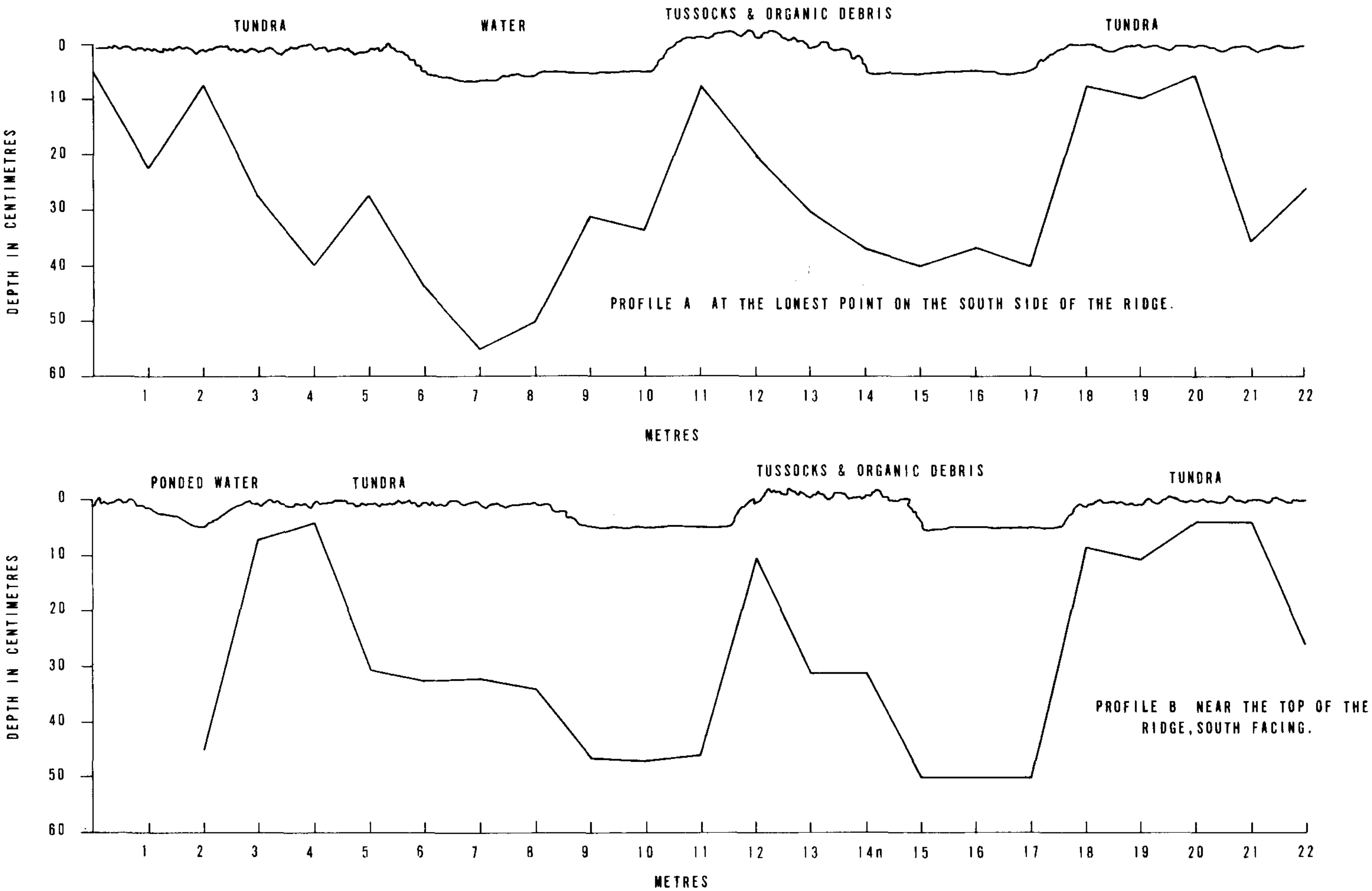


FIGURE XV

No.	DESCRIPTION	DATE	BY	APP.
REVISIONS				

DESIGNED BY:
DRAWN BY:
CHECKED BY:
ENGINEERS APP:
PROJECT MANAGER

NORTHERN ENGINEERING SERVICES LIMITED
CALGARY ALBERTA
ENGINEERS FOR
CANADIAN ARCTIC GAS STUDY LTD.

PERMAFROST PROFILE ACROSS
A SEISMIC LINE ON
THE YUKON NORTH SLOPE

SCALE:
DATE:
PROJECT No.
DRAWING No. -B
REV.

5.0 DISCUSSION

The results of two season's growth of grasses on a simulated pipeline right-of-way in the northern boreal forest show that a binding plant cover can be successfully established and maintained at these latitudes. The results of other research projects (Hernandez 1973, McGrogan *et al.*, 1971, Bliss and Wein 1972) confirm that revegetation of disturbed land surfaces in the north is feasible. To be successful, however, the appropriate grass species and fertilizer treatments must be used. Each species grown in the north reacted differently to fertilization, climate, soils, short growing season etc. The results of two years of research at the Sans Sault test facility are discussed in the following section.

5.1 EVALUATION OF SPECIES SEEDED AT THE ARCTIC TEST FACILITY

Generally, the results of the first season's trials were that all species planted, germinated and grew well. Certain species performed better under the subarctic summer conditions than did others. However, not all species successfully overwintered or demonstrated the same growth behaviour the second season. The following sections discuss the second year results in detail.

5.1.1 Surface Litter Accumulation

The build up of an organic layer on the ground surface is a very important feature if a balanced soil energy budget is to be re-established over the pipeline or other disturbed areas. Measurements taken in the spring of 1972 show the amount of ground covered by dead plant tops after one growing season.

All species except the wheatgrass *Agropyron cristatum*, *A. elongatum*, and *A. intermedium* produced 20% litter cover in at least one test plot (Table III). Eight of the eighteen species produced at least 50% cover in three of the four replications. *Poa trivialis*, *P. palustris*, and *Festuca ovina* produced greater than 50% litter cover in one subplot in all four test sectons.

The effect of the initial fertilization on the amount of ground covered by organic litter was examined. Though four species showed a significant difference between fertilizer treatments and four showed highly significant differences, there was no consistent pattern to the response. Therefore, the differences in litter accumulation is species and site dependent, not a response attributable to either level of fertilization.

5.1.2 First Year Survival

The survival of grasses planned for use in right-of-way revegetation must be understood as this is basic to a successful program.

The data presented in Table III is a measure of the number of seeds initially sown in each plot to have survived successfully the first full growing cycle. As there was very little seed set in the first season, these figures are considered an accurate measurement of the net survival in each plot.

The data show that the survival rate of *Agrostis alba* (Red Top) and *Agrostis tenuis* (Brown Top) was very low following the first winter. Both species did relatively well the first growing season, but were set back severely the first winter. Growth initiation of both was retarded by two or three weeks the second year, but they came on to produce as much as 26% ground cover, in one subplot, by fall.

Again no clear, consistent pattern is shown in the results when analysing the effect of the two rates of initial fertilization on survival in either organic or mineral media.

In the few cases where there is a significant difference between the two fertilizer rates, the greater survival has generally been in subplot 'a', the highest rate. This is shown on test sections II and III where the survival of *Festuca rubra* was highly significant in plot 'a' on the mineral backfill. However, on test section II *Agropyron cristatum* had a significantly higher survival success on both organic and mineral substrate at the lower fertilizer level. A similar response is shown by *Agropyron trachycaulum* in section I on mineral soil.

When comparing the survival success on the two substrates, organic mat and mineral backfill, only *Festuca rubra* (Creeping Red Fescue) showed a consistently higher (highly significant) rate of success on the mineral soil. Four others, *Poa compressa, P. pratensis, P. palustris* and *Festuca elatior*, showed a significant difference between survival on the two media in three of four plots. In every case, survival was greatest on the mineral soil.

5.1.3 Growth of Plants in the Second Season

The percent ground cover is used as a measure of the amount of plant top produced and a relative measure of the ability of each species to grow at the latitude of Sans Sault Rapids.

In evaluating the growth of these grasses, it is most important that they grow well on the mineral backfill mound as this portion of the right-of-way has had all plant cover destroyed. Examination of Table III shows that all species except *Festuca arundinacea* and *Agropyron cristatum* produced 30% ground cover on mineral soil in one of four plots. Eleven of the eighteen managed 50% cover on at least one plot, but only *Festuca rubra* (Creeping Red Fescue) and *Alopecurus pratensis* (Meadow Foxtail) consistently produced greater than 50% cover (Disregard Table III (c)).

It appears that the effects of different rates of fertilization at time of seeding do not carry over into the second season.

In assessing the rate of growth it should be noted that all species attained an average daily growth of root in excess of 2.0 mm in one or more plots and only four failed to attain 3.0 mm/day in at least one plot. The rate and depth of rooting is important when selecting species for soil erosion control.

5.2 SUCCESSIONAL PROCESSES ON THE PIPELINE BACKFILL

The reinvasion of disturbed sites by plants is an important and basic natural process, common, not only in the Arctic, but in every biome of the world. A measurement and understanding of the rate and character of the successional phenomena on the pipeline backfill, or other areas requiring revegetation, is important as the seeding of grasses is not considered a long term restoration measure. It is much more important that a diverse, stable natural plant community quickly establish on these areas.

Table IV (a to d) presents the data collected on the mineral backfill. As the vegetation was completely removed, study of this portion of the right-of-way aid in understanding the processes active in this test area. It is difficult to determine which species have actually invaded the portion of the right-of-way from which only trees and shrubs were removed. Therefore, the data gathered from these areas are inserted as an appendix only.

Examination of Table IV shows clearly that mosses and liverworts have become very well established on the pipeline backfill. Only test section III lacks the heavy cover of bryophytes. This is due probably to the well drained, very dry conditions on the mound itself.

The significance of these data is that the invasion of the backfill mound by mosses appears to be much more rapid than on disturbed seismic lines or winter roads in the region which have not been seeded and fertilized. Considering the importance of mosses in building an insulative organic mat (Brown 1966) on the soil surface, these data indicate that some modification of soil energy exchange, due to bryophyte cover, could be expected in the second growing season (Table VIII).

The apparent acceleration of bryophyte growth in these plots is explained on the basis of the combined effect of improved fertility and the creation of a micro environment at the ground surface by the growth of grasses, conducive to the growth of mosses.

As a general rule, the soils of the Arctic and sub-Arctic are nutrient poor. Fertilization quickly overcomes, at least temporarily, these deficiencies, causing a stimulation of bryophyte growth (Table VII). Observations in the plots on the winter road indicate that fertilization alone is not a guarantee of moss growth. It appears that fertilization stimulates the growth of seeded grasses and legumes which in turn hold a layer of moist air near the ground. Within the plots of better grass growth, consistently better growth of moss cover was observed (Table VII).

Invasion of the mineral backfill mound by native vascular plants has been much slower. Species of highest frequency values are well known pioneer plants such as *Arctagrostis latifolia*, *Epilobium angustifolium*, and *Equisetum arvense*. Photo four shows the north end of test section II where *Arctagrostis*, *Senecio congestus* and *Carex aquatilis* cover much of the area adjacent to the mineral backfill.

As the process of succession continues, the need for the seeded grass cover decreases. Continued monitoring of this phenomena is required over the next several years in order to state accurately the stage at which the grasses are no longer essential for erosion control.

5.3 NUTRIENT REQUIREMENTS FOR ESTABLISHMENT AND CONTINUED GROWTH

Research in northern Canada and Alaska (Younkin 1972 in Bliss and Wein 1972, Van Cleve and Manthei 1971) has shown clearly the need for fertilization to grow the agronomic varieties of grasses available for revegetation. Unlike the native species which have adapted to the relatively low nutrient status of Arctic soils, the forage grasses grow very poorly at these latitudes unless fertilizer is added.

Based on soil tests of composite samples from the backfill mound at Sans Sault, a fertilizer formulation of 10-19-19 was applied at the time of seeding at the rate of 700 and 350 lb/acre. The results of the first years growth of plots indicated that most species grew equally well at 350 lbs/acre, though some did produce better at the higher rate.

Bliss and Wein (1972) report that best results were obtained when 100 kg/ha elemental nitrogen and 200 kg/ha elemental phosphorus were applied at the time of seeding in the Inuvik and Tuktoyaktuk region. As this is even higher than the heaviest rate used at Sans Sault (Table II), it is evident that fertilizer requirements are not uniform throughout the northern end of the proposed pipeline route.

Tests were established on the winter road in June of 1972 to determine a minimum initial rate of fertilization that would produce a strong, vigorous growth the first growing season.

Reviewing Table VII and the results from 1971, a fertilizer recommendation for the Sans Sault region would be 75 kg/ha nitrogen plus 100 kg/ha of both phosphorus and potassium. This recommendation is made with the proviso that a revegetated area would be fertilized a second time, probably in the spring of the second year.

Analysis of soil samples taken from plots one year after fertilization show that mineral elements are quickly used by plants and microbes, leached from the soil, or bound in a form unavailable to the plant roots (Table VI). The apparent lack of nutrients in the rooting zone explains the deficiencies which began to show in the plants only one to two weeks after the samples were taken.

Photo five shows the response of creeping red fescue to 34-0-0 and 11-48-0 after only one month. Ordinarily fertilizer would be applied in the spring. However, as nutrient deficiencies appeared in July, a limited test was established to determine if these deficiencies could be overcome. The data presented in Table V show that generally, there was a major increase in biomass production after one month in the fertilized plots. In general, the greater response was to nitrogen though the wheatgrasses show a greater response to 11-48-0.

Due to the limitations imposed by sample size and shortness of time between application and sampling, the data do not reflect clearly the true response to the second fertilization. Visually, all species responded to the addition of fertilizer even though it came in the middle of the growing season. As shown in photo five, the foliage appeared much healthier and vigorous, generally growing much taller than the unfertilized control.

It appears evident that a second application of fertilizer will be required to maintain a healthy, vigorous growth of grass on the pipeline backfill. Trials established in the fall of 1972 and additional plots to be added in the spring of 1973 will help define the requirements and formulations of fertilizer to be applied in the second or third growing season.

5.4 PLANT COVER EFFECTS ON THE SOIL ENERGY BUDGET AND PERMAFROST TABLE

Brown (1966) states that "vegetation has a direct influence on the permafrost by its thermal properties which determine the quantity of heat that enters and leaves the underlying ground in which the permafrost exists." The importance of vegetation and its influence on permafrost is well known in the literature. A major goal of the revegetation program is to establish a plant cover on disturbed areas which will, within a reasonable time period, restore the balance of energy exchange in order to re-establish the permafrost conditions to near "normal".

The work conducted during 1972 examined, by direct measurement, the influence different plant covers had on heat flow at the soil surface. This has included measurements beneath the understory duff and vegetative layer within the undisturbed black spruce forest at the test site.

Figures V to XIV chart the average hourly heat flux in six revegetated plots, plus the undisturbed site and a mineral backfill location devoid of vegetative growth. The graphs cover the period from mid-July to the end of November.

Figures V and X show an inverse correlation between the amplitude of the midsummer 24 hour heat flux graph and the amount of plant growth covering the soil surface. The identical relationships carry through to the end of September, though the amplitude decreased each month.

During July, August and September there was a constant flow of heat energy into the ground within the undisturbed forest cover. The average hourly heat flow during July was 0.0146 $cal/cm^2 min$ (3.25 $BTU/ft^2 hr$), August was 0.0131 $cal/cm^2 min$ (2.90 $BTU/ft^2 hr$), and 0.0072 $cal/cm^2 min$ (1.61 $BTU/ft^2 hr$) during September. From October through to May there was a net reradiation of heat energy from this site. The two plots of maximum plant cover show a similar trend. For example, the average hourly heat flow in plot #12, section I, *Alopecurus pratensis* (97.5% cover) during July was 0.0139 $cal/cm^2 min$ (3.09 $BTU/ft^2 hr$), 0.0109 $cal/cm^2 min$ (2.43 $BTU/ft^2 hr$) during August and 0.0002 $cal/cm^2 min$ (0.05 $BTU/ft^2 hr$) during September. At the extreme, the average hourly heat flow during July, August and September in the mineral backfill was 0.0271 (6.0), 0.0212 (4.7),and -0.0013 $cal/cm^2 min$ (-0.3 $BTU/ft^2 hr$).

As the amount of plant cover decreases the amplitude of the July heat flux graph increases. During the morning, between midnight and about 1000 hours, there was a reradiation of heat energy from the plots of very little or no cover with a rapid rise in heat flow into the soil between 1000 and 1600 hours, followed by a rapid tapering off. This trend followed through to the end of September with a shift of about one hour in the peak. Note, that as the amount of plant cover increases, the period of reradiation decreases and the maximum peak in the graph decreases. As the amount of plant cover increases, the peak in heat flow into the soil is displaced farther out of phase with solar noon.

Table VIII compares heat flow in the six revegetated plots to the natural plant cover, the undisturbed forest stand. It is evident from this analysis that sample year, 1972, was a warm year with a net heat balance of +0.0019 cal/cm^2 min or +0.421 BTU/ft^2 hr in the undisturbed site. If these data represented a 'normal' year, there would be a slow attrition of permafrost until completely eliminated in approximately 50 years at this latitude.

If these data are adjusted to a balanced condition (0.0 heat flow in the undisturbed site) then the plot of Meadow Foxtail approaches closely (+0.0028 cal/cm^2 min) the heat flow in the forest site in 1972.

The analysis indicates that within two years of construction disturbance, it is possible to restore a plant cover within the northern boreal forest which will provide an effective, though not complete, insulative cover. Recognizing that the two plots of heavy growth do not necessarily represent the type and amount of cover that will be obtained on an operational scale, the data must be viewed with caution. Notwithstanding the fact that 95% cover may not be obtained in two years on a larger scale operation, the results to date are very encouraging, indicating that an insulative plant cover can be re-established within a reasonable time period.

Table IX presents soil temperature data from four test plots recorded during July and August in 1971 and 1972. The purpose of this comparison was to determine if the colder operating temperatures of the pipeline in 1972 affected the temperature of the soil within the rooting zone. As these data show, the soil temperatures, to a maximum of 50 cm, were warmer in every case in 1972 than 1971.

It is evident that air temperature, sunshine, and precipitation during the summer months control the near surface soil temperatures. These data are applicable to only the early years of operation as they cannot be extrapolated into the future when a more complete plant growth and layer of organic litter will cover the pipeline.

The permafrost profile presented in Appendix B (figure B1) show that the depth of active layer over the chilled pipe (section II, -12.8°C) recovered, during the second year of operation, to a level equal to or slightly shallower than the former depth as plotted under the forest cover. This analysis shows that the increase in depth of active layer following construction will be rectified during the second operation season.

Transects crossing a ditchline not containing an active test pipe were monitored during 1971 and 1972 to determine the effect on permafrost of having the pipeline sit inactive for two years before chilled gas is put through. The depth of thaw in the dithline during the first season was 100 to 130 cm. Figure B-2 shows that the depth of thaw was not increased during the second season even though the trench held about 15 centimetres of water throughout the summer.

If water erosion can be controlled in the ditchline during the inactive period between construction and start-up of the line, thermal degradation around the line may stabilize after the first summer. Exceptions to this would include very high ice content soils including massive segregated ground ice features which would probably continue to melt.

5.5 SLOPE STABILIZATION TECHNIQUE

The fundamental objective of the project is the revegetation of disturbed areas to prevent soil erosion. Part of that objective includes the stabilization of side slopes and approaches to rivers and stream crossings. As stabilization of critical areas is essential, measures in addition to broadcast application of grass seed and fertilizer may be required.

It must be recognized from the beginning that biological stabilization techniques cannot correct for poor construction practices. Critical areas must be properly designed for taking into account the soil and permafrost conditions present. Beyond this, the control of soil erosion is possible.

On minor slopes, the broadcast seeding of grass plus the planting of shrub cuttings should be adequate. Experience gained at Sans Sault shows that the propagation of many shrub species, by means of stem cuttings, is a reliable method of revegetating slopes with woody species.

Desiccation of stems above the snow did not appear to be a problem as cuttings one metre tall successfully overwintered and continued to grow the next spring.

The data presented in section 4.7 show that willows and alders can be easily grown from cuttings. *Cornus stolonifera* and *Betula papyrifera* cannot be used for slope stabilization. It can be concluded from this that, though the technique of using cuttings can be successful, planting on a larger scale by larger crews would have to be under the direction of persons experienced in plant identification.

Stabilization of major slopes will probably require the placement of a mat on the soil surface to hold the seed in place until germinated and well established, as well as prevent soil erosion during the establishment period. This mat may be thin and open as the case with woven wood excelsior mats or may be made of other organic or synthetic materials. It may be possible to preseed and fertilize a thicker mat. In either case the purpose is to hold the soil until the plants are successfully rooted.

Mats will have to be pegged down in order to hold them in position. Metal or wire pegs could be used, but shrub cuttings would be an even better choice. In the latter case the pegs themselves would continue to grow and put down roots, further aiding soil stabilization.

Specific recommendations regarding erosion control techniques are contingent on the engineering specifications for side slope stabilization.

5.6 RECOMMENDATIONS FOR RIGHT-OF-WAY REVEGETATION

The seeding recommendations given here apply only to the mid-Mackenzie River valley. Recommendations for revegetating mesic tundra areas are given by Hernandez (1973).

When considering pipeline revegetation, it is important to recognize the types of disturbed land surfaces which must be dealt with. The first is the pipeline right-of-way which, due to the construction procedures, will present two surfaces. One will be the backfill mound over the pipeline. This will consist of a mixture of materials excavated from depths to twelve feet, bermed up several feet above grade, over the ditchline. The remainder of the right-of-way will be covered with the native organic mat which may be somewhat compressed on the working side of the ditchline due to vehicular movements on a packed snow road.

Depending on the source of aggregate, borrow pits will have to be reseeded. These could vary from sand and gravel pits in an esker to rock quarries. The variable sources of borrow material will each dictate a specific restoration procedure.

Haul roads and abandoned stockpile sites present yet another surface which may or may not require revegetation. If they are to be revegetated it will be necessary to mechanically break up the surface in order to create a suitable seed bed.

For the Sans Sault area, a recommended seed mix to be applied by aerial broadcast techniques would include:

Boreal Creeping Red Fescue	@	10-15 lb/ac
Common Kentucky Bluegrass	@	10-13 lb/ac
Common Meadow Foxtail	@	10-13 lb/ac
Frontier Reed Canary Grass	@	10-15 lb/ac

An additional 5 lb/ac Climax Timothy or Meadow Fescue could be used to add diversity to the mix. Timothy could replace the Meadow Foxtail in the mix if the latter is not available. On dryer, well drained soils, it is necessary to add 5 to 10 lb/ac Revenue Slender Wheatgrass. In this case, an equal amount of Reed Canary Grass could be deleted.

Fertilizer recommendations were made in Section 5.3.

In 1972, plantings of alsike clover and alfalfa did not perform well and are, therefore, not recommended for the latitude of Sans Sault. Undoubtedly these legumes would prove beneficial in the seed mix in more southerly locations.

In addition to the seeding recommended by Hernandez (1973) in tundra areas, mechanical stripping of the tundra mat and replacing it to the top of the backfill mound would prove beneficial. Figure XV shows the effect of this technique on the depth of thaw in the active layer in the northern foothills of the British Mountains. An additional benefit of this technique is the fact that it will quickly re-establish an important component of the natural plant community on the disturbed rights-of-way.

Caribou have been reported to seek out and feed on seeded grasses at Prudhoe Bay (W. Mitchell, Personal Communication). The technique of stripping and replacing the tundra mat should reduce the attractiveness of the right-of-way to caribou as it will re-establish a major proportion of the former plant community.

Stripping or sodding could be effectively used in two major areas,

(1) the wet sedge tundra lowlands where there would be an abundance of rhizomes in the sod that would continue to grow. These areas would be difficult to establish grass from seed due to the wetness of the area,

(2) the tussock cottongrass region in the rolling uplands of the Arctic plateau. The tussocks of cottongrass quickly re-establish as shown in photos 6 and 7.

6.1 INTRODUCTION

The seeding and growing of grass on the pipeline right-of-way, for the purpose of erosion control, is expected to create habitat which will be utilized by microtine rodents. The purpose of the study was to gather basic data on populations, food habits, and seasonal habitat preferences of the small mammals in the vicinity of the Sans Sault test site.

A four month study of the small mammal populations was started May 15th, 1972 with the following specific objectives:

1. To determine species of small mammals likely to invade and damage the vegetation covering the pipeline.

2. To determine if linear openings in the forest cover such as seismic lines and pipeline routes present an obstacle to small mammal movements.

3. To determine if the population densities and activities of small mammals in these disrupted areas are similar to those found in the adjacent forest.

4. To determine if there is preferential selection of one or more species of grass, which may result in excessive damage due to overgrazing.

5. To determine the biomass of herbage consumed by rodents in the experimental areas.

6. To suggest possible means of curbing small mammal damage to the vegetation over the pipeline.

6.2 METHODS

6.2.1 Trapping Data

.1 The Study Area - The forest covering in the Sans Sault area is dominated by black spruce (*Picea mariana*) averaging four to five metres in height. Tamarack (*Larix*), willow (*Salix* sp.) Mountain alder (*Alnus crispa*), white birch (*Betula papyrifera*) were present in lesser and varying amounts. A listing of the most frequent plant species, by strata, is given in Table X.

Cover values for the common species of vegetation were obtained by visual examination of a 1 m^2 quadrat at each trap site on the study grids. Percent frequency was calculated on the basis of occurrence compared to the number of quadrats read.

The entire study area was relatively level, resulting in generally poor drainage.

The six study grids staked out around the test site are described below:

Grid A: This area encompassed a section of a four to five year old winter road, situated approximately one hundred metres north of the camp. (Figure XVI). Three parallel traplines, 15.3 metres (50 feet) apart covered this grid. One was laid down the centre of the winter road, while the other two were on opposite sides of the central trapline. Thirty-three trap sites extended along each trapline, adjacent traps were positioned 15.3 metres (50 feet) apart. Thus, the overall dimensions of this grid were 502.9 metres by 30.48 metres, resulting in an area of 1.53 hectares (3.79 acres).

East of positions 27, 40 and 93, the terrain rises approximately five metres, after which it remains level. A small creek with very little flow, was located three metres west of trap site 93. During July and August the small creek was dry.

The vegetation was extremely sparse on the winter road in early June, but changed dramatically during the summer. The dominant vegetation on the road tended to be horsetail (*Equisetum arvense, Equisetum fluviatile*), sedges (*Carex* sp.), Polar grass (*Arctagrostis*), hairgrass (*Deschampsia*), bluejoint (*Calamagrostis*), a rush (*Juncus*) and willow shrubs (Table X). Most growth was found in damp regions, or along the margins of the winter road. Many areas on the old winter road were devoid of vegetation. Throughout the summer, the winter road was damp in most sections, certain regions were under several inches of water.

Labrador tea (*Ledum* sp.), leatherleaf (*Chamaedaphne calyculata*), blueberry (*Vaccinium uliginosum*) and spruce were the dominant species along the southern traplines. Mosses provided the dominant ground cover, but lichens (*Cladonia*) were also abundant. Due to the open nature of the spruce stand and low density of shrubby species, cover was extremely poor.

The northern trapline had a shrub layer similar to the southern line; however, Labrador tea and mosses tend to cover the ground more completely (Table X). Deciduous trees (*Alnus crispa, Salix* sp.) were more abundant when compared to trapline 1. This resulted in better cover for the small mammals. Over all, trapline 3 exhibited a heavy canopy and tended to be cooler and moister than trapline 1. Previously, the northern trapline was itself an old winter road, which explains the presence of more shrubby deciduous vegetation.

Table X: Cover and Frequency values of the most common species of vegetation found in the grids under study.

Notes: 6-point coverage += Present but rare, 1 = 1-5%, 2 = 6-25%, 3 = 26-50%, 4 = 51-75%, 5 = 76-100%.

Species	Common Name	Grid A						Grid B		Grid C		Grids D & E		Grid F	
		Trapline 1		Trapline 2		Trapline 3		Cover	Freq %	Cover	Freq %	Cover	Freq %	Cover	Freq %
		Cover	Freq %	Cover	Freq %	Cover	Freq %								
TREE STRATA															
Alnus crispa	Green Alder	+	19	--	--	1	45	--	--	+	15	+	30	--	--
Betula glandulosa	Dwarf Birch	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Larix laricina	Tamarack	/	20	--	--	+	27	--	--	+	13	+	20	+	14
Picea mariana	Black Spruce	/	29	--	--	+	27	--	--	+	13	/	50	+	14
Salix sp.	Willow	+	8	+	3	1	21	--	--	+	10	/	45	+	17
SHRUB STRATA															
Agropyron sp.	Wheatgrass														
Alnus crispa	Green Alder	+	8	--	--	+	9	+	9	+	9	+	5	--	--
Andromeda polifolia	Bog Rosemary	+	8	--	--	+	6	+	39	1	54	--	10	+	48

Table X (Cont'd.)

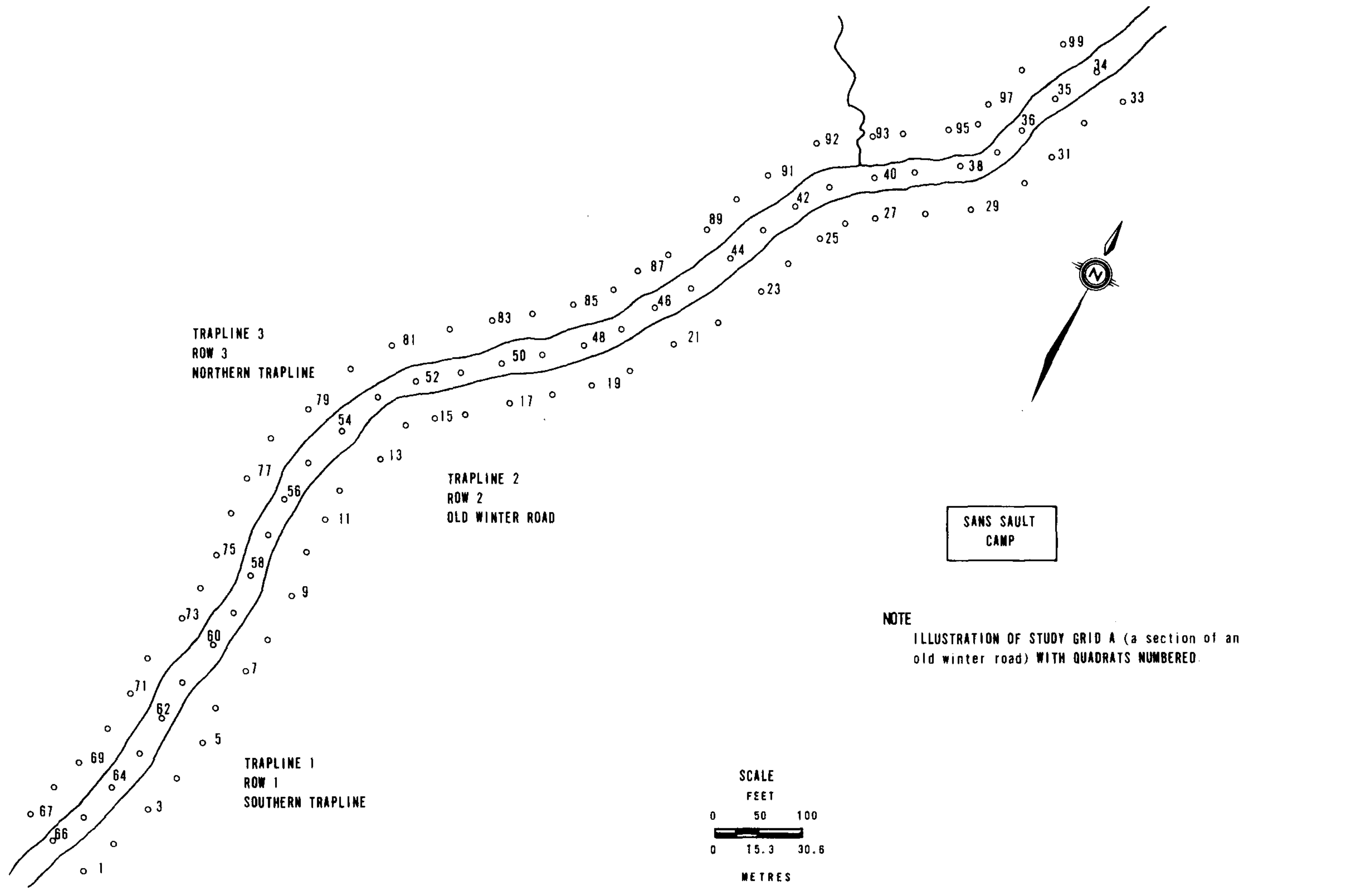
Species	Common Name	Grid A						Grid B		Grid C		Grids D &E		Grid F	
		Trapline 1		Trapline 2		Trapline 3		Cover	Freq %	Cover	Freq %	Cover	Freq %	Cover	Freq %
		Cover	Freq %	Cover	Freq %	Cover	Freq %								
Arctagrostis sp.	Polar grass	+	31	+	48	+	30	+	54	+	46	+	50	+	46
Arctostaphylos rubra	Bearberry	1	38	--	--	+	9	1	49	1	72	+	20	1	72
Betula glandulosa	Dwarf Birch	+	8	--	--	+	12	--	--	--	1	--	--	--	--
Calamagrostis sp.	Reed grass	--	--	1	55	--	--	+	5	--	--	--	--	--	--
Carex sp.	Sedge	+	2	1	42	+	16	1	61	+	41	--	--	+	2
Chamaedaphne calyculata	Leatherleaf	1	46	--	--	+	12	+	54	1	66	+	60	--	5
Deschampsia sp	Hair grass	--	--	+	60	--	--	--	--	--	--	--	--	--	--
Empetrum nigrum	Crowberry	+	27	--	--	+	15	+	12	+	5	--	--	+	30
Equisetum arvense	Horsetail	+	12	1	64	1	60	+	24	+	43	--	--	+	53
Equisetum fluviatile	Horsetail	--	--	1	36	--	--	+	5	--	--	--	--	--	--
Equisetum scipoides	Horsetail	+	42	--	--	+	27	+	41	+	40	+	80	+	73
Eriophorum sp.	Cotton grass	--	--	--	--	--	--	--	--	--	--	--	--	--	--

Table X (Cont'd.)

Species	Common Name	Grid A						Grid B		Grid C		Grids D & E		Grid F	
		Trapline 1		Trapline 2		Trapline 3		Cover	Freq %	Cover	Freq %	Cover	Freq %	Cover	Freq %
		Cover	Freq %	Cover	Freq %	Cover	Freq %								
Geocaulon lividum	Bastard toad flax	+	44	--	--	+	39	--	--	+	6	+	20	+	16
Juncus sp.	Rush	--	--	1	55	--	--	--	--	--	--	--	--	--	--
Larix laricina	Tamarack	+	2	--	--	+	12	+	5	+	12	+	8	+	22
Ledum sp.	Labrador tea	1	87	--	--	1	39	+	44	1	34	2	95	1	82
Linnaea borealis	Twinflower	+	8	--	--	--	--	--	--	--	--	--	--	--	6
Oxycoccus microcarpus	Cranberry	--	--	--	--	--	--	+	5	+	2	+	20	+	6
Parnassia palustris	Grass-of-Parnassus	--	--	+	9	--	--	--	--	--	--	--	--	--	--
Picea mariana	Spruce	+	62	--	--	1	27	+	3	+	48	+	25	1	45
Plantago sp.	Rib grass	--	--	+	27	--	--	--	--	--	--	--	--	--	--
Potentilla fruticosa	Shrubby cinquefoil	--	--	--	--	+	3	+	12	+	20	--	--	+	22
Pyrola sp.	Wintergreen	+	15	--	--	+	3	+	5	+	5	+	50	+	6
Ranunculus sp.	Crowfoot	--	--	--	--	--	--	--	--	+	8	+	10	+	4

Table X (Cont'd.)

Species	Common Name	Grid A						Grid B		Grid C		Grid D&E		Grid F	
		Trapline 1		Trapline 2		Trapline 3		Cover	Freq %	Cover	Freq %	Cover	Freq %	Cover	Freq %
		Cover	Freq %	Cover	Freq %	Cover	Freq %								
Rosa acicularis	Wild Rose	+	8	--	--	+	9	+	3	+	21	+	30	+	7
Rubus chamaemorus	Cloud-berry	+	23	--	--	+	12	+	33	+	43	--	--	+	25
Salix sp.	Willow	+	2	/	48	+	15	+	15	+	7	+	20	+	2
Smilacina trifolia	False Solomon-seal	--	--	--	--	--	--	+	27	+	10	--	--	+	5
Vaccinium uliginosum	Blueberry	+	54	--	--	1	45	1	64	1	82	+	60	1	88
Vaccinium vitis-idaea	Bog cranberry	1	67	--	--	1	54	+	7	1	48	2	100	+	33
Epilobium sp.	Fireweed	--	--	+	30	--	--	--	--	--	--	--	--	--	--
Alopecurus pratensis	Foxtail	--	--	--	--	--	--	+	3	--	--	--	--	--	--
GROUND STRATA															
---------	Mosses	3	88	+	15	4	93	2	90	3	96	2	100	3	88
Cladonia sp.	Lichens	1	60	--	--	1	39	+	39	1	43	4	100	2.4	80
----------	Litter	1	48	--	--	1	45	/	80	++	39	--	--	1	38



NOTE
ILLUSTRATION OF STUDY GRID A (a section of an old winter road) WITH QUADRATS NUMBERED

FIGURE XVI

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	REVISIONS			

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ILLUSTRATION OF STUDY GRID A

SCALE:
DATE:
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Grid B: This area was located over the buried, active section of the cycling loop. (Figure XVII). Approximately one-half of this grid was composed of organic material. Table X shows that the organic region provided poor cover and is characterized by the existence of relatively few species of plants.

The grid was relatively flat. The western quadrats tended to be wet throughout the study, accumulating water after a rain.

Plot B was rectangular, 152.4 metres (500 ft) long and 38.1 metres (125 ft) wide. Each quadrat was 7.62 metres (25 ft) square, which resulted in an overall area of 0.57 hectares (1.43 acres).

Grid C: A service road separated this grid from grid B. (Figure XVIII). Both grids had identical dimensions and quadrat sizes. The first two trap rows sloped gently to the east. Throughout the study, water-filled depressions were present in the western half of this grid. Again, spruce was the dominant tree, mountain alder and willow were uncommon. Labrador tea, leatherleaf, Bog cranberry (*Vaccinium vitis-idaea*) and bearberry (*Arctostaphylos*) comprised the dominant vegetation of the shrub strata. Mosses were the primary constituent of the ground layer (Table X).

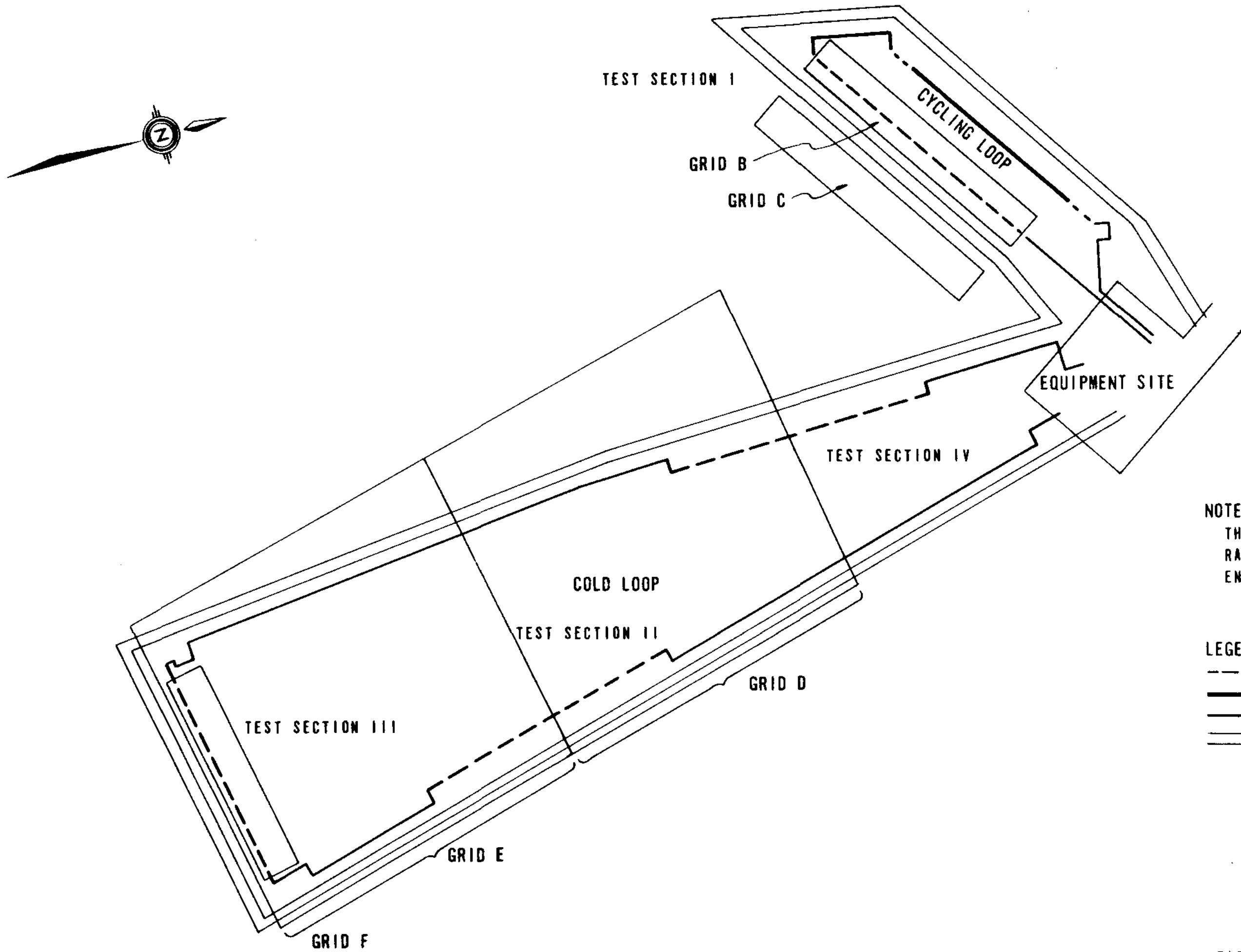
Grids D and E: Because these areas were adjacent to each other and their vegetation was for all intents and purposes homogeneous, one section (20 metres by 20 metres) common to both grids was staked out for vegetation analysis. As is shown, lichens formed a very heavy ground cover. Labrador tea and Bog cranberry were the dominant shrubs and *Picea mariana* was the dominant tree species (Table X). Ground cover was poor, as was generally characteristic in areas displaying an abundance of lichens.

Each of these grids was divided into 22.86 metre square (75 feet square) quadrats; overall grid dimensions were 228.60 metres (750 ft) by 228.60 metres. The total area was 5.23 hectares (12.91 acres).

A moss filled depression occurred in the northwest corner of grid D (Figure XIX). Trap site 1 of grid D and 80, 81 and 100 of grid E were in a region which had been scraped clean of vegetation. At these positions, only segments of sedges and mosses existed. Trap locations 10 and 11 of grid E were situated on an old winter road. Blueberries and mosses dominated as this area was wet. Some grass plots of test sections two and four were within the boundaries of grids D and E.

Grid F: This grid was situated partly on test section three and partly in the spruce forest (Figure XVII). Tree cover was poor due to extensive clearing by survey crews. Lichens were abundant here and the soil tended to be dry. Much of the western part of test section three was under water for the duration of the study. Therefore, a large section of this grid could not be properly studied. Trap sites 3, 4, 93, 97 and 98 were located on the gravel pads upon which refrigeration units were located. Dimensions of this grid were identical to those of grid B.

.2 Trapping Procedures - Trapping commenced at grid A for a three night period. After this time, traps were taken to the next grid in alphabetical order until grid F had been trapped. Thus, each grid was trapped for three days in an eighteen day trap cycle. Having completed a trap cycle, the traps were returned to grid A and the procedure repeated. Thus, during the summer, five eighteen day trap cycles were carried out (Table XI).



NOTE

THE EXPERIMENTAL PIPELINE LOCATED AT SANS SAULT RAPIDS, N.W.T. AND LOCATIONS OF THE STUDY GRIDS ENCLOSING THIS PIPELINE.

LEGEND

- BURIED 48 in PIPE
- ELEVATED 48 in PIPE
- ELEVATED 16 in PIPE
- GRAVELLED ROAD

FIGURE XVII

No.	DESCRIPTION	DATE	BY	APP.

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LOCATIONS OF THE STUDY GRIDS

SCALE: NOT TO SCALE
DATE
PROJECT No.
DRAWING No. -B
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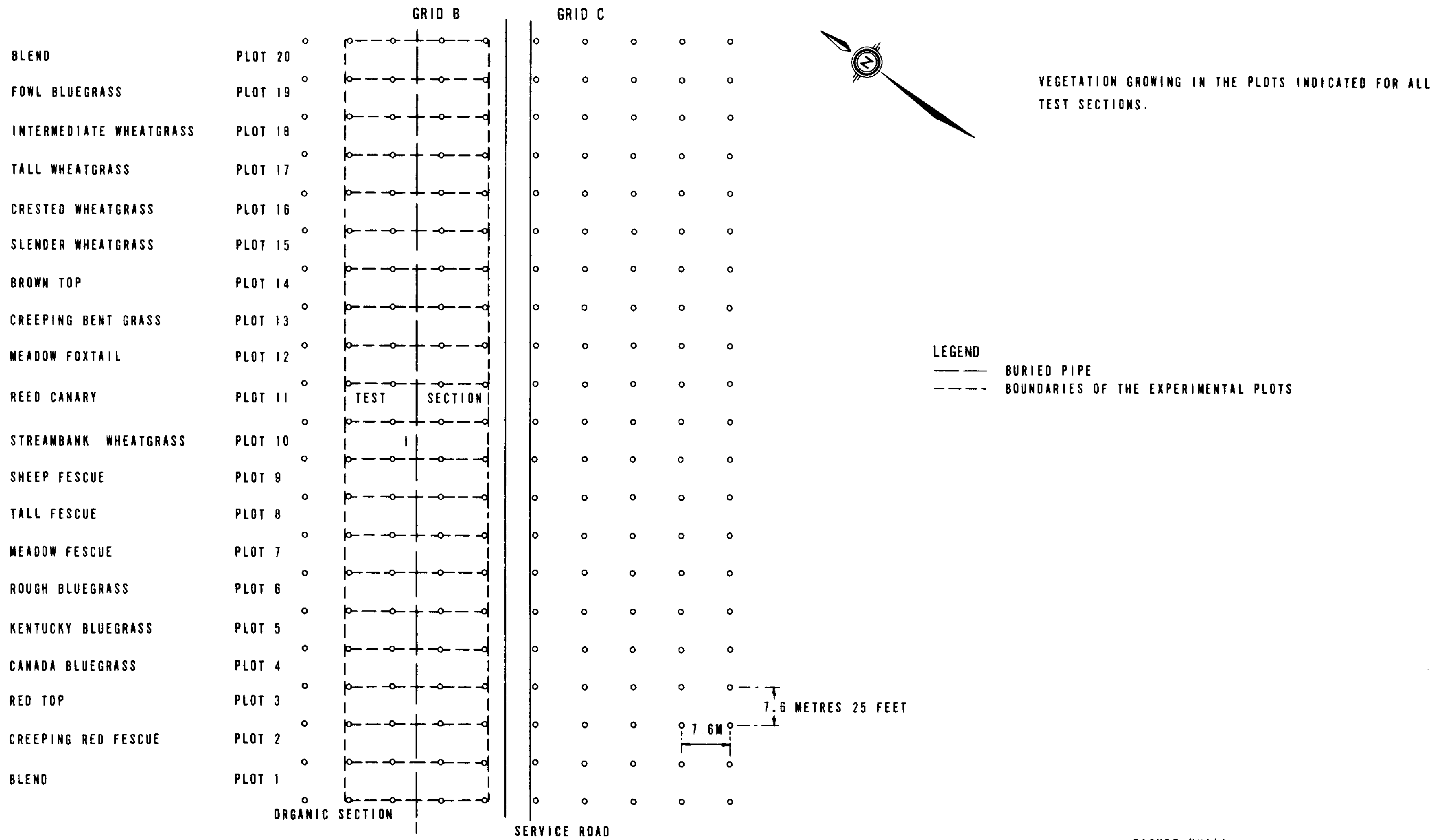

FIGURE XVIII

No.	DESCRIPTION	DATE	BY	APP.

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LOCATION AND DIMENSIONS OF STUDY GRIDS B AND C

SCALE:
DATE:
PROJECT No.
DRAWING No. -B
REV.

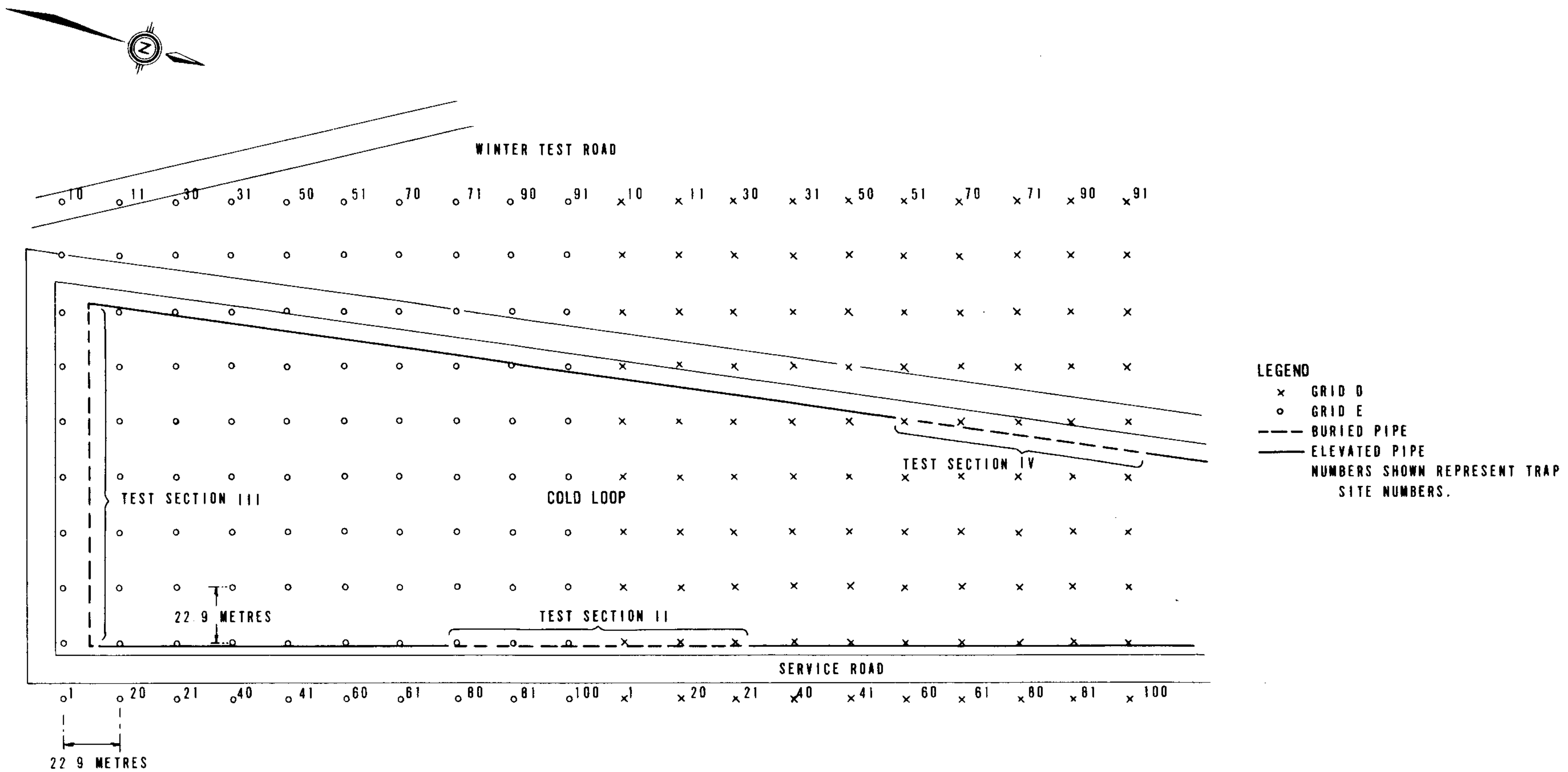

FIGURE XIX

No.	DESCRIPTION	DATE	BY	APP.
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ILLUSTRATION SHOWING THE LOCATION AND ARRANGEMENT OF GRIDS D AND E

SCALE.
DATE
PROJECT No.
DRAWING No. - B
REV.

Table XI. Dates of trapping periods for each of the six study grids.

Period	Grid A	Grid B	Grid C	Grid D	Grid E	Grid F	Trap Cycle
1	6-8/6 -72	9-11/6/ 72	12-14/ 6/72	15-17/ 6/72	18-20/ 6/72	21-23/ 6/72	=1
2	24-26/ 6/72	27-29/ 6/72	30-2/ 7/72	14-16/ 7/72	17-19/ 7/72	20-23/ 7/72	=2
3	24-26/ 7/72	27-29/ 7/72	30-1/ 8/72	2-4/ 8/72	5-7/ 8/72	8-10/ 8/72	=3
4	12-14/ 8/72	15-17/ 8/72	18-20/ 8/72	21-23/ 8/72	24-26/ 8/72	27-29/ 8/72	=4
5	30-1/ 9/72	2-4/ 9/72	5-7/ 9/72	8-10/ 9/72	11-13/ 9/72	14-16/ 9/72	=5

In order to minimize trap mortalities, traps were set at 2200 hours, and examined at 1000 hours the next day. The time, during which the traps were open, was one in which maximum small mammal activity occurred (Hamilton, 1937). Fresh bait, which consisted of peanut butter and rolled oats, was placed on the trap door nightly. Stale bait on the trigger pan was removed at least once every three days and a new bait installed. Traps were positioned within two metres of each grid stake; the location depended on the presence of burrows, runways, droppings and/or grass clippings. Each grid, except grid A, was trapped with 100 Sherman live traps. Grid A was covered by 99 such traps.

All traps were numbered and their positions marked on a cover map of the area. Each study plot was numbered and records from that area kept separate from the others. When an animal was captured for the first time, it was toeclipped for identification. The following data were recorded: species, trap number, trap site number, weight, sex and unusual characteristics. Data pertaining to sex was further broken down as follows: for male, position of testes; and for females, vagina perforate or not, nipples in suckling or non-suckling condition and pregnant or not. Once this data was obtained, the animal was released.

In varying habitats, some distance from the study grids, 50 Museum special snap traps were set and checked daily. These were set for six consecutive days, after which they were relocated. Each capture was dissected and data categorized into the following divisions: species, date, location, habitat type, weight, total length, tail length, hind foot length, ear from notch, kidney weight, and breeding condition. Breeding condition was broken down into:

Female data:

1) lactating or not;
2) perforate or non-perforate vaginal orifice;
3) number, length and weight of embryos.

Male data:

1) scrotal or abdominal testes, weight and length of left gonad;
2) visible or non-visible epididymal tubules.

A positive finding for any of the above sexual characteristics was assumed to represent maturity. These findings as well as data on lab-reared individuals and field observations, were used to divide the animals into three age classes according to weight.

Age classes are considered important in order to understand the population dynamics of a species.

Below are age classes believed to have existed in the environment under study.

Meadow vole (*Microtus pennsylvanicus*):

juvenile < 11gm.
subadult 11 < 24 gm.
adult $\geq$ 24 gm.

Tundra red-backed vole (*Clethrionomys rutilus*):

juvenile < 8 gm.
subadult 8 < 20 gm.
adult $\geq$ 20 gm.

.3 Population Density - Population densities were computed for all grids based on the number of voles captured or assumed present in each period. An animal captured in period X and recaptured in Period X + 4, was believed to be present in the grid during these periods. Densities were calculated in numbers per hectare (2.47 acres) to provide a better understanding of the data. Individuals captured in more than one grid were considered as separate individuals in the density calculations for all study areas. Any vole captured in one period only was termed a migrant. Residents were frequently trapped in the same grid.

.4 Home Range - Blair's (1940) exclusive boundary strip method was employed for determination of home range (Stickel 1946). In order to calculate an animal's home range, it had to be captured a minimum of five times, in at least four different trap sites. Capture sites of grids D and E were combined in order to determine whether regions of the habitat were favoured by a particular vole species. No home range findings for grid A, the old winter road, were determined. Instead, the movements of animals across this thoroughfare were investigated to determine whether or not it constituted an obstruction to small mammal activities.

.5 Capture Frequency - For each period, the number of individuals captured at individual trap sites were calculated for grids B, C and F. This assigned a trap frequency value for each trap site. If the same animal was captured at the same trap location within one period, the capture frequency would be one for that individual.

.6 Weather - Daily weather was recorded at the Sans Sault weather facilities. The average weather data for each trap cycle was computed from the Sans Sault weather data (See Table XII).

.7 Predators - The presence of predators was recorded when observed. No traps were set for predators, however, several masked shrews (*Sorex cinereus*) and dusky shrews (*Sorex vagrans*) were captured in snap traps.

6.2.2 Extent of Small Mammal Activity in Plots

In the first half of June and September, each plot on the four test sections was examined for small mammal activity. The presence of grass clippings, tunnels, droppings, grass pilings, trails and nests was recorded. The extent of rodent activities was categorized as follows:

0 -- no damage to vegetation, no small mammal activity anywhere.
1 -- some evidence that small mammals are present in the plot.
2 -- extensive damage to vegetation in certain regions of the plot
3 -- vegetation destroyed.

The values obtained for the individual grasses of each test section were averaged. Observations concerning the condition of the vegetation growing over the berm were also recorded.

6.2.3 Summer Consumption of the Experimental Grasses

Vegetation studies at Sans Sault have demonstrated the role vegetation plays in controlling soil erosion. This being the case, it was deemed important to establish the utilization of the standing crop by small mammals. In the autumn of 1971, 1/4 m^2 wire exclosures were placed in numerous plots. The vegetation inside and outside the exclosures was clipped, dried and weighed in June. Twenty, 1/16 m^2 exclosures were placed in each of test sections one, three and four in early June, 1972. These, and equivalent sized plots outside the exlosures were clipped in mid-September.

Table XII: Weather summary in the study area (Sans Sault Rapids) by trap cycles.

Trap Cycle	Dates	Mean Temperature °C.			Mean Wind Speed km/hr.	Precipitation (cm.)		
		Maximum	Minimum	Mean		Rain (cm.)	Snow (cm.)	Total
1	6/6/-23/6/72	24.7	10.6	19.4	14.2	.23	--	.23
2	24/6/-23/7/72	26.2	12.7	22.1	11.6	.26	--	.26
3	24/7/-10/8/72	21.7	10.2	15.9	11.9	.31	--	.31
4	12/8/-29/8/72	23.0	10.8	16.9	8.1	--	--	--
5	30/8/-16/9/72	11.1	0.3	6.0	13.2	.06	--	.06

6.2.4 Seed Preference Experiments

A number of meadow voles, chestnut-cheeked voles and tundra red-backed voles were live trapped in regions remote from the study area. Each animal was contained in a cage, all animals being housed in an enclosed shed. Temperatures, in this building ranged from 18-21°C with a photoperiod of eighteen hours daylight/six hours darkness. An unlimited water supply was provided. A choice of Purina lab chow or seeds of grass varieties under study was offered each animal for a six day duration. Consumption values of each food type was determined by weighing the foods daily. This number was subtracted from the previous days value, giving the amount eaten for that particular twenty-four hour period. After each six day test, a new seed variety was introduced to the experimental animal. Daily consumption was not calculated if the animal spilled seed from its container.

6.3 RESULTS

6.3.1 Trapping Data

For the six grids, 806 captures were recorded in a combined total of 9,000 trap nights. Three hundred and thirty-four individuals (144 tundra red-backed voles and 190 meadow voles) were captured. Sex ratios differed for the two species. Meadow voles showed a 1:1 ratio (X^2 = 0.0, p .05), while tundra red-backed voles had a high number of males (X^2 = 7.9, p .05) (See Table XIII).

Outside the study area, 258 animals were snap trapped. This total was composed of 129 tundra red-backed voles, 112 meadow voles, 25 masked shrews, and 2 dusky shrews. Sex ratios were found to be unequal for tundra red-backed voles but within the chi square, random values for meadow voles.

The population densities of each species for the study are shown in Figure XX - XXV. The populations of all grids established in natural habitats exhibited two population density maximums (See figure XXII - XXIV). One of these occurred in June, the other had not been attained at the termination of the study. This would occur when the juveniles and migrant numbers no longer offset the losses by death and emigration.

Grids B and F (enclosing vegetation test sections) did not illustrate these fluctuations (Figures XXI, XXV). Populations peaked in either the late spring or late summer. In early September, the number of inhabitants in these grids began to decline. While the population density in grid B (test section one), was declining, across the road, in grid C, the population density showed an increase (Figure XXII).

Population density per hectare varied greatly among grids. Grids D and E generally illustrated the lowest densities (the maximum number of both being 10.3/hectare). In comparison with the other grids, A and C constantly showed high densities. Grid C exhibited the highest density during the study (48.4 animals/hectare in period two).

The meadow vole and tundra red-backed vole populations showed synchronous fluctuations, meadow voles being the most abundant in all regions except grid A. Age class composition for each of the early summer populations demonstrated that adults and subadults were the main constituents of the population. Late summer peaks were an outcome of an upsurge of subadults, while adult numbers diminished in most instances. (Figures XXVI - XXIX). These trends were not observed in grids B and F (test sections one and three, Figure XXV, XXX).

Table XIII: Sex ratios calculations for the total number of meadow voles and tundra red-backed voles live and snap trapped.

	Males	Females	X^2
Live trapping			
Microtus	95	95	*
Clethrionomys	89	55	7.9
Snap Trapping			
Microtus	71	51	*
Clethrionomys	85	44	6.5

* not significant at $p = .05$, 1dF

FIGURE XX POPULATION DENSITY FOR GRID A
OVER THE FIVE TRAPPING PERIODS

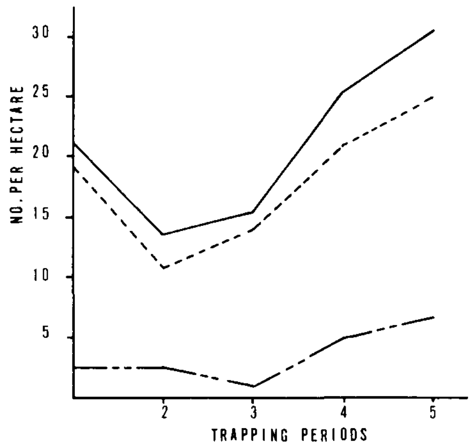
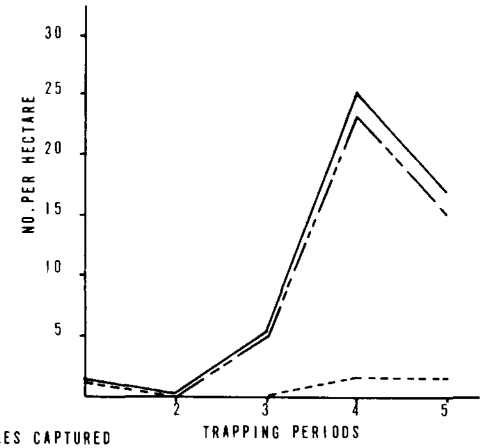


FIGURE XXI POPULATION DENSITY OF MEADOW VOLES AND
TUNDRA RED-BACKED VOLES IN GRID B



LEGEND
——— TOTAL CAPTURED
- - - - - - TUNDRA RED- BACKED VOLES CAPTURED
—— - - — MEADOW VOLES CAPTURED

FIGURE XXII THE NUMBER OF
MEADOW VOLES AND TUNDRA
RED-BACKED VOLES PER HECTARE
IN GRID C

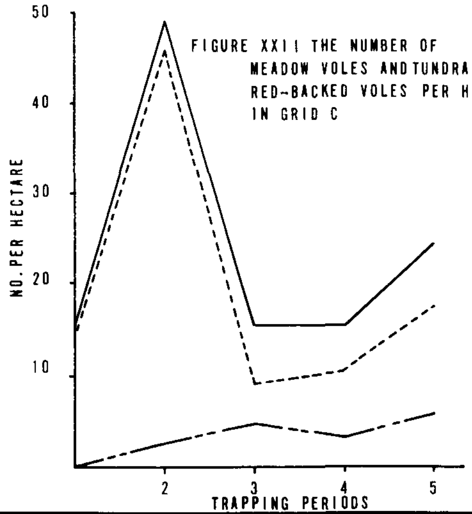


FIGURE XXIII POPULATION DENSITY OF TRAPPED ANIMALS FOR EACH PERIOD
IN GRID D

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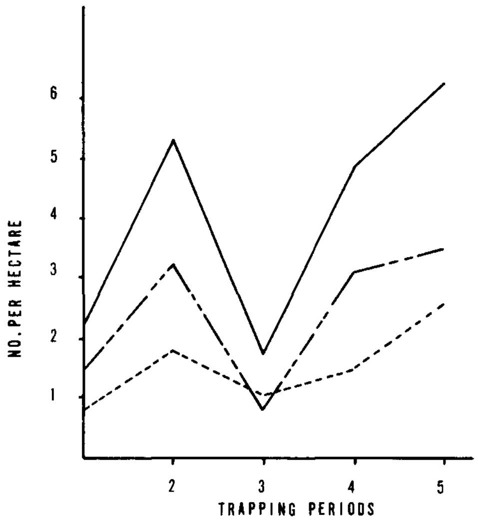
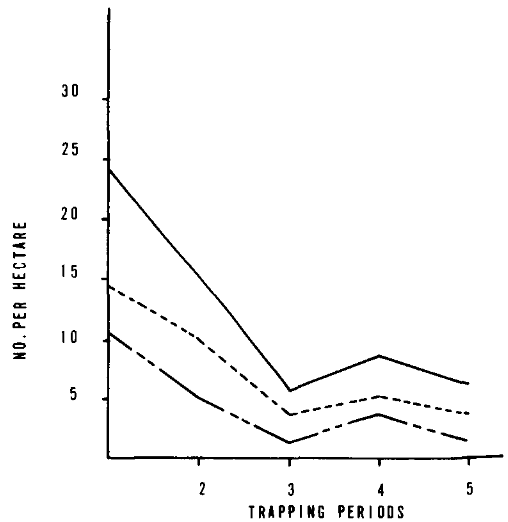
FIGURE XXIV POPULATION DENSITY OF TRAPPED ANIMALS FOR EACH PERIOD IN GRID E



TOTAL CAPTURED
TUNDRA RED-BACKED VOLES CAPTURED
MEADOW VOLES CAPTURED

FIGURE XXV TOTAL POPULATION DENSITY AND AGE CLASS COMPOSITION OBSERVED IN GRID F



TOTAL CAPTURED
ADULT MEADOW VOLES CAPTURED
SUBADULT MEADOW VOLES CAPTURED

No.	DESCRIPTION	DATE	BY	APP.

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FIGURE XXVI THE AGE CLASS COMPOSITION FOR EACH SMALL MAMMAL SPECIES IN GRID A

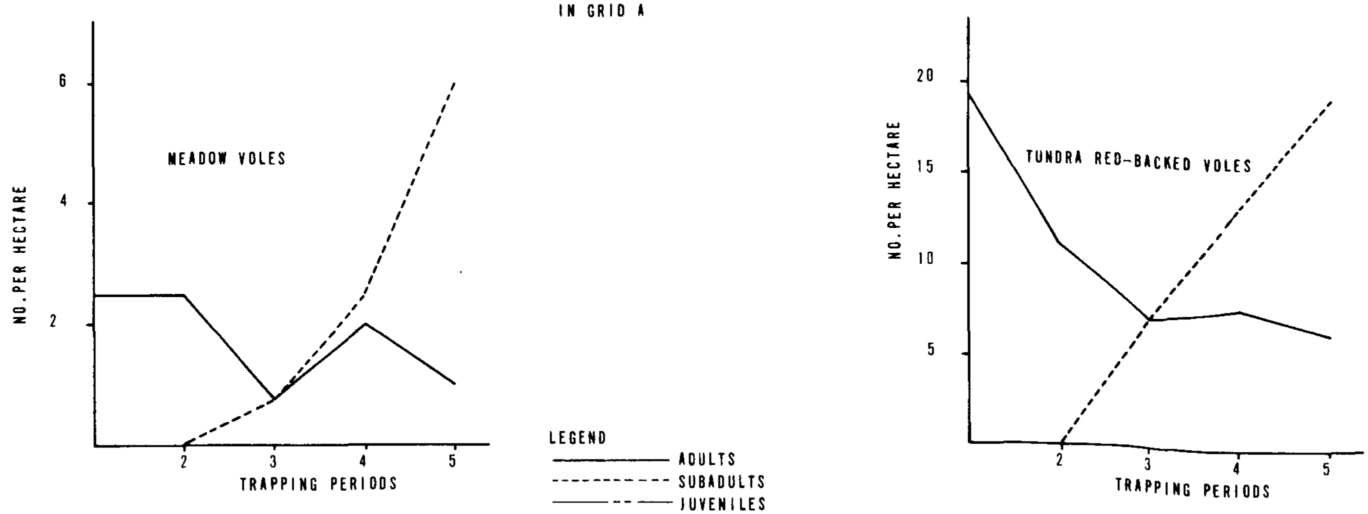

FIGURE XXVII POPULATION DENSITY OF ADULTS, SUBADULTS AND JUVENILES FOR MEADOW VOLES AND TUNDRA RED-BACKED VOLES IN GRID C

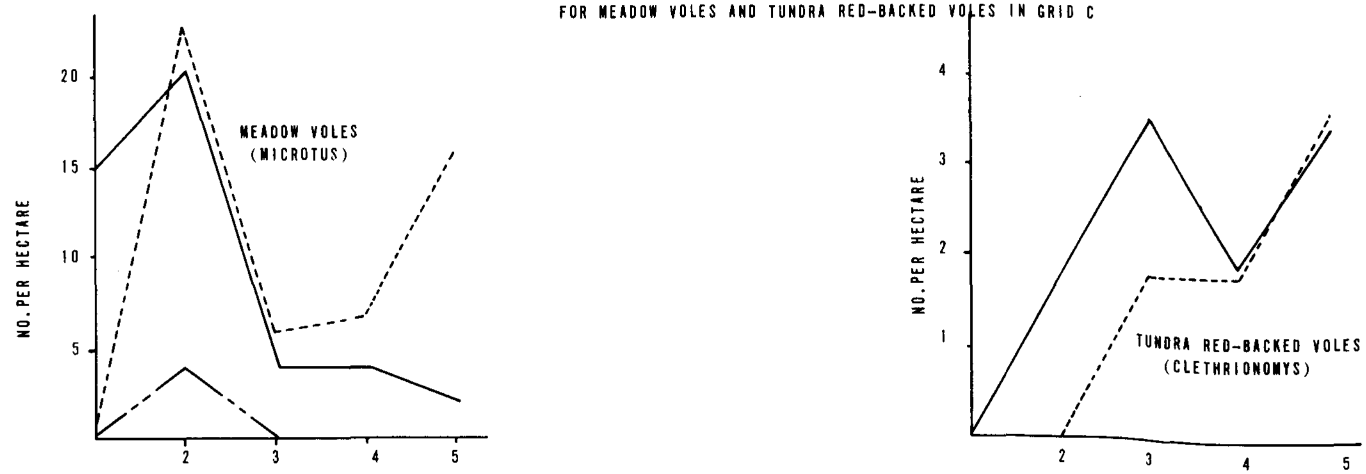

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FIGURE XXVIII AGE COMPOSITION OF EACH SPECIES OF SMALL MAMMALS IN GRID D.

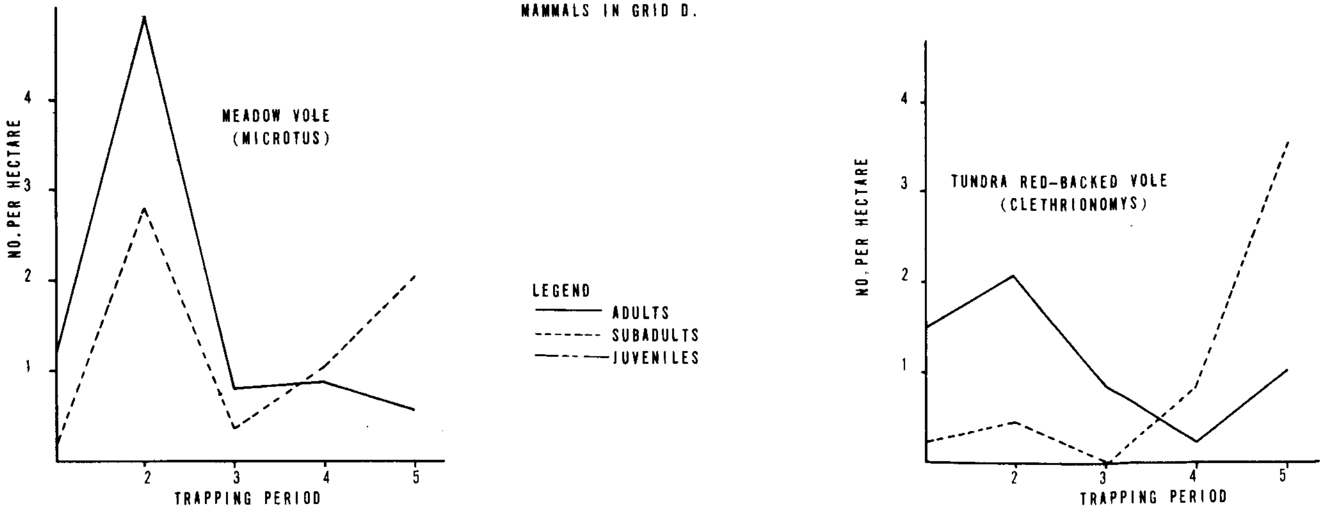
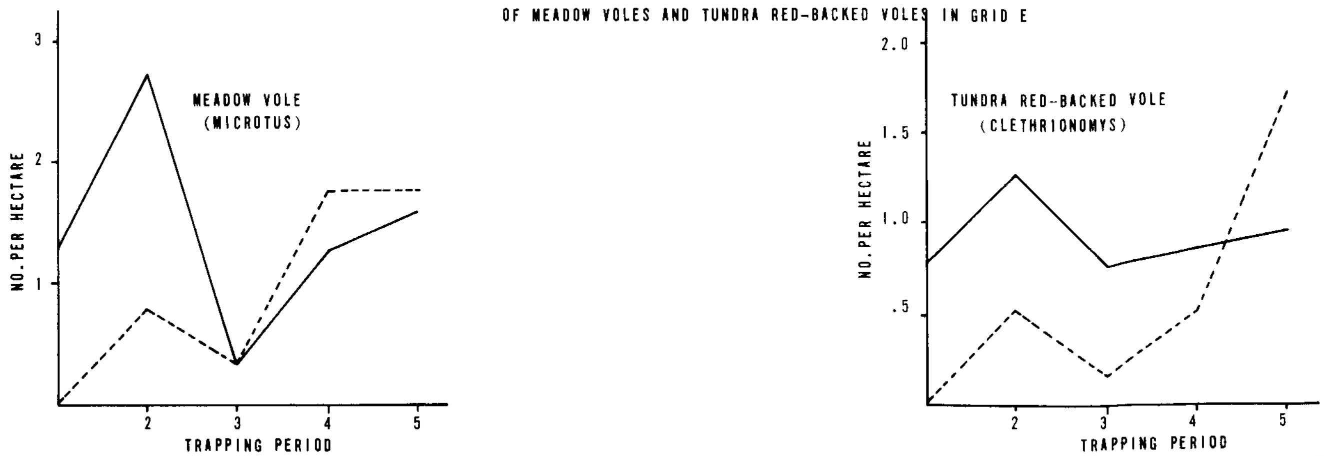


FIGURE XXIX POPULATION DENSITY OF ADULTS AND SUBADULTS OF MEADOW VOLES AND TUNDRA RED-BACKED VOLES IN GRID E



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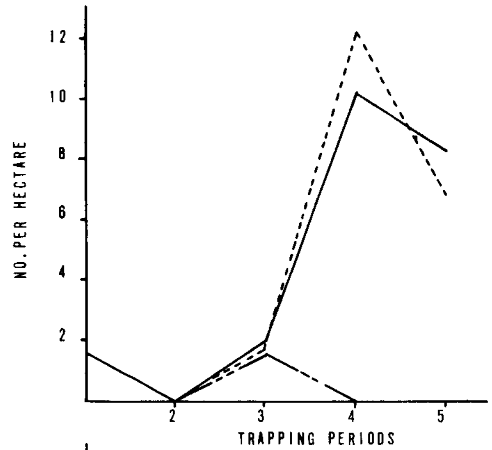
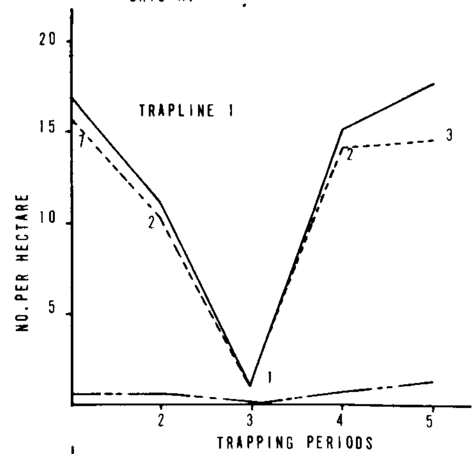
-B

FIGURE XX X AGE CLASS COMPOSITION FOR SMALL MAMMALS SPECIES IN GRID B.



MEADOW VOLES
———ADULTS
- - - - - SUBADULTS
—·—·—JUVENILES

FIGURE XXXI POPULATION DENSITY AND DENSITIES OF EACH SPECIES IN EACH TRAPLINE OF GRID A.



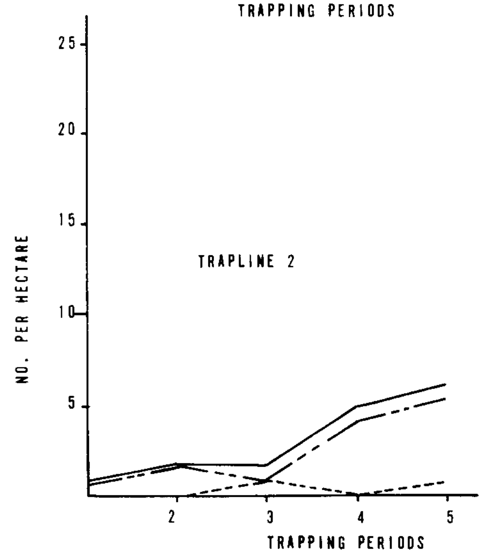
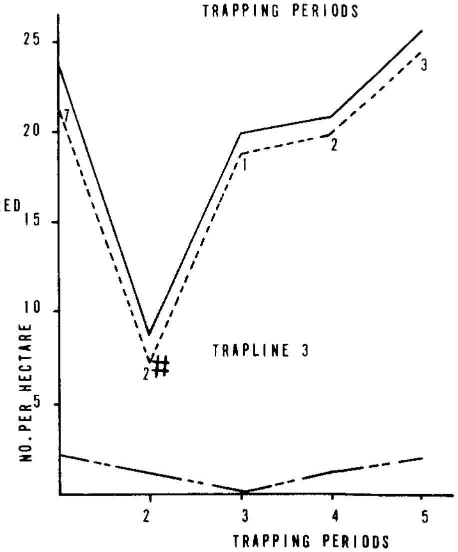


FIGURE XXXI (CON'T) POPULATION DENSITY AND DENSITIES OF EACH SPECIES IN EACH TRAPLINE OF GRID A.

NOTE
———TOTAL CAPTURED
- - - - - TUNDRA RED-BACKED VOLES CAPTURED
—·—·—MEADOW VOLES CAPTURED
NUMBERS REPRESENT NUMBER OF RED-BACKED CAPTURED IN TRAPLINES 1-3 WITHIN THE SAME PERIOD.



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REV.

Adults alone made up the high early summer population in grid A, no subadults of either species were captured until period three. Comparisons of captures for each trapline of this grid were made (Figure XXXI). These calculations illustrated trapline 3 as having the highest population density of all three traplines with the exception of period one. Tundra red-backed voles were rarely captured on the old winter road (trapline 2). However, numerous tundra red-backed voles crossed the winter road within a trapping period (Figure XXXI). Meadow voles were not captured on both sides of the winter road within a trapping period. They were, however, frequently trapped on the winter road on one day, and in an adjacent area the next. Numbers of meadow voles trapped on the winter road tended to increase throughout the study. This region appeared to be unfavourable to tundra red-backs, but constituted part of their home range according to recapture data.

.1 Home Range - Data obtained on grids B, C and F (0.58 hectares) indicate a home range for male meadow voles of 0.08 hectares, while the home range of females averages 0.04 hectares (Table XIV). Only two tundra-red backed voles were captured frequently enough to meet the criteria used in home range calculations. Their individual home ranges were 0.057 and 0.024 hectares for the male and female respectively. The values for both species are considerably smaller than the home range sizes computed in grids D and E. In each case, males of other species exhibited larger home ranges than the females. The home range of tundra red-backed voles appeared to cover a larger area than meadow voles. Home ranges overlapped extensively between both individuals of the same species and of different species.

The home ranges situated in grid B were located on the test section only, those for grid F extended into the forested region of the grid. Few animals in grids D and E extended their home range into the area beyond the cold loop. This was possibly due to the presence of the surrounding service road.

.2 Trap Frequency - This section illustrates important activity differences in natural and experimental areas. Meadow voles were captured frequently in all sections of grid C, while the tundra red-backed voles favoured the eastern quadrats (Figure XXXII, XXXIII). In grid B and F, tundra red-backs were captured on only two occasions (Figure XXXIV, XXXV). In these grids meadow voles appeared to favour certain plots of the test sections. From the trap frequency values, plots composed of creeping red fescue, red top, kentucky bluegrass, meadow fescue, streambank wheatgrass, reed canary, meadow foxtail and a blend of all grass varieties were favoured by the residing meadow voles.

6.3.2 Predators and Climate

Few predators were sighted during the summer. In May, two Great horned owl (*Bubo virginianus*) were observed above the study grids daily. Three short-tailed weasel (*Mustela erminea*) all juveniles, were captured in the area of the Sans Sault Camp. A timber wolf (*Canis lupus*), one black bear (*Euarctos americanus*), two red foxes (*Vulpes fulva*) and a wolverine (*Gulo luscus*) were occasionally observed in the study grids. The timber wolf obviously affected the population densities as it would remove, kill and devour small mammals captured in the Sherman traps. Analysis of fox scats showed evidence of small mammal consumption. These signs were the only indications of predator activity.

Table XIV: Mean home range values for meadow voles and tundra red-backed voles in grids B, C, F and combined grids D and E.

(A) Meadow voles

	Individuals	Average no. of times trapped	Mean home range in sq. metres	Mean home range in acres
Males				
Grid B	--	--	--	--
Grid C	2	5.0	741 ± 289	.18 ± .07
Grid F	3	5.3	794 ± 115	.19 ± .03
Combined Grids D and E	--	--	--	--
Females				
Grid B	2	5.0	523 ± 145	.12 ± .04
Grid C	2	5.0	465 ± 41	.11 ± .01
Grid F	3	5.3	300 ± 115	.06 ± .03
Combined Grids D and E	4	5.3	21165 ± 526	1.01 ± .13

(B) Tundra red-backed voles

Males				
Grid B	--	--	--	--
Grid C	1	5.0	581	.14
Grid F	--	--	---	--
Combined Grids D and E	8	6.1	7534 ± 1254	1.86 ± .31
Females				
Grid B	--	--	--	--
Grid C	1	5.0	262	.06
Grid F	--	--	--	--
Combined Grids D and E	3	7.7	7186 ± 1659	1.77 ± .41

TRAP FREQUENCY VALUES FOR TUNDRA RED-BACKED VOLES IN GRID C FOR THE DURATION OF THE STUDY. NUMBER OF CAPTURES INDICATED BY ARABIC NUMERALS.

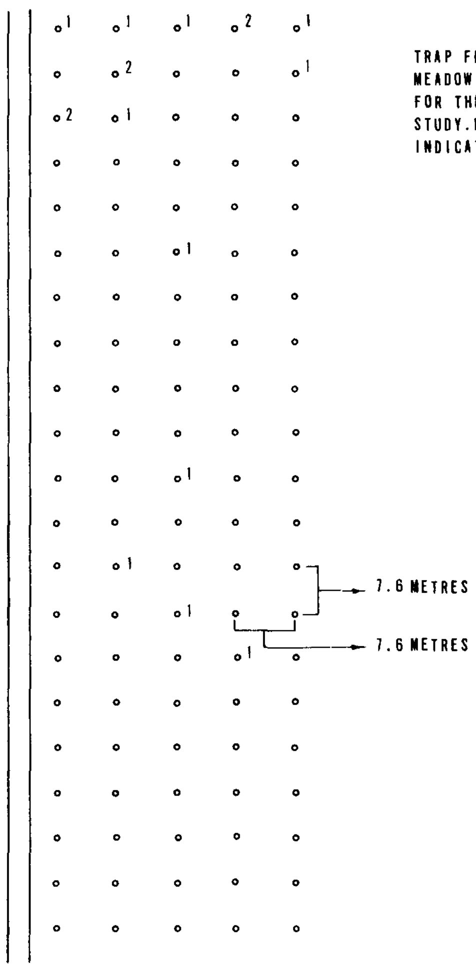


FIGURE XXXIII

TRAP FREQUENCY VALUES FOR MEADOW VOLES IN GRID C FOR THE DURATION OF THE STUDY. NUMBER OF CAPTURES INDICATED BY ARABIC NUMERALS.

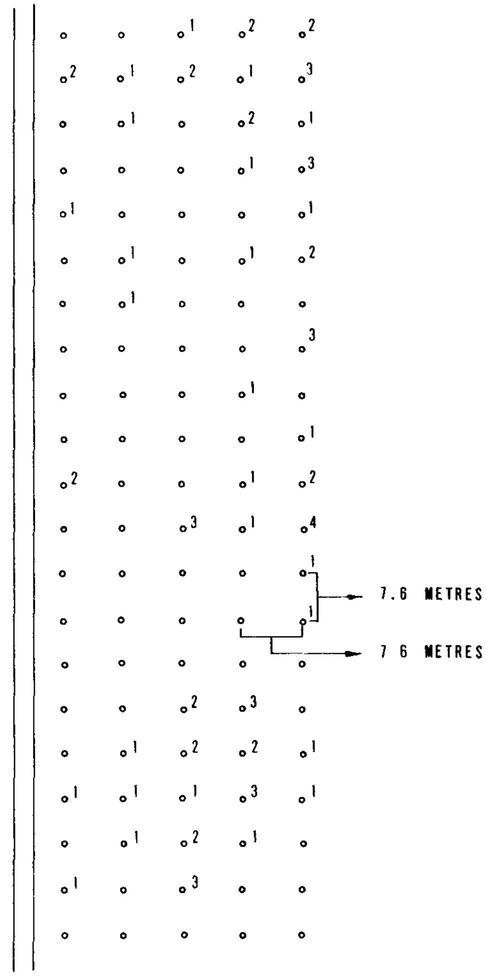


FIGURE XXXII

No.	DESCRIPTION	DATE	BY	APP.

REVISIONS

DESIGNED BY:
DRAWN BY:
CHECKED BY:
ENGINEERS APP.
PROJECT MANAGER

NORTHERN ENGINEERING SERVICES LIMITED
CALGARY ALBERTA
ENGINEERS FOR
CANADIAN ARCTIC GAS STUDY LTD.

TRAP FREQUENCY VALUES

SCALE:
DATE
PROJECT No.
DRAWING No. -B
REV.

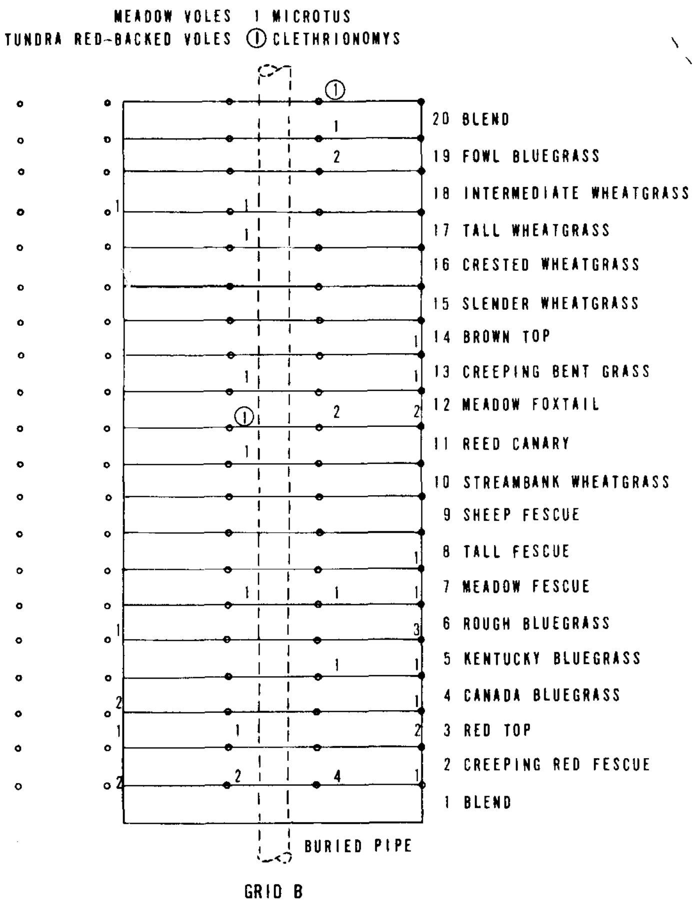
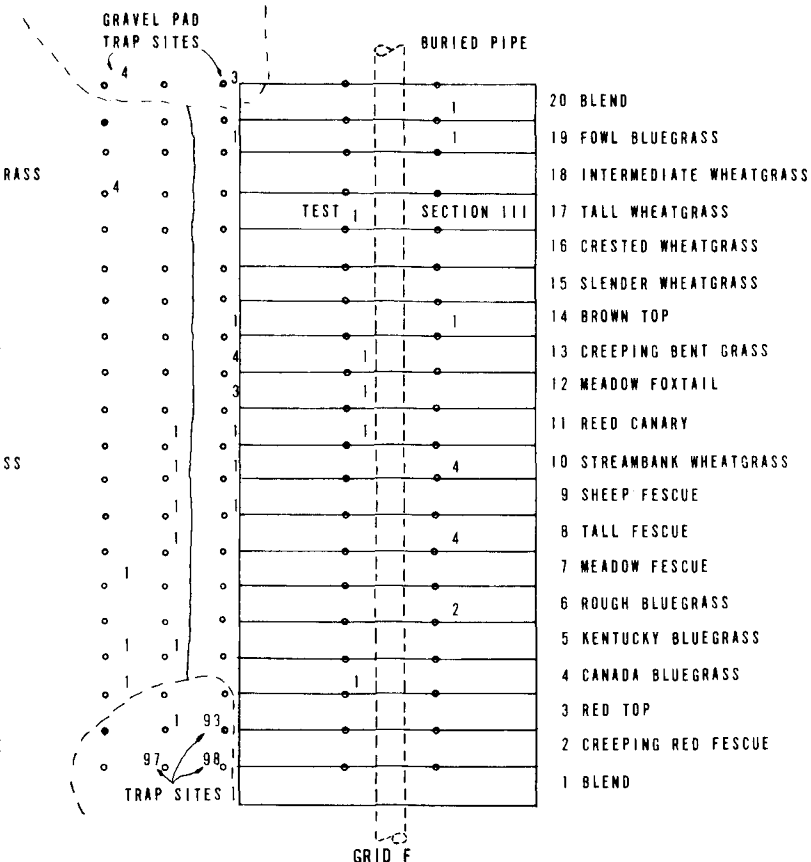


FIGURE XXXIV



NOTE
NUMBER OF RODENTS CAPTURED AT EACH TRAP LOCATION DURING THE STUDY.
ARABIC NUMERALS INDICATE NUMBER OF CAPTURES. (EXCEPT FOR TRAP SITES)

FIGURE XXXV

No.	DESCRIPTION	DATE	BY	APP.
	REVISIONS			

DESIGNED BY:
DRAWN BY:
CHECKED BY:
ENGINEERS APP.
PROJECT MANAGER

NORTHERN ENGINEERING SERVICES LIMITED
CALGARY ALBERTA
ENGINEERS FOR
CANADIAN ARCTIC GAS STUDY LTD.

NUMBER OF RODENTS CAPTURED AT EACH TRAP LOCATION

SCALE:
DATE:
PROJECT No.
DRAWING No. - B
REV.

No correlations between weather and small animal activities were calculated during the study. However, nights of light rain resulted in higher capture numbers as has been previously shown by Odum and Gentry (1957).

6.3.3 The extent of Small Mammal Activity in the Plots

From the average June values, almost all of the experimental grasses were invaded and cropped to varying degrees by small mammals (Table XV). Snap trapping of test section four, in the fall of 1971, indicated that chestnut-cheeked vole were the sole residents. Chestnut-cheeked voles were absent from the other test sections.

When compared to the utilization of the vegetation observed in June, September cropping of the experimental plots was minimal. However, red top, meadow fescue, reed canary grass, fowl bluegrass and blend plots were again extensively utilized. Meadow foxtail and crested wheatgrass did not exhibit signs of vole activity in either June or September. The meadow vole was the only vole frequently captured on the test sections throughout the summer.

6.3.4 Summer Consumption of the Experimental Grasses by Small Mammals

Due to the limited sample size, lack of uniformity in growth of grasses, and an unfortunate placement of exclosures, the data obtained in this study cannot be interpreted in terms of actual consumption. However, the increase in standing crop biomass during the summer for each test section is clearly evident in these data (Table XVI).

6.3.5 Seed Preference Experiments

Findings from this study indicated that tundra red-backed vole preferred the seed of only two grass varieties to lab pellets, (Table XVII). These were creeping bentgrass and brome grass. On the other hand, meadow voles favoured all grass seeds over lab pellets. They showed a definite preference for the seeds of creeping red fescue, reed canary grass, tall wheatgrass and intermediate wheatgrass. Chestnut-cheeked voles showed a preference for all grass seed to lab pellets except reed canary grass, slender wheatgrass and tall wheatgrass. Two of these grass varieties (creeping red and tall wheatgrass) were favoured by the meadow vole, but disliked by the tundra red-backed vole. The combined daily food consumption of seeds and lab pellets for tundra red-backed vole, meadow voles, and chestnut-cheeked voles were 4.17, 6.83 and 6.89 grams respectively.

6.4 DISCUSSION

The two species inhabiting the experimental grids (meadow voles and tundra red-backed voles) exhibited summer population fluctuations similar to those seen in other small mammal populations (Hamilton, 1937, Tanner 1950, Butsch 1954, Getz 1961, Fuller 1969). Population peaks occurred in the early summer and fall. The over-wintering adult population was responsible for the first peak. The second population peak was composed mainly of subadults; adult numbers tended to show either high mortality or a high rate of migration. It is a subadult class which endures the cold winter months (Blair 1948). The two population peaks obtained in the live trapping studies indicated that normal small mammal populations existed in the study areas (Svihla 1929, Coventry 1937, Blair 1948, Gunderson 1950, Butsch 1954). The population densities were not unusually high (Hamilton 1937, Fuller 1969). However, population densities and species composition for tracts on the pipeline and old winter road, illustrated that direct disturbances by man do affect small mammal activities. By collating the

Table XV: Extent of damage to the experimental grasses in the four test sections covering the pipeline in June and September, 1972. See Section 6.2.2. * test section

Plot No.	Grass Species	T.S June	*1 Sept	T.S June	2 Sept.	T.S June	3 Sept.	T.S June	4 Sept.	Mean June Value	Mean Sept. Value
1	Blend of all grasses	3	3	2	3	3	1	2	1	3	2
2	Creeping Red Fescue	0	0	3	0	2	1	2	2	2	1
3	Red Top	2	0	2	2	3	2	3	2	3	2
4	Canada Blue	3	2	1	0	3	1	3	0	3	1
5	Kentucky Bluegrass	1	0	2	0	1	3	2	0	2	1
6	Rough Blue-grass	3	2	1	0	2	3	3	0	2	1
7	Meadow Fescue	0	3	1	3	3	2	3	3	2	3
8	Tall Fescue	3	2	2	0	3	0	3	0	3	1
9	Sheep Fescue	3	0	3	0	3	0	2	0	3	0
10	Streambank Wheatgrass	2	0	2	1	0	1	3	0	2	1
11	Reed Canary	3	3	2	3	1	0	1	2	2	2
12	Meadow Fox-tail	2	0	0	2	1	0	2	2	1	1
13	Creeping Bent	3	0	3	3	1	0	3	1	3	1
14	Brown Top	3	0	3	0	1	0	1	0	2	0
15	Slender Wheatgrass	3	0	3	3	2	0	2	0	3	1
16	Crested Wheatgrass	3	0	0	1	0	0	2	1	1	1
17	Tall Wheat-grass	3	0	3	1	0	0	1	0	2	0
18	Intermediate Wheatgrass	3	0	3	1	0	0	3	0	2	0
19	Fowl Blue-grass	3	3	2	1	0	0	3	2	2	2
20	Blend of all grasses	2	2	3	3	0	0	2	0	2	1

Table XVI: Mean biomass values between enclosed (experimental) and unenclosed (control) areas of the experimental grasses planted in the four test sections covering the buried pipe. Plots showing no June values did not have exclosures installed in them during the fall of 1971.

Plot No.	Grass Species	June Biomass Values: wt. of grass inside the exclosures (gm/m^2)	June Biomass Values: wt. of grass outside the exclosures (gm/m^2)	September Biomass Values: wt. of grass inside the exclosures (gm/m^2)	September Biomass Values: wt. of grass outside the exclosures (gm/m^2)
1	Blend of all grasses	--	--	137.6	118.4
2	Creeping Red Fescue	--	--	316.8	568.5
3	Red Top	93.6(2)	70.8 (2)	291.2	214.4
4	Canada Blue	--	--	56.5	74.1
5	Kentucky Blue-grass	--	--	190.9	187.7
6	Rough Blue-grass	--	--	153.1	184.5
7	Meadow Fescue	10.6 (1)	41.2 (1)	394.7	447.5
8	Tall Fescue	44.8	28.8 (1)	88.5	6.4
9	Sheep Fescue	108.4 (2)	84.0 (2)	32.0	22.4
10	Streambank Wheatgrass	65.2 (1)	41.2 (1)	112.0	105.6
11	Reed Canary	66.8 (1)	144.0 (1)	213.3	244.8
12	Meadow Foxtail	68.8 (3)	64.8 (3)	307.7	162.1
13	Creeping Bent	68.4	67.6 (2)	175.5	269.3
14	Brown Top	99.2 (1)	128.4 (1)	5.9	0.5
15	Slender Wheatgrass	--	--	185.6	217.6
16	Crested Wheatgrass	13.2 (1)	22.8 (1)	59.2	18.1
17	Tall Wheatgrass	--	--	115.2	130.7
18	Intermediate Wheatgrass	--	--	60.8	121.6
19	Fowl Bluegrass	70.8 (1)	88.0 (1)	132.8	70.4
20	Blend of all grasses	65.2 (1)	84.8 (1)	222.9	91.2

( ) Values in parentheses indicate the number of test sections sampled. If no parentheses are shown then the test sections sampled were three.

Table XVII: Daily consumption of grass seeds and lab pellets by meadow voles, chestnut-cheeked voles and tundra red-backed voles in controlled conditions.

Grass Species of Seeds Offered Animals	Meadow voles			Chestnut-cheeked voles			Tundra red-backed voles		
	Average No. of Days Animal Exposed to Seed	Daily Seed Consump-tion (gm)	Daily Lab Pellet Consump-tion (gm)	Average No. of Days Animal Exposed to Seed	Daily Seed Consump-tion (gm)	Daily Lab Pellet Consump-tion (gm)	Average No. of Days Animal Exposed to Seed	Daily Seed Consump-tion (gm)	Daily Lab Pellet Consump-tion (gm)
Creeping Red Fescue	6.0++	6.1	0.2	6.0++	7.5	0.2	5.5++	0.0	3.8
Red Top	6.0++	7.0	0.7	5.0++	8.2	1.6	5.3++	1.2	3.5
Canada Bluegrass	5.5++	7.5	1.7	6.0++	6.8	0.1	5.0++	0.2	3.7
Kentucky Bluegrass	6.0++	3.0	0.6	6.0++	10.2	0.4	5.0++	0.0	4.3
Rough Bluegrass	6.0++	2.6	1.6	6.0++	3.5	0.0	6.0++	2.6	2.3
Meadow Fescue	6.0++	1.4	1.1	5.0++	7.3	0.9	6.0++	0.0	3.2
Tall Fescue	6.0++	5.1	0.0	5.0++	6.2	0.0	6.0++	0.1	4.1
Sheep Fescue	6.0+	6.7	0.0	4.0+	11.1	0.0	6.0++	0.1	5.3
Streambank Wheatgrass	6.0++	5.2	1.1	6.0++	6.0	0.7	6.0++	0.0	3.6
Reed Canary	6.0++	6.2	0.2	6.0+	0.5	4.2	5.5++	3.0	1.7
Meadow Foxtail	6.0++	6.0	0.6	5.0++	3.2	2.7	6.0++	1.0	2.4
Creeping Bent	6.0+	13.8	1.1	6.0++	6.1	0.0	6.0++	2.5	0.9
Brown Top	6.0++	6.8	0.5	4.5++	4.1	1.0	6.0++	0.5	3.4
Slender Wheatgrass	6.0++	3.6	1.0	6.0++	2.3	2.7	6.0++	0.2	4.4
Crested Wheatgrass	6.0++	5.1	1.1	6.0++	5.0	2.6	5.0++	0.4	3.5
Tall Wheatgrass	6.0+	4.5	0.0	6.0+	0.2	5.0	6.0++	0.0	4.2
Intermediate Wheatgrass	6.0+	2.5	0.0	--	--	--	6.0++	2.0	2.1
Fowl Bluegrass	6.0+	11.5	0.0	--	--	--	5.5++	1.3	3.2
Clover	--	--	--	--	--	--	6.0++	2.7	1.7
Fall rye	--	--	--	--	--	--	6.0++	2.7	1.7
Alfalfa	--	--	--	--	--	--	3.0++	1.2	2.1
Timothy	--	--	--	--	--	--	3.0++	0.4	4.7
Brome	--	--	--	--	--	--			
Average		6.83			6.89			4.17	

\+ no. of animals exposed to the particular seed *data from all grids, it is evident that when population densities* are expanding in their natural environment (period 4 and 5 in Grids C, D and E, Figure XXII -XXIV), the number of inhabitants in experimental test sections tended to decline (Figures XXI and XXV).

At this time, small mammal numbers should have been maximal since large numbers perish during the winter. This being the case, population data from Grids B and F suggest that with the coming of winter, small mammals were moving out of the experimental grass areas. However, the high numbers captured in Grid F in period one, and summer vegetation damage data appeared to signify the opposite (Figure XXV, Table XV). The grass plots appear to offer an untapped food reserve and shelter in the winter. It is quite probable that small mammals do occupy this region during the winter months. A notable deviation from the population density values obtained in period one for Grid B appeared in Grid F. This may be explained by the fact that depletion of the vegetation occurred earlier in Grid B than in Grid F. Thus, it would appear that the inhabitants of Grid B had already migrated to more favourable habitats at the time this study commenced. The quantity of vegetation utilized in June on test section three (Grid F) was less than in test section one (Grid B, Table XV).

Live trapping data for Grid A indicates a relationship between population densities and habitat type. Tundra red-backed voles did not inhabit the winter road, but frequently moved across it. Thus, it appears that barren tracts of land do not confine tundra red-backed vole activities. The meadow vole, on the other hand, was a regular occupant of the old winter road. Numbers captured here were low, but a gradual increase beginning in period three suggests an inclination to overwinter here.

In September, several piles of clipped rush (*Juncus*) were noticed on the road, suggesting preparation for winter. The increasing number of meadow voles inhabiting the old winter road may have been a result of tundra red-backed voles excluding them from the woods (Cameron 1964, Clough 1964, Morris 1968). This, however, is not believed to have been the cause as meadow voles did not appear to have been excluded in other grids, nor did their numbers decrease in the forest traplines of this Grid (Figure XXXI). It is also worthwhile to note that the winter road vegetation is preferred more by meadow voles than tundra red-backed voles (Bailey 1924, Ognev 1964). The forest margin may provide shelter, while ample food is available on the winter road. Comparisons of trapline population values in Grids A, B and C indicate that population density differences between natural and experimental regions are quite evident.

Area preferences on the test sections, size of home ranges and seed selection experiments demonstrate the importance of knowing the dominant species of a particular area. No two species eat exactly the same food, prefer the same habitat or behave in the same manner.

In this and other studies, the home range of the meadow vole was found to be small (Blair 1941, Getz 1961). This, combined with understanding of food preferences, points out the ease with which meadow voles could inhabit the vegetation over a pipeline and/or well vegetated roads.

Data on trap frequency for test sections B and F indicate which grass species meadow voles favour as food, nesting material and shelter. This data, together with the findings on utilization of various experimental grasses, illustrates that meadow voles will clip, burrow and feed on creeping red fescue, red top, meadow fescue, reed canary grass and meadow foxtail.

No habitat preferences were evident when the same analysis was conducted on trap frequency values found for Grid C (Figure XXXII). A comparison of biomass data in and out of the exclosures should have provided a quantitative measure of forage consumption by small mammals during the summer. This would have also shown the grass variety most likely to be utilized by small mammals. Unfortunately, the data obtained were inconclusive. The small exclosures used may have restricted the grass plants, causing growth retardation. In addition, roots of the grasses may have been restricted in their development due to barriers imposed by the wire exclosures sunk into the ground.

It is evident that seeds of all grass species were consumed by meadow voles. However, because the number of voles used in seed testing experiments was small, consumption values cannot be considered representative of the species. The results of the seed selection experiments still indicated that meadow voles favoured the seed of all grass species over lab pellets. It is felt that these results can be extended to the animal's natural environment. The findings of this study and other studies show that meadow voles feed on the leaves, stems and seeds of numerous grass species (Bailey 1924).

As chestnut-cheeked voles were not discovered in any of the study areas, statements with regard to the food habits of this vole are limited to information based on seed preference experiments and observations of vegetation in areas where this animal was captured.

The seed preference experiments illustrated that the chestnut-cheeked vole consumed the seeds of all but three varieties. These exceptions were reed canary grass, slender wheatgrass and tall wheatgrass.

Because the chestnut-cheeked vole is extremely rare, no information concerning their food preferences is available. However, clippings of Polar grass (*Arctagrostis*) were observed where these animals were trapped. It is also known that grasses and seeds do constitute a major part of microtine diets (Bailey 1924, Bee and Hall 1956). The October 1971 observations of vegetation cropping in test section four imply that chestnut-cheeked voles have utilized experimental grasses.

The reasons for the chestnut-cheeked vole population moving into test section four in the autumn of 1971 is unknown. This may have been due to a population "high". Microtines are known to exhibit population cycles resulting in abnormally catastrophic numbers every four years (Hamilton 1937, Lack 1954, Schulz 1964). Krebs (1966) believes that it is in arctic and subarctic regions that periodic fluctuations in population size are the most violent.

It is postulated that if these population extremes occur, there may be mass movements onto the pipeline right-of-way which may give rise to erosion problems as the grass cover is consumed. When studying the tawny lemming (*Lemmus trimucronatus*, density of 111/ha) Thompson (1955), found that the standing crop of vegetation at the end of the summer on Alaskan tundra was reduced nearly fifty per cent. In the same area, Schulz (1964) reported fifty to ninety per cent declines in yield after a high of 173 lemmings/ha and declines in nutrient content, particularly phosphorous, calcium and nitrogen. Not only is the vegetation clipped and consumed, but seeds are also eaten.

The formation of extensive, complicated systems of runways may have profound affects on the vegetation. These runways result primarily in removal of any living plant matter which may occur originally, or grow up subsequently in the trail. Small mammals also tend to gnaw the grass tufts which border the runs (Summerhayes 1941). Tunnels tend to damage the root systems of grasses as well. This study has shown that the local small mammals possess different home range areas, food preferences and habitat requirements. By obtaining this information for all small mammals along the proposed pipeline route, a reasonable estimate concerning time and place of invasion by a particular species on pipeline vegetation could be made.

Tundra red-backed voles exhibited larger home ranges than meadow voles. Because of this large home range size and the short distance between trap sites, few home range areas could be calculated on the small grids (Hayne 1949). Movements were not hindered by an old winter road, seismic lines, service roads or revegetated areas. However, unlike meadow voles, the tundra red-backed vole did not occupy these areas for a long duration. These areas appeared to be within tundra red-backed voles' home range. Just as a body of water may be enclosed within a home range, so are these tracts of land. Conversely, meadow voles demonstrated no hesitancy in occupying the vegetation covering the old winter road or grassed test sections.

Tundra red-backed voles favoured few experimental seeds to lab pellets, which strongly implied little desire for grains when in their natural habitat. Their absence in the test section further substantiated the statement that the red-backed vole would have no tendency towards inhabitation of vegetation covering the pipeline.

6.5 CONCLUSIONS

The work at Sans Sault clearly confirms the fact that every species of small mammal exhibits different behaviour and habitat preferences. Meadow voles established small home ranges, situated in damp regions where horsetails, berries and Polar grass were abundant. They were not hesitant to occupy experimentally grassed regions and well-vegetated winter roads. This species was the resident of the above mentioned regions in the autumns of 1971 and 1972. It is evident, from seed preference experiments, that seeds constitute a large part of the meadow vole's diet.

Similar seed preference experiments, with chestnut-cheeked voles, demonstrate this vole to be a seed eater as well. Of the sixteen experimental seeds tested on the chestnut-cheeked vole, tall wheatgrass, slender wheatgrass and reed canary grass were the only species not preferred to lab pellets. Observations of damage to the vegetation in test section three, suggests their preference for numerous grasses.

Tundra red-backed voles preferred drier regions and exhibited a tendency to avoid unfamiliar areas. The favourite foods of this small mammal are berries, nuts, twigs, flesh and some native seeds (Ognev 1950, Peterson 1966). Few of the experimental seeds were consumed in larger quantities than lab pellets by these voles. They do not represent a problem to any of the experimental grasses or vegetation flourishing on the old winter road.

As this study examined only two species, conclusions apply only to the meadow vole and the tundra red-backed vole. The manner in which species, such as the lemming (*Lemmus* sp.), which dwells in tundra regions, and deermice, (*Peromyscus* sp.), which inhabit northern Alberta, will react to the new habitat created cannot be accurately stated. Examination of the feeding habits, habitats and population densities of each rodent encountered along the pipeline route would enable appraisal on the types and quantities of grass to be planted on critical terrain which must have a plant cover for erosion control and may be subject to over grazing by small mammals.

Utilization of the seeded vegetation, during the growing season, by small mammals in the Sans Sault area was relatively light. Observations in the fall of 1971 and spring of 1972 indicated much heavier cropping during the winter months. The strong recovery of grass, as shown by the biomass measurements, indicates that microtine use of these plots has not significantly reduced the erosion protection provided by this vegetation. The conclusion drawn is that species of the genus *Microtus*, in low to moderate numbers, do not present a serious threat to the revegetated cover on the pipeline right-of-way.

This four month study illustrated the fact that small mammals occurring in "average densities", for a particular area, do not cause large scale destruction of the reseeded vegetative cover. However, when small rodent densities for a particular species attain a "population high", extensive destruction to vegetation over the pipeline may ensue. Knowledge of when and where these "highs" will occur would provide the opportunity to initiate measures to minimize vegetation damage or carry out maintenance reseeding.

There is a possibility that a localized stimulation to the population may occur due to the availability of highly nutritional forage. This in time may result in an artificial "high" in populations adjacent to the seeded right-of-way causing unusually high consumption of the grass. A possible example of this may be evidenced with the local occurrence of the chestnut-cheeked vole. The last published report on this rodent was by Preble in 1908. However, in the fall of 1971, chestnut-cheeked voles were abundant on test section four. Extensive utilization of the grasses in this section due to the clipping and burrowing activity of these animals was evident. There is a suggestion here that there may be future problems with this species.

6.6 RECOMMENDATIONS

In order to properly consider the question of small mammals and the impact they may have on the restored plant cover, it would be necessary to conduct similar studies in several locations along the pipeline route. Information on feeding and habitat preferences of each species could then be considered when selecting grass mixtures. If a seed eating small mammal is abundant in an area, then a grass species which propagates mainly by rhizomes would be desirable.

The point in time at which a vole species reaches its population peak for the year must be determined. Considering a seed eating rodent that achieves a high population density in the early summer and fall, the appropriate grass variety to plant would be one which sets seed in July and August. Thus, the small mammals will be less inclined to move into the pipeline vegetation at times of maximum densities.

In critical locations, such as sideslopes and approaches to rivers, special care may have to be taken to protect the vegetative cover maintaining soil stability.

1. The planting of "dummy" or lure crops composed of grass or legume varieties known to be preferential forage would aid in the protection of vegetation over the pipeline.

2. Patented electronic devices are now on the market which emit very high frequency sounds intolerable to mice and rats.

Other possible means of controlling small mammal populations include chemosterilants (Davis 1961, Howard and Marsh 1969, Kennelly *et al.*, 1972), phermones (Muller-Veiter 1966 and Rolls 1971), and chemical repellants. None of these chemical means are recommended for this project.

Insight into the potential problems which small mammals may create, as provided by studies such as this, will aid in maintenance planning and contingency preparations.

7.0 SUMMARY AND CONCLUSIONS

The revegetation research carried out at the Sans Sault test facility has demonstrated that it is feasible to establish and maintain a plant cover over a buried pipeline in the northern boreal forest.

Specific conclusions drawn from this study are:

(1) The best species for revegetation in the Sans Sault area are:
Boreal Creeping Red Fescue
Common Kentucky Blue Grass
Common Meadow Foxtail
Frontier Reed Canary Grass
Climax Timothy
Revenue Slender Wheatgrass
Meadow Fescue

(2) Fertilizer required to establish and maintain growth of the above varieties on a pipeline backfill mound would be applied at the rate of 75 kg/ha nitrogen plus 100 kg/ha of both phosphorus and potassium. It will be necessary to apply additional fertilizer in the second or third growing season. An exact recommendation on a follow-up fertilization must await further field testing.

(3) In two growing seasons, a seeded plant and litter cover can be built up which will substantially modify the heat energy flow into the backfill mound.

(4) The planting of willow and alder stem cuttings has proven to be an effective method to control erosion on sideslopes. In the case of major slopes it may be necessary to stake down erosion control mats to hold the soil until the grass germinates and the seedlings become firmly established.

(5) Mosses and liverworts quickly invade and establish under the seeded grasses over the backfill mound. Vascular plants are slower to invade, except in areas which collect and hold water. These areas are dominated by *Carex aquatilis*.

(6) In addition to seeding and fertilizing the right-of-way in tundra regions, stripping the vegetative mat prior to construction and replacing it to the backfill mound will aid in reducing the depth of thaw and quickly re-establish the former plant community.

(7) Small mammals occurring in "average densities," for a particular area, do not cause large scale destruction of the reseeded vegetative cover.

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APPENDIX "A"

REINVASION OF PLOTS BY NATIVE SPECIES

TEST SECTION: I SUBSTRATE: ORGANIC

PLOT	2		3		4		5		6		7		8		9		10		11		12		13		14		15		16		17		18		19		%
SPECIES SUBPLOT	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	Freq.
Bryophyta																																					
Aulacomnium acuminatum	+	2.6	33.2	18.2	1.3	.9	1.0	.6	.5	.1	1.3	.9	.5	3.8	.6	2.7	3.0	.9	.5	2.6	3.4	.6	1.3	11.3	11.3	1.3	.9	3.4	.6	3.0	5.1	.6	1.0	1.8	9.3	21.4	75.9
Tomenthypnum nitens				6.2	8.8	17.1	3.0	5.4	5.4	10.4	3.0	3.0	.2	+	.6	.9	.6	+	.5	.4	.6	2.6	3.0	.9	5.4	5.9	.4	.1		.4	+	+	+	.8	+	.5	42.1
Marchantia polymorpha	.4	+	+	.5	.5		.1	.2	.1	+	.8	.8	2.6		+	.4	.2	7.1	.9	.8	.1	.2	.1	2.5	+	+	2.9	3.0	.5	1.3	.9	2.5	.2	+	+		41.7
Moss 214											.4	.5	+	+			+	6.7	8.8	+	+	3.0	.4	.4	+		+				.1	+	+	+	.1	+	18.0
Hylocomium splendens	.4	.4	.4	.6	.4	.4	.2	.6		.3	.4	1.9	+	+	+	.1	.4	+	.4	.4	.8	.2	.6	.2	.1	.2	+	.3	.2	2.7	.9	.6	3.0	.5	.2	.2	48.2
Leptobryum pyriforme											.5	+	.6	+	.6	+	.2	.1	.9	.4	.5	.2	1.0	.5	.1	.1	.8	.5	.9	.5	.1	.4	.6	6.7	.4	+	37.0
Ceratodon purpureus													.4		+	+	.9	+	+	+	+	.5	.5	+	+	.1	.9	.9	3.0	.6	.1	3.0	.5	.5	.4	+	44.9
Splachnum sterile													.5	+	+	+	.5	+	+	+	+	.4	+	+	+	+		.1	.4	+	+		2.5	.9	.5	+	19.9
Calliergon richardsonii											6.2	+	+												+												1.8
Sphagnum spp.			+	+			+	.5			+	+									.9	.5	+	+	.8	.5	.4			+						.6	11.1
Bryum pseudotriquetrum													.4	+	+	+	.4	.5	.9	+	+	.5	.2	.2	+	+	+	.1	.1	+	.1	+	.1	+	+	.1	30.1
Pleurozium schreberi			.4	.2	.1	.2		.3	+	.2	.1	.7					.1				.2					.2		.2									11.1
Funaria hygrometrica	+						+												+			+	+			+	+	.1	.4	+			.4	+	+		13.0
Ditrichum flexicaule																				+	.5							+	+	+	.5	.1			+	+	10.6
Drepanocladus vernicosus	.4	.4																																			1.4
Cinclidium stygium	+				+	+	+	+		+						+	+								+	+											6.9
Polytrichum juniperinum					+												.1													+	+		+	+			5.1
Mycophyta																																					
Cladonia spp.									+	.4	+						+	.1	+	.1	.1	+	+	+	+	+	+	+		+	.9	.9	.6	.1	+	+	12.5
Peltigera spp																+					+	+	+	+	+		+				+			+	+	+	6.0
Cetraria nivalis																+	+																				0.5
Vascular Plants																																					
Carex aquatilis	20.0	13.0	.1	3.8	3.8	.8	2.5	2.5	3.3	.9	.4	3.0	.4	2.5	.4	+	2.5	.4	.4	.8		.4	+														24.5
Vaccinium uliginosum	+	.5	.4	3.8	1.0	1.4	1.0	1.3	3.0	3.0	1.8	1.3			.5	1.0	+	.1		.5	+	.8	1.2	1.2	1.7	1.7	.9	.9	.1	1.2	.9	1.2	1.3	.5	1.3	3.0	54.2
Arctostaphylos rubra				+		.7	.4				.5	.8	.4	.4		.4				+	+	.4	.9	3.3	1.7	1.2	1.3	1.3	.8	.9	1.3	1.3	3.8	1.7	.9	3.4	25.0
Chamaedaphne calyculata	3.0	.9	.5	.5	1.3	.1	+	+	.1	3.0	.2	+	+	+	1.3	.5	+	+	.4	+	.5	1.3	.2	1.7	1.4	.9			+	.4	.9	.2	.9	1.0	.8	.9	50.9
Rubus chamaemorus				+	+	1.2	.4	.5	.8	.8	.4	+	1.2	+	+	.4	.5	.4	.4	.2	.5	.5	.4	.4		+	.8	.4	.5	.9	1.0	.9	.9	.5	1.0	1.2	32.4
Equisetum palustre	.5	.2	.5	1.0	1.4	1.3	.5	1.0	.5	3.0	.5	.9	.8	+	.5	.5	.4	.4	.5	.4	+	.1	+	+	+		+										39.4
Ledum groenlandicum		+		.1	+	1.3	+	+	.8	.9	.2	.4			+	.1	.4	.8	+	+	.4	+	.1	.5	+	.4	.5	.5	.5	+	.5	.5	.9	.5	1.7	.5	38.4
Arctagrostis latifolia		.4			+	+			+	.6			.4	+	.5	.8	.4	+	+	.9	.5	.4	.1	.4	.2	+	.2	.1	.4	.5	.2	.6	1.0	1.0	1.0	.6	44.4
Salix planifolia	.4	.4									10.4																										1.8

Figures Represent Percent Ground Cover

+ - Species is present but rare

REINVASION OF PLOTS BY NATIVE SPECIES

TEST SECTION: I SUBSTRATE: ORGANIC

PLOT	2		3		4		5		6		7		8		9		10		11		12		13		14		15		16		17		18		19		%
SPECIES SUBPLOT	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	Freq.
Andromeda polifolia	.8	.5	.2	.1	+	+	.2	+			.2	.2	+	.1	.5	.2	.1	+	+	+	.9	.5	.9	.5	.5	.9	.1	.2	.1	.1	+	.1	+	.2	+	.5	44.4
Smilacina trifolia		+	+	+		+	2.5	.4	.4	3.0	.1	+			.4		+		.4		+			+	+		.9										14.4
Carex spp.						.6	3.3	+	+						+		+				+		+	.5	.9	.2			.5		.5	.4	+	+	.4	.4	18.5
Equisetum scirpoides							+				+	+	.1	+		+	.1	+	+	+	.1	.2	.2	.2	.1	.1	.1	.2	.5	.1	.5	.6	.2	.2	.2	.5	28.7
Vaccinium vitis-idaea						+	+	+	.4	.4				+	+	+	.4	.4	+	+	+	+	+	+	.2	.2			.5	.1	.2	.6	.1	.2			30.1
Epilobium angustifolium					+											+	+		+	+			+	2.5		+				.4		.4	.4				5.1
Betula glandulosa	.5	.1	.4	.4			.4				.4			+							.4				+	+		+									6.9
Rosa acicularis								+	.1		.8						+			.4	.4	.4							+						+	+	5.1
Ranunculus lapponicus			+			+				+	+			+		+	+		+	+	.4	.4			+	.1			+	+	+	+	.2	+	+	.1	16.7
Potentilla fruticosa	+	+	+	.4	.7			+	+	+															+			+			.4						6.5
Calamagrostis lapponica								2.5									.4		+					+	+	+		+	.4								3.7
Empetrum nigrum											+														+		.4	.4				.4	+		.4		2.8
Eriophorum angustifolium						1.2							+			+					+					+											2.8
Equisetum arvense							+																	+			+	.2		.1	+	.4	+	+			10.6
Epilobium spp.				+		+							+				+	+		+	+	+	+	+				+	+	+	+	+	.1	+	+		12.5
Eriophorum spp.															+				.4	.4																	1.8
Salix spp.	+			+	+								+					+	+	+	+	+				+				+		+	+	+			6.0
Salix alaxensis					+													.4														+					1.8
Salix glauca																														.4							0.5
Betula papyrifera																			+			+									.1			+	+	+	4.6
Oxycoccus microcarpus	+															+					+	+								+						+	2.8
Picea mariana						+																			+			+								+	1.8
Achillea borealis				+																																	0.5
Senecio congestus																																				+	0.5
COMPOSITAE																		+																			0.5
Agrostis alba															.5	.4																					2.3
Hordeum jubatum																	+	.4																			1.4
Alopecurus pratensis																		.4																			0.5
Poa palustris																														+	+		+	+			1.8
Poa pratensis																+																					0.5
Phalaris arundinacea																		+																			0.5
Poa compressa													+																								0.5

REINVASION OF PLOTS BY NATIVE SPECIES

TEST SECTION: II SUBSTRATE: ORGANIC

PLOT	2		3		4		5		6		7		8		9		10		11		12		13		14		15		16		17		18		19		%
SPECIES SUBPLOT	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	Freq.
Broyphyta																																					
Ceratodon purpureus	.2	.1	1.2		.1	1.2	.1	2.5	.1		8.8	2.5	.2	.2	7.6	18.9	2.5	1.2	26.2	7.5	26.2	8.8	8.8	.1	18.9	26.2	38.8	31.2	8.8	18.9	18.9	8.8	32.5	15.0	7.6	7.6	79.2
Leptobryum pyriforme	7.6	.2	1.4	7.6	26.3	7.6	.1	2.5	15.0	8.8	26.2	8.8	26.2	7.6	8.8	2.5	15.0	7.6	8.8	1.2	1.4	7.6	8.8	.1	.1	1.4	2.5	1.4	8.8	20.0	18.9	2.5	8.8	8.8	1.4	.2	93.1
Aulacomnium acuminatum	1.4	15.0	.2	18.9	1.4	.2	8.8	.2	.2	1.4	1.4	1.4	7.6	1.2	1.4	1.4	7.6	1.4	7.6	18.9	.2	1.4	1.4	1.4	7.6	1.4	38.8	1.4	2.5	8.8	1.4	18.9	1.4	8.8	26.2	20.0	97.2
Marchantia polymorpha	1.2				.2	.1	.1	.2	1.2		1.4	.1	2.5		8.8	.2	7.5	1.2	8.8	.2	2.5	20.0	2.5	1.2	1.4	2.5	2.5	8.8	15.0	26.2	37.5	15.0	26.2	8.8	.1	1.4	76.4
Tomenthypnum nitens	.1	1.4		.1		.2	.1	.1			.1	1.4		7.5	1.2				.2	.2			1.4	.2	1.2	1.2	7.6	31.4	18.8	7.6	18.9	18.9	2.5	8.8	7.5	1.4	55.6
Hylocomium splendens	.2	.2	1.4	1.2	.1	7.5	2.5	.2	.1	.1		.2	1.2	.2	1.2	1.4		1.4	.2	15.0	.1	2.5	1.4	7.6	1.2	.2			7.5	1.2	7.5	18.9	7.6	18.9	1.4	18.9	69.4
Moss 214	1.2	.1	1.4	.1	.2	.2	.2	.2	.2	1.4	1.2	7.6	1.4	.2	1.4	.2	.2	.2	1.4	.2	1.4	2.5	1.4	8.8	1.2	1.4	1.4	.1	.2	.2	1.4	.2	1.4	.2	1.4	18.9	91.7
Sphagnum spp.	.1			.1			.1					7.5	1.2	7.5			.1		.2		.1	1.2			.1	.1	.1	.1	1.2	.2	7.6	8.8	.1	1.4	1.2		36.1
Bryum pseudotriquetrum	.1		.5				.1	.1		.1	.2	.2			.2	.2	.1		.2	1.2	.2	.2	1.4	1.2	1.4	1.4	7.5	1.2	2.5	1.4	.2	.2	7.6	.2	1.4	1.4	65.3
Splachnum sterile	1.2	.1	.2	.2	7.5	1.2		7.6		.1	2.5	7.5	1.2	.2	.1	.1		.2		.1	.1	.2	.1	.1	.1		.1	.1	.2	.1	.1	.1		1.4	.1	.1	52.8
Pleurozium schreberi	.1		.1				7.6		.1			.1				1.4	.1	.1	1.4	.2	.1	1.4	.2		.1		.1	.1	.1		.1	.1		1.4	.1	.1	38.9
Polytrichum juniperinum			.1												.1		.1	.1	.2	.1	1.4	1.2	1.2	.1	1.2	1.4	1.4	1.2	1.2	1.2		.1	.2	.1	.1	.2	37.5
Ditrichum flexicaule	.1	.1	.2	.1			.1					1.2							.2			.1	.1			.1						.1		1.2	.1	.1	18.1
Pohlia nutans					.1														1.2		1.2				.1									1.2			6.9
Drepanocladus fluitans																														.1	1.2						2.8
Cinclidium stygium																												.1				.1					2.8
Paludella squarrosa																														.1							1.4
Calliergon richardsonii																												.1									1.4
Mycophyta																																					
Cladonia spp.	.1	1.2	.1			.1	1.2		.1		.1						1.4	1.4	.1	.1		1.2	.1	.1		1.2	.1				.1			.2	.1		29.2
Peltigera spp.		.1				.1														.1																	4.2
Cetraria nivalis																		.1		.1																	4.2
Vascular Plants																																					
Arctagrostis latifolia	1.2	7.6	31.2	18.8	7.5	7.6	.1		1.2	1.2			7.5		.2	.1			.1			.1		.1	.1	1.2		2.5			2.5	26.2	.2	2.5	1.4	8.8	51.4
Carex aquatilis										1.2																	18.8	18.8	8.8	8.8	18.9	8.8	18.8	7.5	.1		22.2
Vaccinium uliginosum	1.2	1.2	1.2			.1	.2	.1		.1	.1				.1		1.2	.1	2.5	2.5	.1	.2	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	8.8	8.8	15.0	8.8	8.8	65.3

REINVASION OF PLOTS BY NATIVE SPECIES

TEST SECTION: II

SUBSTRATE: ORGANIC

PLOT	2		3		4		5		6		7		8		9		10		11		12		13		14		15		16		17		18		19		%
SPECIES SUBPLOT	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	Freq.
Equisetum scirpoides	1.4	.1	.2	.2	15.0	.2	.2	26.2	7.5	.1	.2	1.2	2.5	.1				.1	.1	.1	.1	.1			.1	1.4	1.4	.2	1.4	.1	1.4	1.4	.2	.1	.1	.1	68.1
Rubus chamaemorus	.2	.2	.1	.1	.1	.1	1.4	2.5	.1		1.4	7.6	8.8	.1	.2	.1			1.4	1.2	2.5	2.5	.2	.1	1.4	2.5	1.2	1.2		.1	.1	.1	1.2	2.5	2.5	2.5	73.6
Chamaedaphne calyculata	.1	1.2	.1	7.5	.1	1.2	.1	1.4		1.2	.1	.2	7.5	1.2	.1				1.2	.1	.1	.1		.1		.1	1.2	1.2	1.2	.1	1.2	7.5	1.4	2.5	1.4		50.0
Equisetum silvaticum	.2	.1	.1		1.2		1.4	7.6		1.2	7.5	1.2		.1				.1	.1	.1		1.2		.1	.2	.2	1.2	1.2	8.8	.1	1.2		.1		.1		40.3
Andromeda polifolia		.1	.1	.1	.1			1.4		.1	.1	7.5	1.2	1.2	1.2	.1	.1	.1	1.2	1.2	.2	.2	.1	.2	1.4	1.4	2.5	1.4	2.5	.1	.1	1.4	1.4	2.5	1.4	.1	59.7
Calamagrostis lapponica	1.2						7.5	1.4	1.2	1.2		1.2	.1		.1	1.2	.1	2.5	1.4	.1	.1	1.2	.1		.1	7.5	1.2	1.2				1.4		.1	.1		38.9
Ledum groenlandicum	1.4	1.4	.1		.1	1.2	1.4	1.4	.1	1.2	.2	.1	1.2	.1		.1		.1		.1	.2	1.4		.1	.1	.1	.1	.2	.1			.1	1.4	1.4	1.4	1.4	51.4
Oxycoccus microcarpus							.1	.1			.1		1.2	1.2	.1	.1	.1		1.2			.2	.1		1.2	1.2								7.5			19.4
Vaccinium vitis-idaea	.1	1.1		.1		.1	2.5	.2	.1			1.4	.2	.2	.1	1.4	.1	.2	.1	.1	.1	.2	.1			.1						.1		.2	.1	1.2	47.2
Eriophorum angustifolium																							1.2		1.2	7.5	.1										6.9
Ledum decumbens		.1	.1			.1	.2			.1		.1	1.2	.1	.1		.1		.1	1.2	.1	2.5		1.2		.1	.1		.1					.1			27.8
Ranunculus lapponicus	.2	1.2	.2	.2	1.2	.1	2.5	.2			.1	1.2							.1								.1			.1			.1				26.4
Equisetum arvense					1.2			1.2													1.2	.1								1.2	.1			.1			5.6
Rosa acicularis	.1		.1	.1	.1		.1	1.2		.1	.1	1.2	1.2			.1			.1															.1	.1		16.7
Epilobium spp.	.1				.2				.1										.1	.1			.1	.1	1.4	.2	.1	.1	.2	1.2			.2	.1	.1		30.6
Salix spp.			.1		.1	.1			.1		.1	.1						.1		.1		.1	.1	.1	.1		.1	.2	1.4	.1	.2	.1		.2	.1		30.6
Alnus crispa	.1		.1		1.2		.1			.1		1.2		.1																	.1		.1				11.1
Carex spp					.1																		.1	1.2					.1				.1			1.2	11.1
Eriophorum spp										.1					1.2			.1				1.2				.1	.1										9.7
Arctostaphylos rubra								1.2															.1				.1					.1			1.2	.1	12.5
Epilobium angustifolium	.1		.1						.1					.1	.1	.1	.1	.2			.1	1.2															6.9
Picea mariana	.1				.1						.1			.1					.1		.1				.1										1.2		9.7
Potentilla spp																																	.1		.1	1.4	5.6
Betula glandulosa																									.1			1.2			.1				.1		5.6
Linnaea borealis																																1.2					1.4

REINVASION OF PLOTS BY NATIVE SPECIES

TEST SECTION: II SUBSTRATE: ORGANIC

SPECIES / PLOT	2		3		4		5		6		7		8		9		10		11		12		13		14		15		16		17		18		19		%
SUBPLOT	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	Freq.
Betula papyrifera		.1						.1			.1		.1			.1						.1				.1			.1				.1				12.5
Salix alaxensis	.1		.1		.1						.1				.1										.1				.1		.1						12.5
Populus tremuloides								.1			.1		.1		.1												.1		.1			.1		.1			11.1
Achillea borealis			.1	.1		.1							.1		.1																				.1		9.7
Smilacina trifolia										.1				.1											.1			.1			.1						6.9
CRUCIFERAE																											.1			.1	.1	.1			.1		4.2
Larix laricina											.1															.1					.1						4.2
Potentilla fruticosa																	.1																	.1	.1		4.2
Salix glauca				.1																																	1.4
Ranunculus gmelinii			.1																																		2.8
Pyrola spp.		.1																																			1.4
Trifolium spp.																	.1																				1.4
Juncus spp.										.1																											1.4
Agrostis alba															8.8	1.4									.1								1.2		.1		11.1
Poa pratensis															1.4	.1																		.1			5.6
Phleum spp.					.1										.2																					1.2	5.6
Poa trivialis											1.4			.1			.1																				5.6
Festuca rubra			1.2								.1																										4.2
Hordeum jubatum																	1.2																				1.4
Poa palustris																											.1			.1			.1	.1			6.9
Alopecurus pratensis																	.1													.1							2.8
Phalaris arundinacea																						.1					.1										1.4
Festuca elatior					.1																										.1						2.8
Agrostis tenuis																															.1						1.4
Bromus secalinus																												.1									1.4
Avina spp.																	.1																				1.4
Agropyron trachycaulum																													.1								1.4

REINVASION OF PLOTS BY NATIVE SPECIES

TEST SECTION: III SUBSTRATE: ORGANIC

PLOT	2		3		4		5		6		7		8		9		10		11		12		13		14		15		16		17		18		19		%
SPECIES SUBPLOT	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	Freq.
Bryophyta																																					
Leptobryum pyriforme	.9	+	.9	.9							8.8	18.9					50.0	15.0																			75.0
Splachnum sterile	1.2		.5	.4							.1	7.5					37.5	26.2																			45.8
Bryum pseudotriquetrum	5.0	.4	2.5	+							7.6	7.6					.1	.2																			64.6
Funaria hygrometrica	+		+								.1	.1					20.0	.2																			56.3
Marchantia polymorpha	.1		+	+							1.4	.1					7.6	1.4																			56.3
Aulacomnium acuminatum	+	+	+	+							2.5	1.4					1.4	2.5																			70.8
Ceratodon purpureus	+		+	+							.2	.2					7.6	1.4																			58.3
Moss 214	3.4	+	.5	.4							.1	.2					1.4	.2																			72.9
Tomenthypnum nitens	+	+	.9	2.5							.2	.2					.1	1.4																			58.3
Drepanocladus vernicosus	+	2.5	+	+																																	14.6
Cinclidium stygium	+		+	.4																																	8.3
Hylocomium splendens			+								.1	.1					.1	.1																			27.1
Ditrichum flexicaule												.1																									6.3
Paludella squarrosa			+																																		2.1
Calliergon richardsonii	+																																				2.1
Mycophyta																																					
Cladonia spp.											1.2	.1																									12.5
Vascular Plants																																					
Equisetum palustre	2.5	3.0	3.0	22.5																																	20.8
Equisetum arvense	11.2	.2	2.6	+							1.2	.2					2.5	7.6																			70.8
Vaccinium uliginosum	.5	.4	.4	.4							1.2	18.8					1.2	.1																			39.6
Carex aquatilis	2.5	6.3	3.0								1.2																										18.8
Arctostaphylos rubra		+	.4	.4							.1	7.5																									18.8
Equisetum scirpoides	.4	+	+	+							.1	.2					1.4	1.4																			52.1
Ledum groenlandicum		+	+	.4							.1	1.2					.1																				25.0
Salix spp.	+	+	+								1.4						.2																				22.9

REINVASION OF PLOTS BY NATIVE SPECIES

TEST SECTION: III SUBSTRATE: ORGANIC

PLOT	2		3		4		5		6		7		8		9		10		11		12		13		14		15		16		17		18		19		%
SPECIES SUBPLOT	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	Freq.
Potentilla fruticosa				.4								1.2						.1																			14.6
Arctagrostis latifolia	+		+	+							1.2	.1						.1																			25.0
Carex spp.			+	+													.1	1.2																			16.7
Eriophorum spp.				+							1.2						.1																				16.7
Salix glauca												1.2						.1																			12.5
Salix alaxensis	.4																	.1																			8.3
Eriophorum angustifolium	+	.4																																			4.2
Andromeda polifolia	.1	+	+	+													.1																				20.8
Vaccinium vitis-idaea											.1	.1																									12.5
Ledum decumbens																	.1	.1																			12.5
Chamaedaphne calyculata				+													.1																				8.3
Epilobium spp.			+														.1																				8.3
Ranunculus lapponicus			+	+																																	4.2
Stellaria spp.																	.1																				6.3
Achillea borealis			+																																		2.1
Epilobium angustifolium			+																																		2.1
Festuca ovina																	1.2	.1																			12.5
Hordeum jubatum																		.3																			18.8
Phalaris arundinacea																		.1																			6.3
Festuca elatior																	.1																				6.3
Agrostis alba																		.1																			6.3

REINVASION OF PLOTS BY NATIVE SPECIES

TEST SECTION: IV

SUBSTRATE: ORGANIC

PLOT	2		3		4		5		6		7		8		9		10		11		12		13		14		15		16		17		18		19		%
SPECIES SUBPLOT	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	Freq.
Bryophyta																																					
Aulacomnium acuminatum					+	2.6	.2	+	1.0	3.4	1.1	3.0	1.0	1.3	1.0	5.9	1.0	3.4	1.0	4.1	.6	8.0	3.1	15.9	3.1	1.4	3.1	6.3	5.5	5.5	9.3	17.6	7.6	1.3	13.8	5.5	73.1
Leptobryum pyriforme	.1	+	+	+	2.5	.4	2.9	2.5	2.5	6.4	.9	6.7	3.8	5.5	3.4	2.6	7.2	3.4	5.5	7.5	1.0	3.4	3.4	.5	3.0	3.0	1.0	6.3	3.4	1.3	1.7	.9	1.4	.9	3.0	2.9	63.4
Ceratodon purpureus	.5	.2	.1	+			.8	+	.4	.5	.5	.4	.2	3.4	.2	+	.5	1.0	5.5	.5	.5	1.3	3.8	2.5	.5	3.0	5.8	.9	1.0	.5	1.7	.9	3.1	.9	2.9	2.9	46.8
Splachnum sterile	+	+	.4		+	2.5	.4		.4	.4	6.7	.4	.9	3.0	3.4	+	.9	.9	.5		.4	3.0	+		+	.5	+	.5	+	.5	2.6	+	.9	1.2	3.0	+	36.6
Moss 214	.4	+	5.0	6.2	2.9	.4	.4	+	.4	.4	.5	.5	.1	.5	1.8	.5	.5	+	+	1.0	.6	.1	.5	.5	.5	.1	.9	+	.5	.9	.9	+	.5	+	.2	+	47.2
Marchantia polymorpha		+	+			+	+	.4	+	+	.4	.1	+	.5	.5	+	.5	.5	.8	.6	.2	.6	3.0	+	2.7	1.3	1.3	1.0	3.4	3.4	2.1	.6	.9	.9	.5	+	51.9
Funaria hygrometrica	+	+	+		+	.4	+	+	.4	.4	.4	2.5	2.6	3.0	.6	2.5	.9	.9	3.0	3.0	.4	.2	.4			.4	+	.5	+	.1	.1	+	.5	.5	.4	.4	35.2
Tomenthypnum nitens							+	+	+	+	.1	.5	+	.6	.2	.2		2.7	.5	3.4	.1	1.0	3.4	.4	.1	3.4	.9	6.3	1.3	2.6	.5	.4	+	+	.1	+	43.5
Hylocomium splendens	.1	+	+	.2	.1	.2	.2	+	.9	.6	.2	.6	.2	1.3	.6	.5	.5	.9	.5	.9	.2	.9	.9	.5	+	.2	+	.2	.9	.6	3.0	+	.5	.6	1.3	.9	64.4
Bryum pseudotriquetrum	.1	+	.4	+			+	+	.1	.1	.2	+	.1	.2	.6	+	.2	.2	1.2	.6	.2	.2	1.0	.1	.6	.2	1.0	.5	2.7	1.2	.2	.1	.2	1.0	.5	.1	57.4
Sphagnum spp													+		+	.4			+	+	+	1.3	.5	+		.1	+	+	.9	+		+	+		+	+	16.7
Drepanocladus fluitans																			.4			+	2.5		+	+		+									3.7
Ditrichum flexicaule									+	+		.4	+	+	+	.5	+		+	+		+	.5	+				+			+			+	+	+	12.5
Polytrichum juniperinum																			+	+	+	+		+				+						+			4.2
Cinclidium stygium																			.1				+				+	+									3.2
Calliergon richardsonii																			+							+											0.9
Drepanocladus vernicosus																									+												0.5
Meesea trifaria																			+																		0.5
Mycophyta																																					
Cladonia spp.						+		+	+	.9	.4	.5	+	2.5	+	.9									+								+	+	3.0		13.4
Peltigera spp.										+	+	.4	+	+	.2	+		.4	+	+	+		+						+					+	+		11.1
Cetraria nivalis															+																						0.5
Vascular Plants																																					
Equisetum arvense													+	+	+	.5	6.3	6.3	.2	.5	+	10.5	3.0	6.7	.9	.9	+	2.5	.5	8.8	6.7	.4	2.5			+	25.9
Vaccinium uliginosum					2.5	.4	2.6	.5	1.3	.3	.9	3.0	1.3	1.7	.4	.9	.5	.9	+	3.4	.1	.9	3.4	3.0	.2	.5	.9	1.0	.2	.4	.5	.5	3.4	.9	3.8	.5	53.7
Arctostaphylos rubra					.4	2.5	.4	.4	2.5	1.7	1.2	7.1	1.7	3.3	7.1	.9	.8	2.9	.4	+	.4	+	.8	+					+				.4		.5	.4	24.5

REINVASION OF PLOTS BY NATIVE SPECIES

TEST SECTION: IV SUBSTRATE: ORGANIC

PLOT	2		3		4		5		6		7		8		9		10		11		12		13		14		15		16		17		18		19		%
SPECIES SUBPLOT	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	Freq.
Arctagrostis latifolia						.4	+			+	+	.5	1.0		+	+	.2	.2	.4	.5		.4	.5	6.7	.4		.5	1.3	3.4	6.7	.8	.6	.9	.5	3.4	.9	37.0
Ledum groenlandicum			.4	.4	.9	.1	.1	.8	.5	.2	.8	.9	1.0	1.3	.5	1.2	.9	.5	+	+	.5	.9	.4	.4	+	.4	.5	.1	+	+	.5	+	2.5	.4	1.3	1.3	39.8
Equisetum scirpoides		+	+	.1	.5	.2	.2	.6	.2	3.0	1.0	.9	1.8	3.8	.9	.9	.6	.6	+	.1	+	.5	.2	.5		+	.1	.8	.2	.1	.1	.4	.1	.6	.2	.2	62.5
Carex vaginata																															3.0	10.8	.4	3.0			4.2
Chamaedaphne calyculata								+	.4				+	.4	.9	.9	.1	.9	.9	3.0	.5	.5	1.0	.6	+	.1	.2	.6	.4	.1	+	+	.4	+	1.0	.2	38.4
Rubus chamaemorus									.4	+	.9	+	.9	2.6	1.2	1.3	.4	.4	.4	.1	.5		.4	.4			.4	.4	+	+	.1	+		+	+	.4	22.2
Vaccinium vitis-idaea	.4	+	.4	.5	2.5	+	+	.4	1.3	.1	.4	+	.1	.1	+	.4	.4	+		+	+	.1	+	.4	+	.4	.4	+			.4	+	+	+	.5	.2	29.2
Eriophorum spp.																			.4	+				.4	2.9		+	+		3.0			.4	2.5	.4		7.4
Andromeda polifolia													+	.4	.5	.9	+	.1	.9	.4	+	.9	.6	+	.4		.1	.2	.2	+	.2	+	.4	+	.2	.5	29.6
Equisetum silvaticum													+	+	+	+	.6	.4	.2	1.3	.2	.6	.4	+		.4	+	.1	+	.1	.9	.1	.5	+	.2	.4	28.7
Salix spp.				+		+							.4	+	+		+	+	.4	.1	+	+	.4		.2	1.0	1.0	.1	.5	.4	.4	+	+				17.1
Carex spp.						+	+	.5	.4	.4		.9	.1	.5	+				+	+					.4					.4							11.6
CRUCIFERAE															+						+		.4	.4	1.3	.1	.4	+	+	.4	.4	+	+				10.6
Alnus crispa					2.4																	+		.4					+								1.9
Ranunculus lapponicus							+	+			+	+	+	+	+		+	+	+	+			+	+	+			+		.4	.4				+	.4	15.3
Rosa acicularis				+	+		.4								.4		+		+															.4	.4		3.7
Salix alaxensis														+		+	+	+				+	.4	+	+			.4	.1	.4	+		+				8.8
Potentilla fruticosa																	.4			.8																	1.4
Epilobium angustifolium			.8														+	+							+	+					+						4.2
Equisetum palustre																			.9	+																	2.3
Potentilla spp.																																			.5	.4	2.3
Salix glauca							+						.4	.4																							1.4
Populus tremuloides																	+										+		.2	.4			+				1.4
Betula papyrifera						+	+		+		+	+			+	+	+		+	+		+							+	+	+				+		8.3
Calamagrostis lapponica																	+	.4							+	+	+	+			+						3.7
Empetrum nigrum											.4					+						+															1.9

REINVASION OF PLOTS BY NATIVE SPECIES

TEST SECTION: IV SUBSTRATE: ORGANIC

PLOT	2		3		4		5		6		7		8		9		10		11		12		13		14		15		16		17		18		19		%
SPECIES SUBPLOT	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	Freq.
Senecio congestus							+																							+	.4						1.4
Epilobium spp.												+	+							+			+	+	+	+			+		+						6.0
Carex aquatilis																													.4								0.5
Eriophorum angustifolium																															.4						0.5
Smilacina trifolia																									+		+	.2									3.2
Achillea borealis			.1	+											+																						2.3
Picea mariana																				+											+				+		1.9
Betula glandulosa																						+			+												0.5
Oxyoccus microcarpus																											+		+								0.9
Geocaulon lividum															+	+																					0.9
ORCHIDACEAE															+	+																					0.9
Sparganium spp.																											+										0.5
COMPOSITAE																																				+	0.5
Stellaria spp.						+																															0.5
Pyrola secunda														+																							0.5
Pedicularis spp.																	+																				0.5
Agrostis alba															1.8	.9																					4.6
Festuca rubra			.4	+																																	2.3
Agrostis tenuis																												.4	+								0.9

APPENDIX "B"

LEGEND

GROUND SURFACE

PERMAFROST TABLE — SEPT. 21, 1972

SCALES

VERTICAL 0 50 100 CENTIMETRES

HORIZONTAL 0 5 METRES

NOTES

PR-B — ALONG CENTRE LINE OF PIPE

PR-A & PR-C — 5 METRES FROM ℄ & PARALLEL TO PROFILE B

PR-D, E & F — PERPENDICULAR TO PR-A, B & C

DESIGNED BY:	NORTHERN ENGINEERING SERVICES LIMITED CALGARY ALBERTA ENGINEERS FOR CANADIAN ARCTIC GAS STUDY LTD.	
DRAWN BY:		
CHECKED BY:		SCALE:
ENGINEERS APP:	GROUND SURFACE AND PERMAFROST TABLE PROFILES OVER TEST SECTION II AT THE SANS SAULT TEST FACILITY	DATE PROJECT No.
PROJECT MANAGER		DRAWING No. PROFILE B-1 - B REV.

DESIGNED BY:	NORTHERN ENGINEERING SERVICES LIMITED CALGARY ALBERTA ENGINEERS FOR **CANADIAN ARCTIC GAS STUDY LTD.**	
DRAWN BY:		
CHECKED BY:		SCALE:
ENGINEERS APP:	GROUND SURFACE AND PERMAFROST PROFILES ON TEST SECTION V AT THE SANS SAULT TEST FACILITY	DATE:
PROJECT MANAGER:		PROJECT No.
		DRAWING No. PROFILE B2-B / REV.