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July 18, 1980

Mr. P. Dean,
Environmental Coordinator,
Cyprus-Anvil Mining Corp.,
355 Burrard Street,
Suite 330,
Vancouver, B.C.
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810641

Dear Peter:

Re: Soil and Terrain Analysis of the Tulameen Coal Project Area

Please find enclosed our report concerning the soil and terrain mapping and assessment program of the Tulameen Coal Project Area. A folio of maps and accompanying legends also form part of this assessment and is included with this report.

Both myself and Mr. Maynard have enjoyed working with you on this project and trust the information we have gathered will be valuable to you in your planning and engineering program.

Yours truly,

M. Walmsley

Mark E. Walmsley, P.Ag.

GEOLOGICAL ASSOCIATION OF CANADA
M. E. WALMSLEY
FELLOW

MW:pr
encl.

* A partnership of Mentiga Pedology Consultants Ltd., Quiet Nook Pedology Consultants Ltd., Pedocan Land Evaluation Ltd., and Pacific Pedology Consultants Ltd.

TERRAIN AND SOIL ASSESSMENT

OF THE

TULAMEEN COAL PROJECT AREA

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INTRODUCTION

The method for planning coal development, ensuring a rational approach to managing land-use, environmental, and community impacts, is described in the Guidelines for Coal Development (E.L.U.C., 1976). Terrain and soil information provides data for assessing such biophysical factors as geological hazards and land capability, allowing evaluation of specific impacts and management proposals.

Cyprus Anvil Mining Corporation, which intends to develop the Tulameen Coalfield, initiated some environmental investigations designed to satisfy the coal guidelines. Mr. Peter Dean, Environmental Coordinator of the company, outlined the following terrain and soil information needed for a stage II assessment:

1. Identify basic terrain and soil features at a scale of 1:10,000
2. Qualitatively assess the tailing pond area for permeability and general suitability
3. Determine areas of soils which may be worth stock-piling for reclamation purposes
4. Assess characteristics of waste rock material important for plant growth to determine any problems associated with revegetating waste dumps.

LOCATION AND DESCRIPTION OF THE STUDY AREA

The Tulameen Coalfield is located in southwestern British Columbia, about 170 km east-northeast of Vancouver. The proposed area of development is centred south of the town of Tulameen and west of the town of Coalmont within NTS map sheets 92 H 7 and 10 (Figure 1). Existing access from Coalmont is along a logging road, a distance of 11 km.

The coalfield underlies an oval-shaped area of about 20 km^2. The mineable coal beds occur in a narrow zone of fine-grained Tertiary sedimentary rocks.

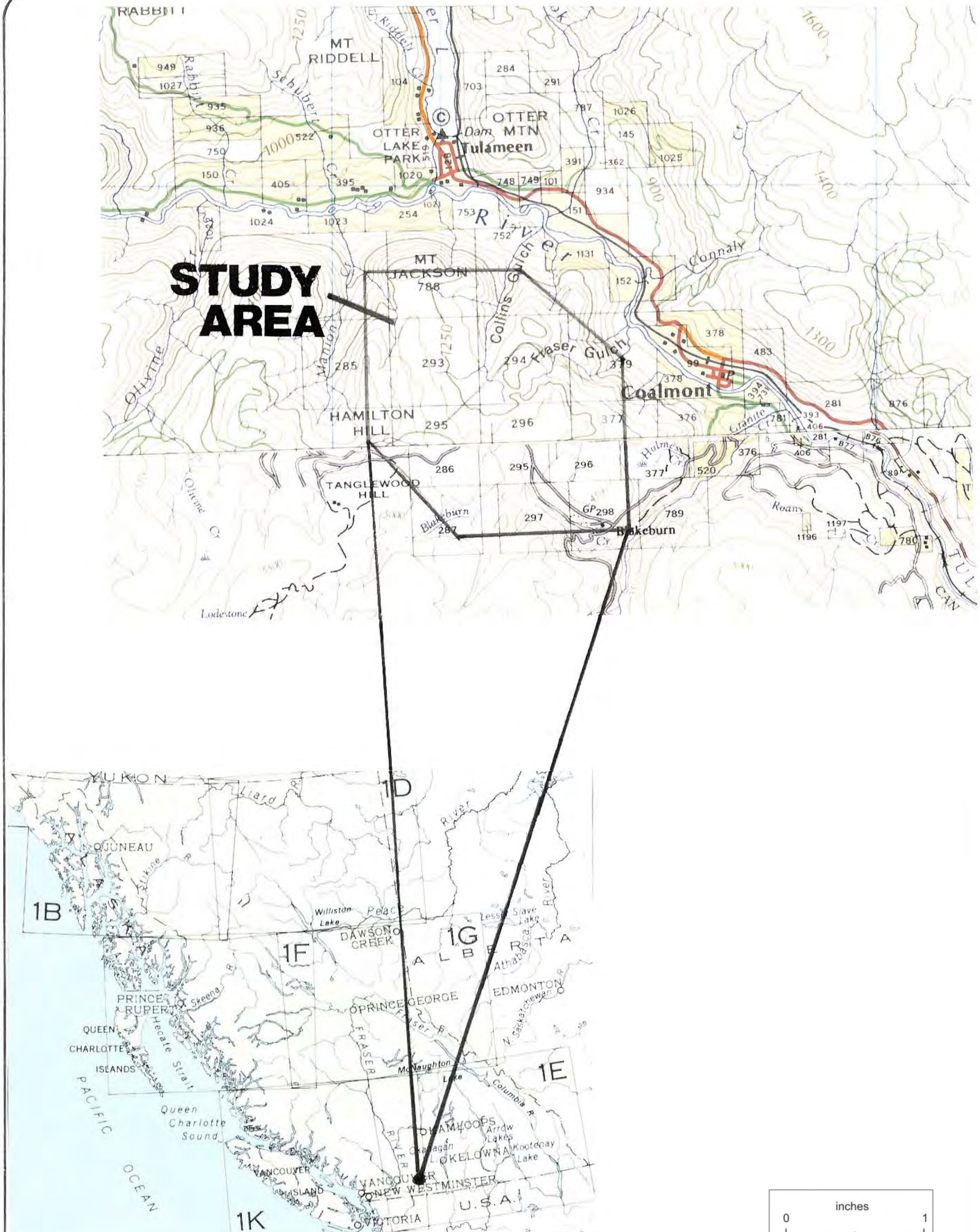

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Figure 1. Location of Study Area

Coal was mined along the southwestern margin of the coalfield by Coalmont Colleries Ltd. The historic townsite of Blakeburn, now deserted, is situated at the southeastern extremity of the old development. The northwestern margin of the field was prospected at a number of places, noteably Collins Gulch and Fraser Gulch, but there was no commercial production from these areas.

The map-area lies at the boundary of the Hozameen Range of the Cascade Mountains Physiographic Region and the Thompson Plateau which is a subdivision of the Southern Plateau and the Mountain area of the Canadian Cordillera (Holland, 1964). The plateau topography consists of relatively flat-topped ridges, usually above 1200 m. elevation, separated by deep and, in places, steep-walled valleys. The main drainage is along the easterly trending valley of the Tulameen River. In the vicinity of the study area the largest streams are Granite Creek and its tributary, Blakeburn Creek. However, the largest watershed in the area of interest is that of Collins Gulch, a short but steep-gradient tributary of the Tulameen River (Figure 2). Both Fraser Gulch and Holmes Creek also have substantial watersheds in the map-area.

OBJECTIVE AND METHODS

Pedology Consultants Ltd. outlined and carried out a program of terrain and soil assessment which meets the criteria of the coal guidelines and which can be useful in planning mining activities. Our objective is to describe the soil and surficial geologic landscape of the study area and to use this information as a basis for determining vegetative growth characteristics of the soils and engineering capability of the geologic materials. When properly used, terrain and soil analysis provides a solid data base for cost-efficient and environmentally acceptable use of the land. In any area the natural features and processes present a range of advantages and disadvantages for different land uses. Evaluating terrain and soil capability within a biophisical framework of various land areas enables effective planning for the location of activities and developments associated with the construction and operation of a coal mine.

The data collection and inventory program involved two phases. The initial work consisted of examining existing information including geologic, topographic, soil, and vegetation maps and reports. Preliminary aerial photographic interpretation of the study area was done to provide information about landforms, surficial and bedrock geology, soils topography, drainage, vegetation, land-use, and access. This was carried out on two sets of aerial photographs; B.C. government1:20,000 - scale and those flown by Burnett Resource Surveys Ltd. at a scale of 1:25,000 (Appendix 1).

The second phase of this program, carried out May 21 - 26 1980, was the field mapping inventory. Standard methods of terrain analysis (Terrain Classification System, E.L.U.C. Secretariat, 1976) and soil survey (Canadian System of Soil Classification, C.S.S.C., 1978) were used to compile information at a level of reliability comparable to a 1:10,000 - scale survey. Ground traverses were made along all major roads, most of the disused logging roads, and many of the trails (Figure 2). The aerial photographs and 1:15,000 - scale orthophoto mosaics were used for identifying field locations.

Detailed observations were made to a depth of at least 1 metre at 18 sites (Figure 2 and Terrain Maps) and at some of these sites key geological materials and soils were sampled for laboratory analysis (Appendix 2). Many more site inspections were made where surficial material was exposed in road cuts, creek and gully banks, and exploration trenches. The laboratory data and field observations combined to provide information necessary to finalize map-unit boundaries on the aerial photographs.

Soil and terrain inventory data and interpretations are presented on the 1:5,000 - scale orthophoto mosaics prepared by Burnett Resource Surveys Ltd. for Cyprus Anvil Mining Corporation. The soil and terrain maps present the base data. The two interpretive themes summarize pertinent information taken from this inventory data. The terrain interpretive maps depict the terrain conditions, including the presence of natural hazards, which affect land capability. The maps of soil reclamation potential describe those soil types which contain the necessary characteristics for vegetative growth. Each map theme is accompanied by an extended legend which allows the map folio to

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be self explanatory. The report is intended as a supporting document; describing methods, defining and describing surficial geologic and soil terminology and assessing terrain and soil capability for coal-related developments.

RELIABILITY OF THE INFORMATION

It is important to be aware that although the information is presented at a scale of 1:5,000, the level of reliability is that of 1:10,000 - scale mapping. Such soil and terrain inventories are intended to serve as a guide for indicating favourable or unfavouable conditions but are not of sufficient detail to determine site-specific potential. By their nature, soil and terrain classifications are somewhat generalized therefore, conditions described are averages for each map unit. These assessments are a necessary tool for determining feasibility at the planning stage of developing an area but the data for design and construction must come from detailed site analysis.

The quality and scale of the aerial photographs were sufficient to enable accurate delineation of map-unit boundaries. Field observations were more concentrated in the prime area of interest, southwest of Collins Gulch (figure 2), consequently the information obtained from this area is more detailed. Areas which were not traversed were mapped by aerial photographic interpretation and extrapolation of conditions from similar terrain.

The quality of the orthophoto mosaics is not good and locating specific, small-scale features is at times difficult. However, because the mosaics are enlargements of the 1:25,000 - scale aerial photographs used for mapping, it was possible to transfer the soil and terrain map-unit boundaries with a high degree of accuracy.

BEDROCK GEOLOGY

Bedrock geology of the Tulameen Coalfield consists of a thick sequence of Tertiary rocks (Princton Group), comprising a sedimentary formation underlain and overlain by volcanic rocks, resting on a basement of metamorphosed Triassic volcanic rocks. Bedrock mapping has been carried out by Rice (1947) and Shaw (1952).

The Triassic Nicola Group is a large and varied assemblage of vari-coloured dacitic to basaltic volcanics, argillite, tuff, limestone, chlorite and sericite schists. The oldest Tertiary rocks consist of massive and banded andesitic lavas and breccias. The sedimentary rocks of the Princton Group overlie the lower Tertiary volcanics at the northwestern edge of the coalfield, but toward the southeast they rest unconformably on the Triassic basement.

Three lithologic units are distinguished in the sedimentary sequence; from bottom to top they are: mainly sandstone and siltstone; shale, siltstone, coal, bentonite, and minor sandstone; and sandstone and granule conglomerate. The upper basaltic volcanic rocks unconformably overlie the coal bearing sediments. They form a thick, flat-lying plateau that covers most of the southeastern half of the coalfield. An outlying remnant of the plateau lies west of the headwaters of Collins Gulch. In general the outline of the plateau is well marked by steep cliffs.

TERRAIN ASSESSMENT

The area is mapped according to the Terrain Classification System (E.L.U.C. Secretariat, 1976). Within this scheme, the character of a surficial material is expressed by texture and genesis whereas surface form is described by the use of a morphologic descriptor. Materials that have undergone modification by geomorphic processes are identified by an attached process modifier (see the Legend accompanying the Terrain Maps). Textural terms are not applied to those materials which were not field checked nor to those materials whose texture is extremely variable. In these cases the textural characteristics are assumed to lie somewhere within the range expressed in the definition of the genetic materials.

Quaternary Geology

The Quaternary period is subdivided into the Pleistocene epoch, that time when glaciation was dominant, and the Recent or Holocene epoch, the time since the last major glaciation, about 10,000 years ago. The last glacial period is referred to as the Fraser Glaciation. The present landscape of the study area, as for most of B.C., is dominated by surficial sediments and geomorphic processes originated from the last glacial and post-glacial periods.

Till or moraine is the dominant material deposited during the Fraser Glaciation. Throughout Holocene time colluvium has accumulated on or at the foot of slopes and fluvial and organic sediments have been deposited on valley floors and in depressions. Since deglaciation bedrock has been exposed to the processes of weathering which, if severe enough, may decompose the rock to form saprolite.

Description of Geologic Materials and Landforms

Morainal - moraine (till) is the most extensive Quaternary setiment in the area. It is material deposited directly from glacier ice that is moderately compact, non-stratified, and contains a heterogeneous mixture of particle sizes, usually in a fine sandy and silty matrix. The material most commonly occurs as a thin mantle over bedrock (veneers and blankets) (Plate 1) or, less commonly, as thicker deposits of low-relief ground moraine. Weathering of the upper metre or so of till causes a looser structured, more permeable material which provides adequate subsurface drainage (Plate 2).

Fluvial - materials which are transported and deposited by streams. They consist mainly of sand, silt, and gravel and are usually moderately to well sorted and stratified. Fluvial landforms are not common to the study area. Small and isolated raised fan and terrace deposits related to former higher water levels are mainly gravelly textured with good subsurface drainage. Thin, non-extensive gravel and sand deposits occur along the stream channels. Depressional areas in the low-gradient headwaters of many of the streams have infilled with fine sand and silt. The water table is usually high in these basins, impeding subsurface drainage. Thin organic deposits often accumulate over the fluvial material (Plate 3).

Colluvial - materials which are the products of mass wastage and have reached their present position by direct, gravity-induced movement. Chiefly occurs

1. Observation site 2. A thin mantle of moraine overlies undulating bedrock ($\frac{Mbv}{Rh}$).

2. A thin mantle of weathered moraine overlies coal-bearing bedrock ($\frac{Mbv}{Rh}$).

3. Upper reaches of Holmes Creek. Thin organic venear overlies fluvial sediments $\left(\frac{\text{Ov}}{\text{S\$Fm}}\right)$.

as talus (rockfalls) and mantles (blankets and veneers) of disintegrated rock. Texture and lithology of the colluvium is dependent on the charact-teristics of the bedrock from which it was derived. Blocky talus fields accumulate at the base of the plateau basalt scarps (Plate 4). Sediments of the Princton Group disintegrate to fine textured colluvium; fine rubbly to fine sandy material depending on the lithology of the sedimentary rock (Plate 5). Sharply angular rubble is formed by the disintegration of Nicola volcanies and schists. Colluvial deposits are usually very loose structured and, depending on their texture, allow rapid groundwater percolation.

Organics - materials resulting from vegetative growth, decay, and accumulation in and around closed basins or on gentle slopes, where the rate of accumulation exceeds that of decay. Generally consists of unstratified peat which is water absorbant and may be difficult to drain. A high water table is common where varying depths of organic material have accumulated over till or fine-grained fluvial deposits (Plate 6). Organic fens commonly occur where surface water is ponded in depressions in the bedrock.

Bedrock - this genetic term is applied to all outcrops and rock covered by a thin mantle (less than 10 cm. thick) of unconsolidated material. Distinction is not made between different types and lithologies of bedrock. The dominant bedrock landform in the study area is the flat-lying basaltic plateau with its steep escarpment (plates 7 and 8). Sedimentary bedrock generally displays gently hummocky to undulating landforms (Plate 1) except where fluvial downcutting has created deeply incised ravines such as Collins Gulch and Holmes Creek. Nicola Group rocks are exposed mainly along the steep slope of the Tulameen Valley.

Saprolite - weathered bedrock, decomposed in-situ principally by processes of chemical weathering. The rock remains in a coherent state, interstitial grain relationships are undisturbed and no downhill movement due to gravity has occurred. No textural terms have been applied to the saprolite because

4. Blocky colluvium (talus) accumulates at the foot of a plateau basalt scarp (Rs//bCa).

5. Fine, rubbly colluvium derived from sedimentary bedrock and minor moraine mantles a steep slope ($\frac{frCbMv}{Rs}$). Active ravelling of the material occurs in response to the oversteepening caused by the road cut.

6. Organic material infills a depressional area along a stream channel at the base of the plateau scarp $\left(\frac{Obv}{S\$F1}\right)$.

7. View from the remnant basaltic outcrop south-west of Collins Gulch to the main, flat-lying volcanic plateau.

8. Escarpment of the main basaltic plateau (Rs).

they vary depending on the type of underlying bedrock. Weathering of up to a metre depth was observed in coarse sandstone-granule conglomerate to produce a compact, well-sorted, coarse sand (Plate 9). Lesser amounts of weathering were found in the fine-textured sedimentary rocks. Low permeability silty clayey weathering products occur on siltstones and mudstones. Deep weathering, up to 2 metres in places, occurs where coal is exposed at the surface. Highly permeable, crumbly, coarse-textured coal detritus blankets the coal-bearing sediments (Plate 10).

Anthropogenic - geological materials modified by man's actions; including those associated with coal mining and waste disposal at the Blakeburn deposit. The original physical properties of the materials have been drastically altered by this modification. Anthropogenic sites are described for a small open cut into the coal-bearing bedrock and for the waste debris from this cut which was dumped down the slope. Waste debris from the underground workings was also used to construct a berm for rail-haul equipment. This created a narrow, level, well drained rail-bed across the sloping landscape.

Terrain Hazards and Conditions

Important physical characteristics of the landscape which affect terrain capability are identified on the Terrain Interpretive Maps. The nature of terrain classification necessitates somewhat generalized interpretations, therefore, the conditions and features described are averages for the map-unit and may not necessarily be encountered everywhere in that unit. However, the interpretations can be reliably used to describe those terrain hazards and conditions which most commonly occur and which most likely will be encountered during development activities. Terrain hazards and conditions which affect land capability in the study area are slope instability (mainly rockfall hazard; gullying and fluvial channeling (potential erosion hazard); high water table; near-surface seepage; restricted subsurface drainage; adverse topography; shallow depth to bedrock; organic deposits; and gravelly texture.

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9. Sandy saprolite derived from sandstone-granule conglomerate ($\frac{Sv}{Rh}$).

10. Bedrock trench at observation site 6. A very thin soil mantles weathered, coal-bearing sediments (down to the first bench). The main coal seam is exposed in the lower trench wall.

Slope Instability - Slopes can fail in a number of different ways, depending on the type of material present and the physical conditions which cause the failure. Rockfalls are common along the basaltic scarp. The hazardous area is generally confined to the foot of the scarp or immediate downslope areas. A major rockslide is identified on the steep slope of the Tulameen Valley. This probably occurred in immediate post-glacial time and does not affect the study area. Surficial movement occurs along most colluvial slopes and on the waste dump from the old open pit. Undercutting or oversteepening these slopes, such as by road cuts, could increase downslope movement of the surficial material and cause maintenance problems although a major failure is unlikely (Plate 5).

Gullying and Fluvial Channeling - gullied and rilled slopes indicate that erosion processes are occuring. The gullies are not presently highly active but they indicate areas potentially subject to increased erosion. Active stream channels are fairly stable, confined within ravine banks of mainly colluvial and morainal veneers over bedrock. Disrupting the creek hydrology, including bank seepage, could cause erosion of these shallow surficial materials. Exposing bare soil or surficial material by removing vegetation for any type of development, particularly on a hillside, causes accelerated run off and increased erosion. Problems associated with this, such as downstream sedimentation, obviously increase with the size of the area being developed.

High Water Table - position of the water table, particularly under level or gently sloping terrain, will play an important role in determining how water is removed from an area. Where the water table is at or near the ground surface, subsurface drainage is severely restricted and movement depends on lateral seepage or runoff, even in highly permeable materials. Excavations extending into saturated sediments may require extensive shoring or draining to permit safe and effective construction. Roads built across areas of a high water table would require fill to build up the subgrade.

Near-Surface Seepage - surface and near-surface flow is generally controlled by the depth and permeability of the surface materials, vegetation conditions, and the topography. It is an important form of drainage on slopes which have a capping of permeable sediment or soil over an impervious material such as bedrock. Road beds oriented across a slope are efficient interceptors and divertors of near-surface seepage, converting it to surface runoff. This may cause increased gullying and washouts on the impermeable slopes. The potential impacts increase with an increase in slope gradient, in part because road cuts must often penetrate deeper, intercepting more seepage. On gently sloping or depressional terrain underlain by impervious material, surface ponding may occur.

Restricted Subsurface Drainage - downward subsurface movement of water through permeable surface material is restricted by an impermeable horizon. In areas of gentle or level slope a perched water table may develop, causing a zone of saturation which leads to problems associated with high water tables. On sloping terrain, subsurface flow is concentrated along the upper boundary of the impervious layer. Excavations and cuts which intersect this boundary are subject to seepage flow and subsequent surface runoff or ponding. If the impervious horizon intersects the natural slope face a zone of constant seepage occurs which may ultimately cause instability or erosion of the slope.

Adverse Topography - constraints on construction imposed by topography are mainly those of steepness of slope, although gullied terrain and landscape position may also be factors. Construction on slopes exceeding 30% gradient will require a considerable amount of cut-and-fill which substantially increases building costs. As gradients increase, the depth of the backslope cut increases, thereby making it more likely to encounter seepage or bedrock. Roads built across undulating or dissected terrain will encounter higher cut-and-fill requirements in the topographically high areas and restricted drainage in the low areas. Construction at the base of a slope may be subject to seepage or runoff from upslope and downslope movement of colluvial material. Depressional areas

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underlain by impermeable material may have seasonal ponding and will require fill to elevate the subgrade.

Shallow Depth to Bedrock - bedrock at or near the surface restricts conventional development because, compared to surficial materials, it is usually difficult to excavate and impermeable. Development in areas where bedrock is near the surface must consider that drainage is mainly by surface and near-surface runoff and consequently may be easily disturbed by construction. The presence of bedrock near the surface of sloping terrain is potentially restrictive because any excavation will require rock cuts. The ease of excavating rock depends on its structure, strength properties, and degree of fracturing and weathering.

Organic Deposits - organic material accumulates in closed depressions and is associated with areas of restricted subsurface drainage, high water table, and near-surface seepage. Peat is highly compressible and has poor internal drainage. Constructing a road bed or a foundation on deep organic material requires extensive preloading to avoid excessive setting. Organic areas may also serve an important hydrologic function. They act as surface storage areas, providing recharge for a creek during low flow and providing space to accomodate excess water during high flows.

Gravelly Texture - the most desireable surficial materials for construction purposes are the coarse, granular sediments. Sand and gravel deposits usually are very permeable, allowing good subsurface drainage and have good load-bearing capacity for road subgrade or foundation material. Gravel deposits associated with deglaciation (raised fans and terraces) usually provide a good source of granular aggregate because they are not covered with overburden and are well drained.

SOIL ASSESSMENT

Soil mapping description and analysis was carried out within the project area in order to determine the distribution of the various soil groups and

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describe their capability for use as reclamation material. To this end, soils were examined and mapped according to the Canadian System of Soil Classification (C.S.S.C., 1978). The soil map produced by this exercise, illustrates the geographic distribution of the soil groups and some of their pedologic characteristics. The main factors used to differentiate the soil groups included texture, drainage, slope, genetic group (soil subgroup classification, thickness and chemical characteristics). These characteristics are described in the soil map legend and in this report.

In order to cartographically illustrate the potential capability of the soil to support vegetative growth relative to mine reclamation activities, an interpretive map was assembled and drafted. This map, entitled "Soil Capability For Reclamation Use", outlines the geographic distribution of those soils which are considered to have High, Moderate or Low capability for reclamation use.

This section describes briefly the characteristics of the mapped soils. Reference to the 'Soil Map', the 'Soil Capability For Reclamation Map' and their respective legends will add further to an understanding of the soil landscapes of the project area.

The Mapped Soils

The soil map is set up to clearly illustrate those soils which have developed on similar parent materials (See Terrain Maps). In addition, soil landscape characteristics such as drainage, texture, thickness, chemical make up and topography are shown. Appendix 2 contains the laboratory analysis of the sampled soils.

The morainal materials generally reflect the nature of the underlying bedrock; however in the project area, glacial advance from the west has provided an influence of Coast Intrusive granodiorites with a subsequent increase in the amount of coarse textured, moderately acidic morainal materials. Since glaciation, soils have been developing on these deposits and geomorphic processes have been occuring which have modified the original characteristics of the materials. The main modifications are three-fold; firstly, processes of mass-wasting have created colluvial deposits usually at the base of steep slopes and bedrock escarpments; secondly, fluvial processes have eroded and re-deposited the surficial geologic materials along stream courses; thirdly, vegetative growth in and around poorly drained areas and lakes has resulted in the formation of organic deposits.

A total of seventeen individual soil map units were recognized. They are shown on the soil map and grouped according to the parent material from which they are derived. There are six main groups:

1. Soils on Morainal Deposits
2. Soils on Colluvial Deposits
3. Soils on Fluvial Deposits
4. Soils on Organic Deposits
5. Soils on Bedrock Dominated Areas
6. Soils on Anthropogenic Deposits

1. Soils On Morainal Deposits

Morainal or glacial till materials are the most extensive surficial geologic material type in the study area. Soils developed on these materials are dominantly Eluviated Eutric Brunisols; other soil types such as lithic (shallow over bedrock) phases and Gleyed Eutric Brunisols depending upon specific landscape characteristics. Orthic Dark Gray Chernozem soils occur on south and southeast facing slopes where the tree canopy is open and tree distribution somewhat sparse.

These soils are dominantly gravely sandy loam to gravelly loam textured and slightly acid to neutral. They are dominantly well drained with slow runoff and moderate permeability. pH ranges from 6.0 to 6.6 and organic matter content ranges from approximately 2 to 0.2 %.

2. Soils on Colluvial Deposits

Soils developed on the colluvial materials of the study tend to be similar to those developed on the morainal deposits. The main differences being an increase in the amount of lithic (shallow to bedrock) phases,steepness of the topography and the amount of coarse fragments contained in the soil.

The dominant soil development is an Eluviated Eutric Brunisol which is very gravelly loamy sand to very gravelly sand texture. In many areas the soil contains a significant volume of shattered bedrock fragments. pH ranges from 6.0 to 7.0 and organic matter content from 1.5 to 0.3 percent.

In specific areas, the soils are subject to colluvial processes due to the steepness of the slope. Disturbance or removal of vegetaion is likely to increase the risk of increasing surface soil erosion in these areas.

3. Soils on Fluvial Deposits

These soils constitute a minor portion of the study area. They occur sporadically as terraces and fan landforms overlying bedrock.

The most significant soil is an Eluviated Eutric Brunisol which is very coarse textured, dominantly well to rapidly drained, highly pervious and exhibiting rapid run-off.

The soils are normally low in organic matter (1 to 0.2%) with pH ranging from 5.5 to 6.5.

4. Soils on Organic Deposits

There are two main types of organic deposits in the area. Those that have developed on poorly and very poorly drained areas of morainal or bedrock dominated landscapes. These are normally depressional areas or at the base of a slope which is providing seepage water. The second type occuring as poorly drained areas around the margins of water bodies and effemeral stream channels. The dominant soil type is a Terric Fibric Mesisol. This soil is usually less than 40 cm thick over mineral soil material (morainal or fluvial) and strongly acid (pH ranging from 5.0 to 5.5). Organic matter content is usually greater than 70%. The topography is normally level to flat and the drainage is very poor with a water table at or very close to the surface throughout the year.

5. Soils on Bedrock Dominated Areas

Soils in these areas are characteristically non-existent to very thin. The dominant soil type is an Eluviated Eutric Brunisol, lithic phase and has characteristics similar to those discussed under the heading for soils developed on colluvial deposts.

Where the bedrock is a mudstone or siltstone and exposed at the surface, the soil is formed dominantly in the weathered bedrock. These soils are usually fine textured (clay to silty clay) and highly plastic. Permeability is slow and the soils are often imperfectly drained.

6. Soils On Anthropogenic Deposits

These are soils that occur on these deposits which have been influenced by mans' activity. Within the study area, they occur specifically near the mine working associated with the Blakeburn open-pits.

The soil is dominantly an Orthic Regosol. Drainage is imperfect and textures vary from very gravelly loamy sands to cobbles and stones. For the most part, the soil material is waste rock and posseses a low inherent fertility. Certain areas are undergoing active mass wasting processes.

USE OF THE SOIL AS RECLAMATION MATERIAL

The most important things to consider when rating the soils capability for reclamation use are:

1. texture (water holding ability)
2. fertility
3. presence of toxic substances (eg. salts)

As well as these, one must consider landscape features which will influence the use of the soil material. They include, among others:

1. slope.
2. drainage (including seepage).
3. thickness of the material ovdr bedrock.
4. occurence of active mass wasting or fluvial processes.

It was these factors which were used to determine the capability of the mapped soil types for use as reclamation material. The ratings applied to the soil types are by design general. They are intended to point out those areas where it may be feasible to save and stockpile soil material from during the mining activity. The use of this material being as topsoil to be placed on top of disturbed areas such as rock waste dumps and tailings ponds in order to facilitate good vegetative growth.

The ratings used are defined as follows:

High Capability: the soil has adequate water holding capacity, has moderate fertility and no toxic elements; the landscape imposes none or few limitations to use of the material

Moderate Capability: the soil has adequate water holding capacity, has low to moderate fertility which can be increased if required and contains no toxic substances; the landscape imposes some limitations to use such as inadequate drainage and moderate to steep slopes.

Low Capability: the soil has poor water holding capcity, often low fertility and in some instances contains substances toxic to plant growth; the landscape imposes severe constraints to use such as active geomorphic process (gullies), steep slopes and a thin to non-existant soil mantle.

A summary of the ratings applied to each soil map unit is presented in Table 1. While it is important to consider the characteristics of the soils when considering their use as reclamation material, it is also of importance to consider the climate of the area and the restrictions imposed by factors such as amount of rainfall, growing degree days (the number of days during the growing season with temperatures above 5.5^{o}C) and frost-free period (the number of summer days with temperatures greater than 0^{o}C). In this particular area, the climate is considered semi-arid with a mean annual precipitation of 33 to 53 cm. The mean annual temperature is 3 to 5.5^{o}C. The frost-free period ranges from less than 50 to about 90 days, and the growing season ranges from 1650 to 2150 degree-days. Much of the precipitation during the winter tends to fall as snow with an average of 600 to 750 cm. recorded at climate stations near the area (B.C.D.A., 1970.)

Table 1. Summary of Reclamation Capability Ratings Applied to soil Map Units.

Soil Map Unit	Rating	Soil Map Unit	Rating
1	H	13	M-H
2	H-M	14	L-M
3	M	15	L
4	M	16	L
5	L	17	L
6	L		
7	L		
8	M		
9	L		
10	M		
11	M-H		
12	M		

The data points out that the area is generally suitable for the growth of most grass, forb and shrub species. However, it must be noted that there is a moisture deficiency during the summer months which may have to be overcome by irrigation immediatly following planting for the first year. Also, species should be selected that are hardy enough to overcome severe frosts which occur during the fall and spring periods.

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SUMMARY

Through an examination of the terrain and terrain interpretation maps, one can easily determine the possible constraints related to the proposed location of the waste dump, tailings pond and preparation plant.

While there appear to be no serious problems related to the proposed locations of these facilities, it is important to consider some of the landscape features which would affect or be affected by the proposed developments.

The location of the waste dump north and east of the open-pit would appear to be a satisfactory location with the exception of some considerations. Firstly, and foremost, the occurrence of the upper basaltic volcanic rock plateau which overlies the coal bearing sediments to the southeast terminates abruptly in a steep cliff. The steep cliff is currently undergoing rockfall and colluviation with a considerable amount of debris accumulated at its base. Due to the occurrence of this cliff which will underlie the waste dump at its eastern portion consideration should be given to the effects of the instability of the rock face on the stability of the waste dump. Further, consideration should be given to the fact that groundwater tends to flow at the contact between the basalt and the underlying sedimentary rocks. While it is not believed that undesireable elements will be leached from the waste rock and consequently end up in this ground water system, the potential for this to occur should be considered. The remainder of the constraints relate mainly to the presence of high water tables occuring in some isolated locations throughout this area and the presence of surface drainage channels which eventually flow into Collings Gulch. These two aspects may further aggrevate the situation referred to earlier related to leaching from the waste dump.

The location of the Tailings Pond appears to be satisfactory from the perspective of terrain constraints. The only factors to consider are as follows. There are isolated occurences of organic deposits within the area which naturally have high water tables and likely act as feeder systems for ground and surface water flow. Consideration should be given to the problem of leachate from the tailings pond entering these systems. In order to avoid some of these areas, it is suggested that the tailings pond location be moved slightly closer to the preparation plant location but definitely not too close to the existing drainage channel to the north. This slight change in location may also help to alleviate any potential problem of leachate entering Blakeburn Creek by way of the existing stream system to the southwest. This particular stream, which is for the most part well entrenched in a gully, also drains the southern part of the open-pit and should be considered in the design for the mining activity to ensure that water quality does not deteriorate.

The preparation plant appears to be located in a satisfactory location characterized by thin morainal deposits overlying hummocky bedrock. The only concern is that the location is between two drainage systems which eventually flow into Collins Gulch. Final design for the location of the plant should ensure that these drainage systems are not impaired.

The discussion given in Appendix 2 provides a thorough assessment of the present road on the south slope of the Tulameen River to where it connects with the trail on the eastern side of Collins Gulch. While this route appears feasible, it is suggested that a considerable amount of up-grading would be required and that several sections of steep grade would be encountered. With these considerations in mind, it would appear most feasible to up-grade the existing road on the west side of Granite Creek, particularly in the area of the switch-backs at the north-eastern end of the road. Relocation of the existing road to the west side of the open pit is feasible. However, some adverse slopes will be encountered as the road crosses the two gully systems which drain to the east and south.

The soil assessment outlines that a considerable amount of material suitable for re-vegetation exists in the vicinity of the mining activities. In this

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respect, consideration should be given to retaining(stockpiling)these soils from areas beneath the proposed waste dump in particular. There appears to be little soil material worth saving in the area of the open pit due mainly to the shallow nature of the soil over bedrock. No fertility problems were indicated by the laboratory analysis of the soils sampled from the study area. However,it is suggested that at least one and perhaps several applications of fertilizer will be required during the reclamation program to ensure satisfactory growth.

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<u>APPENDIX</u> 1

Assessment of existing access road; location of field mapping traverses; location of watershed boundaries; and location of detailed field examination sites.

The following figure, presented on a 1:25,000 scale aerial photograph, illustrates four items:

1. Location of watershed boundaries shown as dashed lines -------.
2. Location of field traverses undertaken during the field mapping program shown as a solid line ______ .
3. Location, by number, of detailed site inspections of soil material.
4. Location of existing access road, subdivided into sections; each section is given a letter for reference to the discussion which follows.

The following is an assessment of the existing access road from the point it leaves the main road to Blakeburn, past Fraser Gulch to the logged area on the ridge east of Collins Gulch. Points or sections along the road are indicated by letters illustrated on the following aerial photograph.

ROAD SECTION	DESCRIPTION
A	the road leaves the main road by climbing a steep sided morainal hummock; existing road grade is 30%.
B	the road begins its traverse across the steep south face of the Tulameen Valley; existing road grade is 15-20%; cuts are mainly into deep rubbly colluvium although bed-rock with a thin till veneer is commonly exposed.
C	hummocky, steep bedrock with a variable thickness of colluvium mantling the surface; existing road grade is 20-25%.
D	till and colluvial veneers mantle steep bedrock slope; existing road grade is 5-10%.
E	A gully is eroded into the steep hillside; thick till and colluvial materials occur along the gully sides; it appears as though the gully carries water most of the year, however, the gully appears stable with no indication of debris flow activity.

Figure 2. Location of roads and watersheds

ROAD SECTION	DESCRIPTION
F	thick morainal materials occur throughout most of this section; bedrock is exposed in a few of the deeper road cuts; existing road grade is 10 - 15%.
G	bedrock occurs at the surface of the steep slope over most of the section; in places, variable thicknesses of rubbly colluvium mantle the rock; existing road grade is 5%.
H	thick moraine dominates the steep slope with some bedrock exposed in the deeper road cuts; existing road grade is 5 - 10%.
I	moraine and colluvial veneers mantle the steep bedrock slope; existing road grade is 5 - 10%.
J	minor depression in the steep slope (95% slope) which is infilled with deep moraine.
K	thick moraine dominates the steep slope with some bedrock exposed in the deeper road cuts; existing road grade is 15%.
L	A gully is eroded into the steep hillside; thick moraine and colluvium occur on the gully sides; no surface flow was evident at time of examination, however, seepage through the thick surficial materials may be high; surface flow probably occurs during high rainfall events or rapid snowmelt; the gully channel appears stable.
M	bedrock is exposed over most of the steep slope; morainal and colluvial materials are present in some minor areas; existing road grade is 10 - 15%.
N	bedrock is exposed at the surface of the steep slope; extensive road cuts have produced a grade of 5%.
O	thick morainal materials cover most of the steep slope; bedrock outcrops occur in some areas; existing road grade is 5%.
P	bedrock is exposed at the surface of the steep slopes; a thin layer of colluvium is present in some places; existing road grade is 15%.

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ROAD SECTION	DESCRIPTION
Q	the mouth of a drainage ravine tributary to Fraser Gulch; an old debris fan consisting of blocky, rubbly colluvial debris, probably deposited during deglaciation occurs here; surface water flow is present in a channel which cuts through the fan; the channel appears stable; excessive seepage from the colluvial deposit may be a source of instablility for the road cut and may cause drainage problems on the road; existing road grade is 5 - 10%.
R	thick morainal materials subject to considerable seepage; minor gullying indicates surface flow may occur at times of high precipitation; drainage may pose problems to road location; existing road grade is 5%.
S	blocky colluvium mantles the gullied morainal slope; seepage flows through the deeper colluvium in the gullies and may be a source of drainage problem along the road; existing road grade is 10%.
T	thick morainal material creates a subdued landscape; existing road grade is 5%.
U	the road is cut through and around the edge of a morainal hummock at an existing road grade of 5 - 10%; the road avoids a large and probably deep organic deposit; access to the corrifor through the upper reaches of Fraser Gulch could be obtained by following along the base of the slope on the south side of the bog.
V	the beginning of this section is the outflow of the bog into lower Fraser Gulch; the topography of the terrain is subdued, consequently water flow is slow and drainage is poor; the rest of this section consists of thick moraine infilling a subdued landscape; existing road grade is 5%.
W	morainal and colluvial veneers mantle hummocky bedrock slope; bedrock outcrops are common; existing road grade is 15 - 20%.

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ROAD SECTION	DESCRIPTION
X	hummocky, steep bedrock slope with a variable thickness of rubbly colluvium mantling the surface; in places deeper moraine is present; existing road grade is 20 - 25%.
Y	bedrock is exposed over most of the steep slope; colluvial and morainal veneers are present in some areas; existing road grade is 15 - 20%.
Z	thick morainal and colluvial materials infill the depressions between the bedrock ridges; a stream gully cut into the surficial materials occupies most of this area; existing road grade is 5 - 15%.
AA	morainal and colluvial veneers mantle the steep bedrock slope; existing road grade is 15 - 20%.

APPENDIX 2.

Laboratory Analysis of Sampled Soils

DESCRIPTION OF SOILS ANALYZED

SAMPLE SITE	NUMBER	DESCRIPTION
2	2B	B horizon of soil derived from morainal material; adequate pH range and good supply of nutrients for vegetative growth.
	2C	morainal material overlying bedrock at depth; adequate pH range for vegetative growth; low in nitrogen.
3	3C	C horizon of soil derived from morainal material; good texture and adequate pH range for vegetative growth; low in nitrogen
6	Ah	A horizon of soil overlying oxidized coal seam; this thin horizon has good supply of nitrogen and nutrients for vegetative growth.
	Bmt	B horizon overlying weathered coal seam; this thin horizon has an adequate pH range and is abundantly supplied with the nutrients required for vegetative growth.
7	A	bentonite material interbedded with coal seams; clay texture with moderate plasticity; pH is highly acidic and will be detrimental to plant growth.
	B	shale bedrock interbedded with coal seams; material is highly acidic; contains an adequate supply of nutrients for vegetative growth; material contains a low level of soluble salts.
9	Ahe	very thin material overlying bedrock; moderately acidic; material has low level of nutrients required for vegetative growth.
12	Ahe	A horizon of soil derived from morainal material overlying bedrock; adequate pH range and supply of nutrients for vegetative growth.
	BC	B horizon of morainal material overlying bedrock; adequate pH range for vegetative growth.
15	BC	B horizon of soil derived from morainal material; very good material for supporting vegetative growth.
16	C	C horizon of soil derived from weathered conglomerate bedrock; low supply of nitrogen and elements necessary for vegetative growth.
18	C	C horizon of very thin soil derived from basaltic coluvium; adequate supply of nutrients required for plant growth; very low nitrogen content.

Field Number	pH	Electrical Conductivity (mmhos/cm)	CEC (meq/100g)	Exchangeable Cations (meq/100g) Ca	Mg	Na	K	Available Nutrients (ppm) NH_4-N	NO_3-N	P	K	S	Total % N	Total % C
2 B	4.8		18.8	59.6	2.81	0.20	1.08	4.2	3.5					
2 C	5.2												0.01	0.7
3 C	5.5												0.03	0.9
6 Ah	5.0		18.9	9.40	1.98	0.15	0.46	13.1	1.6					
6 Bmt	4.9		21.0	13.6	3.26	0.17	0.31	18.0	3.5					
7 A	3.6													
7 B	3.2	2.4								9.0	108	300		
9 Ahe	4.9	.14								2.0	600	60		
12 Ahe	4.9		15.6	7.23	2.36	0.15	1.08	23.4	2.6					
12 BC	4.6													
15 BC	5.1												0.03	0.6
16 C	5.3												0.004	0.1
18 Bt_2	5.6		31.6	23.6	6.82	0.15	0.77	4.4	1.6					

Field Number	SAR	Sat. (%)	Soluble Ions (meq/l) Ca	Mg	Na	SO_4	Texture	PSA (%) Clay	Silt	Sand	Atterburg Limits % Water Plastic	Liquid
2 B							SCL	24	22	54		
2 C							SCL-SL	20	22	58		
3 C							SL	14	28	58		
6 Ah												
6 Bmt							SCL	28	20	52		
7 A							C	43	28	29	57.7	96.7
7 B	0.12	37.7	19.2	8.14	0.44	5.6						
9 Ahe	0.27	33.6	1.76	0.33	0.28	0.6						
12 Ahe												
12 BC												
15 BC							SCL	26	21	53		
16 C							SL-LS	12	12	76		
18 Bt_2							SL	10	31	59		