EFFECTS OF REPLACED SURFACE SOIL DEPTH ON RECLAMATION SUCCESS AT THE JUDY CREEK TEST MINE

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ABSTRACT

The effects of replaced surface soil depth on establishment of seeded grass/legume vegetation and lodgepole pine (*Pinus contorta*) was investigated on study plots at the Judy Creek Test Mine from 1979 to 1983. Nine plots representing replicates of three treatments of soil depth (0 cm, 30 cm and 70 cm) were established in a randomized block design. A grey luvisol surface soil with mixed A and B horizons was placed over a till subsoil. The till material, based on pre-study analysis, showed no inhibitory properties to plant growth.

Results of five years of study indicate that vegetation cover was continually higher on the 0 cm treatment than on either the 30 cm or 70 cm treatments. Differences in total cover were most pronounced during the first three years of study and decreased with succeeding years. The Alfalfa component of the revegetation seed mixture was the major contributor to total cover on the 0 cm plots due to the slightly alkaline soil conditions on this treatment.

An opposite relationship between soil depth and reforestation success was observed. The 0 cm treatment afforded lower survival and reduced growth than either the 30 cm or 70 cm treatments. Reduced survival of pine on the 0 cm treatment is attributed to the greater herbaceous cover which resulted in competition between tree seedings and vegetal species and increased the potential for small rodent-caused mortality. Reduced tree growth on the 0 cm plots is related to lower soil moisture and pH and a tendency for compaction of the till.

INTRODUCTION

Considerable attention has been placed on the topic of optimal soil depth replacement for adequate reclamation. For example, the United States Bureau of Mines recently supported a large scale research study to determine optimal soil depth replacement on mined lands within the Northern Great Plains. (Colorado School of Mines, 1983). Results from this study indicate that soil depth requirements appear to depend primarily on the quality of the spoil to be covered.

Spoil materials may be unsuitable for adequate plant growth for a variety of reasons including low fertility, droughtyness, and high salt levels. Sodic spoil materials are particularily difficult to revegetate due to physical instability and undesirable properties related to water infiltration, movement and retention. (Doering and Willis, 1975).

Several research studies have evaluated the effectiveness of applications of various thicknesses of "topsoil" possessing characteristics suitable for plant growth to sodic mine spoil. Pole et al. (1979) grew Spring wheat and corn on sodic spoils covered with 5 to 61 cm of suitable "topsoil". These authors concluded that "topsoil" 61 cm in depth provides the greatest yields but 30 cm is often as good. Sandoval and Gould (1978) reported that productivity of Crested wheatgrass grown on 30 cm of good quality surface soil progressively decreased during four years of study. This decline in productivity suggests that a deterioration in surface soil quality may be expected through time.

In Alberta, quidelines provided in Alberta Agriculture (1981a) indicate that soil material suitable for plant growth should be stockpiled and respread on the surface following disturbance. Various depths of soil replacement are suggested depending on the soil region in which the reclamation is carried out. For Northern forest soils two lifts of soil are suggested; an upper lift (30cm) of surface material (organic and A horizons), and a lower lift (170 cm) of subsurface material (lower horizons and parent material).

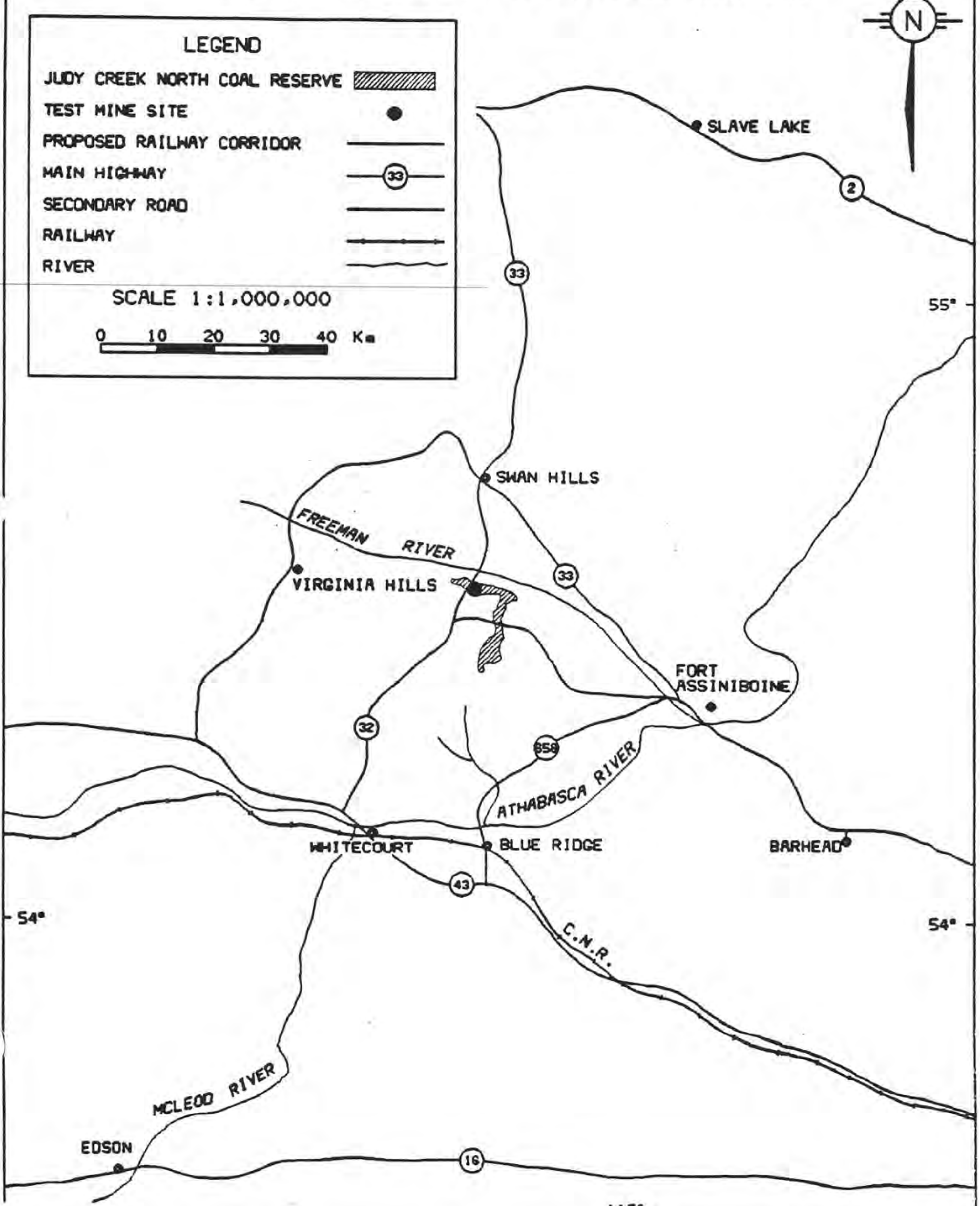
During the winter of 1978 Esso Resources Canada Ltd. constructed a test mine on the Judy Creek North Coal Reserve. The test mine was designed to secure a 10,000 tonne bulk coal sample for a test burn (Esso Minerals Canada, 1979). Constructon and subsequent reclamation procedures provided a site suitable to examine effects of various soil depth replacements on reclamation success. The present paper describes the soil depth study methodology and discusses the results of five years of study.

STUDY AREA

The Judy Creek Test Mine is located within the Judy Creek North Coal Reserve approximately 56 kilometers (km) south of Swan Hills, Alberta and 2 km east of Highway 32. The test mine is located in the NW 1/4, Section 14, Township 64, Range 10, west of the 5th meridian (Figure 1).

An area of 17.3 hectares (ha) was cleared for test mine operations in December, 1978; of which the test pit itself comprised 1.5 ha. An additional 2 ha area (2 km in length) was cleared as an access road to highway 32.

FIGURE 1. LOCATION MAP FOR JUDY CREEK TEST MINE



The test mine area is regionally characterized by warm summers and cold winters. Mean daily temperatures vary from a low of -17 degrees C (in January) to a high of 20 degrees C (in July). Average annual total precipitation is about 53 centimeters (cm) of which approximately 33% is received as snowfall. The prevailing wind directions are west and northwest.

The test mine lies at the western edge of the western plains physiogeographic region, in what is termed the Rocky Mountain Foothills area of Alberta. Elevations in the area range from 600 m on the Freeman River to over 1400 m in the Swan Hills. The hydrography of the area is dominated by the Freeman River, the Judy Creek, and the Christmas Creek; all tributaries of the Athabasca River.

Forest cover in the test mine area is dominated by stands of white spruce (<u>Picea glauca</u>) and the lodgepole pine. Pine and spruce occur as a mosaic of even-aged pure stands, depending on slope, or as stands of various mixtures of pine and spruce mixed-wood forests of either pine or spruce and aspen (<u>Populus tremuloides</u>) or balsam poplar (<u>Populus balsamifera</u>). Shrublands occur as clumps of mainly willow (<u>Salix sp.</u>) along the riparian sites or, to a minor extent on roadways and access clearings.

METHODS

The soil depth study consisted of nine 20 m X 40 m plots numbered 1.1 through 1.9 (Figure 2). Different depths of surface soil were placed over till overburden in spring 1979. Surface soil included all material in the A and B horizons and was collected in two lifts and stockpiled prior to placement on study plots in 1979. Analysis of the till overburden indicated no parameters limiting growth (Table 1; Esso Minerals Canada, 1979). Study plots 1.1, 1.2 and 1.3 received 70 cm (27.5 inches) of surface soil; plots 1.7, 1.8, and 1.9 were topsoiled with 30 cm (11.8 inches) of surface soil; the remaining plots (1.4, 1.5 and 1.6) had no surface soil replacement.

Each plot was planted with a complete grass/legume seed mixture by hand broadcast seeding. A description of the seed mix and broadcast rate is given in Table 2. Based on previous soil sampling (Esso Minerals Canada, 1979), fertilizer (23-N, 23-P, 0-K) was applied to each plot at a rate of 160 Kg/ha. No further ammendments or fertilizers have been applied. In addition to the application of an agronomic seed mixture ninety-eight lodge-pole pine seedlings were planted within each of the study plots. Twenty-four of these trees were randomly selected as study trees and permanently marked with wooden stakes equipped with metal identification tags. Planting occurred on June 1 and 2, 1979 using both V-bar and shovel mattock techniques. All trees were one-year old at planting and were spaced at 2.4 to 2.7 intervals within each plot.

Revegetation success for each soil depth treatment was evaluated through the measurement of plant cover. During August of 1979, and June and August of 1980, 1981 and 1983 vegetation cover estimates were made in each plot. Vegetation cover in each plot was determined through the observation of the proportion of ground covered by seeded revegetation species in forty evenly spaced 20 cm by 50 cm quadrats. Cover within each quadrat was estimated using the Braun Blauquet method (Kershaw 1973).

FIGURE 2. PLOT PLAN FOR SOIL DEPTH STUDY

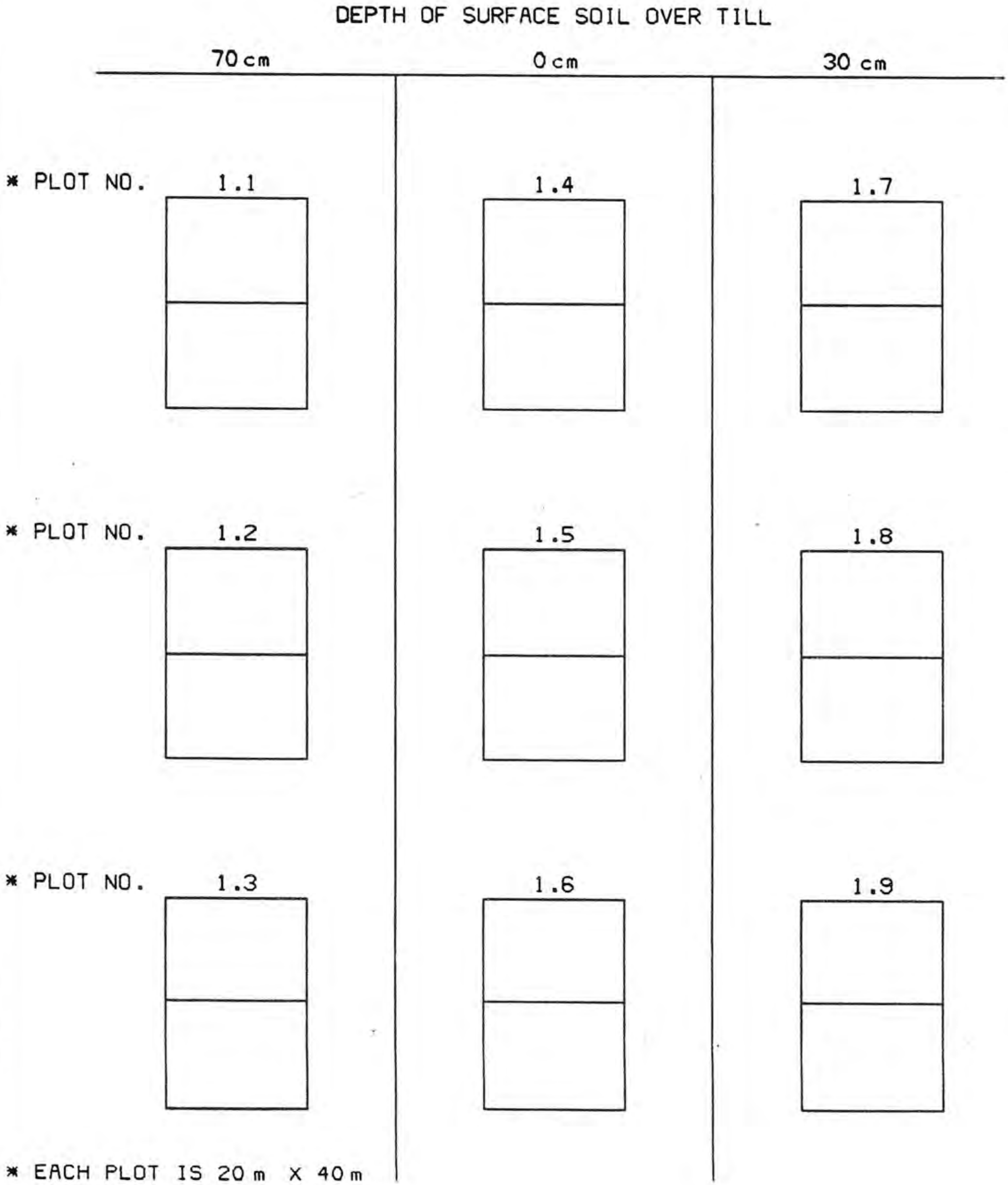


Table 1. Chemical Analysis Of Till Overburden Material

PARAMETER	Sample Number				
	1	2	3	4	Average Value
pH (aqueous)	6.7	6.4	8.0	7.5	7.15
pH ($CaCl_2$)	6.2	6.4	7.2	7.4	6.80
S.A.R.	0	0.08	0	0	0.02
Exchangeable Cations (Meq/100g)					
NA	0.15	0.25	0.25	0.30	0.24
K	0.55	0.55	0.30	0.60	0.50
CA	17.50	21.20	14.1	13.20	16.50
Mg	5.90	5.50	2.7	5.80	4.90
C.E.C.	23.20	27.70	13.4	27.70	23.00
Available P (ug/g)	7.50	19.00	-*	12.00	12.80
Available N (ug/g)	0.80	2.55	0.85	0.45	1.16
Available K (ug/g)	260.00	260.00	140.00	285.00	236.30
Organic Matter (%)	1.4	2.2	0.90	2.00	1.60
$CaCO_3$ Equivalent (%)	-	-	21.90	25.70	23.80

* Dash indicates data not available.

Table 2. Description Of Seed Mixture Applied To Soil Depth Treatment Plots

Species	Variety	Percent of Mix (by wt.)	Broadcast Seeding (kg/ha)	Features and Tolerances
Grasses				
Canada bluegrass (Poa compressa)	Common	20	6.0	Low maintenance, tolerance to grazing, aggressive, drought tolerant
Creeping red fescue (Festuca rubra)	Boreal	15	4.5	Tolerant to grazing, good seedling vigor, sod forming
Slender wheatgrass (Agropyron trachycaulum)	Revenue	10	3.0	Strong root system for erosion control
Crested wheatgrass (Agropyron (cristatum)	Fairway	15	4.5	Good seedling vigor, can withstand traffic
Timothy (Phleum pratense)	Climax	10	3.0	Rapid establishment, fibrous roots
Smooth brome (Bromas inermis)	Carlton	10	3.0	Long-lived, sod forming
Legumes				
Alfalfa (Medicago sativa)	Drylander	10	3.0	Superior winter hardiness, drought resistant
Red clover (Trifolium pratense)	Altaswede	10	3.0	Short-lived, winter hardy, acid tolerant
		100	30.0	

Reforestation success for each soil depth treatment was determined through evaluation of the survival and growth of each permanently marked tree. Estimation of tree survival and growth was conducted during August, 1979 and June and August of 1980, 1981 and 1983. Only tree survival was evaluated during June, 1982. Tree survival was determined through evaluation of the survival status of each marked tree (ie. living or dead). As a method of data reduction a mean total survival value was calculated for each treatment based on the equation; TL/TM x 100; where TL equals total living marked trees per plot, and TM equals the total marked trees per plot. Growth was recorded by measuring the height of each marked tree with a graduated meter stick. Height is considered a true indicator of growth, and therefore basal diameter was not measured. Incremental growth was determined through measurement of the new vertical leader growth for each year.

Soil samples were taken from each study plot in 1979, 1980, 1981 and 1983. Four subsamples were taken at randomly spaced locations within each study plot and combined by treatment for analysis. Samples were taken from the 0 to 15 cm soil layer. Analysis of soil samples followed procedures reported in McKeague (1978). During 1979, 1980 and 1981 the level of available macronutrients including Nitrogen (NO_3-N), phosphorous (P), potassium (K), and sulphur (SO_4-S), pH, electrical conductivity, and percentage organic matter, were recorded for each treatment. During 1983 the pH, conductivity, available macronutrients, calcium carbonate equivalent, extractable and soluble cations, cation exchange capacity, percentage saturation, sodium absorption ratio, particle size distribution, moisture content (percentage) and bulk density were determined for each treatment.

Statistical analyses were conducted using the SAS Proc Anova Statistical test (SAS 1982).

RESULTS

SOIL CONDITIONS

The chemical and physical parameters of the soils for each soil depth treatment by year are given in Table 3. Soil pH during the study ranged from 5.3 to 7.5 with the 30 cm and 70 cm plots consistently having lower values. Values of calcium carbonate equivalence recorded in 1983 indicated that all treatments have no capability problem with respect to alkalinity but the 0 cm plots were more alkaline than the 30 cm or 70 cm plots. All study plots had sodium absorption ratio values (in 1983) corresponding to a 'good' soil capability rating (Alberta Agriculture 1981a) indicating no sodicity problems.

Levels of all macronutrients (NO_3-N, P, K) on each treatment were well above those reported values required to support graminoid growth (Williamson et al., 1982). Very little between plot variability was recorded and nutrient availability was consistent within any one treatment.

The organic matter content was found to be consistently higher (for years 1979-1981) for the 70 cm study plots than the 30 cm and 0 cm plots. An inverse relationship between bulk density on the 70 cm and 30 cm plots was observed. The cation exchange capacity (CEC) in each study treatment was very similar, possibly due to the higher clay component of the 0 cm plots which would offset the cation exchange ability of the organic material in the 70 cm and 30 cm plots. All CEC values recorded were well above those recorded for typical natural forest soil types of similar chemical and physical make-up (Williamson et al., 1982).

Based on the particle size distribution conducted in 1983 the surface soil on the study plots can be characterized as follows. The 70 cm and 0 cm treatments are considered a clay loam and the 30 cm treatment a loam.

REVEGETATION

Percentage cover data for grasses, legumes and total living cover are shown in Figure 3. Cover increased dramatically from 1979 to 1980 on all plots and tended to level off from 1981 to 1983. Legume cover was consistently higher than graminoid cover throughout the study period.

The 0 cm soil depth treatment provided highest cover estimates in terms of total living cover for each year of study. This difference was statisticaly significant (F = 3.44, probability less than or equal to 0.05). Graminoid cover was also more apparent on the 0 cm plots for all years with the exception of 1983. Cover values for graminoids were statistically different for each treatment (F = 3.67, probability less than 0.05). Legume cover was also recorded at higher levels on the 0 cm plots than the 30 and 70 cm treatments (F = 6.16, probability less than or equal to 0.05).

able 3. Results of Soil Sampling Analyses for Soil Depth Study, 1979-1983

epth of oil cm)	Year	pH	Conductivity (mmhos/cm)	Organic Matter %	NO_3-N (ppm)	P (ppm)	K (ppm)	SO_4-S (ppm)	Bulk Density (g/cc)	Moisture Content %	$CaCo_3$ Equiv. %	CEC (Meq/100g)	Saturation %	SAR	Particle Size (%) Sand	Silt	Clay
	1979*																
70		6.0	0.1	3.1	1.7	9.0	126.7	3.0	***								
30		6.4	0.2	1.7	2.0	8.3	93.3	4.0									
0		7.5	0.4	1.7	2.0	5.3	123.3	9.0									
	1980*																
70		5.5	0.2	2.5	1.0	11.0	162.0	2.0	1.2	32.8							
30		5.9	0.3	2.0	1.0	11.0	160.0	7.0	1.3	26.3							
0		7.4	0.6	1.4	1.0	9.0	188.0	8.0	1.5	23.7							
	1981*																
70		5.3	0.1	2.9	2.0	10.0	152.0	3.0									
30		5.8	0.2	1.6	2.0	10.0	137.0	3.0									
0		7.3	0.5	1.4	3.0	7.0	173.0	9.0									
	1983**																
70		7.1	0.2		0.9	8.0	135.0	5.0	1.2	32.9	0.21	24.1	46	1.2	29.1	40.9	29.9
30		5.5	0.3		0.9	7.0	110.0	12.5	1.2	27.1	0.12	20.2	38	0.5	36.9	37.1	25.9
0		7.0	0.4		1.4	3.5	140.0	14.0	1.4	23.8	1.94	22.8	50	0.4	33.6	32.2	34.2

* Measurements based on mean values for three plots
** Measurements based on composite sample for 3 plots per treatment
*** Blank ind[illegible]tes measurement not available

Cover estimates for each planted species by soil depth treatment are given in Table 4. Timothy and Creeping red fescue were consistantly the most abundant seeded graminoid species on all of the soil depth plots. Other seeded species such as Canada blue grass and Crested wheatgrass were recorded at low cover values, and other species such as Slender wheatgrass and Smooth brome were recorded at only marginal abundances. Red clover had consistently high cover estimates on all treatments during each year of study. Alfalfa, the only other seeded legume, was recorded at low cover on all treatments with the exception of the 0 cm treatment. The increased cover of Alfalfa on these plots is due to the more alkaline soil conditions making the 0 cm plots more condusive to Alfalfa growth (Alberta Agriculture, 1981b)

REFORESTATION

Data on the mean percentage survival of lodgepole pine outplanted in 1979 for soil depth treatments are shown in Figure 4. The 0 cm soil depth treatment consistently showed lower mean survival than the 70 cm or 30 cm soil depth treatments. Further, the difference in survival became more pronounced in subsequent years of study. Differences in total mean percent survival between the 70 cm and 30 cm soil depth treatments were negligible for all years of study.

The total yearly growth and total incremental growth as indicated by height measurements, is shown in Figure 5 and Figure 6 respectively. Growth, in terms of total height was significantly reduced on the 0 cm treatment from

FIGURE 3. PERCENTAGE COVER OF GRASSES, LEGUMES AND TOTAL LIVING COVER FOR SOIL DEPTH TREATMENTS

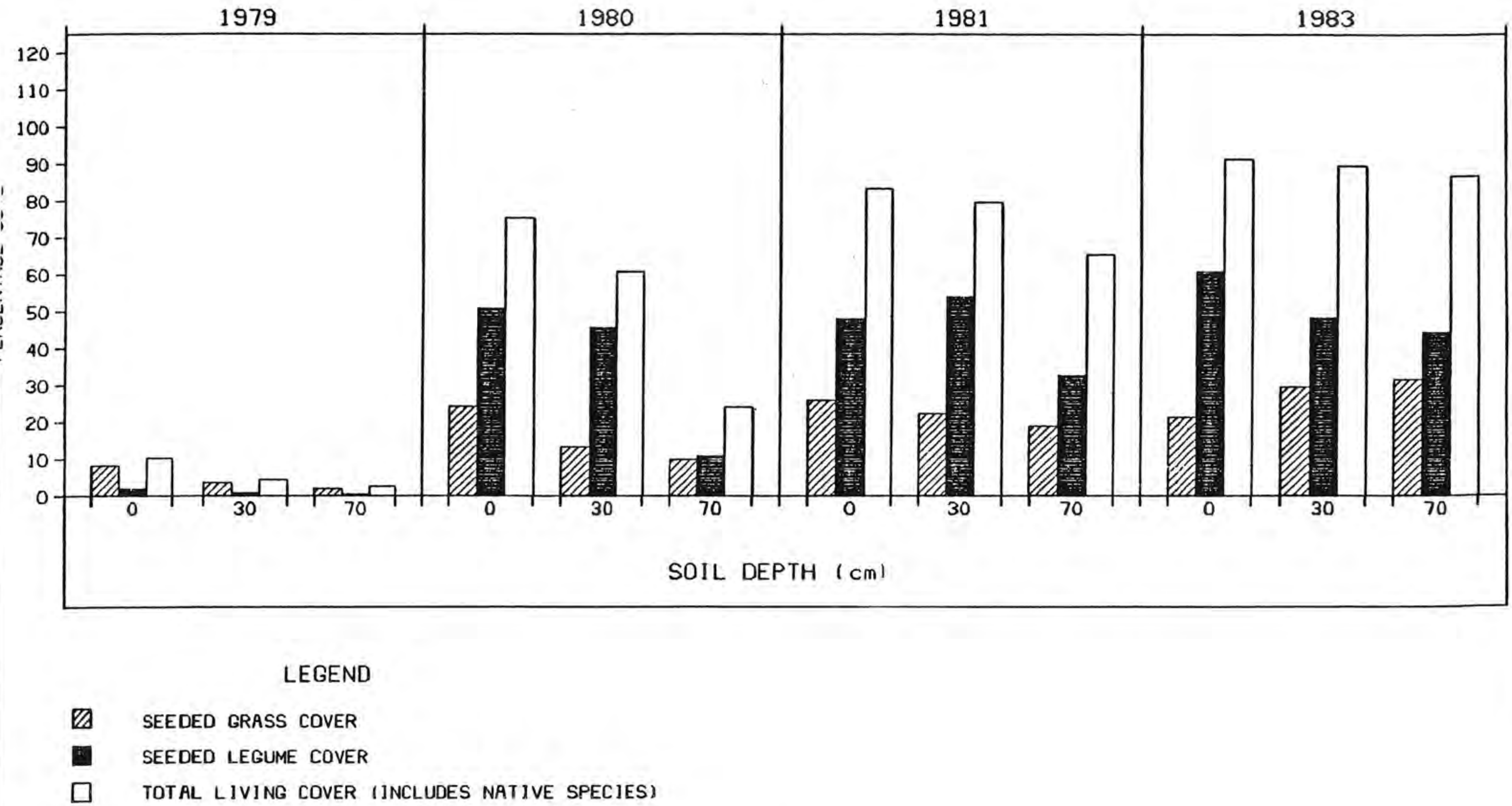


Table 4 Average Percentage Cover Values By Species Recorded For Soil Depth Treatments

Seeded Species	MEAN PERCENTAGE COVER *								
	70 cm TREATMENT			30 cm TREATMENT			OCM TREATMENT		
	1980	1981	1983	1980	1981	1983	1980	1981	1983
Canada Bluegrass	0.80	1.56	3.35	0.37	1.70	3.08	0.63	1.70	2.08
Crested Wheatgrass	0.13	0.10	0.00	0.20	0.23	0.10	1.60	0.60	0.19
Slender Wheatgrass	0.43	0.43	0.48	0.57	1.13	2.49	3.26	2.10	1.26
Smooth Brome	0.40	0.00	0.11	0.00	0.00	1.00	0.80	0.00	2.23
Creeping Red Fescue	3.77	7.83	21.37	6.97	9.67	15.16	7.90	9.80	11.69
Timothy	4.66	9.03	6.12	5.23	10.23	7.72	10.03	12.16	3.69
Red Clover	10.83	32.13	43.83	52.30	53.90	48.25	44.80	35.47	26.53
Alfalfa	0.10	0.10	0.34	0.10	0.00	0.00	6.03	12.67	34.08

* Based on average of 120 quadrats per treatment for each year.

that observed on the 70 and 30 cm treatments (F = 7.15, probability less than or equal to 0.05). Pine growth was similar between the 70 cm and 30 cm treatments (F = 1.34, probability greater than or equal to 0.05).

DISCUSSION

Previous research by Pole et al. (1979); Sandoval and Gould (1978); Huntington et al. (1980) has shown that soil depth replacement over mine spoil can affect revegetation success. Power et al. (1976) further report that yield (tons/ha) of spring wheat will increase with depth of topsoil up to about 71 cm, with greater thicknesses resulting in no further yield increases. Power et al (1981) reported that vegetal yield increases with soil depth to a maximum of approximately 90 cm. Additional soil replacement does not appear to provide increases in yield. Logan (1983) concurred with the results of Power et al (1981) and stated that reduced soil thickness may relate to a reduced productivity but not to no productivity at all.

Data from the Judy Creek study indicate that soil depth replacement on suitable till subsoil does not have a pronounced effect on revegetation success. In the present study reduced soil depth replacement over till did not appear to limit vegetal growth as has been observed in other sodic spoil soil replacement studies.

FIGURE 4. SURVIVAL OF LODGEPOLE PINE BY SOIL DEPTH TREATMENT

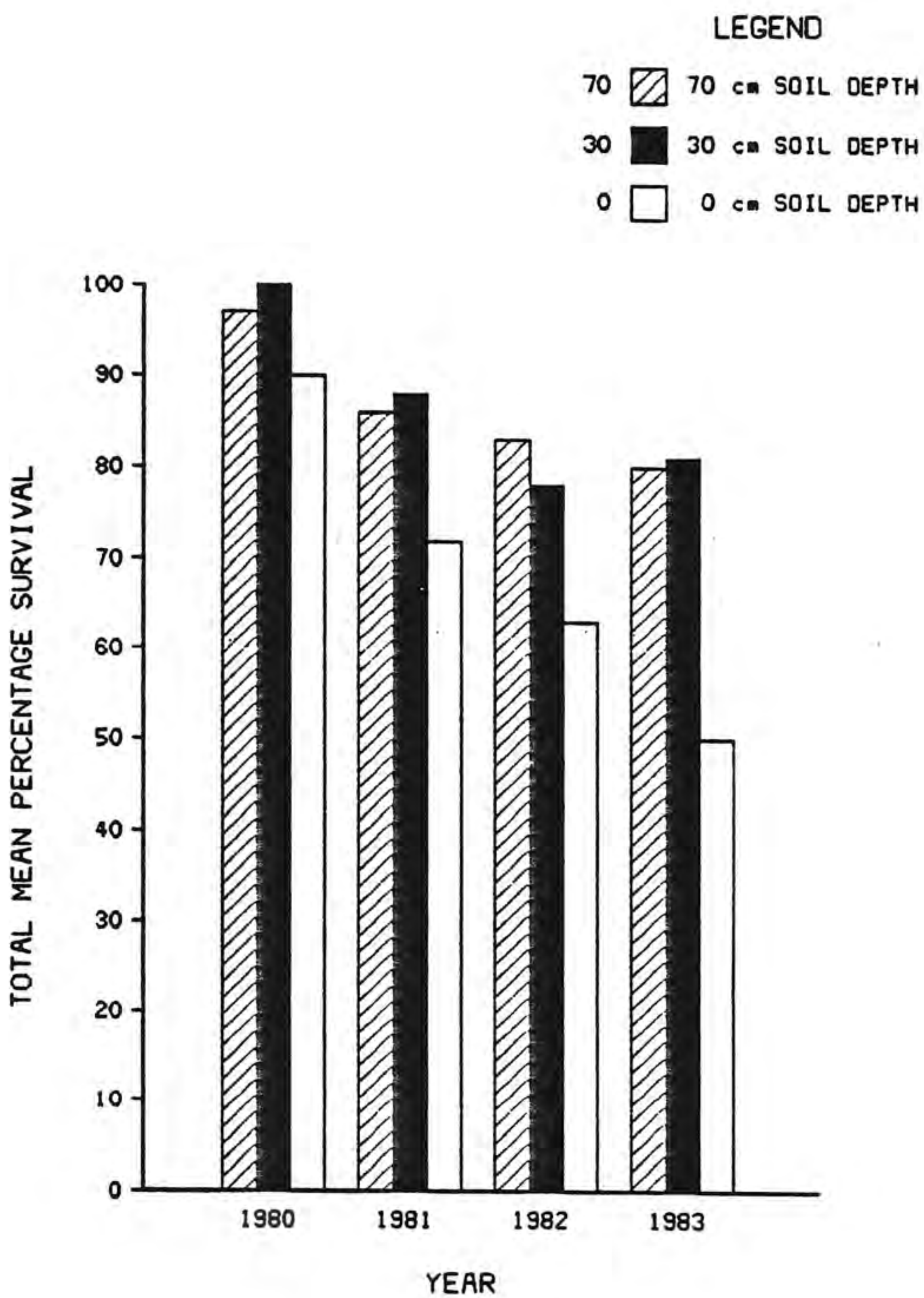


FIGURE 5. LODGEPOLE PINE HEIGHT MEASUREMENTS FOR SOIL DEPTH STUDY

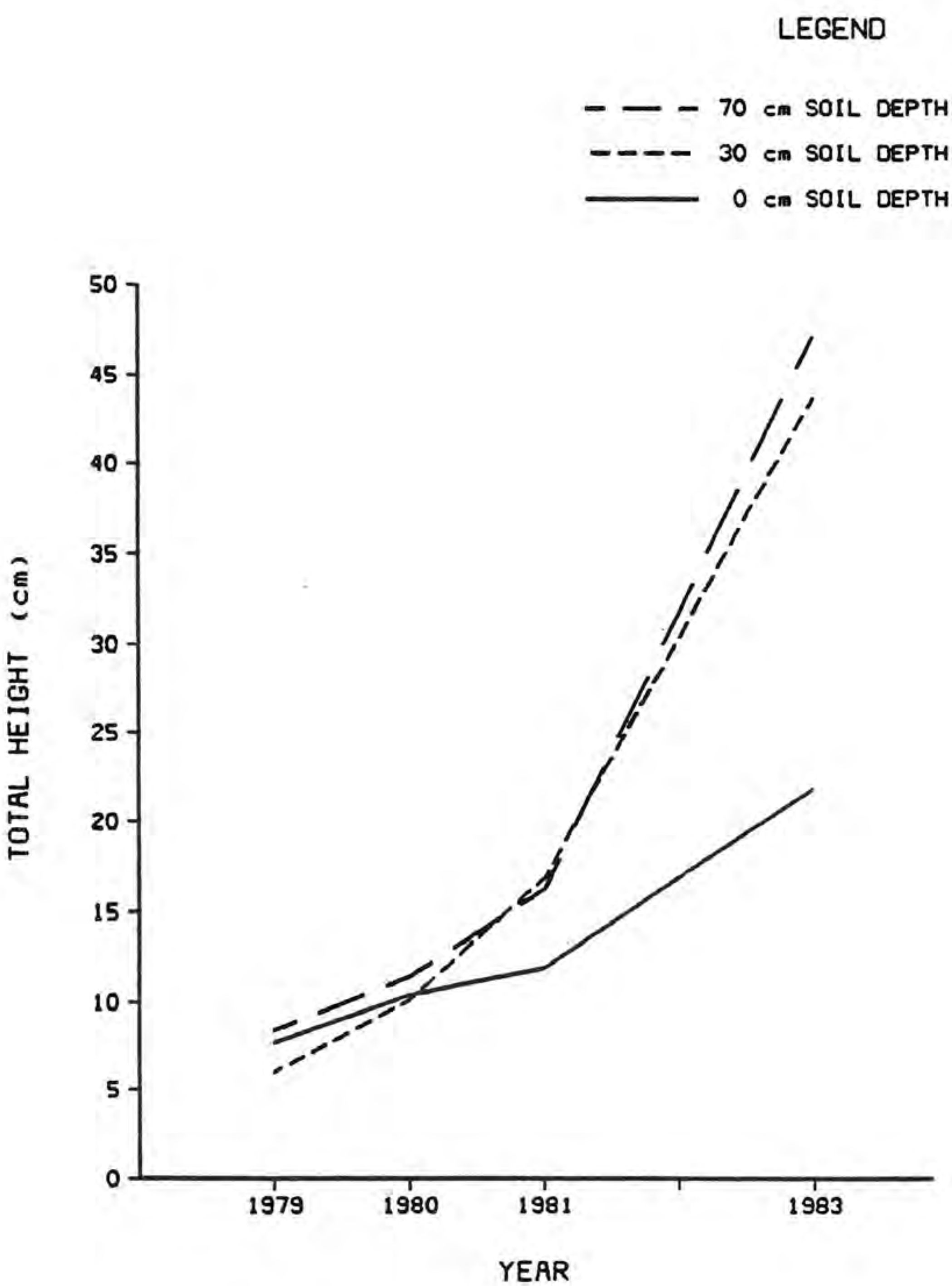
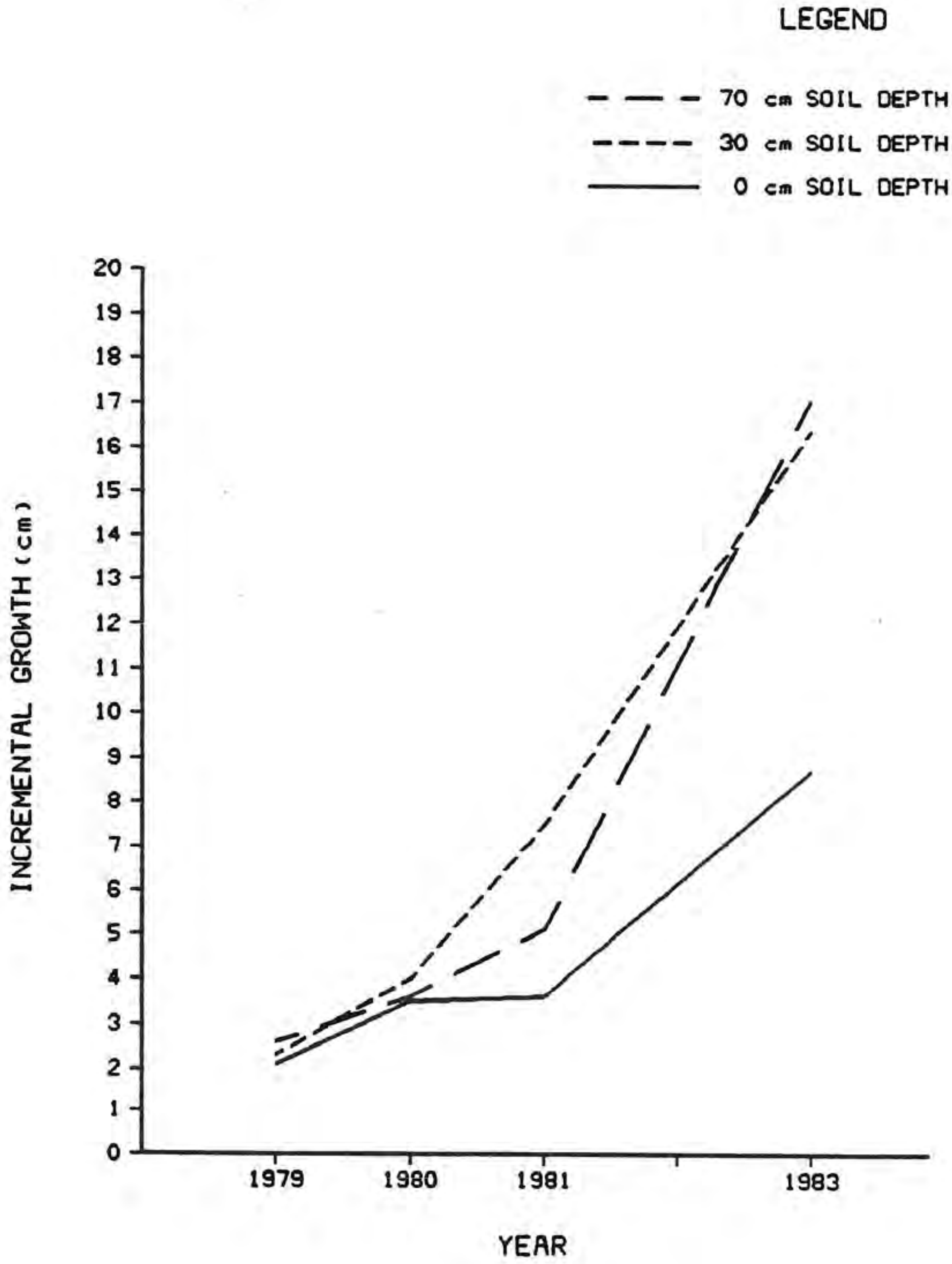


FIGURE 6. LODGEPOLE PINE INCREMENTAL HEIGHT MOVEMENTS FOR SOIL DEPTH STUDY



Research on the topic of appropriate soil depth replacement for reforestation has not been forthcoming. However, Krumlik (1980), in a study designed to examine soil and tree rooting depth relationships in Alberta, reported that the relationship between soil depth and tree growth appears to be poorly correlated. Other soil parameters such as pH, moisture, texture and temperature appear to more strongly influence tree growth. Further, tree growth on reclamation sites has been shown to be influenced by competiton from herbaceous vegetation and by small mammal damage (Green, 1982).

Results from the Judy Creek study concur with these previous studies. Reduced lodgepole pine servival and growth on the 0 cm soil depth treatment is most likely due to the combined effects of lower soil moisture, lower pH, compaction of the till material and competition by dense herbaceous cover. Further, the more dense herbaceous cover on the 0 cm plot increased the potential for small rodent caused pine seedling mortality (Esso Resouces Canada Ltd., 1984).

CONCLUSIONS

Results from this study have implications related to materials handling in reclamation programs in boreal regions of Alberta. Addition of forest soils as "topsoil" over suitable till subsoil may not be required to provide improved revegetation cover. However, on sites where little or no "topsoil" is added, monitoring of reforestation success is recommended.

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18. Gas Research Institute Pipeline Right of Way Research Activities
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27. An Agricultural Capability Rating System for Reconstructed Soils
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