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Reconnaissance of Vegetation and Soils along the Dempster Highway, Yukon Territory: II. Soil Properties as Related to Revegetation

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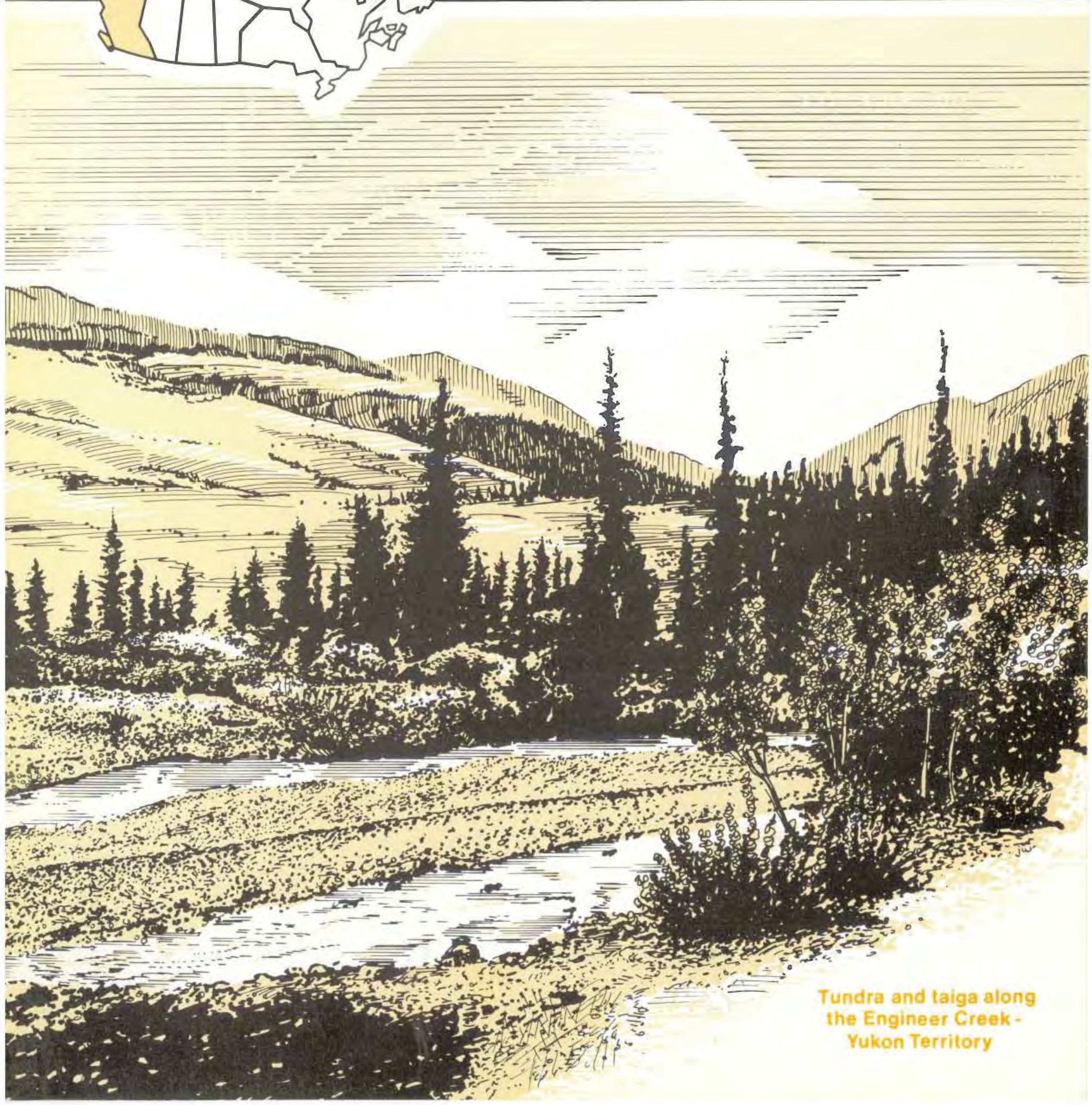
BC-X-236



Tundra and taiga along the Engineer Creek - Yukon Territory

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RECONNAISSANCE OF VEGETATION AND SOILS ALONG THE DEMPSTER HIGHWAY, YUKON TERRITORY: II. SOIL PROPERTIES AS RELATED TO REVEGETATION

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Abstract

This report complements the reconnaissance of vegetation (Stanek *et al.* 1981) along 450 km of the Dempster Highway from North Fork Pass in the Ogilvie Mountains, Yukon Territory, to the Peel River, Northwest Territories.

The pH and content of major nutrient elements (N, P, K, Ca, and Mg) were determined on soil samples collected from 100 plots along the Dempster Highway in the Yukon Territory. Information was obtained on depth to permafrost in September, generic soil types, thickness of the organic horizons, and slope.

The survey indicated that mainly Static and Turbic Cryosols, intermixed with Regosols and sporadic Brunisols, occur in this area. The mapping at a scale of 1:250,000 utilized three major groups of soils according to the pH of their organic layers.

The report contains data on some soil properties as related to vegetation and is aimed primarily at providing information for revegetation projects and ecological inventories.

Resumé

Le présent rapport complète les travaux de reconnaissance de la couverture végétale (Stanek *et al.* 1981) effectués sur une distance de 450 km le long de la route de Dempster, entre le col North Fork dans les monts Ogilvie, au Yukon, et la rivière Peel, dans les Territoires du Nord-Ouest.

On a déterminé le pH et la teneur en éléments nutritifs majeurs (N, P, K, Ca, et Mg) d'échantillons de sols prélevés dans 100 placettes. On a recueilli des informations sur l'épaisseur de la couche active en septembre, les types de sols, l'épaisseur des horizons organiques et la pente.

Les sols de cette région sont surtout des cryosols stables et turbiques entremêlés de régosols et de brunisols sporadiques. Pour la cartographie à 1:250 000, on les a divisés en trois groupes principaux d'après le pH de leur couche organique.

La rapport contient des données sur certaines propriétés des sols relatives à la couverture végétale, et son but principal est de fournir des renseignements pouvant servir à la végétalisation et aux inventaires écologiques.

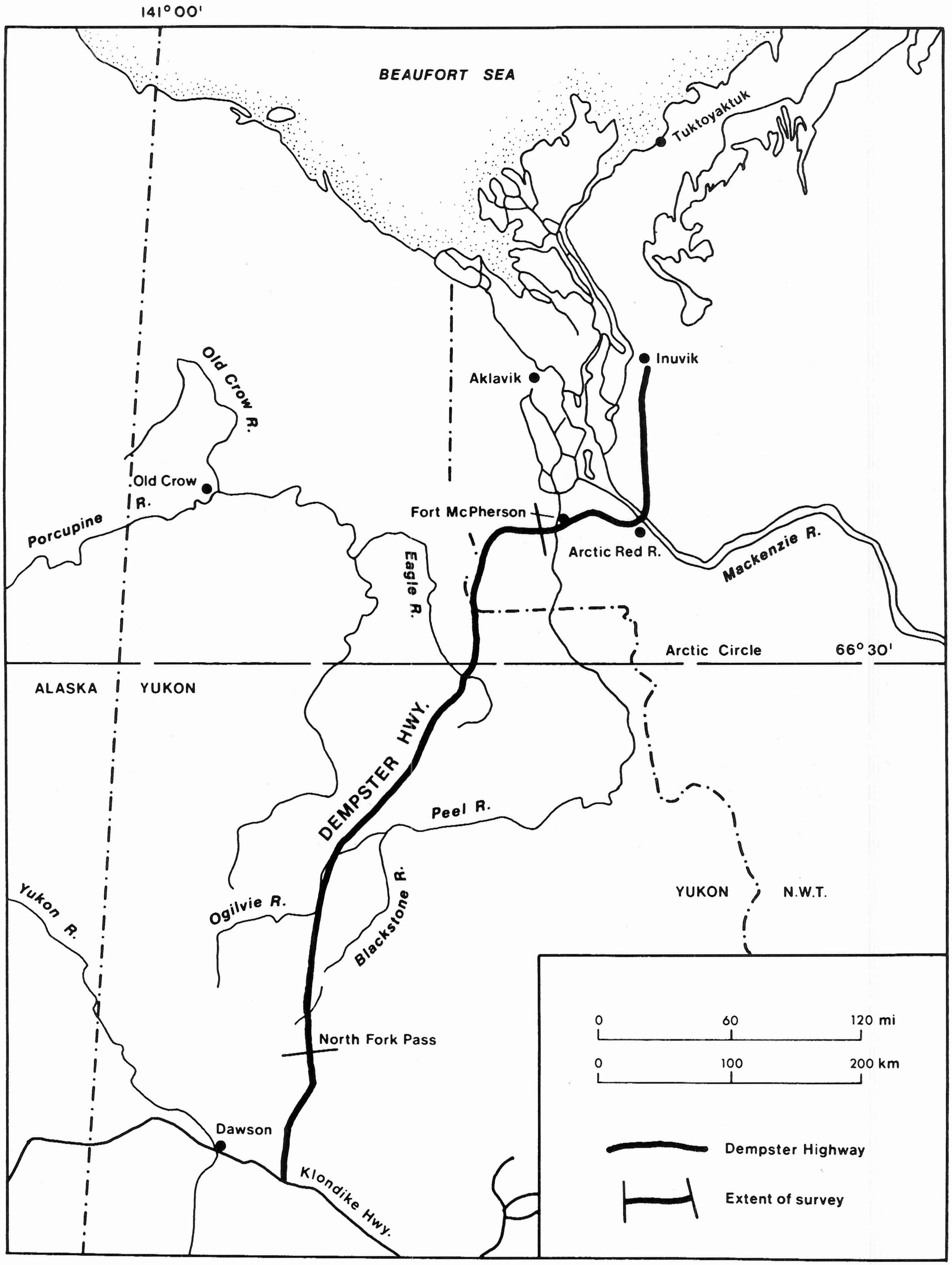


Figure 1. Map showing the surveyed part of the Dempster Highway from North Fork Pass to Peel River.

● Rock River Valley west of Richardson Mountains. The gas pipeline will cross this terrain from left background to the right middle ground. The gently sloping flatlands support tussock sedge tundra with extremely acid soils and shallow active layer.

Introduction

In July 1979, Foothills Pipe Lines (Yukon) Ltd. (henceforth referred to as the Proponent) filed plans with the National Energy Board to construct and operate a 1200 km lateral gas pipeline from the Mackenzie Delta, Northwest Territories (NWT), to a point near Whitehorse, Yukon Territory (YT). The results of a reconnaissance of vegetation along the Dempster Highway were published (Stanek *et al.* 1981). This report is concerned with revegetation aspects of soils occurring along the proposed pipeline route from North Fork Pass to Peel River (Fig. 1). In this area, the general ecology has been reported on (Oswald and Senyk 1977); however, little information on soils is available.

Although most of the surrounding area has been glaciated at some time, the North Ogilvie Mountains, the Eagle Plain, and the western slopes of the Richardson Mountains show little evidence of glaciation (Ricker 1968, Hughes 1972).

From the North Fork Pass to the arctic circle, the pipeline route lies within the zone of widespread discontinuous permafrost and a little north from there, at about the YT/NWT border, the zone of continuous permafrost (Brown 1970).

To prevent thermokarst formation as much as possible, excavation and pipe laying will take place during the winter months. Surface restoration methods proposed for much of the Dempster section of the pipeline are designed to protect permafrost from thawing and to provide a suitable seedbed (Foothills 1979). For those reasons, the topsoil of mainly organic material will be stockpiled and used as capping of the ditch backfill.

The objectives of this report are to identify soil properties as they could relate to revegetation of the surveyed section of the pipeline right-of-way and to complete the vegetation and soil survey of that area begun by the reconnaissance of vegetation (Stanek *et al.* 1981).

Methods

Sample collection was undertaken during the latter part of August and the beginning of September 1979, along the Dempster Highway from North Fork Pass, YT (64^o 30'N, 138^o 15'W) to the Peel River, NWT (67^o 22'N, 134^o 55'W), a distance of 450 km (Fig. 1).

A total of 100 plots, 20 m in radius and located about 50 m from the highway, were surveyed and are the sample plots that were used in the vegetation survey (Stanek *et al.* 1981). In each plot, soil samples from four randomly located subplots were taken. Depth to frozen ground up to 1 m was measured. In this report, permafrost is termed frozen ground persisting into September in a layer that could not be penetrated by hand drilling 10 cm deep. Frequently, the presence of permafrost was verified from drill-hole records reported by Klohn Leonoff 1978.

Soil types are according to the Canada Soil Survey Committee (1978) and were determined using existing natural and man-made profile exposures and soil auger drillings. Separate composite samples were taken of both the organic and mineral horizons to a total depth of 50 cm, soil texture and frozen ground permitting.

Organic samples were ground in a Wiley Mill using a 2 mm sieve. Mineral samples were passed through a 2 mm sieve. In total, 732 soil samples were analyzed.

The pH was determined using a 1:1 slurry of 0.01N $CaC1_2$ solution. The corresponding terms used for ranges in pH (according to U.S.D.A. 1951) are as follows: extremely acid (pH below 4.5), very strongly acid (pH 4.5 to 5.0), strongly acid (pH 5.1 to 5.5), medium acid (pH 5.6 to 6.0), slightly acid (pH 6.1 to 6.5), and neutral (pH 6.6 to 7.3). In general, the methods of chemical analysis follow those in Black *et al.* (1965).

The organic soils were digested with nitric-perchloric acid to determine total potassium, calcium, magnesium, and phosphorus. The exchangeable potassium, calcium, and magnesium of the mineral soil were extracted with neutral normal ammonium acetate in a 1:10 soil solution ratio. The exchangeable phosphorus was extracted with 0.03N ammonium

• Shallow rendzina-like soil over Carboniferous fossil bearing limestone (probably Hart River Formation) on the Eagle Plain.

fluoride plus 0.025N hydrochloric acid in a 1:10 soil solution ratio (standard Bray-P1 method). Total nitrogen contents were determined by the standard Kjeldahl method. In addition, organic matter carbon of twenty selected soils was determined by the Walkley-Black method; pH of 27 selected sites was determined in the field by the same method as used in the laboratory.

Sum-of-squares clustering (Orloci 1978, Sneath 1957) grouped the soils into similar types using 12 variables: organic soil pH and total nitrogen, potassium, calcium, magnesium, and phosphorus; mineral soil pH and total nitrogen and exchangeable potassium, calcium, magnesium, and phosphorus. Where shown, the depth to frozen ground (permafrost), organic layer thickness, and slope class are mean values.

• Drunken forest caused by Dempster Highway construction in sloping terrain with ice-rich permafrost. The thaw causes collapse of the soil. The slumped permafrost-free portions are colonized by vegetation dominated by willows.

• Foothills of Richardson Mountains. The pipeline will traverse close to the highway. The area is within the continuous permafrost zone and the soils are mainly extremely acid, Regosolic and Brunisolic Static Cryosols.

Results

Based on the presence or absence of an organic horizon (L, F, H, or O), three broad groups of soils (clusters G_1 to G_3 in Table 1) are differentiated:

G_1: Peats consisting only of organic matter (O-layer). In all these cases, the mineral soil material is either inaccessible or permanently frozen (see "Control Section" in Canada Soil Survey Committee 1978).

G_2: Soils consisting of only mineral materials. The soil profile does not have L, F, H, or O horizons.

G_3: Soils consisting of both the organic horizon (L, F, H) and the mineral horizons.

Further cluster analysis reveals more meaningful branches termed E-clusters (70% classification efficiency) in the dendrogram (Fig. 2). Table 2 identifies the plots contained in each E-cluster. Table 3 holds the relevant data.

Cluster G_1 contains E_1 of three plots and E_2 of a single plot consisting of organic soils (peats). The two clusters differ mainly in that E_1 has a higher pH (5.8 in contrast to 4.4) and a higher total calcium content (2.1 in contrast to 0.9). Coincidental with these are other differences which should be re-examined in the light of more representative samples.

Cluster G_2 contains E_3 of four plots and E_4 of ten plots; all are Regosols and lack any recoverable organic horizons. The main difference is that E_3 has a lower mineral soil pH than E_4 (pH 3.7 in contrast to 6.6), lower exchangeable calcium contents (0.04% in contrast to 0.27%), and 90% of the E_4 plots are without permafrost. Most of these latter samples stem from alluvial sites near active streams.

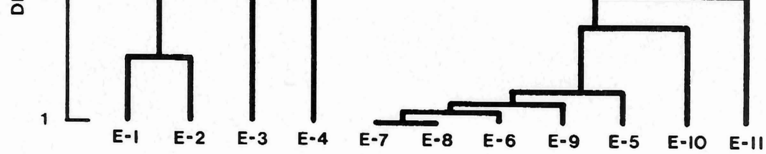


Figure 2. Dendrogram showing hierarchical relationships of E-clusters and G-clusters. The analysis is Single Link Clustering. The data include 100 plots and 12 soil chemical variables. Vertical scale indicates fusion distance. The plots contained in the E-clusters are listed in Table 2.

Table 1. Mean values ($\overline{X}$) in % of ovendry weight and standard deviations of the mean (S) for ratio variables within G-clusters.

Cluster		G_1		G_2		G_3	
Variable		$\overline{X}$	S	$\overline{X}$	S	$\overline{X}$	S
Organic	N	1.16	0.072	A		0.98	0.032
	P	0.14	0.021	B		0.12	0.004
	Ca	1.77	0.322	S		0.89	0.120
	Mg	0.43	0.126	E		0.27	0.033
	K	0.27	0.056	N		0.29	0.023
	pH	5.4	0.4	T		4.1	0.1
Mineral	N	A		0.18	0.019	0.33	0.024
	P	B		0.00	0.000	0.00	0.000
	Ca	S		0.20	0.030	0.17	0.020
	Mg	E		0.03	0.000	0.02	0.002
	K	N		0.00	0.000	0.00	0.000
	pH	T		5.7	0.4	4.5	0.1

Table 2. Identification and totals of plots in E-clusters (Fig. 2).

E_1	E_2	E_3	E_4	E_5	E_6		E_7		E_8	E_9	E_{10}	E_{11}
70	69	20	58	68	67	94	10	23	96	22	31	73
35	1	19	29	55	64	93	43	6	95	1	1	1
33		37	85	2	2	30	54	90	92			
3		53	56			83	28	87	66			
		4	26			82	46	57	25			
			76			86	44	52	63			
			89			75	42	49	61			
			88			98	74	97	62			
			91			18	16	34	60			
			41			11	15	3	80			
			10			14	50	48	65			
						39	38	21	71			
						7	5	79	59			
						9	2	84	78			
						17	36	24	81			
						45	4	99	77			
						8	1	72	100			
						12	40	51	32			
								47	27			
								13	19			
								56				

Table 3. Description of E-clusters based on determined variables. Means ($\overline{X}$) and standard deviations (S) are given. The values for N of mineral soil and N, P, Ca, Mg and K for the organic layers are total contents in % of dry weight; those for P, Ca, Mg and K of mineral soil are exchangeable cations in ppm.

	E_1		E_2	E_3		E_4		E_5		E_6		E_7		E_8		E_9	E_{10}	E_{11}
Variable	$\overline{X}$	S	$\overline{X}$	$\overline{X}$	S	$\overline{X}$	S	$\overline{X}$	S	$\overline{X}$	S	$\overline{X}$	S	$\overline{X}$	S	$\overline{X}$	$\overline{X}$	$\overline{X}$
Organic layer																		
N	1.15	0.101	1.17	-------	---------	--------	---------	0.82	0.096	1.41	0.056	0.91	0.031	1.41	0.052	2.16	0.62	0.44
P	0.15	0.028	0.12	-------	---------	--------	---------	0.13	0.010	0.09	0.007	0.12	0.004	0.10	0.005	0.21	0.13	0.24
Ca	2.05	0.204	0.91	-------	---------	--------	---------	2.65	0.028	3.38	0.302	0.30	0.025	1.77	0.141	0.06	4.38	5.54
Mg	0.50	0.149	0.22	-------	---------	--------	---------	0.96	0.029	0.18	0.002	0.19	0.014	0.32	0.027	0.05	0.89	2.46
K	0.25	0.078	0.31	-------	---------	--------	---------	0.36	0.049	0.11	0.011	0.33	0.031	0.19	0.025	0.18	0.61	0.43
pH	5.8	0.232	4.4	-------	---------	--------	---------	6.5	0.000	6.5	0.100	3.5	0.053	5.2	0.108	3.2	6.5	5.9
Mineral soil																		
N	-------	---------	-------	0.19	0.039	0.17	0.022	0.18	0.020	1.00	0.035	0.30	0.028	0.35	0.036	0.32	0.32	0.19
P	-------	---------	-------	4	0.000	3	0.000	4	0.000	2	0.000	9	0.000	4	0.000	4	1	4
Ca	-------	---------	-------	404	0.007	2660	0.026	3030	0.042	7426	0.118	721	0.008	3613	0.000	86	3470	3147
Mg	-------	---------	-------	195	0.004	273	0.003	269	0.002	221	0.004	181	0.002	432	0.036	30	81	230
K	-------	---------	-------	119	0.004	25	0.000	22	0.000	14	0.000	57	0.000	24	0.000	9	18	12
pH	-------	---------	-------	3.70	0.054	6.60	0.151	7.00	0.050	6.40	0.204	3.80	0.055	5.90	0.156	3.50	7.00	7.20
Average depth (cm) to frozen ground	41	41	33	63	9	NP[1]	0	65	10	68	8	47[2]	5	51[3]	10	40	NP	NP
Organic layer thickness (cm)	59	21	33	0	0	0	0	22	16	40	0	13	1	25	3	25	17	5
Slope Class[4]	3	1	1	6	1	1	0	1	0	8	1	4	0	4	1	4	4	1
E-group size	3		1	4		10		2		2		56		19		1	1	1

NP — No Permafrost.

1 Except 1 plot with permafrost at 75 cm.

2 Except 9 plots with permafrost at below 1 m and 2 plots without permafrost.

3 Except 5 plots where no permafrost was detected at 1 m.

4 Slope Classification:

level.	1	strong slopes.	6
nearly level.	2	very strong slopes . .	7
very gentle slopes . .	3	extreme slopes. . . .	8
gentle slopes	4	steep slopes	9
moderate slopes . . .	5	very steep slopes . .	10

Cluster G_3 contains soil profile with both organic (L, F, H) and mineral soil horizons. E_7 makes up a dense core of 56 plots and 19 plots constitute E_8. In contrast to E_8, E_7 has a lower pH (pH 3.8 as compared with 6.0), lower contents of calcium, and also a lower organic N content.

The remaining E-clusters (E_5, E_6, E_9, E_{10}, E_{11}) contain outlier plots which tend to represent distinct conditions and therefore are retained in the descriptions, although further sampling would be necessary to show their representativeness.

Scrutiny of Table 3 reveals that pH is related to calcium content (total and exchangeable); the relationship of the remaining nutrient element contents to pH is less apparent, but in general, the higher nutrient element contents tend to be associated with the higher pH values. These relationships would merit a separate study.

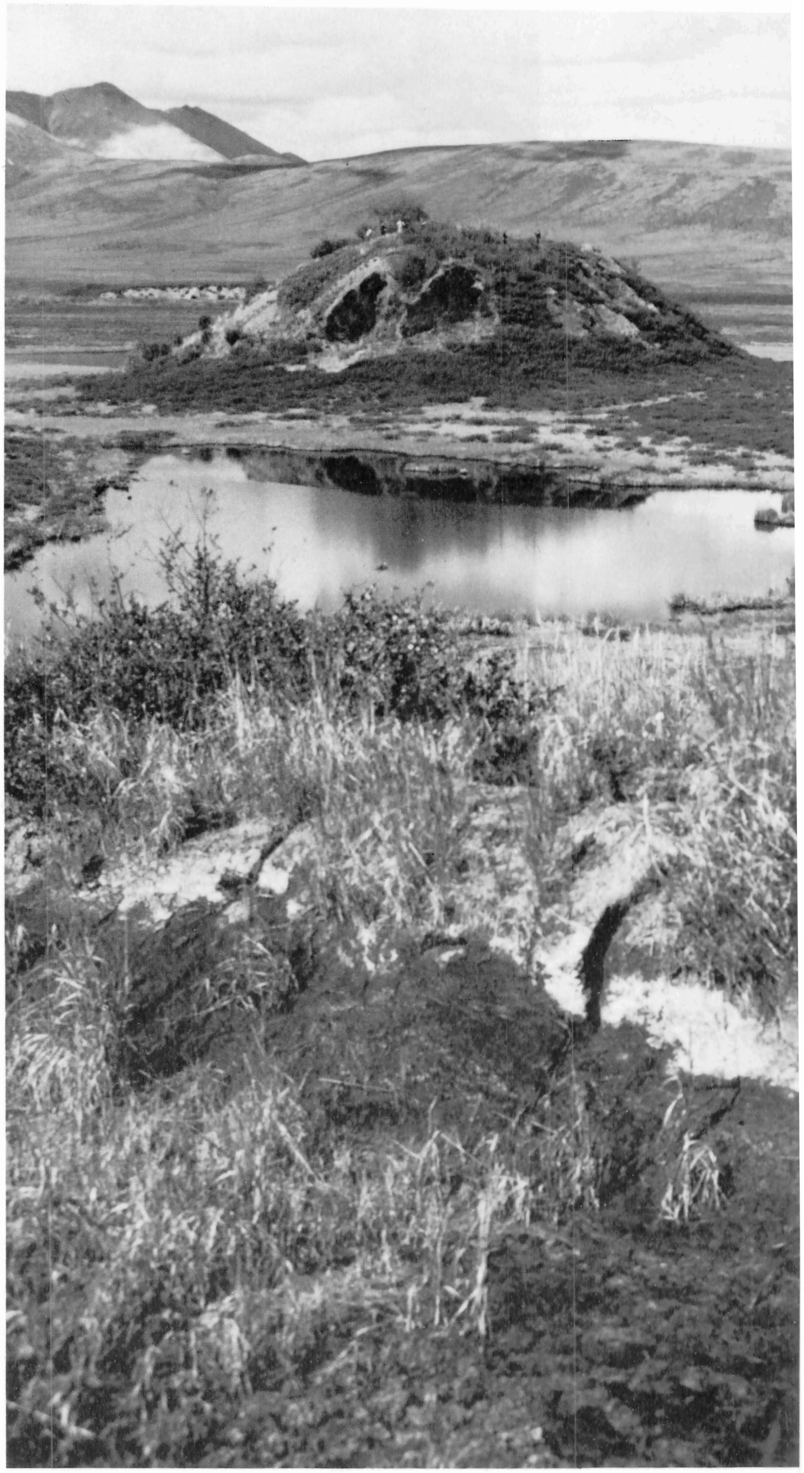
The carbon content and the C/N ratio of 14 organic samples are shown in Table 4. It appears that the pH and the C/N ratio are reciprocally related. At the lowest pH of 3.2, the C/N ratio is 55; at the highest pH of 6.5, the C/N ratio is 19 and 23. This relationship is perhaps more than coincidental and should be investigated further.

The soils identified during the survey are according to nomenclature of the Canadian Soil Survey Committee (1978).

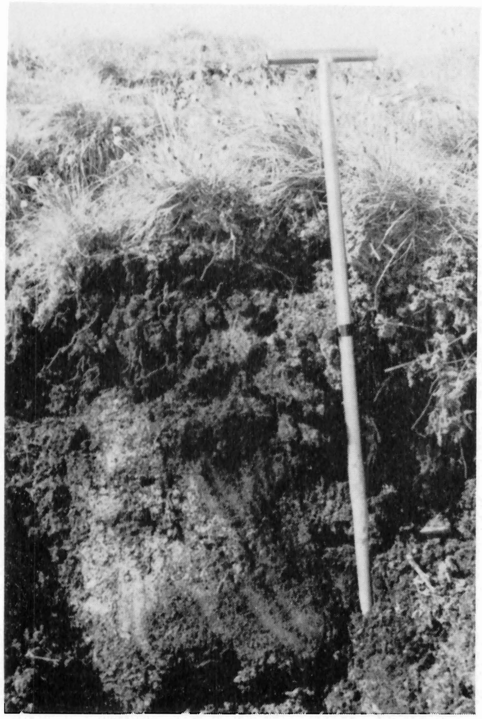
Brunisols are few but they occur in well-drained sandy soils in sunny, relatively warm locations.

Cryosols represent the majority of the surveyed soils, most of them with an active layer less than 1 m thick. The peatlands always contained permafrost and are included among the Cryosols. In fine-textured soils in moist or wet locations, permafrost is ice-rich, and cryoturbation causes the formation of polygons, sorted and nonsorted circles, and occasionally even pingos develop. Elsewhere permafrost gives rise to extensive hummock and tussock fields.

In the surveyed area, Gleysols as such are not common, but gleying occurs frequently as a characteristic of the other soil orders. South of the limits of continuous permafrost, in our case the NWT/YT border, the streambeds and the immediate vicinity of the streambeds are permafrost-free and Regosols prevail.



● Organic soils (peats) are usually associated with wet terrain. In the foreground is typical peat (apparently mesic organic cryosol). The rising topography in the foreground would indicate that perhaps a new pingo, such as the one shown in the background, is beginning to develop. For size comparison, note the human figures on top of the pingo.



• Turbic Cryosol on the Eagle Plain. A wedge of hard ice formed in gleyed, silty soil is protected from thawing by a mat of peat under Eriophorum tussocks.

Table 4. C/N ratio, content of carbon and nitrogen in % of dry weight, cation exchange capacity (C.E.C.) in milliequivalents per 100 g of dry weight, pH and E-groups (see Table 3) of the organic material (F, L, H or O layers) of selected samples.

Plot No.	E-group	pH	C	N	C/N	C.E.C.
10	7	3.2	30.78	.56	55	106
52	7	3.3	22.14	.80	28	130
94	7	3.6	34.08	1.27	27	------
28	7	3.3	32.97	.81	41	107
98	7	3.9	19.44	.68	29	------
66	8	4.5	35.74	1.36	26	158
25	8	4.8	25.15	.99	25	100
96	8	5.4	33.36	1.15	29	150
70	1	6.2	10.09	.52	19	------
33	1	5.8	31.76	1.57	20	------
35	1	5.4	25.70	1.07	24	------
55	5	6.5	14.61	.79	19	75
67	6	6.4	29.06	1.55	19	172
31	10	6.5	18.69	.82	23	81

Mapping and Description of the Mapped Corridor

It appears that pH is a good criterion for differentiating and mapping of the soils for purposes of revegetation. Generally, pH is related to the availability of several plant nutrients and the activity of soil organisms. It is also a measure of the intensity of the acidity and provides the basis for predicting the lime needs of acid soils (U.S.D.A. 1951) and strongly affects natural species composition and plant growth. The geological makeup of the parent materials obviously affects the pH values of the soils. For example, where shales, siltstones, and sandstones surface in the Eagle Plains (Canada Geolog. Survey 1981) or schists occur in the North Fork Pass (Ricker 1968), the soils are generally extremely acid; in terrain with limestone or dolomitic formations of the Central Ogilvies, the soils are slightly acid to neutral.

From projects similar in scope to the one in question here (Foothills 1981), one may deduce that the Proponent will stockpile the topsoil for revegetation purposes. Obviously, the organic layers of the natural soils will make up most of that topsoil. Because the data in Table 3 provide information on the properties of the "in situ" soils, of which the organic layers are an integral part, they can be used to infer the properties of the stockpiled topsoil. A simple map showing the extent along the pipeline corridor of organic layers with characteristic pH ranges, which in turn relate to soil properties, should significantly enhance planning, execution, and ultimately the success of revegetation measures.

Based on pH of the organic layer, the investigated soils fall into three mapping groups (compare pH of E-groups in Table 3):

Extremely acid soils—pH below 4.5. These are the most common soils of the survey. They are represented by E_7 and E_9; the Regosols E_3 and the peat E_2 are included here—in total, 62 plots.

Strong to medium acid soils—pH 5.1 to 6.0. These are the second-most common soils of the survey. They are represented by E_8 and the peat E_1,—in total, 22 plots.

● Sea of stones located in the Richardson Mountains north of the Yukon-Northwest Territory border. The rocks have been sorted by permafrost.

● Tombstone Range and the source of the North Klondike River viewed from the North Fork Pass.

Slightly acid soils--pH 6.1 to 6.5. These soils are the least common among the surveyed soils. They are represented by E_5, E_6, and E_{10}. The Regosol E_4 is included here. There are 15 plots in this group.

The three major pH groups are used in mapping of large representative and, at the same time, meaningful units. The mapping is done on four map sheets (3 to 6) at a mapping scale 1:250 000 (1 cm = 2.5 km).

A corridor 6 km wide, centered on the proposed gas pipeline route (Foothills 1979), is mapped. Mountains (montane slopes) within the corridor were not surveyed. The description of the mapped corridor proceeds in sections defined by the distance in miles given on the map sheets (as provided by the Proponent).

Mile 420 to About Mile 390

(Map Sheet 6)

At the North Fork Pass, the proposed pipeline route passes over bedrock and materials of Precambrian quarzite and schists and in the broad valley of the East Blackstone River traverses morainic materials (Ricker 1968) to about 10 km north of Chapman Lake.

The majority of the soils are extremely acid. Along the highway in the North Fork Pass, mainly shallow Regosols or bedrock occur; the surveyed plots appear to be without permafrost (see drill log, Klohn Leonoff 1978). Along the southern portion of the East Blackstone River valley and around Chapman Lake, Turbic Cryosols prevail with pockets of Organic Cryosols. The areas of slightly acid Regosols and Gleysols (see E_4 in Table 3) found on floodplains of the East Blackstone and Blackstone rivers, and the seepage slopes east of the highway just north of North Fork Pass with moderately acid Gleyed Regosols (see E_8, Table 3) are too small for mapping.

In the North Fork Pass, the average organic layer is 5 cm thick, except along seepage slopes and the valley bottom where thicker organic horizons do build up. In the East Blackstone River Valley, the organic horizons are in average 20 to 25 cm deep, but small peatlands occur frequently in the flat or depressed portion of the valley.

Mile 390 to About Mile 325

(Map Sheet 6 and 5)

The proposed route follows the Blackstone River for about 19 km and, at that point, deviates up to 20 km from the highway. Through the Soldier Creek valley, the route approaches the highway again and then winds north through the Central Ogilvie Mountains of Devonian limestone (Ricker 1968) and along the Ogilvie River valley to pipeline mile 325, where the route crosses the river.

Medium acid Cryosols (E_8 in Table 3) are common, except in the Central Ogilvie Mountains where the soils are slightly acid Cryosols (E_5 and E_6). In the Soldier Creek valley and in the broad Ogilvie River valley, the route traverses terrain with tussock tundra and polygon fields and presumably strongly acid Cryosols (E_7).

Along the floodplain of the Ogilvie River, peatlands (E_1, E_2) and sites with neutral Gleyed Regosols (E_{11}) and slightly acid Regosols (E_4) were not mapped, because of small size.

The area where the proposed pipeline route passes through the Soldier Creek valley was not surveyed, but data from apparently similar soils along the Engineer Creek make it permissible to infer that the soils belong to E_8 and E_7.

Mile 325 to About Mile 220

(Map Sheet 5, 4, and 3)

Leaving the Ogilvie River valley, the proposed pipeline route ascends to the Eagle Plain, crosses the Dempster Highway and traverses more directly than the highway toward the Richardson Mountains at the YT/NWT border.

The Eagle Plain consists of Jurassic, Devonian, and Cretaceous sandstones, siltstones, and shales (Canada Geological Survey 1981). With the exception of few limestone outcrops, the soils are extremely acid (E_7). Along the floodplains of the Eagle and Rock rivers and some of the creeks, there are slightly acid soils similar to E_4, E_5, and E_6.

The soil types of the Eagle Plain are mainly Turbic Cryosols with frequently occurring nonsorted and sorted circles. In locations with well-drained soils, Brunisols occur. In depressions, there are pockets of Organic Cryosols.

Mile 220 to About Mile 200

(Map Sheet 3)

The proposed pipeline route traverses the Richardson Mountains almost parallel to the Dempster Highway. From the YT/NWT border, the pipeline descends gradually and follows elevations ranging from 900 to 300 m with cross-slope gradients of 10 to 30% (Komex 1979).

The soils are predominantly extremely acid and Cryosols prevail. Regosols form on lower slopes. Sparse tundra vegetation, exposed bedrock, and scree-covered slopes are common. In areas where snow lies late into the summer, vegetation communities occur along the drainage runnels on gleyed permafrost soils.

Mile 200 to Mile 177 at the Peel River Crossing

Across the eastern foothills of the Richardson Mountains, the proposed pipeline route generally follows the Dempster Highway, traversing a landscape of rolling hills (310 to 500 m a.s.l.), many small lakes, streams, and creeks, and descends to approximately sea level at the Peel River. In general, the soils surveyed in this section are extremely acid.

Though Static and Turbic Cryosols prevail, Brunisols and Gleysols and small, mainly topogenic, generally shallow peat deposits occur along the route.

Discussion

The proposed pipeline route generally follows the Dempster Highway, although in the Central Ogilvie Mountains and on the Eagle Plain, it deviates many kilometres from the highway. The decision to use 100 plots located along the highway was influenced by monetary restrictions. It was assumed that a sample of that size would suffice to identify the soil criteria needed for revegetation planning and implementation, especially when at a mapping scale of 1:250 000, only sufficiently large areas could be mapped, and stockpiling of the topsoil would lead to mixing and probably elimination of substantial differences of soil properties. Based on the fact that the organic horizons or peat would constitute the bulk of the topsoil stockpiled for revegetation projects (compare Foothills 1981), the use of pH values determined on the organic horizons for mapping in this report is justified. The distribution of the pH classes within the mapped corridors is the result of ground-truthing along the highway and extrapolation of information from areas of known geology, vegetation cover, and pH into areas not covered by the survey.

The availability to plants of nutrient elements present in the soil depends on the pH. The best pH for nutrient availability is about 6.8. Mg and Ca decrease in availability below pH 6.7 and K, P, and N are readily available from pH 6.0 to 8.0. Since the survey showed the majority of the soils as being extremely acid, and acid soils are considered relatively infertile, the revegetation measures perhaps should include liming as part of the site preparation. Many tons of finely ground limestone would be required to raise the pH level even by one pH grade. For example, in soils of cool temperate and temperate regions, the approximate amounts of finely ground limestone needed per 0.4 ha (1 acre) to raise the pH of a 18 cm (7 inch) layer of muck are as follows: from pH 3.5 to 4.5, about 2.9 t; from pH 4.5 to 5.5, about 3.8 t; from pH 5.5 to 6.5, about 4.3 t (U.S.D.A. 1951). Probably larger amounts will be needed in the subarctic. In contrast, there are soils where free carbonates are present, as is the case in many locations along the Engineering Creek, the Central Ogilvie Mountains, and in places along the western slopes of the Richardson Mountains.

For interpreting soil properties, the C/N ratio is as important as the pH. Values for selected organic soil samples are shown in Table 4. Assuming that the microbial cells have a C/N ratio of about 10, that is, require 1 kg of N for each 10 kg of C assimilated, and that they usually assimilate 35% of the material and liberate 65% in the form of CO_2 gas, the soils having a C/N ratio higher than 32 must have additions of N-fertilizers to prevent deficiencies in the plants. To create a surplus of N, all ratios over 10 would benefit from added N. Of interest is the fact that the N-levels in many of the organic horizons of the subarctic soils are low when compared to a range of organic soils from boreal regions of Canada (Stanek 1977, Stanek *et al.* 1977) or elsewhere (Stanek 1976). Levels of more than 1.2% total N content would be expected in most of the boreal peatlands, whereas in the organic layers of soils under study, levels higher than 1.2% are exceeded only in about 20% of the samples.

Relatively high total P contents (Table 3) are in the organic layers of the analyzed soils. Most of the values exceed those of organic soils elsewhere (Stanek 1976). The results in Table 3 show also that more P is contained in the more acid organic matter (for example, pH 3.5, P content 0.21%; pH 5.23, P content 0.10%). In general, the total amount of P in the organic layers of the surveyed soils is higher than the minimum content required for sustenance of tree growth (Malmstroem 1956). One assumes that, under favorable conditions, the organic matter will decompose and P in plant available form will be released in amounts sufficient for grasses, herbs, and shrubs intended for the revegetation projects. In extremely acidic soils, liming would improve the availability of P (Truog and Engelbert 1954). It appears that little, if any, addition of phosphate fertilizers to the stockpiled topsoil will be required. In contrast to the total P contents in the organic layer, the amounts of exchangeable P in the sampled mineral soils are extremely small. If mineral soils are used as seedbed, the required minimum desirable level is 40 ppm of P_2O_5 by the Bray-P_1 method of analysis

(ISMA 1981). Most of the surveyed mineral soils would then require addition of phosphate fertilizers.

As far as potassium is concerned, the levels in the organic layers, as well as of the mineral soils, are satisfactory. In fact, some of the values exceed those reported for agricultural soils (1 to 2% exchangeable K) (Buckman and Brady 1960).

The levels of magnesium found in the mineral soil are mostly below those that one would expect to find in agricultural soils. Acceptable levels of exchangeable Mg in surface mineral soils are about 0.08 to 1.5%. As stated before, the revegetation will rely greatly on the nutrient content of the topsoil. The contents of Mg in topsoil (Table 3) are such that, even if one assumes a complete decomposition of the organic topsoil and release of the Mg present, some additions of fertilizer containing MgO would be desirable.

In the subarctic climates, the development of hydrogen-satured lignoproteinates (ranker-Kubiena 1953), as well as base-saturated lignoproteinates (redzina-Kubiena 1953), takes place. The former are mainly associated with strongly acid soils, the latter with weakly acid to alkaline soils. Both types should be studied in detail.

In general, the organic soils, on a percent of dry weight basis, contain relatively high levels of total nutrient elements which become available on decomposition. Combined with the relatively high cation exchange capacity (compare Table 4) and other inherent properties, the organic soils are valuable as seedbed or rooting medium for revegetation purposes and ideal as backfill topping. However, their bulk density, about 0.4 when mixed with mineral soil, indicates that at least three times the volume will be required to replace the original mineral soil.

Although not a subject of this investigation, it should be mentioned here that observation of many disturbed sites along the Dempster Highway revealed a successful natural regeneration. The exceptions to the rule were found in locations with active thermokarst, solifluction, active floodplains, nonstabilized scree slopes, and turbic cryosols (active permafrost soils). This indicates that it would pay the Proponent to study aspects of natural revegetation, which would be not only cheaper than artificial revegetation but also aesthetically preferable in that it would restore the vegetation as close as possible to its original state.

● Melting of ice under the organic layer of the soil creates large fissures in the tundra landscape of the Blackstone River Valley.

GLOSSARY OF TERMS

Hummock . . . . An elevated, comparatively dry microtopographic feature in a relatively wet terrain such as treed bog or in areas with permafrost under tundra or taiga.

Icing . . . . Large sheet of ice ranging from 10 feet thick and one-half mile long, usually associated with drainage in permafrost areas (Brown 1970).

Muck . . . . Generally a mineral-rich, well-decomposed material, dark in color and accumulated under conditions of imperfect drainage, containing 50-80 percent ash.

Nonsorted Circle . . . Circular stone mesh, stone border is absent, centres are of silt, sand and/or gravel. Usually occurs over permafrost (Brown 1970).

Polygon . . . . Patterned ground caused by permafrost with recognizable trenches or cracks forming a polygonal circumference. Is mainly found in terrain with good moisture supply.

Sorted Circle . . . . . Formation consisting of clean stone borders surrounding fine-grained soil, sometimes with gravel or pebbles. Usually occurs over permafrost (Brown 1970).

Thermokarst . . . . . . The irregular topography resulting from the process of differential thaw settlement or caving of the ground because of the melting of ground ice in thaw-unstable permafrost. So named because of superficial resemblance to the karst topography typical of limestone regions subject to solution by surface and ground waters (Brown 1970).

Tussock . . . . Dense tuft usually of sedges (Eriophorum), forms one of many firm bunches ("tetes des femmes") in shallow marshes or tundra.

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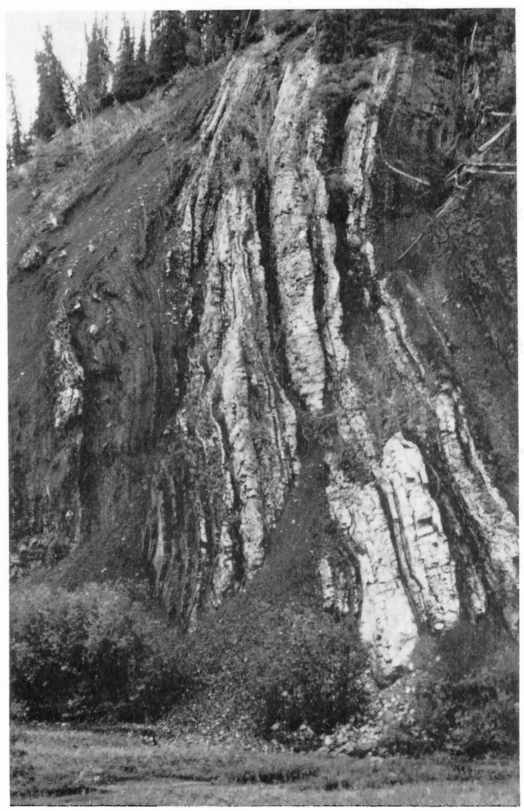
● Ground patterned by permafrost. Nonsorted circles on the Eagle Plain, Yukon Territory. In the background are the Richardson Mountains.

● Brunisolic Static Cryosols are common on the Eagle Plain in relatively well-drained locations. The silty-sandy soils are extremely acid. They have a relatively thin (up to 10 cm) LFH layer and are slightly gleyed above the frozen horizon (here at the level of the auger point).



● Steeply folded formations in Engineer Creek area. Soils developing on this material are generally slightly alkaline.

APPENDIX A

Major Plot Characteristics

Plot No.	Physiognomic Vegetation Group[1]	E-cluster	pH organic	pH mineral	Depth to frozen ground (cm)
1	ST	7	3.15	3.15	65
2	ST	7	3.31	3.89	70
3	STD	7	3.66	3.59	60
4	STD	7	3.30	3.34	75
5	ST	7	3.16	3.76	75
6	STD	7	3.10	3.40	90
7	STD	7	2.93	3.38	70
8	TSTD	7	2.96	3.34	35
9	STT	7	2.73	3.30	60
10	STT	7	3.15	3.46	33
11	STT	7	3.20	3.52	65
12	STT	7	3.07	3.62	65
13	RPS	7	4.79	4.33	N/R
14	TSTD	7	3.18	3.40	60
15	STD	7	3.39	3.63	45
16	LcSTD	7	3.44	3.56	80
17	TSTD	7	3.10	3.45	60
18	LcSTD	7	3.16	3.44	60
19	LcSTD	3	-------	3.66	60
20	ST	3	-------	3.70	60
21	LcSTD	7	3.85	3.86	N/R
22	TSTD	9	3.18	3.49	40
23	TSTD	7	3.51	3.52	40
24	STD	7	3.88	4.23	50
25	STT	8	4.78	5.15	55
26	RPS	4	-------	6.94	N/R
27	STT	8	5.93	6.51	65
28	STT	7	3.33	3.39	N/R
29	RPS	4	-------	6.82	N/R
30	TSTD	7	3.48	4.03	70
31	RPs	10	6.53	6.98	N/R
32	STT	8	5.30	6.41	80
33	RPS	1	5.78	-------	45
34	STD	7	3.65	3.74	N/R
35	RPS	1	5.42	-------	45
36	STD	7	3.34	3.69	83
37	STD	3	-------	3.81	45
38	TSTD	7	3.40	3.64	38
39	LcST	7	3.00	3.35	N/R
40	LcST	7	3.10	3.20	100

Plot No.	Physiognomic Vegetation Group[1]	E-cluster	pH organic	pH mineral	Depth to frozen ground (cm)
41	RPS	4	-------	6.24	N/R
42	ST	7	3.26	3.86	45
43	LcST	7	3.04	3.76	N/R
44	ST	7	3.13	3.80	53
45	LcST	7	3.78	4.76	N/R
46	ST	7	3.21	3.93	65
47	ST	7	3.78	4.76	N/R
48	STD	7	3.89	3.91	55
49	TSTD	7	3.56	3.66	50
50	STD	7	3.36	3.80	50
51	ST	7	3.98	4.23	50
52	TSTD	7	3.26	3.55	48
53	TSTD	3	-------	3.55	90
54	ST	7	3.35	3.43	N/R
55	RPS	5	6.53	7.00	75
56	RW	4	-------	6.98	75
57	SBT	7	3.51	3.33	75
58	RPS	4	-------	6.83	N/R
59	C	8	4.43	6.24	N/R
60	ST	8	5.21	6.08	35
61	C	8	5.03	6.93	45
62	ST	8	5.32	6.44	40
63	C	8	5.49	6.92	N/R
64	ST	6	6.59	6.15	75
65	ST	8	4.84	5.80	55
66	ST	8	4.50	5.38	43
67	C	6	6.39	6.56	60
68	C	5	6.53	7.10	55
69	ST	2	4.35	-------	33
70	ST	1	6.23	-------	33
71	SBT	8	4.71	5.85	45
72	ST	7	3.71	4.75	33
73	RW	11	6.90	7.20	N/R
74	SBT	7	3.36	3.96	100
75	LcST	7	3.71	4.75	30
76	ST	4	-------	7.10	N/R
77	ST	8	6.01	5.46	45
78	C	8	5.68	6.97	N/R
79	ST	7	3.35	3.78	45
80	C	8	5.59	6.55	70
81	LcST	8	5.85	5.85	30
82	TSTD	7	3.89	4.24	45
83	TSTD	7	4.12	4.38	45

Plot No.	Physiognomic Vegetation Group[1]	E-cluster	pH organic	pH mineral	Depth to frozen ground (cm)
84	TSTD	7	3.43	4.34	50
85	RW	4	-------	6.83	N/R
86	TSTD	7	4.11	4.60	53
87	TSTD	7	3.25	4.11	50
88	RW	4	-------	6.09	N/R
89	RW	4	-------	5.99	N/R
90	LcSTD	7	3.53	4.14	55
91	RW	4	-------	5.80	N/R
92	C	8	4.85	5.27	75
93	TSTD	7	3.69	3.94	50
94	TSTD	7	3.64	4.05	30
95	TSTD	8	5.10	4.88	30
96	RW	8	5.40	4.83	N/R
97	LcSTD	7	4.47	4.44	N/R
98	LcSTD	7	3.86	4.21	N/R
99	C	7	3.94	4.63	N/R
100	C	8	5.42	5.94	N/R

[1] Key to Physiogonomic Groups (see Stanek et al. 1981)

STD	Shrub Tundra
TSTD	Tussock-Sedge Tundra
LcSTD	Lichen-Shrub Tundra
ST	Spruce Taiga
LcST	Lichen-Spruce Taiga
Stt	Spruce-Tamarack Taiga
SBT	Spruce-Paper Birch Taiga
RW	Riverine Willow
RPS	Riverine Poplar-spruce
C	Conifer

N/R = Permafrost not found at depths of 1 m.

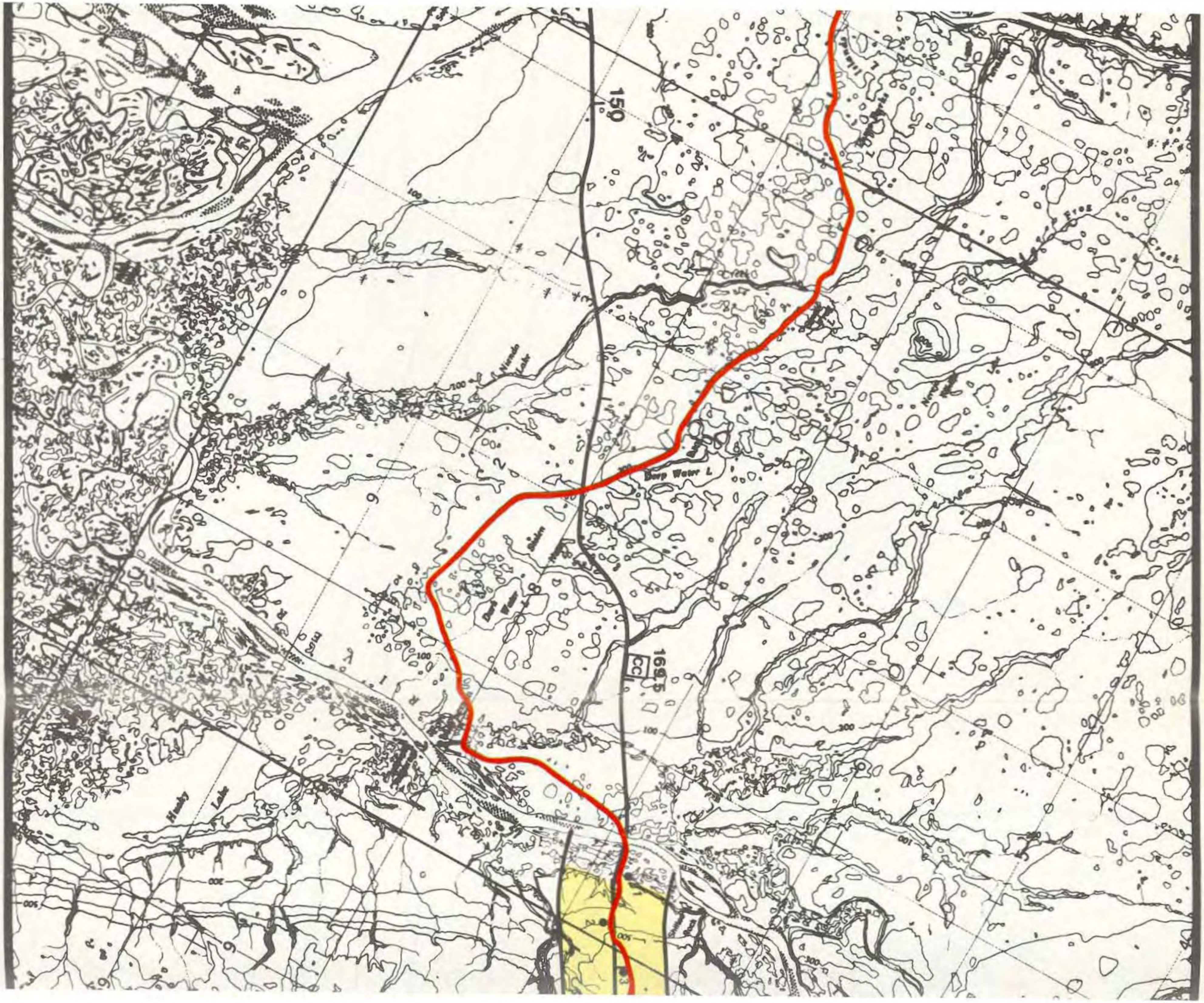
APPENDIX B

Nutrient Element Contents of Total N, P, Ca, Mg, and K in Organic Soil and N in Mineral Soil (in % Dry Weight) and Exchangeable P, Ca, Mg, and K in Mineral Soil (in ppm) for the 100 Plots

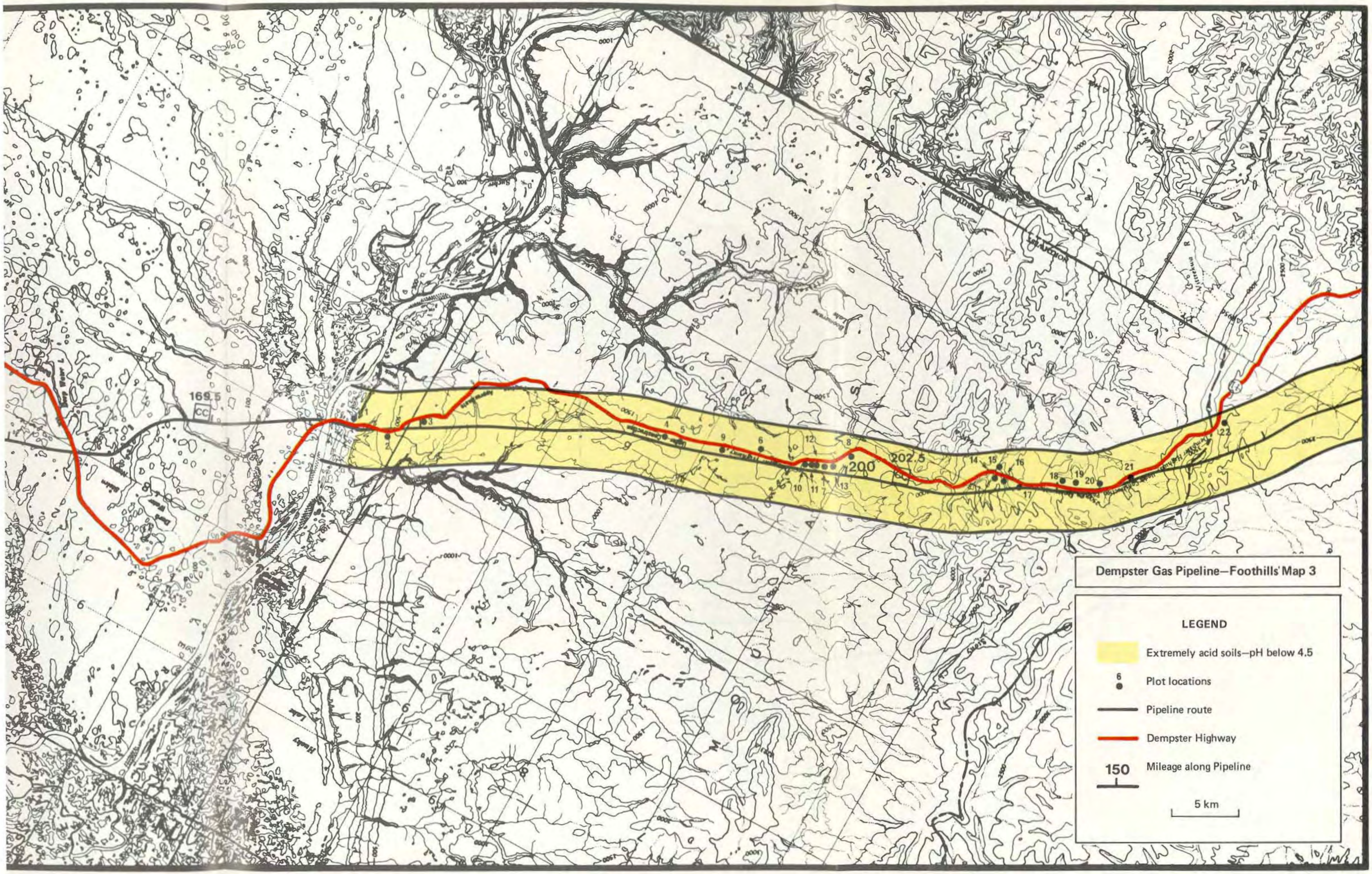
Plot	Organic					Mineral				
No.	N	P	Ca	Mg	K	N	P	Ca	Mg	K
1	0.94	0.11	0.15	0.17	0.40	0.16	7	130	60	120
2	0.72	0.13	0.23	0.23	0.36	0.14	6	1750	470	110
3	0.52	0.16	0.28	0.53	0.70	0.14	12	650	270	90
4	0.88	0.14	0.28	0.20	0.43	0.14	9	450	180	90
5	0.85	0.14	0.28	0.24	0.43	0.17	15	1260	500	120
6	1.13	0.14	0.23	0.23	0.49	0.16	13	490	190	90
7	0.78	0.11	0.13	0.15	0.28	0.16	7	290	110	80
8	0.56	0.10	0.10	0.17	0.37	0.28	8	220	110	60
9	0.74	0.09	0.06	0.12	0.27	0.20	9	580	220	70
10	0.57	0.12	0.23	0.11	0.23	0.24	8	680	190	60
11	0.75	0.13	0.22	0.32	0.84	0.23	9	730	220	110
12	0.61	0.08	0.26	0.08	0.15	0.21	7	980	240	60
13	1.02	0.23	1.04	0.39	0.60	0.10	15	1340	230	70
14	0.57	0.14	0.13	0.25	0.59	0.28	7	390	150	90
15	0.85	0.14	0.28	0.22	0.50	0.24	8	770	260	70
16	0.88	0.12	0.22	0.19	0.49	0.23	10	540	300	60
17	0.92	0.12	0.20	0.18	0.32	0.29	8	460	210	100
18	0.78	0.14	0.12	0.27	0.77	0.20	7	240	60	40
19	0.00	0.00	0.00	0.00	0.00	0.19	8	230	70	60
20	0.00	0.00	0.00	0.00	0.00	0.11	6	340	210	80
21	0.76	0.16	0.33	0.45	0.99	0.23	6	1010	50	120
22	2.17	0.21	0.06	0.05	0.18	0.32	4	90	30	10
23	1.17	0.20	0.09	0.17	0.48	0.19	2	130	60	70
24	0.86	0.16	0.48	0.38	0.86	0.40	6	1460	80	20
25	0.87	0.10	1.38	0.23	0.45	0.54	2	3940	200	20
26	0.00	0.00	0.00	0.00	0.00	0.10	1	4120	110	20
27	0.96	0.11	3.00	0.35	0.25	0.28	2	5990	150	30
28	1.03	0.11	0.36	0.11	0.32	0.45	7	280	30	50
29	0.00	0.00	0.00	0.00	0.00	0.16	1	3290	80	20
30	1.36	0.14	0.29	0.11	0.25	0.73	3	750	80	60
31	0.62	0.13	4.38	0.89	0.61	0.32	1	3470	80	20
32	1.27	0.09	3.07	0.22	0.11	0.58	2	7980	120	10
33	1.34	0.10	2.46	0.21	0.11	0.00	0	0	0	0
34	0.63	0.13	0.20	0.41	0.65	0.24	2	540	150	60
35	1.14	0.19	1.81	0.61	0.28	0.00	0	0	0	0

Plot No.	Organic					Mineral				
	N	P	Ca	Mg	K	N	P	Ca	Mg	K
36	1.13	0.11	0.20	0.25	0.52	0.25	2	460	220	50
37	0.00	0.00	0.00	0.00	0.00	0.18	2	540	280	90
38	0.95	0.15	0.22	0.16	0.34	0.38	9	410	50	70
39	0.87	0.09	0.11	0.08	0.15	0.31	2	130	30	50
40	0.92	0.09	0.27	0.22	0.60	0.30	3	760	140	110
41	0.00	0.00	0.00	0.00	0.00	0.32	6	2950	390	60
42	0.92	0.14	0.35	0.11	0.11	0.25	5	990	220	30
43	0.66	0.12	0.09	0.11	0.22	0.09	38	590	130	40
44	0.86	0.10	0.13	0.17	0.23	0.25	4	660	220	50
45	0.92	0.12	0.10	0.05	0.08	0.14	10	90	20	20
46	0.94	0.12	0.20	0.14	0.23	0.21	5	830	220	70
47	1.49	0.12	0.70	0.18	0.18	0.75	5	3560	490	30
48	0.54	0.11	0.27	0.33	0.41	0.25	8	810	240	50
49	1.21	0.15	0.17	0.08	0.08	0.40	7	310	100	30
50	1.07	0.13	0.29	0.21	0.31	0.31	5	810	280	60
51	1.70	0.18	0.60	0.15	0.13	0.30	4	1890	480	40
52	0.82	0.13	0.17	0.20	0.33	0.72	3	300	130	100
53	0.00	0.00	0.00	0.00	0.00	0.30	1	500	220	250
54	1.12	0.15	0.29	0.19	0.39	0.29	28	520	180	90
55	0.73	0.12	2.63	0.99	0.41	0.20	2	3450	290	20
56	0.00	0.00	0.00	0.00	0.00	0.22	3	3400	280	20
57	1.17	0.14	0.54	0.20	0.51	0.12	45	1130	150	120
58	0.00	0.00	0.00	0.00	0.00	0.15	5	2810	220	20
59	1.18	0.09	1.24	0.21	0.15	0.38	4	3450	680	20
60	1.11	0.10	1.77	0.36	0.22	0.29	5	3140	590	30
61	1.04	0.10	1.81	0.52	0.22	0.27	4	3350	390	20
62	1.23	0.13	1.80	0.41	0.17	0.32	4	3600	920	20
63	0.95	0.11	2.12	0.58	0.21	0.25	4	2820	270	30
64	1.46	0.08	3.68	0.17	0.12	1.03	1	8610	180	10
65	1.10	0.12	1.58	0.20	0.08	0.48	3	3880	610	20
66	1.04	0.09	1.25	0.18	0.03	0.47	3	3440	530	20
67	1.35	0.09	3.07	0.18	0.10	0.96	3	6240	260	10
68	0.92	0.14	2.68	0.93	0.31	0.16	6	2610	250	20
69	1.17	0.12	0.91	0.22	0.31	0.00	0	0	0	0
70	0.99	0.16	1.91	0.69	0.37	0.00	0	0	0	0
71	1.08	0.08	1.11	0.32	0.42	0.54	3	3800	860	30
72	0.99	0.08	0.44	0.22	0.32	0.41	4	1480	340	30
73	0.44	0.24	5.54	2.46	0.43	0.19	4	3150	230	10
74	1.02	0.07	0.38	0.09	0.17	0.14	9	570	70	30
75	1.06	0.08	0.63	0.08	0.07	0.45	73	1140	120	20
76	0.00	0.00	0.00	0.00	0.00	0.10	2	1590	320	10
77	1.33	0.11	2.08	0.37	0.11	0.19	1	2370	440	40
78	0.66	0.11	1.57	0.47	0.20	0.10	3	2220	460	20
79	0.71	0.09	0.22	0.05	0.04	0.97	4	220	30	10
80	0.96	0.08	1.68	0.35	0.25	0.35	2	3720	660	40

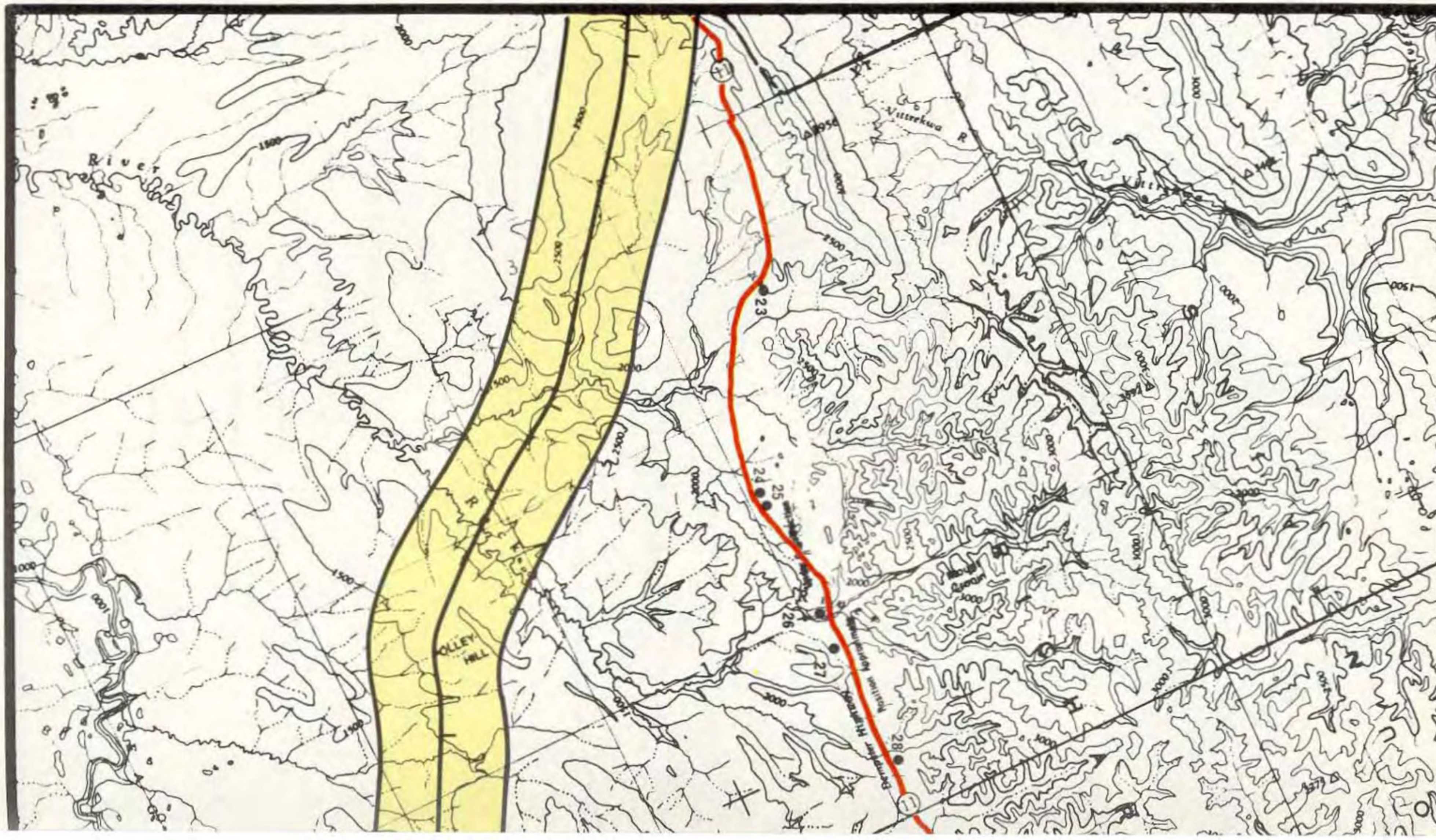
Plot No.	Organic					Mineral				
	N	P	Ca	Mg	K	N	P	Ca	Mg	K
81	1.40	0.16	2.24	0.31	0.09	0.58	14	3910	280	10
82	0.98	0.10	0.47	0.14	0.04	0.19	2	640	150	20
83	0.90	0.10	0.46	0.13	0.03	0.17	7	490	110	10
84	1.17	0.12	0.23	0.08	0.04	0.38	4	550	130	10
85	0.00	0.00	0.00	0.00	0.00	0.12	2	1860	380	20
86	0.72	0.09	0.45	0.18	0.12	0.20	3	1120	210	20
87	0.75	0.09	0.24	0.09	0.06	0.32	7	350	60	10
88	0.00	0.00	0.00	0.00	0.00	0.14	3	1650	340	20
89	0.00	0.00	0.00	0.00	0.00	0.24	3	2760	320	20
90	0.80	0.08	0.38	0.17	0.11	0.36	12	460	70	10
91	0.00	0.00	0.00	0.00	0.00	0.18	3	2160	280	30
92	1.53	0.12	1.28	0.29	0.20	0.17	4	2220	240	20
93	0.96	0.09	0.26	0.08	0.04	1.06	3	260	50	10
94	1.05	0.12	0.31	0.05	0.03	0.71	3	310	40	10
95	1.51	0.12	1.14	0.12	0.06	0.18	6	1760	130	20
96	1.37	0.14	1.00	0.33	0.26	0.17	4	1360	380	30
97	0.82	0.09	0.45	0.34	0.14	0.12	3	680	360	50
98	0.75	0.11	0.40	0.25	0.25	0.05	9	500	80	40
99	1.30	0.12	0.74	0.20	0.31	0.19	5	1230	140	20
100	1.15	0.06	2.60	0.27	0.21	0.53	2	5710	300	20

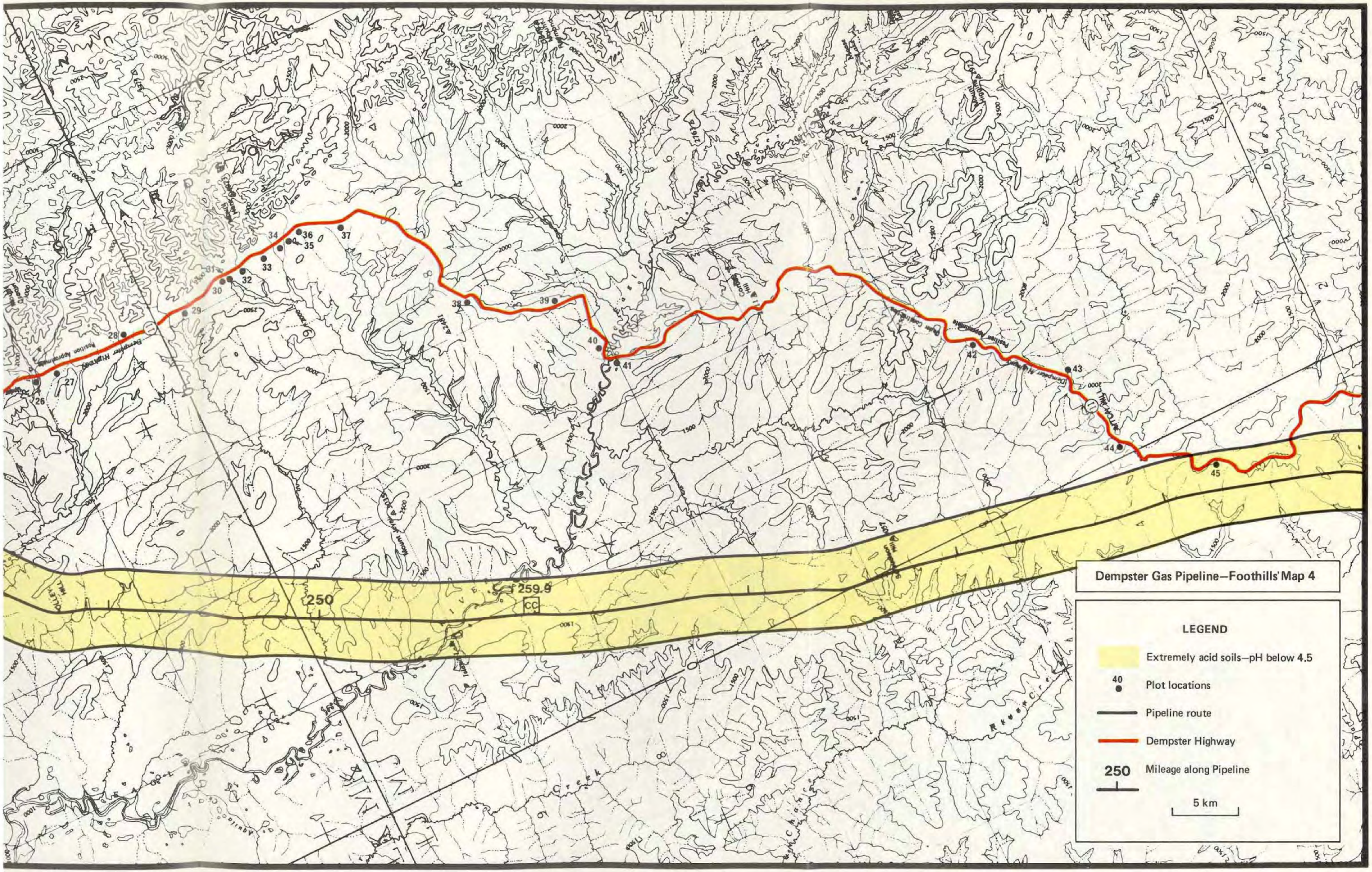


150
Deep Water L
Creek
169.5
CC

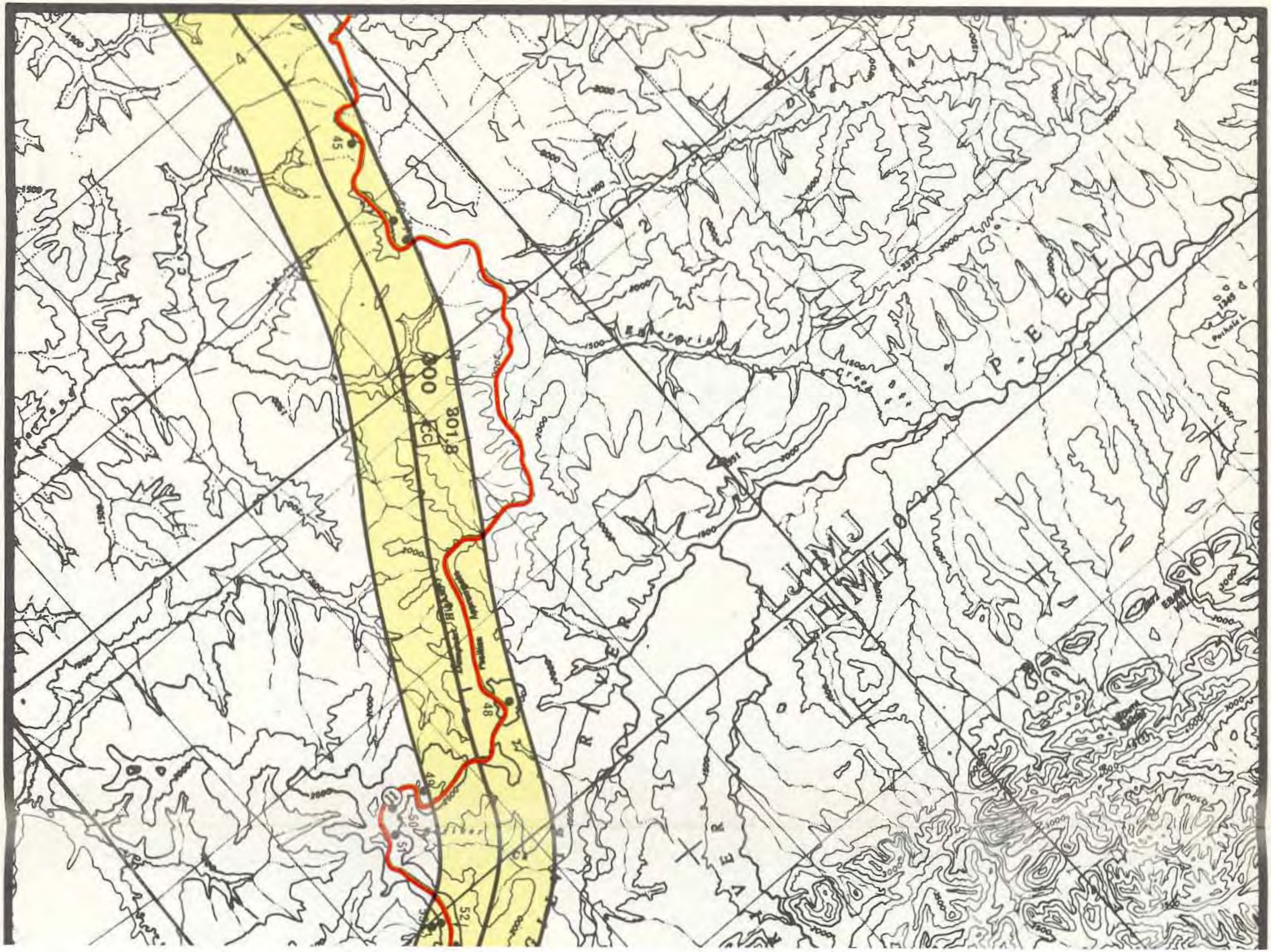


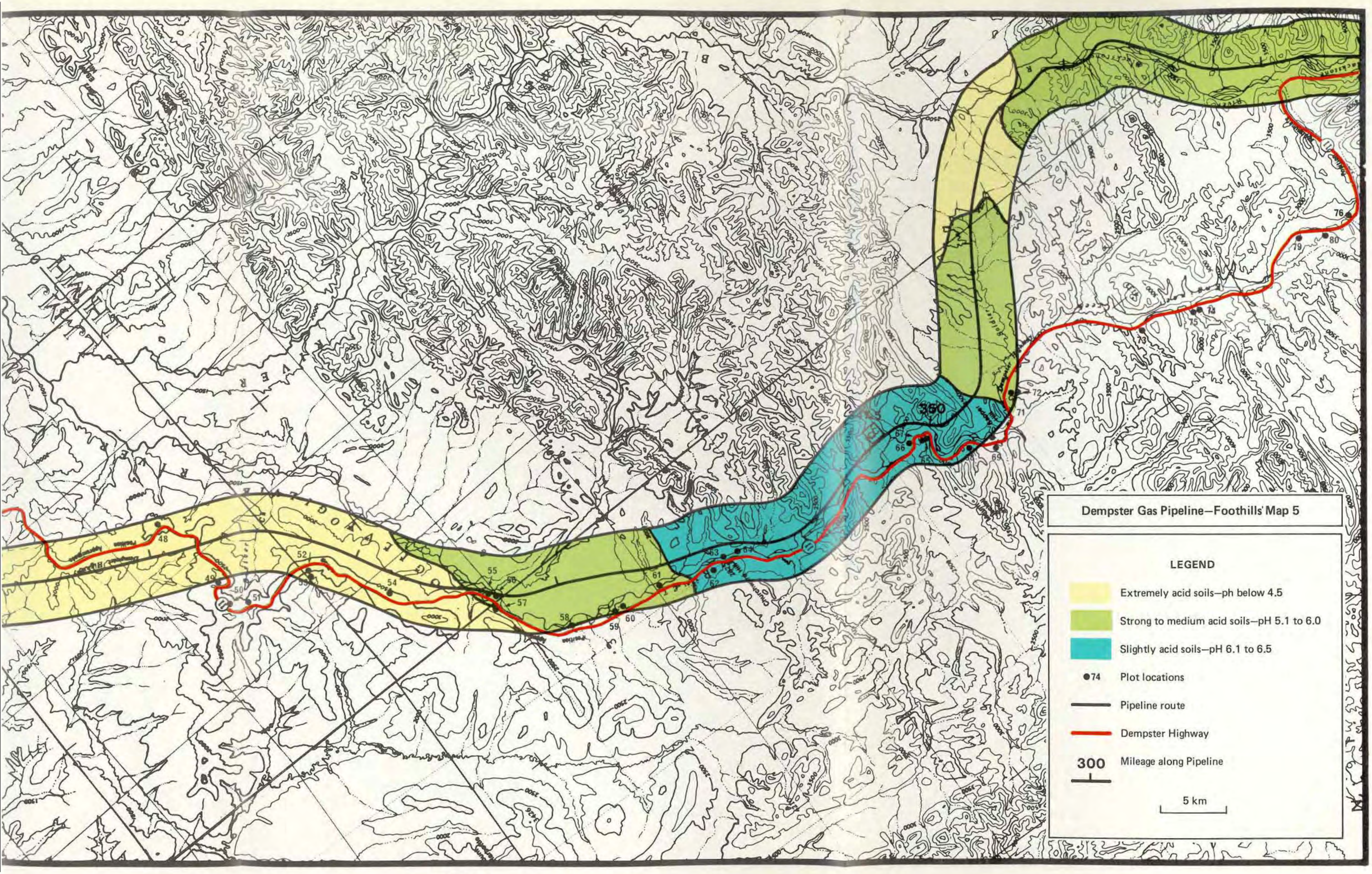
169.5
200
202.5
Dempster Gas Pipeline—Foothills' Map 3
LEGEND
Extremely acid soils—pH below 4.5
Plot locations
Pipeline route
Dempster Highway
150
Mileage along Pipeline
5 km


River
Vittrekwa R
23
24
25
26
27
28

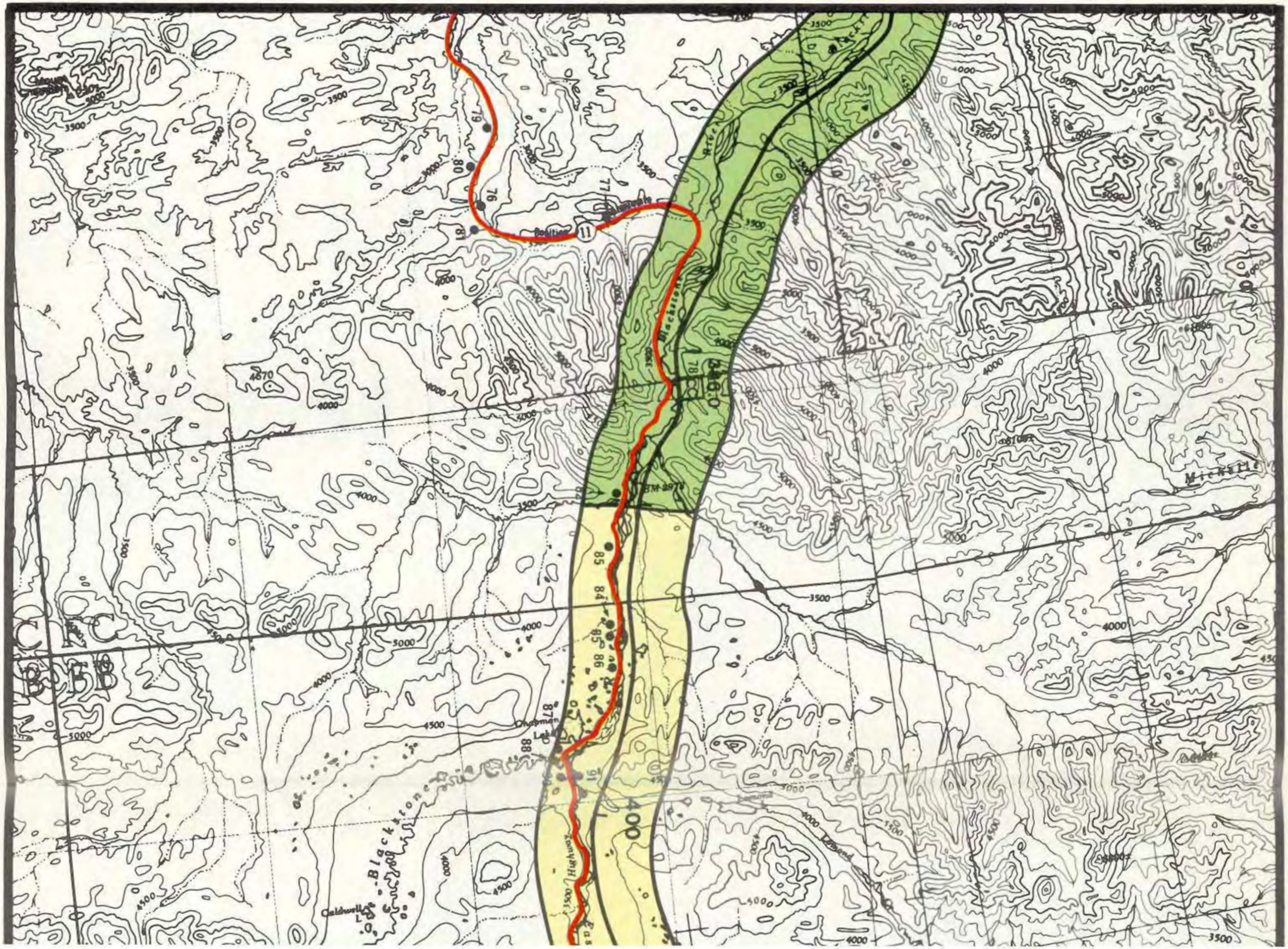


Dempster Gas Pipeline—Foothills' Map 4
LEGEND
Extremely acid soils—pH below 4.5
Plot locations
Pipeline route
Dempster Highway
250
Mileage along Pipeline
5 km


301.8
300
EC
45
48
49
50
51
52
Pothole L.
2377
1500
2000
3000

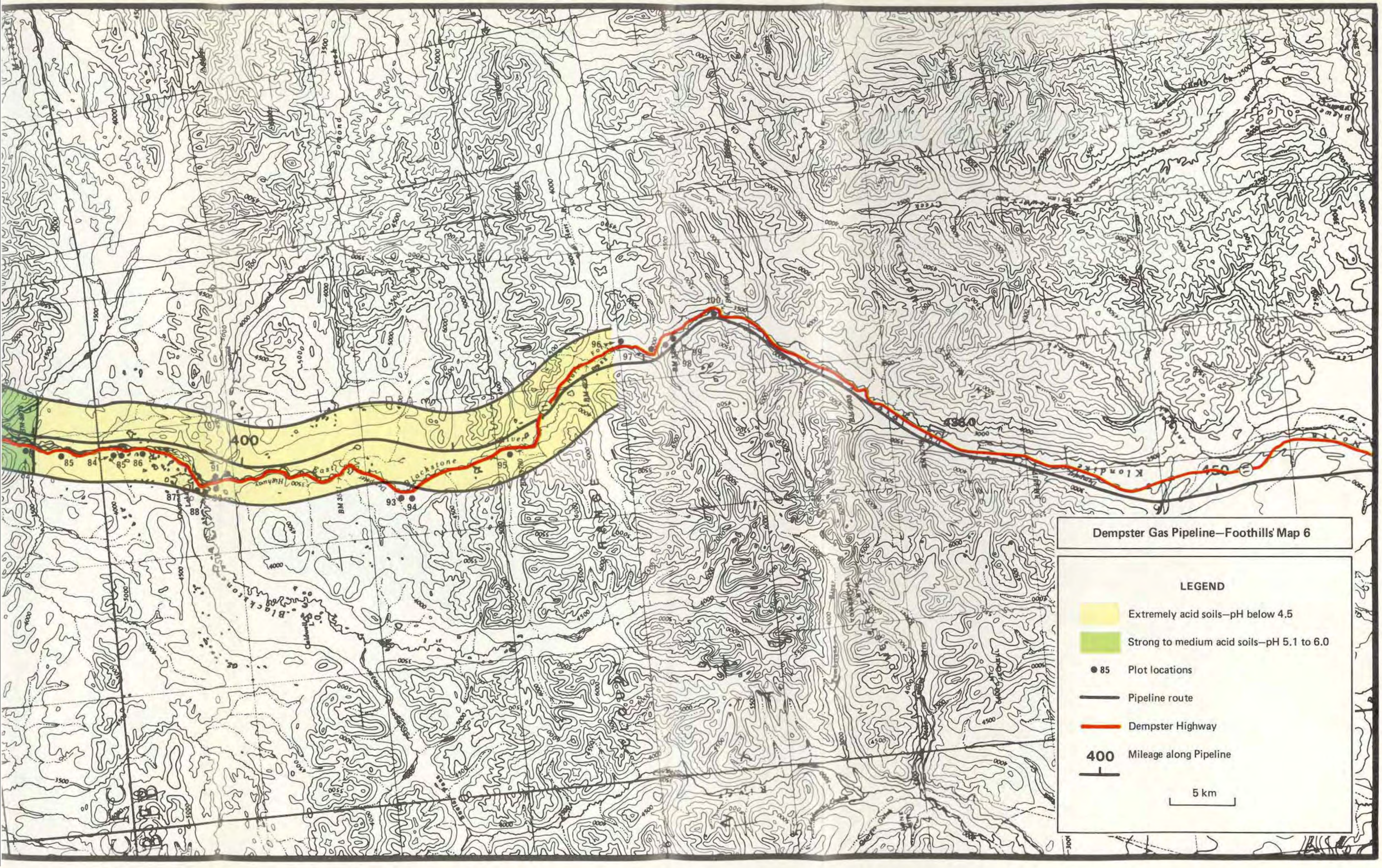


Dempster Gas Pipeline—Foothills' Map 5
LEGEND
Extremely acid soils—ph below 4.5
Strong to medium acid soils—pH 5.1 to 6.0
Slightly acid soils—pH 6.1 to 6.5
●74 Plot locations
Pipeline route
Dempster Highway
300 Mileage along Pipeline
5 km
350



3500
4000
4500
5000
4670
Chapman Lake
Blackstone
400
11

Bcx-2


Dempster Gas Pipeline—Foothills' Map 6
LEGEND
Extremely acid soils—pH below 4.5
Strong to medium acid soils—pH 5.1 to 6.0
● 85 Plot locations
Pipeline route
Dempster Highway
400 Mileage along Pipeline
5 km
400
450
Blackstone
Klondike

ADDENDA

Since the completion of this report, it has come to my attention that the physiography of the Northern Yukon has been revised by H.S. Bostock (Geological Survey of Canada, Map 1254A, 1970) and the Central Ogilvie Range has been renamed the Taiga Range to signify their geological difference from the Ogilvie Mountains. Of interest also is that D.K. Norris and his coworkers at the Geological Survey of Canada have published new bedrock geology maps at a scale of 1:100 000. It should be brought to the reader's attention that, in Part I of this report (BC-X-217), K.E. Richer should have been correctly spelled K.E. Ricker.