THE USE OF UNCONSOLIDATED RUNOFF MATERIAL IN COAL WASTE DUMP RECLAMATION

ALAN J. KENNEDY, ENVIRONMENTAL CO-ORDINATOR, ESSO RESOURCES CANADA LTD.,
237 - 4th AVENUE S.W., CALGARY, ALTA T2P OH6

BILL M. KOVACH, ENVIRONMENTAL TECHNOLOGIST, BYRON CREEK COLLIERIES,
P.O. BOX I960 SPARWOOD, B.C. VOB 2GO

RECLAMATION AND TREATMENT OF ACID GENERATING MINES
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ABSTRACT

The effects of using unconsolidated runoff material collected from interceptor ditches as an amendment to soil material on waste dumps was investigated on study plots at Byron Creek Collieries from 1983 to 1986. Thirty-two plots representing replicates of two treatments of runoff material Incorporation were established in random block design on a "typical" coal waste dump.

Data were collected on soil quality, vegetation cover and biomass, and tree survival and growth. Results from three years of study indicate the following conclusions.

1. Unconsolidated runoff material appears to improve texture and moisture holding capacity of the soil.

2. Revegetation potential is increased by using unconsolidated runoff material as a soil amendment.

3. Mortality of outplanted trees is reduced on sites incorporated with unconsolidated runoff material.

Further evaluation of the study plots is required to determine long term effects of this amendment on reclamation success.

INTRODUCTION

Amendments to mine waste Include any material that when added to a mine spoil reclamation site can: improve nutrient status, mask or buffer toxicity, Increase cation exchange capacity, Increase moisture retention, improve structure aeration, or organic matter content, and increase flora and fauna (Sims et al. 1984). A wide variety of materials have been experimented upon to determine their suitability as a candidate for a mine waste amendment. Some materials that have been suggested Include; topsoil, peat, overburden, sewage, coal ash, gypsum, mulches, soil stabilizers and conditioners, and fertilizer/soil mixtures.

Topsoiling has been shown to be an effective surface amendment (Power, Ries and Sandoval, 1976) although the depth of replacement and effectiveness of topsoiling may vary with site specific conditions (Kennedy, 1986).

Peat has been shown to be as excellent soil amendment where available (Rowell 1978, 1979; Takyi et al, 1977). Peat tends to improve spoil structure, moisture status and adds essential elements. Mixing peat with spoil appears to be the optimum application procedure (Berry and Klyn, 1974).

Mulches generally improve temperature and aeration, decrease runoff, increase infiltration, increase snow catch, and decrease erosion (Graves and Carpenter 1978; Vogel, 1975). However the use of mulches depends on availability, cost, and expectations. These factors vary considerably with different materials (Kay 1977, 1978, 1979).

Soil stabilizers are used to reduce erosion and stabilize slopes (Dean et al, 1971). Numerous types are available, however, costs are often high. Therefore combining stabilizers and mulches may be the most cost effective treatment (Plass, 1978).

Soil conditioners have been demonstrated to be effective to enhance physical or chemical properties of spoil materials. Derivatives of peat have been used to Increase soil aggregation and moisture retention and decrease hydraulic conductivity and leaching (Lopotko et al, 1980).

Coal ash may be used to raise pH or neutralize acidity, enhance fertility, improve structure, improve moisture capacity and provide a barrier to vertical moisture flux <Josh1, 1981). However, amendment with coal ash may also result in direct and indirect toxlcities, groundwater contamination and deteriation of soil structure (Pluth et al, 1981).

Sewage sludge and effluent is usually very rich in nutrients and 1s thus considered an excellent source of nutrients and organic matter 1n place of more conventional amendments. Sewage is often, however, also rich in heavy metals, bacteria, and other pathogens and Is also an odour source. Sewage varies considerably In Its constituents and should be analyzed carefully before decisions are made as to use. (Halderson and Zenz, 1978).

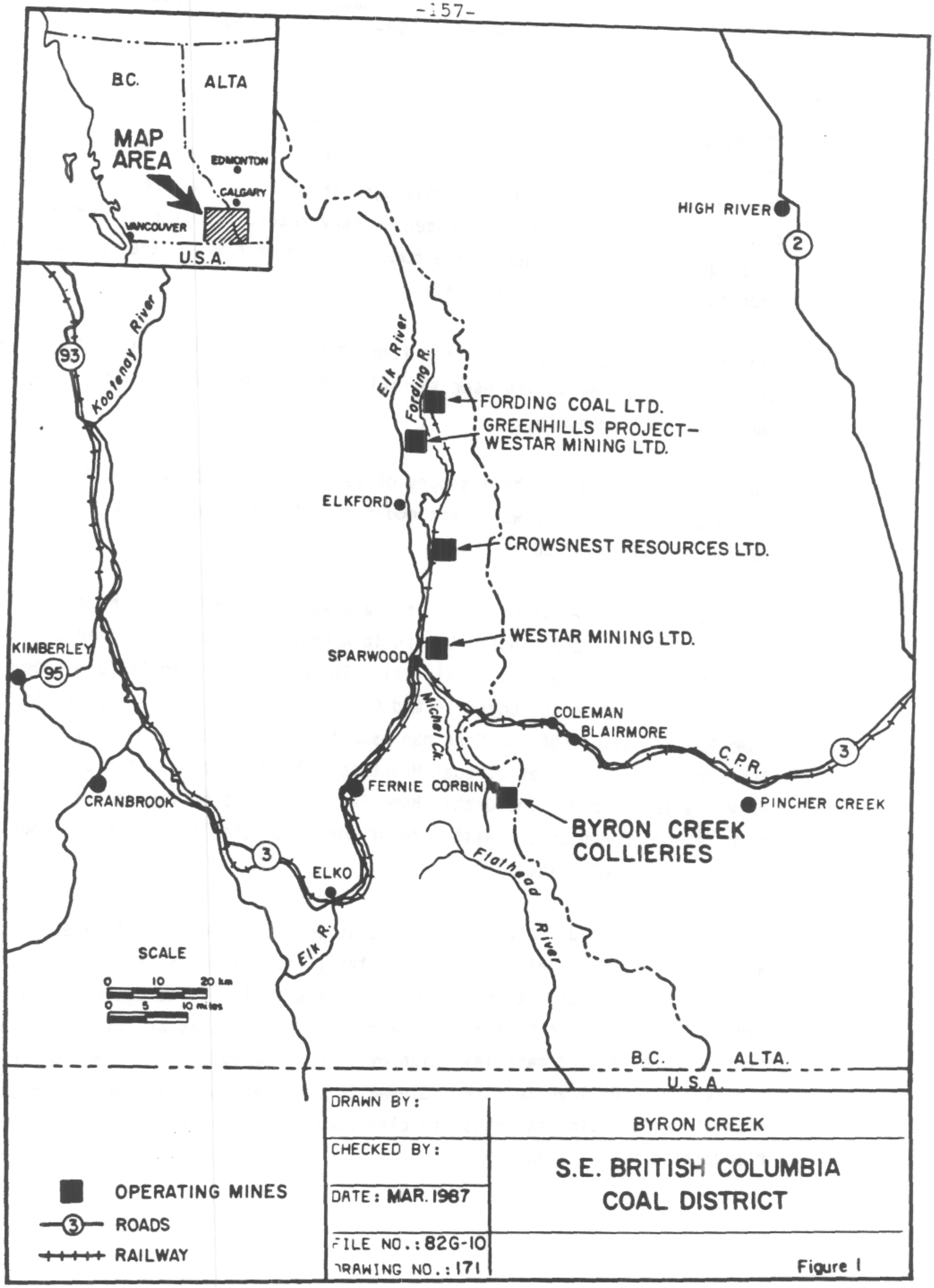
To our knowledge no previous work has been published regarding the use of unconsolidated runoff material as an amendment to waste dump reclamation. The purpose of this paper Is therefore to provide Information on the use of this material 1n terms of Its effects on soil structure and revegetation potential. The term unconsolidated runoff material as used In this paper is any material that has been carried by water from the mining areas of Coal Mountain and been collected in the interceptor ditch system surrounding Coal Mountain. The material therefore includes finely ground particles of mudstones, shales, coal and other sedimentary rocks.

STUDY AREA

Byron Creek Collierie's mine operation is located on Coal Mountain near Corbin, in southeastern British Columbia (Figure 1). Coal Mountain is located in the Front Ranges of the Rocky Mountains, west of the continental divide. The mine area is drained by Corbin and Michel Creeks which flow north to the Elk River.

The dominant land use in the area is coal mining. Although mining began on Coal Mountain in 1907 and Corbin grew to a town of 2,000, only ten permanent dwellings remain. The closest major town is Sparwood, approximately 32 km by road northwest of the mine.

The Byron Creek Collieries area is characterized by variable elevation, topography, slope, aspect, and local wind patterns, and therefore experiences a multitude of micro-climates and fluctuations 1n weather patterns. Mean monthly temperatures vary from a low of -3^{0}C or below during winter to a high of over 10^{0}C 1n summer. Average annual total precipitation is about 112.6 cm of which 73.0 is received as rain and 39.6 as snow. The prevailing wind directions are north (26%), west *(22TL)* and southwest (17%).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FORDING COAL LTD.
GREENHILLS PROJECT-
WESTAR MINING LTD.
ELKFORD
CROWSNEST RESOURCES LTD.
WESTAR MINING LTD.
KIMBERLEY
95
SPARWOOD
Michel Ck.
COLEMAN
BLAIRMORE
C.P.R.
3
CRANBROOK
FERNIE
CORBIN
PINCHER CREEK
BYRON CREEK COLLIERIES
Flathead River
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S.E. BRITISH COLUMBIA
COAL DISTRICT

Figure 1

The Byron Creek Collieries mine area lies within the Columbia Mountains and Southern Rockies physiographic region of British Columbia. In the southern Rocky Mountains portion of this physiographic region, the topography is controlled by folded and faulted sedimentary rocks. Erosional landforms such as cirques, troughs and horns are commonly asymétrie: where they are cut in moderate to steeply dipping strata.

Elevations in the study area range from about 1,370 m above sea level (a.s.l.) in the Michel Creek Valley near the rail loop to about 2,075 m a.s.l. at the summit of Coal Mountain.

The valley bottom areas have slopes of less than 5° with gently undulating topography. The valley walls are moderately to steeply sloping with slopes in some areas exceeding 50°.

The most common soil association in the area Is the McCorn. The dominant soils of this association are Luvisollc Humo-Ferric Podsols formed on moderately fine textured glacial till. The predominant soils formed on colluvlum belong to the Corrigan and Crossing Associations. The Orthic Humo-Ferric Podsols of the Corrigan Association are found on stony material on the steep eastern slopes of Coal Mountain. Parent material texture is gravelly sandy loam. The Orthic Humo-Ferric Podzols of the Crossing Association, found on the west side of Coal Mountain, are formed on moderately fine textured colluvium.

There are several different soil associations found on fluvial materials within the Coal Mountain area. The Grizzly Association 1s found on fluvioglacial terraces along the Michel Creek Valley. The dominant soils are Luvisollc Humo-Ferric Podsols. Parent material textures are silty clay loams of the shale derived material which overlies fluvioglacial gravels which have a gravelly sandy loam texture. Gleyed Cumulic Regosol soils of the Forum Mountain Association having silty clay loam textures are found along stream floodplains 1n the area.

The Byron Creek Collieries mine area lies in the Engelmann Spruce-Subalpine Fir zone which ranges between *1,212* to 2,270 m in southern British Columbia. British Columbia biophysical classification places the area in the Interior Rocky Mountain Douglas-Fir Zone and Subalpine Engelmann Spruce-Alpine Fir zone. These zones are characterized by young seral stands of lodgepole pine (Pinus contorta) with varying regeneration of Engelmann spruce (Picea engelmannii) and alpine fir (Abies lasiocarpa). Whltebark pine (Pinus albicaulis) occurs on steep exposed colluvlal slopes. F1re has played an important role In forming the vegetation mosaic. Localized pockets of regeneration produce a complex understory which further varies with the sharp change 1n altitude (from approximately 1,370 to 2,075 m), slope, aspect and soil moisture. In the absence of fire, climax stands of alpine fir and Engelmann spruce are expected to develop on well drained soils.

METHODS

Plot Scheme

The amendment incorporation study was conducted on a waste dump to the north and west of the active mining area (Figure 2) on Coal Mountain. The study consisted of 32 plots (25 m x 25 m) as shown in Figure 3. Sixteen plots were placed on the amendment incorporated portion of the waste dump; eight plots on the upslope position and eight plots on the downslope position. Sixteen plots were also placed on the non-Incorporated portion of the waste dump, again on the upslope and downslope positions.

Chemical and physical analyses of the waste material indicated no parameters limiting growth (Table 1). The waste can be characterized as an inert, very coarse textured material with low nutrient status. Analysis was also conducted on the unconsolidated runoff material with the following results obtained. Moisture (%) 41.4, pH 7.6, conductivity 0.56 mohs/cm, SAR 0.27, exchangeable cations (meq/100 gm); Na^{++} 0.24, P^{++} 0.15, Ca^{++} 3.53 Mg^{+} 1.19, and textural class a clay-loam.

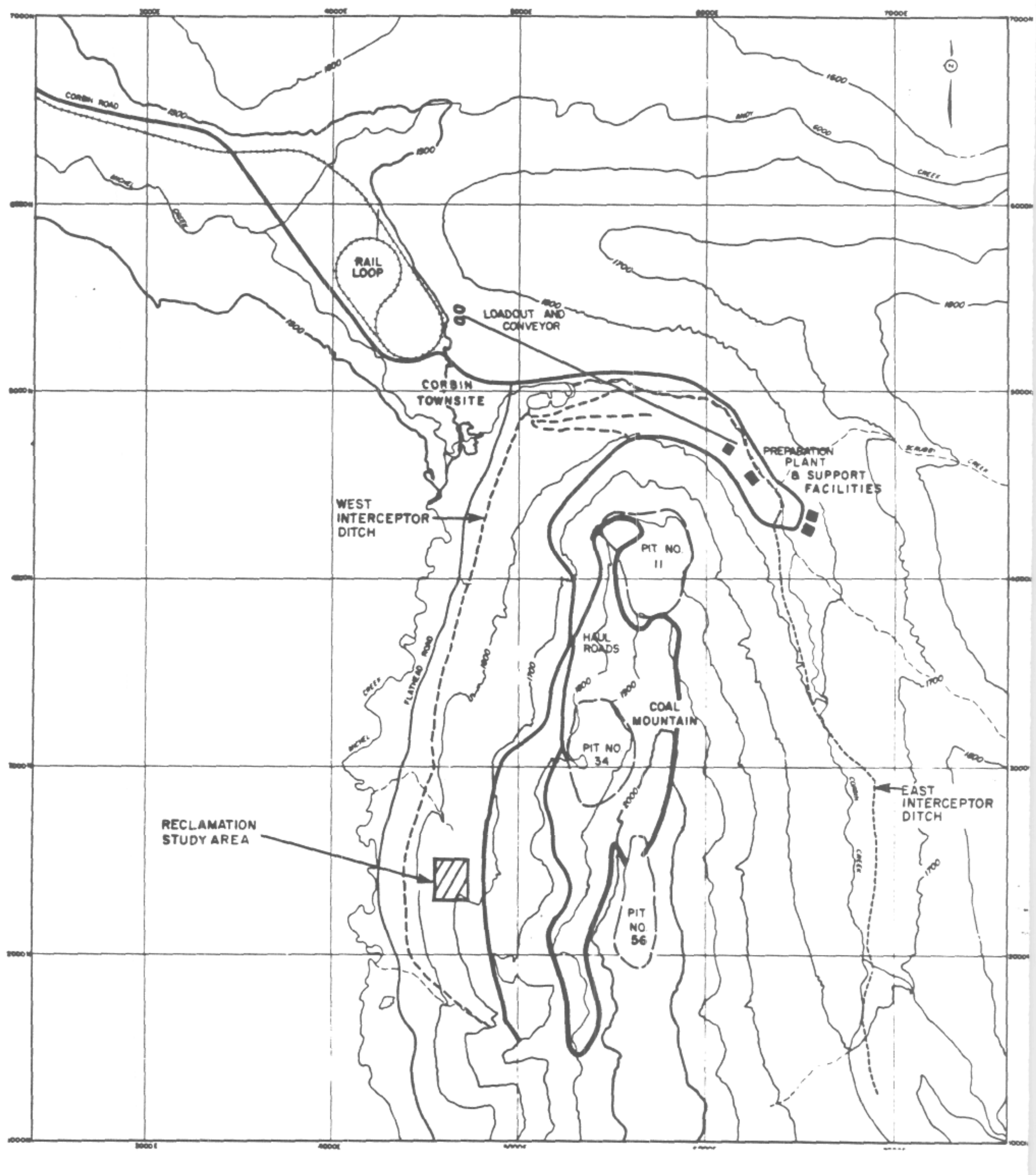

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FIGURE 3: PLOT LAYOUT FOR AMENDMENT INCORPORATION STUDY.

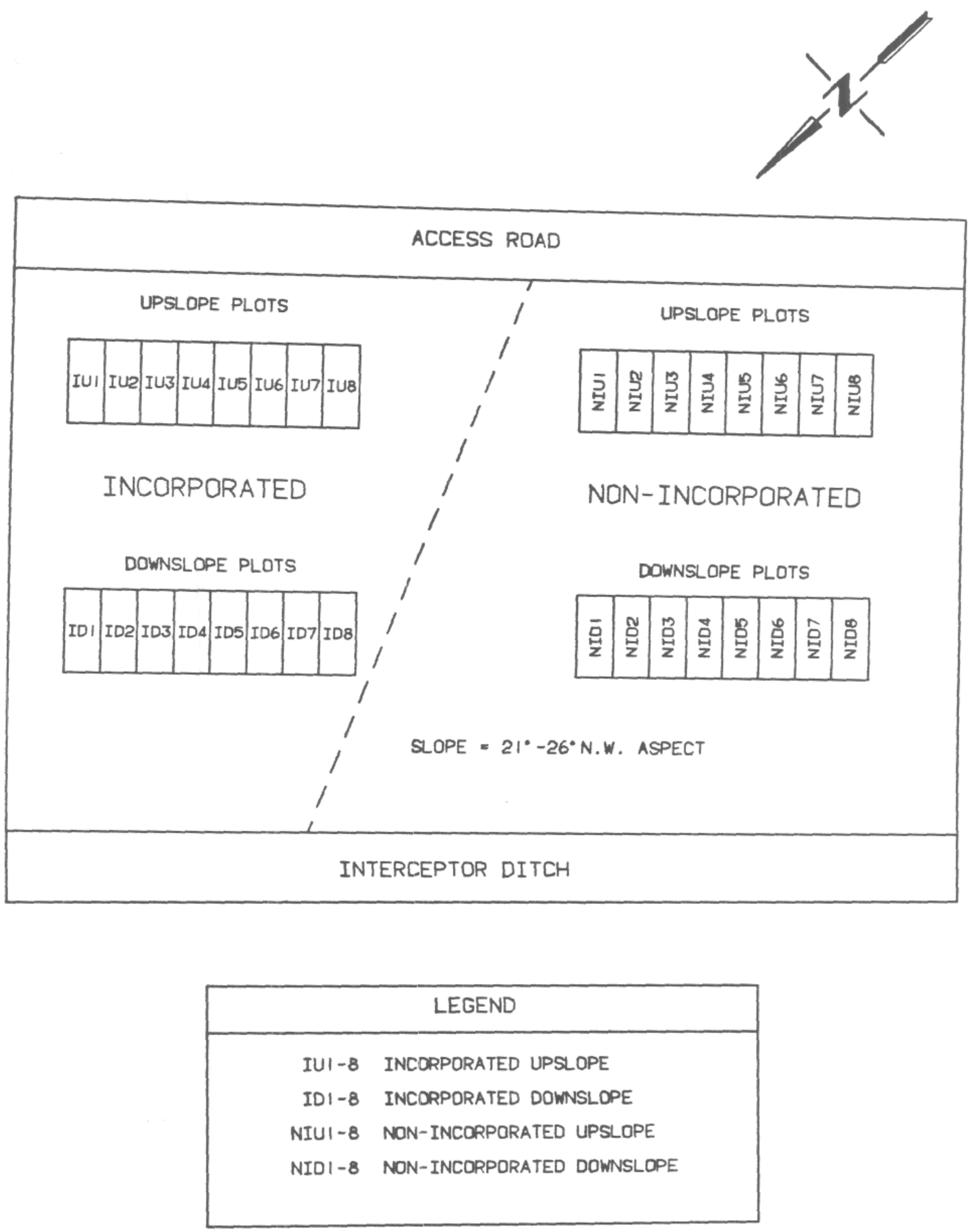

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TABLE 1

CHARACTERISTICS OF WASTE MATERIAL RECLAIMED FOR INCORPORATION STUDY

Samples	pH	Conductivity	Nutrient Status (kg/ha)			Exchangeable Ions (meq/100 gm)				CEC	$CaCo_3$	SAR	Texture		
		(mohs/cm)	NO_3N	P_2O_5	K_2O	NA	K	CA	Mg	(meq/100 gm)	Equivalence (%)		%Sand	%Silt	%Clay
1	6.7	0.30	23.6	2.1	243.0	1.1	0.6	6.0	6.0	10.7	9.8	0.5	77	16	7
2	7.1	0.40	14.6	0.2	256.5	0.3	0.4	2.7	2.7	7.2	14.7	0.3	71	17	12
3	6.3	0.28	10.1	2.9	216.0	0.2	0.1	2.3	2.3	4.1	3.8	0.2	86	11	3
Average Values	6.7	0.32	16.1	1.7	238.5	0.53	0.37	3.7	3.7	7.3	9.4	0.3	78	15	7

INCORPORATION TECHNIQUES

All unconsolldated material running off the active mining areas, roads, and waste dumps is collected through a system of Interceptor ditches surrounding Coal Mountain (see Figure 2). The Interceptor ditch system is designed to optimize the settling rate of material through the use of wiers constructed from coarse rock which provide small settling pools. Flocculant is also added to ditches to increase settling rate 1n areas easily accessible for clean out. The material that collects in the ditch is removed annually as a routine maintenance function. Material is removed from the ditch with a backhoe and trucked to a site within the mine lease boundary.

Initially the waste dump was resloped to 21° - 26° prior to any incorporation procedures. For the present study wiers were dewatered and unconsolidated material was trucked to the dump site using the mine access roadway system. As the material when removed from the ditches has up to 40% moisture content it was initially dumped at the top of the waste dump slope within containment berms to prevent runoff.

Cross-cut ditches at appropriate Intervals from the top to the bottom of the dump slope were then constructed using a D-9 caterpillar. The unconsolldated material was then allowed to run down the slope and fill the ditches. The material was then left to dewater in the ditches for approximately 24 hours. The dried material is then worked into the entire waste dump with a caterpillar blade to a depth of about one meter. For the present study approximately 10,000 m^3 per ha were incorporated into the waste dump. Following sediment incorporation and resloping activities the entire slope was "tracked" crosswise with a caterpillar to prevent surface erosion and to provide micro-sites to improve revegetation potential. The study site was then revegetated with the seed mix and fertilizer regime Indicated in Table 2. A small berm (less than one meter) was left at the top of the slope to redirect runoff and reduce the erosion Impact of heavy rainfall events.

TABLE 2

REVEGETATION SEED MIXTURE SPECIFICATIONS AND FERTILIZATION REGIME FOR STUDY

PLANT SPECIES	SEEDING RATE	FERTILIZATION
Creeping Red Fescue	25%	
Chinook	20%	
Climax Timothy	10%	
Norlea Perennial Rye Grass	10%	
Red Top Fescue	2%	
Sanfoin	10%	
Vernal Alfalfa	15%	
Alsike Clover	8%	
	100%	80-100 kg/ha at 13 N-16P-10K

DATA COLLECTION AND ANALYSES

Soil samples were taken from each study plot in 1984 and 1985. Two subsamples were taken at randomly spaced locations within each study plot and combined by treatment for analysis. Analysis of soil samples followed procedures reported in McKeague (1978). Soil chemistry analyses included the level of available macro-nutrients including nitrogen (NO_3-N), phosphorous (P), potassium (K), calcium (Ca), and magnesium (Mg), CEC and pH. Physical soil analyses included particle size distribution, moisture holding capacity (percentage) and bulk density.

Revegetation success for each soil depth treatment was evaluated through the measurement of plant cover. During June and August of 1984 and August of 1985 and 1986 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 40 evenly spaced 20 cm by 50 cm quadrats. Cover within each quadrat was estimated using the Braun-Blauquet method (Kershaw 1973).

Above ground biomass was determined for each soil treatment in 1986. Samples were obtained by clipping to ground level all standing vegetal material within a 0.25 m^2 quadrat placed randomly at three sites within each plot. Samples were placed in appropriately sized paper bags and returned to the laboratory where they were air dried and weighed.

Reforestation success for each treatment was determined through evaluation of the survival and growth of each permanently marked tree. Estimation of tree survival and growth was conducted during June and August of 1984 and August of 1985 and 1986. Tree survival was determined through evaluation of the survival status of each marked tree (i.e., 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.

RESULTS

Soil Conditions

The chemical parameters of the soil material for each study treatment are given in Table 3. Soil pH during the study has ranged from 7.2 to 7.8 (pH units) with the incorporated plots consistently having higher values. However, all study plots had pH values acceptable to plant growth. Levels of macro-nutrients (N, P, K) on each treatment were above those reported values required to support gramlnoid growth (Williamson et al 1982).

Very little variability was recorded between treatments Indicating that nutrient availability was similar among plots. The quantity of exchangeable ions was also consistent between treatments. However, Cation Exchange Capacity was lower on the non-incorporated treatments indicating a reduced capacity on these plots. Techman, (1983) estimated that a minimum CEC requirement for a mixed wood stand should be 14 meq/100 gm in the top 15 cm of the solum.

The physical parameters of the soil material for each study treatment are given in Table 4. Based on particle size distribution analysis the surface material was characterized as coarse-sandy in texture. There was little variability in soil texture between treatments for the initial two years of study. However, during the 1986 growing season textural differences were becoming evident In that the incorporated treatment was observed to have more fine textured particles. Texture analysis will be conducted in summer 1987 to confirm these observations. Data on bulk density indicated that the incorporated plots had a less dense rooting medium than the non-incorporated plots. Minore (1979) has recommended a range of bulk density between 1.2 to 1.6 g/cm^2 for lodgepole pine.

Data on moisture content (Table 4) showed a large variability between sampling periods but little variation between treatments. It appears that during dry early summer months the soil material is prone to dessication but during wet early fall periods more moisture is present. During 1985 soil moisture tension measurements were conducted to determine the amount of water held in the soil and available to the tree seedlings. A soil moisture calibration curve was produced to evaluate soil moisture content on the study plots (Figure 4). Based on the texture of the soil and estimates of soil water retention the maximum field capacity and maximum wilting point of the Byron Creek soil material is estimated at 7% and 14% respectively.

The soil on the plots are therefore considered to have been close to or less than wilting point during the summer 1984 and 1985, and greater than field capacity in fall 1985. No moisture content measurements were taken in 1986. The non-incorporated plots most often had less available moisture than incorporated plots. The data on moisture holding capacity indicates the non-incorporated treatment have less water available to outplanted trees.

REVEGETATION SUCCESS

Percentage cover data for grasses and legumes are shown in Figure 5. Cover remained approximately equal in the first two years of study but increased dramatically from 1985 - 1986. Legume cover increased substancially from 1985 to 1986 on the incorporated treatment and was a major contributor to total cover on the study. By 1986 legume cover was significantly greater on the incorporated treatment than on the non-incorporated treatment (Probability = .014). Grass cover was also significantly greater on the Incorporated treatment (Probability = .014).

Cover estimates for each planted species by treatment are given in Table 5. Red Fescue and Chinook Orchard grass are consistently the most abundant seeded grass species on all plots. Timothy had become established by 1986 and Rye grass was recorded at only marginal abundance. Clover and alfalfa were recorded at a higher cover than Sanfoin.

TABLE 3

CHEMICAL PROPERTIES OF SOIL MATERIAL ON SEDIMENT INCORPORATION STUDY*

Treatment**	pH	Nutrient Status (kg/ha)			Exchangeable Ions (meq/100 gm)				CEC (meq/100 gm)
		N	P	K	NA	K	CA	Mg	
1	7.8	6.7	12.2	240	0.07	0.50	12.75	2.7	16.2
2	7.8	2.5	7.6	218	0.06	0.64	13.20	2.9	16.8
3	7.5	4.1	18.5	239	0.07	0.54	7.29	3.2	11.8
4	7.2	5.9	9.2	260	0.07	0.54	5.97	3.8	10.9

* Values expressed as mean of eight samples

** Treatments are: 1 = incorporated upslope
2 = incorporated downslope
3 = non-incorporated upslope
4 = non-incorporated downslope

TABLE 4

PHYSICAL PROPERTIES OF SOIL MATERIALS ON SEDIMENT INCORPORATION STUDY

TREATMENT*	TEXTURE			SOIL PROPERTY					
	% Particle Size			Bulk Density (gms/cm^2)	Moisture Content (%)				Moisture Holding Capacity (%)
					1984		1985		
	Sand	Silt	Clay		July	August	July	September	
1	64.5	19.4	16.1	2.2	7.70	6.49	3.60	24.09	7.12
2	67.5	21.4	14.8	2.1	7.60	5.41	3.33	22.72	6.57
3	71.9	17.8	10.4	1.8	6.36	4.60	3.68	23.19	5.80
4	67.5	20.3	13.0	1.9	6.10	4.81	3.30	23.37	5.00

* Treatments are: 1 = incorporated upslope
2 = incorporated downslope
3 = non-incorporated upslope
4 = non-incorporated downslope

FIGURE 4. SOIL MOISTURE RETENTION CURVE FOR BYRON CREEK RECLAMATION STUDY

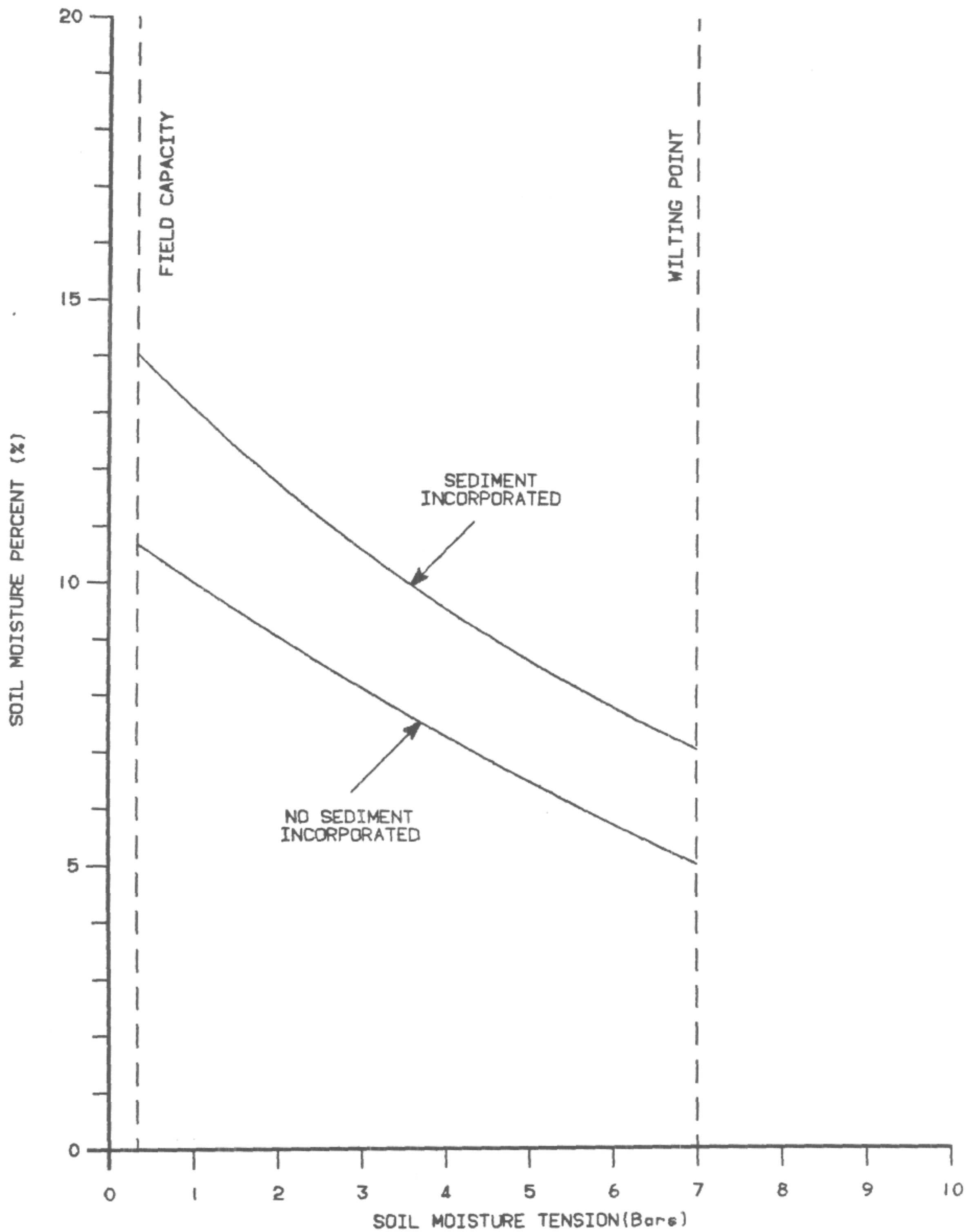

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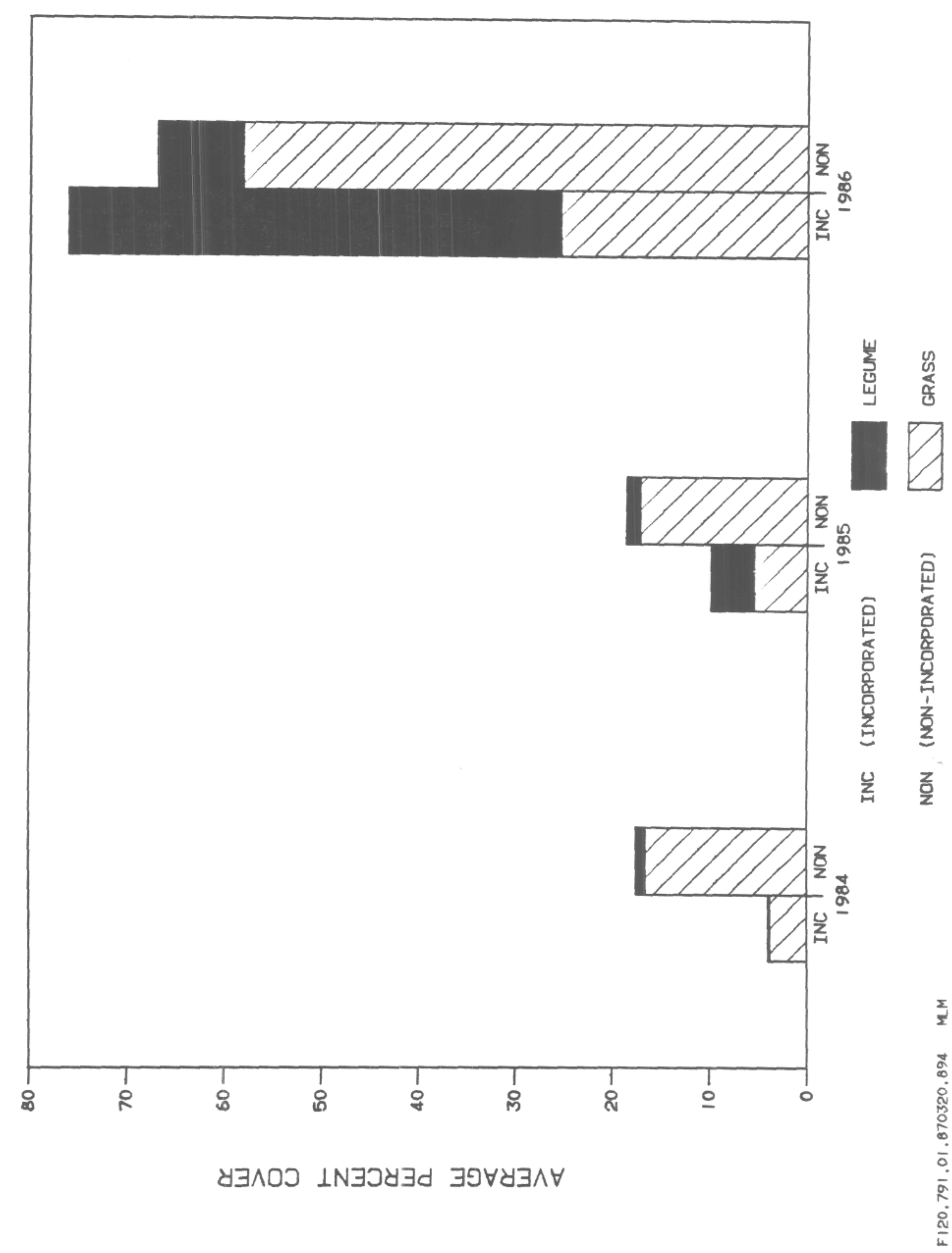
FIGURE 5: PERCENT COVER OF GRASS AND LEGUMES.



Proceedings of the 11th Annual British Columbia Mine Reclamation Symposium in Campbell River, BC, 1987.
The Technical and Research Committee on Reclamation

FIGURE 6: AVERAGE BIOMASS OF VEGETATION(1986)

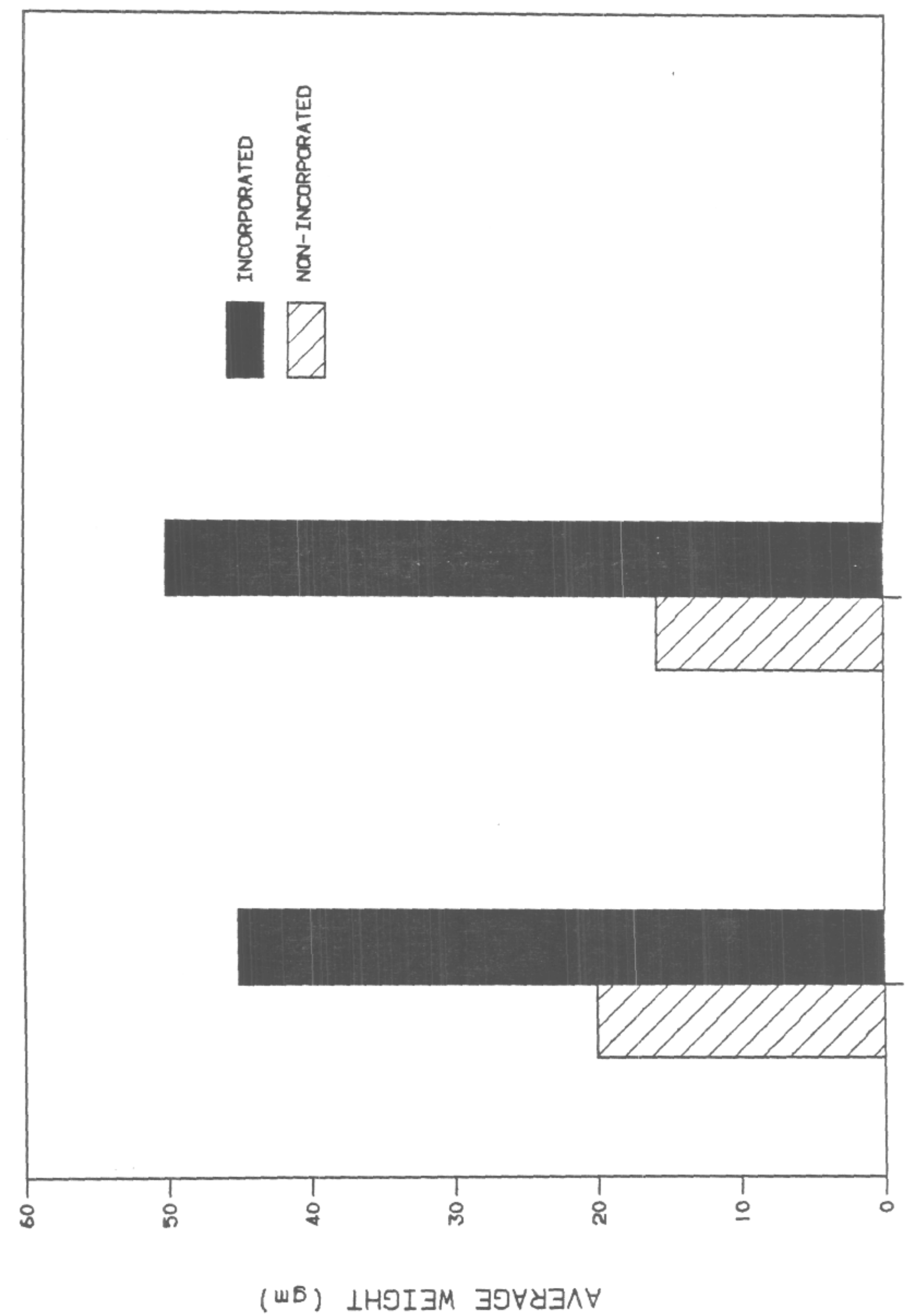
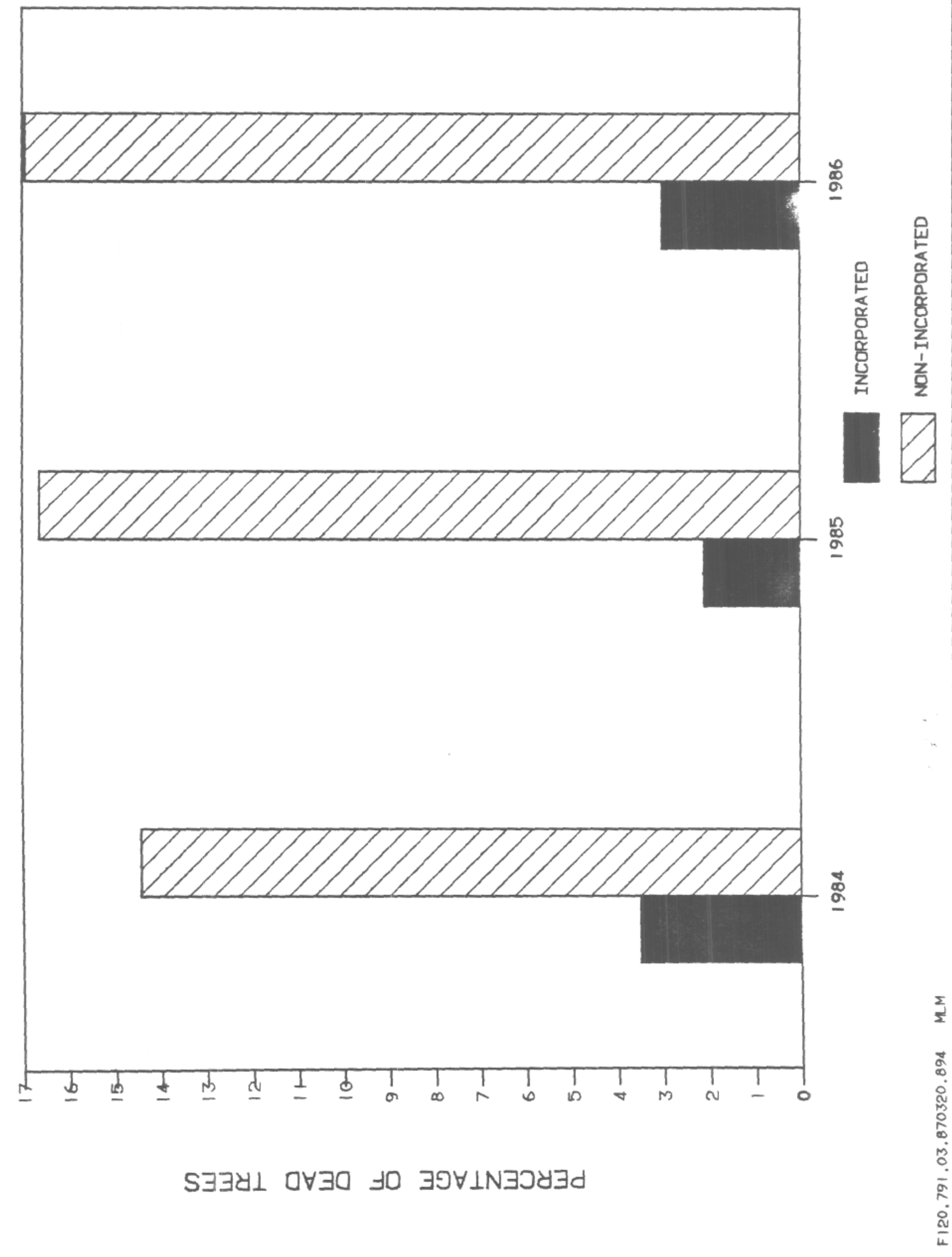


FIGURE 7: TREE MORTALITY ON STUDY PLOTS.



Data on plant blomass from the study was complimentary to the cover data the incorporated treatment had significantly higher biomass than the non-incorporated treatments (Figure 6).

REFORESTATION

Data on the percentage mortality of lodgepole pine by treatment are shown In Figure 7. The non-incorporated treatment consistently showed lower mean survival than the incorporated treatment. The total growth (Figure 8) and incremental yearly growth (Figure 9) of lodgepole pine were found to be quite similar between incorporated and non-incorporated treatments.

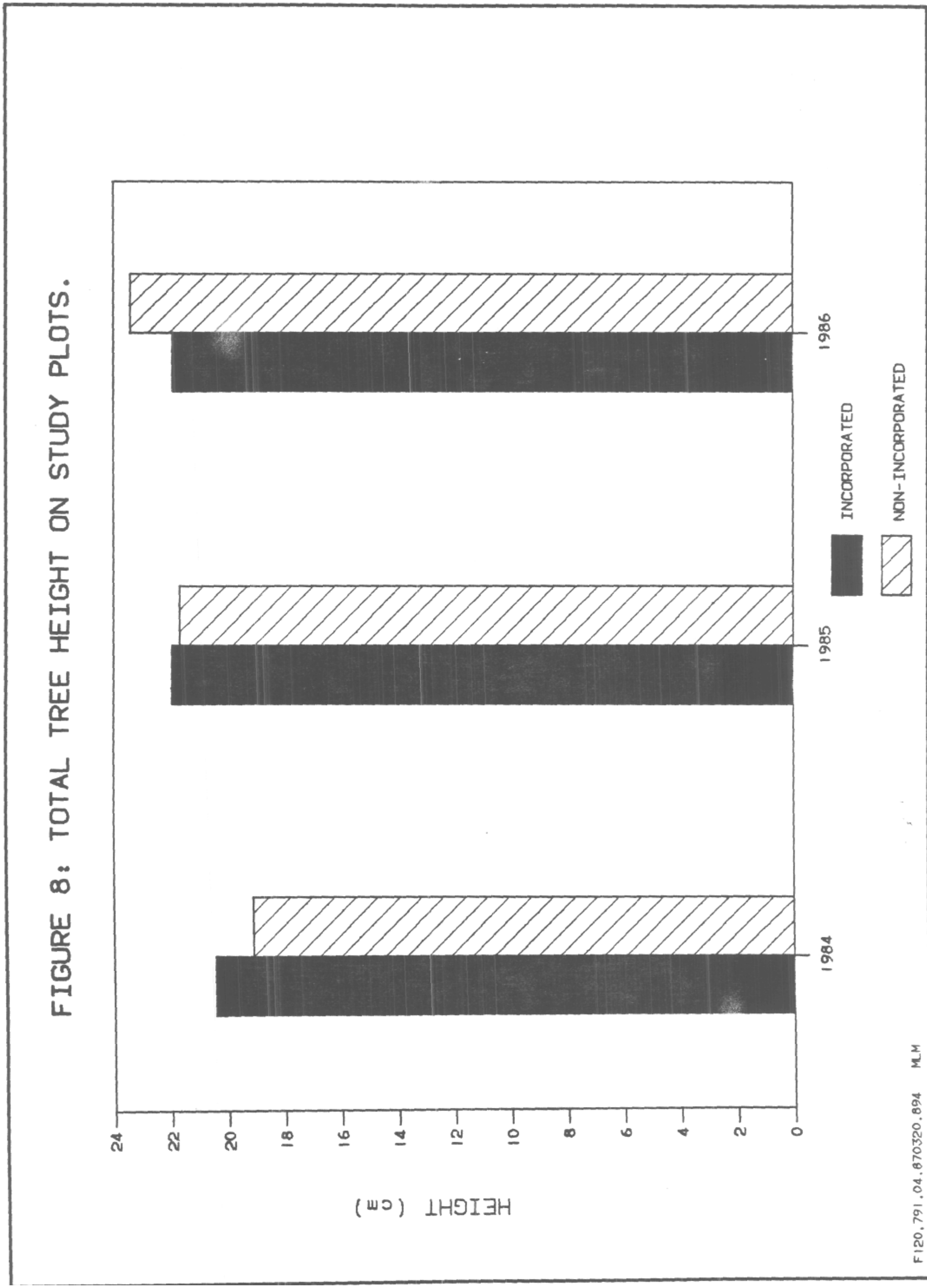


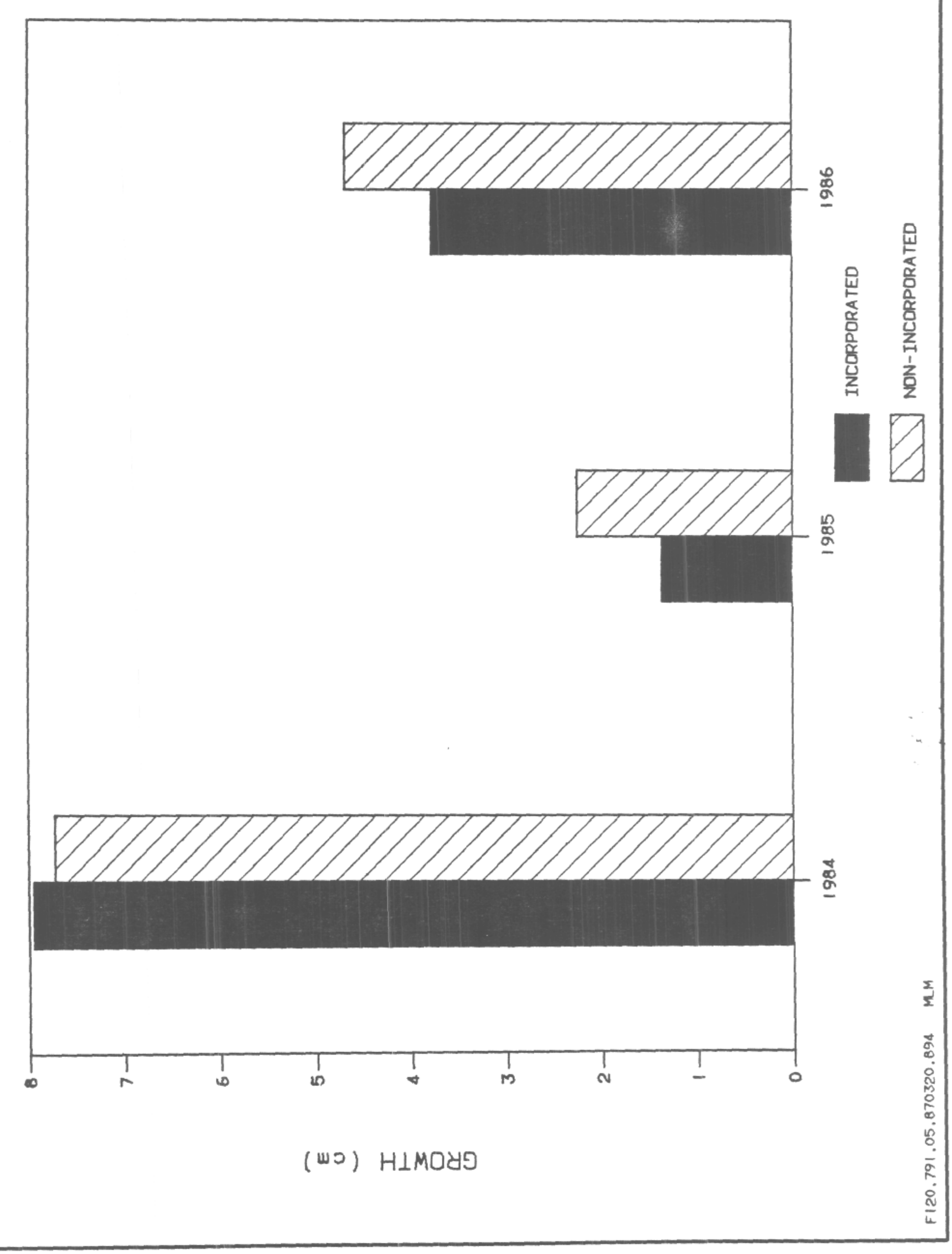
FIGURE 8: TOTAL TREE HEIGHT ON STUDY PLOTS.

TABLE 5

AVERAGE PERCENT COVER OF VEGETATION BY SPECIES FOR THE STUDY

TREATMENT	YEAR	BARE GROUND	DEAD COVER	TOTAL LIVING COVER	TOTAL GRASS COVER	RED FESCUE	CHINOOK ORCHARD GRASS	TIMOTHY	RYE GRASS	TOTAL LEGUME COVER	ALFALFA	SANFOIN	CLOVER
Up Inc	84	88.0	0.0	5.1	4.9	3.0	2.6	1.5	0.0	0.3	0.0	0.4	0.4
Dwn Inc	84	88.0	0.0	2.9	2.9	2.6	2.3	1.1	1.1	0.0	0.0	0.0	0.0
Up Non	84	81.1	0.0	18.9	17.4	3.9	12.5	3.8	0.0	1.4	0.0	0.0	2.3
Dwn Non	84	84.3	0.0	15.8	15.6	5.3	9.1	3.2	0.4	0.1	0.0	0.0	0.4
Up Inc	85	89.8	0.0	9.5	5.5	2.6	2.3	2.6	1.6	4.0	0.0	0.4	4.1
Dwn Inc	85	89.9	0.0	10.1	5.9	2.8	2.6	3.3	1.1	4.2	0.0	0.4	4.6
Up Non	85	79.6	0.0	21.5	20.7	6.9	12.1	3.1	2.6	1.1	0.0	0.4	1.6
Dwn Non	85	84.0	0.0	16.0	14.1	4.3	8.1	2.6	3.7	1.9	0.0	1.5	2.8
Up Inc	86	38.4	0.0	58.1	17.2	8.6	6.8	7.7	0.4	40.9	27.7	9.3	22.8
Dwn Inc	86	40.1	0.0	95.6	34.4	16.6	15.0	11.8	2.6	61.2	28.2	19.4	33.7
Up Non	86	58.3	11.8	59.0	52.4	22.7	25.5	12.7	3.3	6.6	3.9	2.6	18.8
Dwn Non	86	56.7	9.5	77.0	65.6	29.8	28.3	23.6	6.1	11.4	12.5	13.8	16.4

FIGURE 9: INCREMENTAL YEARLY TREE GROWTH ON STUDY PLOTS.



CONCLUSIONS

Results from this study have implications related to use of unconsolidated runoff material as a waste dump material amendment at Byron Creek Collieries. Advantages of using this material for amendment purposes are as follows:

1. Unconsolidated runoff material appears to improve rooting medium texture and moisture holding capacity.

2. Revegetation potential appears to be increased by using unconsolidated runoff material as an amendment.

3. Mortality of outplanted trees 1s positively influenced through the use of unconsolidated runoff material.

4. In the long term using runoff material will be economical in reducing handling and eliminating storage. Further evaluation of the study plots 1s required to determine long term effects of the amendment on reclamation activities at Byron Creek Collieries.

ACKNOWLEDGEMENTS

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