LAND CLASSIFICATION AND SOILS IN THE ROCKY MOUNTAINS OF ALBERTA ALONG THE NORTH SASKATCHEWAN RIVER VALLEY

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Alberta Institute of Pedology
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INTRODUCTION

A survey of soils in the Front Ranges of the Rocky Mountains, along the North Saskatchewan River Valley, was undertaken in 1967. Soils, vegetation, and landform characteristics were noted along selected traverses which covered the area from the center of the valley to the orographic tree line.

Investigations revealed that the soils are dominantly comprised of Orthic Gray Luvisols and Degraded Eutric Brunisols on the uplands, Cumulic and Orthic Regosols and Eutric Brunisols on the fans, and Orthic Regosols on the steep slopes. Many shallow soils underlain by rock are also present. Podzolic soils occur near the tree line. The majority of soils are developed at least partially from a 4 to 6 inch silty aeolian mantle. Soils on the fans adjacent to the river are characterized by little more than the addition of organic matter, but with increasing distance from the center of the valley and increase in elevation, pedological weathering and profile differentiation becomes increasingly pronounced.

Some of the more important features governing soil formation in the area are: the high carbonate content of much of the material which retards weathering and restricts the depth of pedogenic influence, the valley winds which strongly influence micro-climate and are active in deposition, the high volcanic ash content in the almost continuous layer of loess which influences surface soil character and weathering phenomena, and the activity of mass wasting and its disruption of soil materials.

This report is written from a biophysical approach with an expanded section on soil formation. Included are capability ratings for forestry, wildlife, and recreation. An accompanying map, at a scale of 1:50,000, shows the distribution and relationships of the units described in the report.

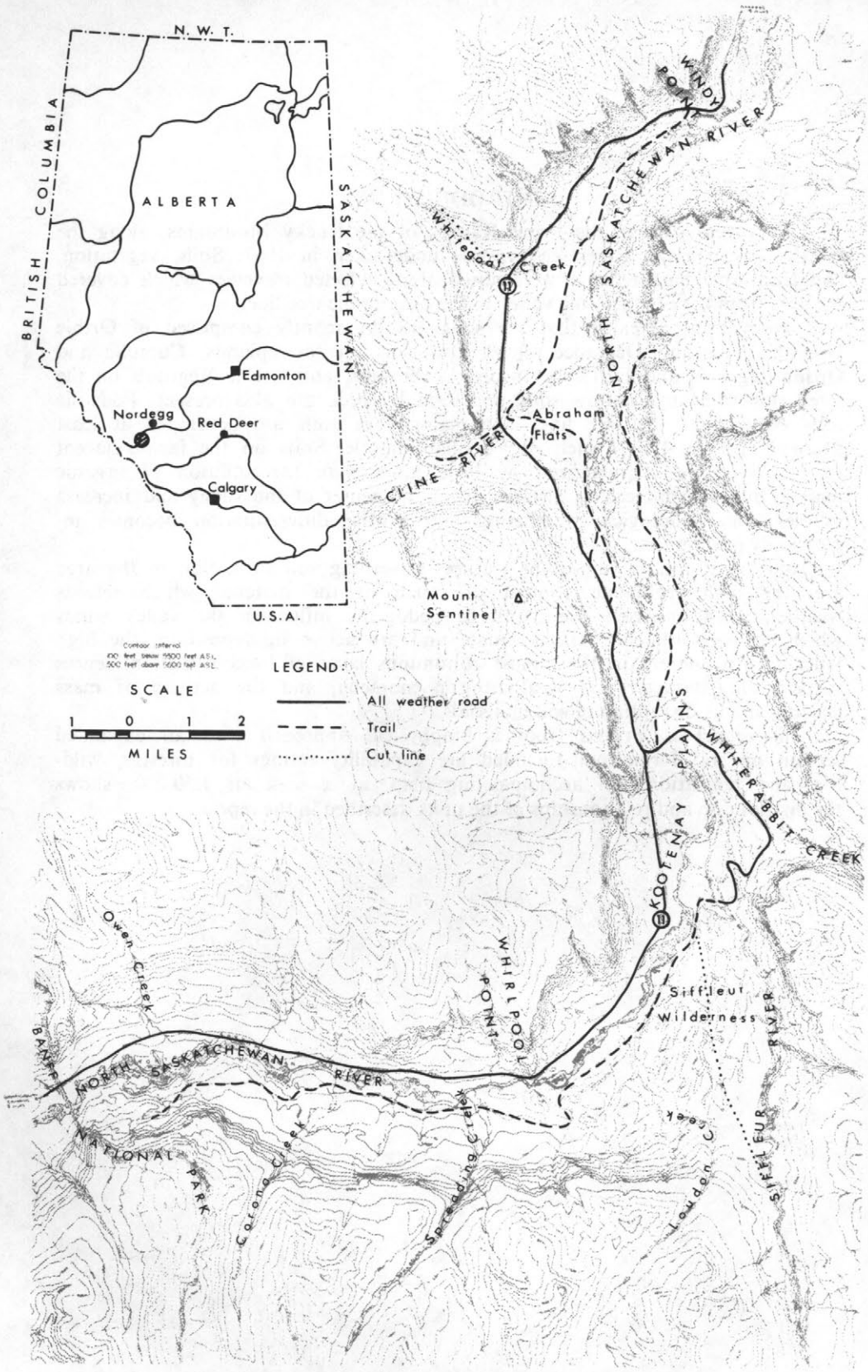

Figure 1—Location and orientation maps of the project area

LAND CLASSIFICATION AND SOILS IN THE ROCKY MOUNTAINS OF ALBERTA ALONG THE NORTH SASKATCHEWAN RIVER VALLEY

GENERAL DESCRIPTION OF AREA

LOCATION, EXTENT AND ACCESS

The project area, centered around 52° N latitude and 116° 25'W longitude, is located in the Front Ranges of the Rocky Mountains (Fig. 1). It encompasses the North Saskatchewan River valley from the boundary of Banff National Park (Tp 35, R 19, W5) east and north to Windy Point (Tp 38, R 17, W5). The valley was surveyed up to the tree line giving an average width of about 4 miles and a mapped area of approximately 100,000 acres. The hamlet of Nordegg is about 15 miles to the east.

Access is provided by the David Thompson Highway (No. 11) which follows the North Saskatchewan River west from Rocky Mountain House and joins with the Banff-Jasper Highway (No. 93) 3 miles west of the survey area. There is a bridge across the river in the Kootenay Plains area and a road to the Siffleur River.

PHYSIOGRAPHY

The area consists of a large glaciated mountain valley transecting the Front Ranges first in an easterly and then a northerly direction. The elevation of the valley floor rises from 4,100 feet AMSL at Windy Point to about 4,500 feet at the Park boundary with the mountain peaks rising to 8,500 feet in the east and 10,500 in the west. The Siffleur and Cline Rivers and several creeks flow into the North Saskatchewan River (Fig. 1). A typical cross-section (Figs. 2 & 3) indicates a U-shaped valley with lateral benches and large fans in the valley center.

BEDROCK GEOLOGY

The Front Ranges of the Rocky Mountains are comprised of a series of sub-parallel, west dipping thrust blocks (15). They resulted from a thrusting of Paleozoic formations over the Mesozoic beds found east of the McConnel Thrust fault at Windy Point. The individual blocks are rather strongly folded with younger Carboniferous and Devonian, dominantly limestone, formations exposed in the eastern ranges and older Paleozoic formations such as Cambrian quartzites in the western ranges. The rocks are dominantly limestones and dolomites with minor amounts of argillites and sandstones.

The valleys in the Front Ranges are asymmetric as a result of differential erodability. The southwest valley walls are backslopes comprised of varying lithologies and are less stable than the northeast valley walls which are generally dip slopes and comprised of single rock types.

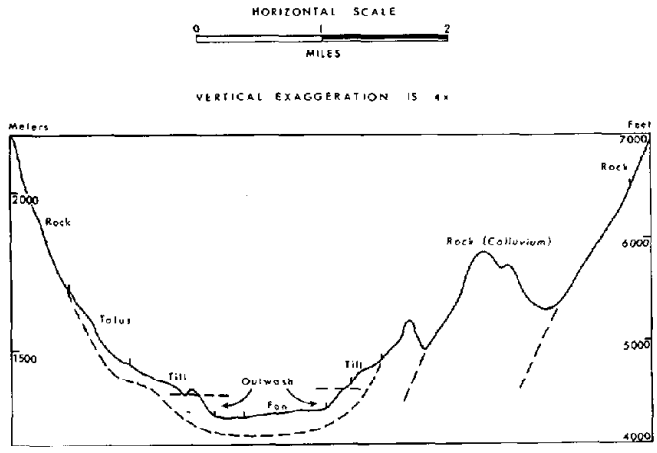

Figure 2—Valley cross-section (for location see Figures 3 and 4)

QUATERNARY GEOLOGY

There is evidence of at least two major glacial advances in the eastern Rocky Mountains in the latter part of the Wisconsin Stage—40,000 to 10,000 years ago (12, 20). The glaciers originated along the continental divide with only minor amounts of ice and debris from further west. Ice from a 60 mile front (Columbia Icefields to Bow Pass) was probably channelled into the North Saskatchewan River valley although much of the northern ice might have been diverted over the Sunset Pass and down the Cline River valley. The glacial advances modified the valleys into U-shapes and scoured the walls up to elevations of at least 7,000 feet, at the same time depositing debris along their bases and against the

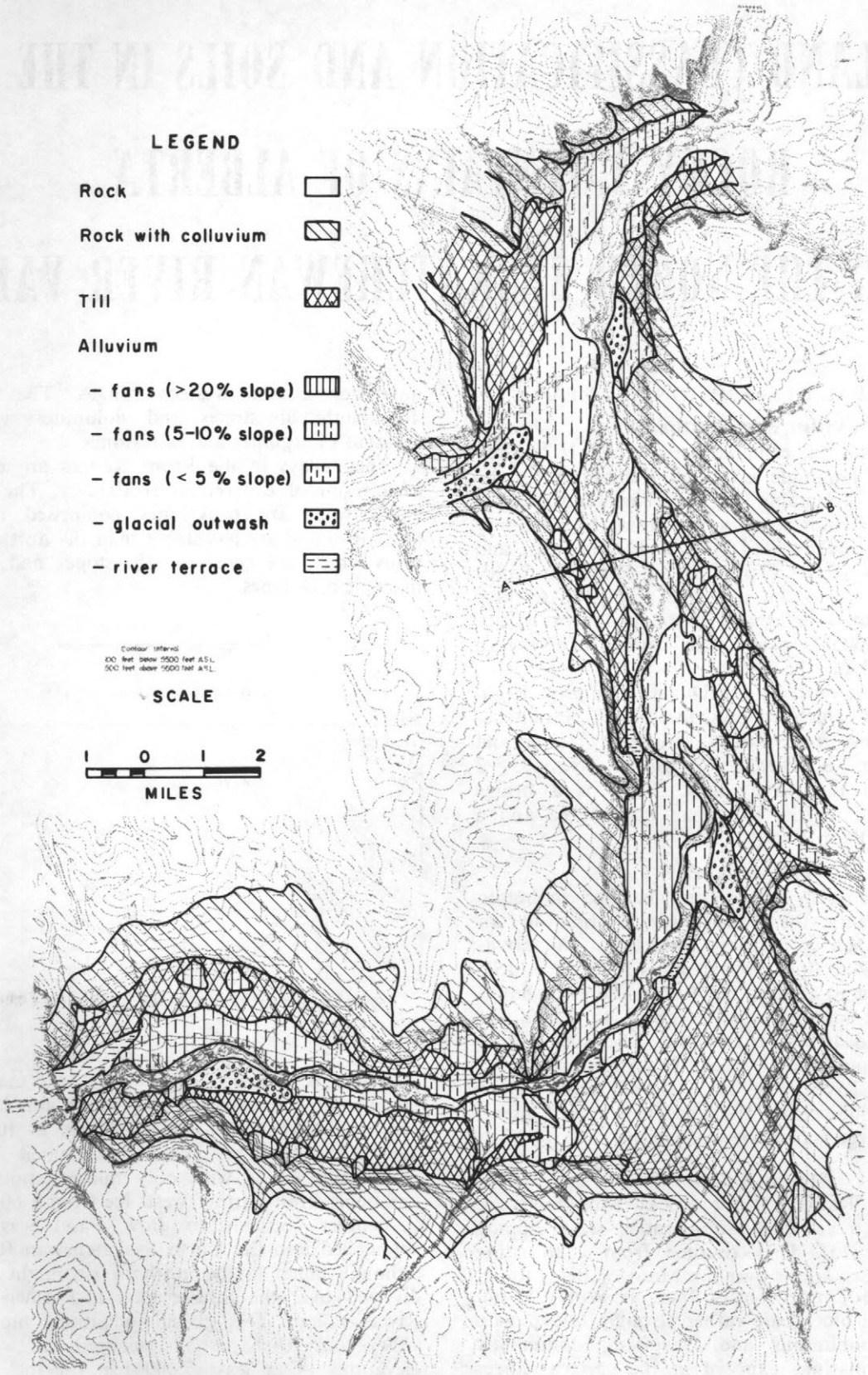

Figure 3—Map of (a) Parent material distribution (b) Section location

Figure 4—Stereotriplet illustrating valley features (for locations see Figure 3—section AB)

valley walls. During ablation attendant outwash facies were laid down. A minimum date of about 9,300 years B.P. has been suggested for final deglaciation of the area (25).

The major geomorphic phenomenon of the Recent Epoch has been the development of fans. This is particularly significant in the central portions of the valley. Figure 4 illustrates the distribution of the surficial quaternary materials in the area (12,17). Another recent geologic phenomenon of significance from the standpoint of soil formation has been the deposition of loess over much of the less steeply sloping land forms. This material has a high content of volcanic ash and ranges up to 10 inches in depth.

CLIMATE

Climatic data for the mountainous regions are limited and for the most part confined to lower elevations and valley locations. Banff and Jasper, stations with long term records to the south and north of the area, are both located in large valleys in the Front Ranges. While Jasper is about 1,000 feet lower in elevation than the project area, records from both these stations should be relevant to the valley bottom. Nordegg, immediately to the east of the project area, is in the foothills. Data are shown in Table 1.

At Jasper, Banff, and Nordegg, July is the only month normally free of frost. At Lake Louise frost occurs in all months. The Lake Louise data is included to show the effect of high elevation, namely, lower temperatures, and increased precipitation with a higher snow contribution.

In 1954 the Eastern Rockies Forest Conservation Board set out a network of storage precipitation gauges in the headwaters of the North Saskatchewan River. The records for those gauges located in the project area are given in Table 2.

Site 2, located on the grassed Kootenay Plains, is a very arid location (in 1966-67 this gauge recorded only 5.6 inches precipitation). This probably reflects a "rain shadow" effect. However, another factor may be the valley winds which undoubtedly influence the climate in the area. There is no quantitative measure of the effect of these winds, but their influence on evapotranspiration and on storm patterns, particularly as they affect the valley bottom, is of major significance.

Other precipitation records indicate that by an elevation of 6,000 feet AMSL the precipitation is probably well in excess of 20 inches per annum, and that by 7,000 feet it likely exceeds 25 inches. With this in mind and using the available storage gauge records a isohyet map was drawn (Fig. 5). It must be emphasized that this map is partly conceptual and was prepared only to indicate the disparities in precipitation which may occur over short distances.

In general, the area has a cold, subhumid-humid climate with a short growing season. However, generalities can be very misleading in mountainous regions because of the extreme climatic variability

TABLE 1—Selected Climatic Data[1]

Station	Elevation (feet A.S.L.)	Mean Ann.	Temperature (°F) January Max.	January Min.	July Max.	July Min.	Precipitation (in.) Mean Ann.	% as Snow
Jasper	3,480	37	22	2	73	45	16.4	30
Banff	4,583	36	21	3	72	44	18.7	42
Nordegg	4,300	34	22	2	66	39	22.2	38
Lake Louise	5,032	32	20	-6	71	38	30.8	63

[1]Data taken from McKay, Curry and Mann (1963).

TABLE 2—Storage Precipitation Gauge Data[1]

Gauge[2]	Elevation (feet A.S.L.)	Years of Record	Precipitation (inches) Oct.-May	May-Oct.	Annual
1	4,800	4	7.0	8.8	15.8
2	4,400	10	3.7	7.4	11.1
3	5,200	4	10.1	10.6	20.7
4	4,500	8	9.0	7.2	16.2
5	5,300	4	8.2	9.4	17.6

[1]Data taken from Management Report No. 2 (1968), Eastern Rockies Forest Conservation Board. Comparison with standard Meteorological Service gauges indicates approximately 20% undercatch for the storage gauges.

[2]Gauge locations are plotted on Fig. 5.

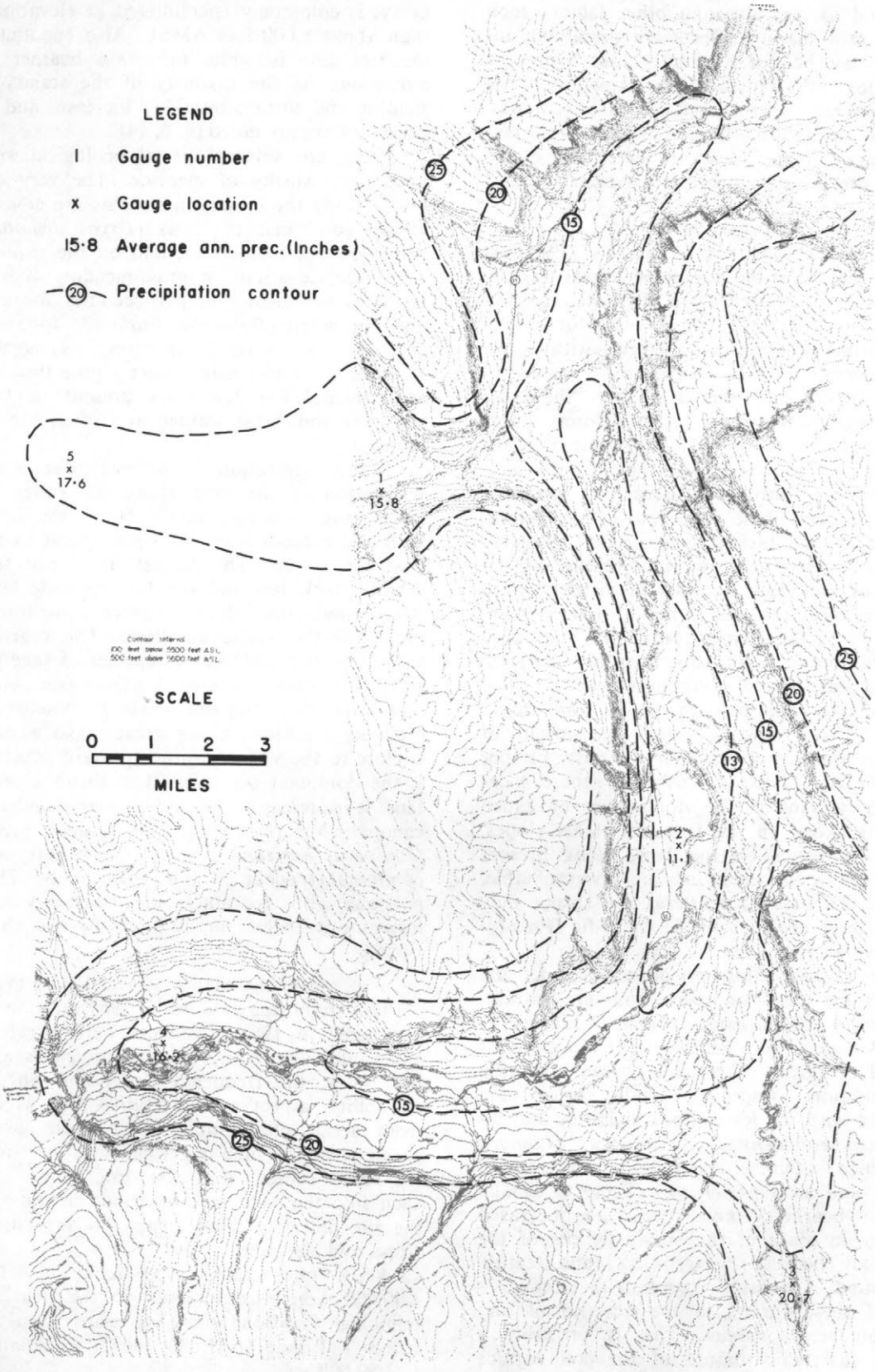

Figure 5—(a) Location map for precipitation gauges (b) Speculative isohyetal map

over short distances. The differences are mainly due to elevation and aspect, although other factors such as winds and rain shadow effects are modifying influences and may be locally important. Aspect is probably the most important single factor, with marked differences between north and south exposures. Aspect affects insolation, hence evaporation, and therefore plays a major role in determining the humidity of a site. This in turn affects vegetation and soils.

VEGETATION

The project area falls within Rowe's (19) East Slope Rockies Section of the Subalpine Forest Region. This region is characterized by a vegetative climax of Engelmann spruce (*Picea engelmanni*)[1] or Englemann-white spruce *(Picea glauca)* hybrids with alpine fir *(Abies lasiocarpa)* (14, 19).

Cormack (4) states of this area that "the most striking and important feature of the forest cover is the disturbance caused by fire". The result of burning is the dominance of lodgepole pine *(Pinus contorta* var. *latifolia).* Only small areas of spruce-fir forest were noted and these were found in generally cooler, moister, north-facing sites or at relatively high elevations and were generally more mature stands. The majority of the forest consists of virtually pure stands of pine with lesser amounts of mixed pine-spruce stands. Both these types readily fall into stage two (immature forest stage), described by Cormack (4) in his four stage forest succession proposal. The extremely arid sites on exposed slopes and ridges have very sparse tree growth although the amount of deadfall indicates a denser stand in the past. Limber pine *(Pinus flexus)* often dominates in these locations. Another variant is the dominance of aspen *(Populus tremuloides)* on the fans and talus slopes. In the very moist sites on the fans, along present stream channels or in areas of high water table, balsam poplar *(Populus balsamifera)* and spruce may dominate. The presence of some Douglas-fir *(Pseudotsuga menziesii)* is noteworthy.

The dominant lesser flora encountered under the drier pine sites and the more open stands are buffaloberry *(Sheperdia canadensis),* junipers *(Juniperus spp.),* rose *(Rosacea sp.),* bearberry *(Arctostaphylos uva-ursi),* and rye grass *(Elymus innovatus).* As the moisture conditions improve, small spruce are generally noted with the lesser flora including bunchberry *(Cornus canadensis),* twinflower *(Linnaea borealis),* arnica *(Arnica cordifolia),* wintergreens *(Pyrola spp.),* and aster *(Aster sp.).* There is usually a decrease in bearberry and rose with increased moisture. Also, in place of the crusty lichens of the drier sites, leafy lichens *(Peltigera sp.)* and feather mosses are found. A notable exception to Cormack's description of these forests in the absence of any Vaccinium (blueberry) species. This is probably a result of the calcareous nature of the soil surface in the project area. *Vaccinium scoparium* (grouse berry) is commonly encountered at elevations greater than about 6,000 feet AMSL. Also encountered near the tree line is white mountain heather *(Cassiope tetragona).* As the maturity of the stands increases, shading and surface humidity increase, and a myriad of lesser flora are noted (4, 6, 14).

There are several special ecological sites noted which are worthy of mention. The very coarse deposits along the mountain streams are covered by an almost solid mat of dryas *(Dryas drumondii).* Approaching the alpine zone and on the exposed ridges at higher elevations, a grass-meadow type of vegetation is prevalent. Juniper becomes more prevalent and cinquefoil *(Potentilla fruticosa)* appears. Besides the grasses, several legumes *(Astragalus spp., Lupinus spp.)* and many other alpine flowering herbs are present. The few trees present in these locations are somewhat stunted and often show signs of layering.

Prairie vegetation is present over a significant proportion of the area along the valley floor and lower fans. It occurs within 50 to 100 feet of river level and extends from Whirlpool point to the Whitegoat Creek fan. The largest areas are the Whiterabbit Creek fan and the fan opposite the Siffleur River confluence which together constitute the area known as the Kootenay Plains. The vegetation consists of grasses and various species of sage *(Artemesia spp.),* including wormwood *(Artemesia dracunculus),* and wild flax *(Lenum lewisii).* Where subsurface moisture is present, along streams and where bedrock is close to the surface, spruce prevail; otherwise aspen is the dominant tree type. The shrub layer on these fans is dominated by buffaloberry under a forest canopy while rose, cinquefoil, juniper, ground cedar *(Juniperus horizontalis),* and silver berry *(Elaeagnus commutata)* occur in the open areas. The grassed portions also contain some bearberry and many leguminous species in addition to the shrubs mentioned.

SOIL CLASSIFICATION AND MAPPING

This study was initiated in 1967 and the field work completed in 1968. Transects were selected at irregular intervals up to two or more miles apart along the valley, the frequency depending on land form variability, aspect and vegetative type as determined from aerial photographs. Soils were examined at about one-tenth mile intervals along the traverse from the valley center up to the orographic tree line. At each stop the soils were described in some detail and the site described with respect to vegetation, aspect, slope, and elevation.

Aerial photographs at a scale of 1:15,000 and 1:40,000 were used to assist in the field work. The mapping was done on base maps at a scale of 2 inches = 1 mile (1:31,680) which were later reduced to 1:50,000.

Close examination of the soils made possible the

[1] Vegetation classification is according to Moss (14).

recognition of individual kinds of soils. Those developed on similar parent materials and having similar external and internal features are called *soil series.*[2] The majority of map units are dominated by a single recognizable soil (usually a series) but have inclusions of other kinds of soils as well. Where series are not established, the soils are recognized at a higher classification level—the *Subgroup.* The subgroups represent divisions of the second highest level of the classification system—the *Great Group*—which encompasses soils having broadly similar genetic relationships. The major great soil groups represented in the area are Gray Luvisol, Eutric Brunisol, and Regosol with minor inclusions of Gleysol and Humo-Ferric Podzol.

The initial separation for mapping of the soils was based on the major land forms. These land forms have broadly defineable geologic, and usually climatic and vegetative, parameters and are roughly equivalent to the Level 3 (Land System[2]) category of the Bio-physical Land Classification (8) and to the Terrain System of Valentine (24). Four principal separations were recognized (Figs. 6, 7, and 8).

I Fans and flood plains of the central valley
II Lateral benches and till plains
III Mountain slopes
IV Rocklands

To be aligned more closely to the "Land System" concept, Part I may be subdivided based on vegetative (and climatic) differences into forest and forest-prairie systems (I and I[1]).

Closely associated groups of soils were recognized and delineated within the bounds of the larger land forms or systems. These *map units* are generally dominated by a single soil series or complex. When vegetation and geology are included in the description, the map unit becomes equivalent to the Level 4 (Land Type) category of the Bio-physical Land Classification. The term Land Unit (21) is preferable to Land Type[3] and will be used in this report to designate subdivisions of the Land System.

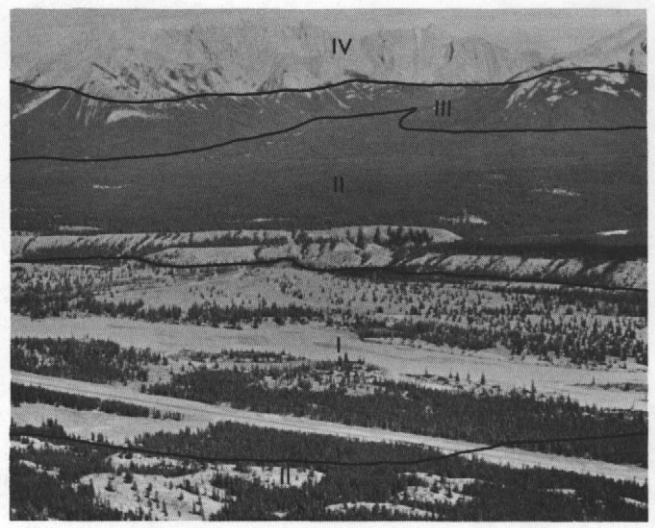

Figure 6—Photograph illustrating Land Systems. (Looking S. into Siffleur Wilderness from above Whirlpool Point)

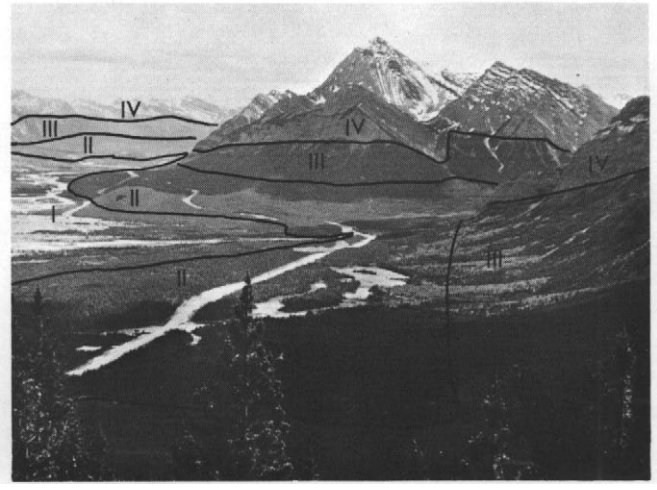

Figure 7—Photograph illustrating Land Systems (Looking S. toward Mount Sentinel). Abraham flats are apparent in the left center with the Whitegoat Lakes in the foreground to the right of the David Thompson Highway

[2] See Glossary for definitions.

[3] This avoids confusion with the established soil survey usage of the term "land type".

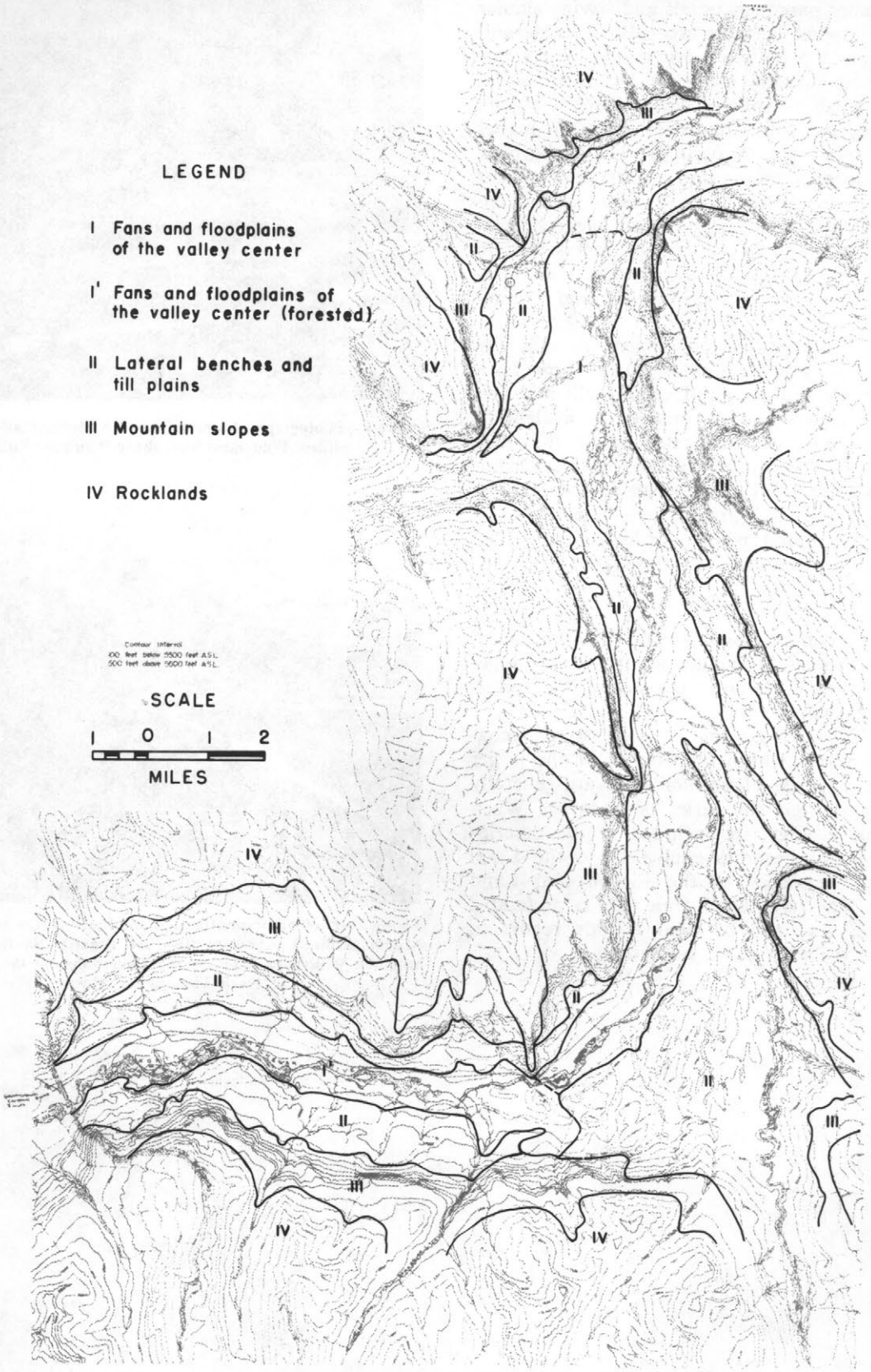

Figure 8—Land Systems distribution in the North Saskatchewan project area

DESCRIPTION OF LAND SYSTEMS AND LAND UNITS

LAND SYSTEM I

Fans and Floodplains Land System—(27,000 acres, 27% of area)[4]

This system takes in the central portion of the valley and includes the North Saskatchewan River. The river is quite fast-flowing and has a braided character. It is, however, commonly confined laterally by large fans, often into a single channel. The width varies from 75 feet to almost one mile and the channel materials are mainly coarse gravels with lenses and cappings of sand. Some abandoned or cut-off channels have silty and sandy surface deposits.

Two types of fan are recognized. First, and most prevalent, is the kind formed by the small, but permanent, mountain streams at the break in slope from the benches to the valley center. The slopes vary from 5 to 9% and individual fans may be a mile or more in width at the toe. Several fans may coalesce to give a continuum several miles across. The material is moderately sorted, gravelly to cobbly, with common sand lenses. Longitudinal sorting may be noted on some of the larger fans with more fines near the toes. A silty aeolian mantle is present but quite variable (0-8 inches). Adjacent to the river it may be thicker, sandier, have less volcanic ash and be more calcareous.

The second type of fan is that formed by the larger confluent streams, the Siffleur River, Cline River, and Whiterabbit Creek. They have gentler slopes (<5%) and are generally moderately well sorted. The material varies from the coarse gravels of recent stream beds to deposits of stratified fines 3 feet or more thick (mostly sands). Some small terraces are present within 30 feet of river level between the western edge of the area and the Siffleur confluence, but most have been covered by fans.

The vegetation on the intermediate slope (5-9%) fans is composed of an aspen or pine tree layer at the heads of the fans which gives way to a grass-shrub prairie vegetation near the toe of the fan at the river.[5] The low angle fans are dominated by prairie vegetation with spruce or aspen occuring where moisture is readily available. Stunted spruce, swamp birch, and willow dominate in the floodplain areas.

The soils have dark surface horizons reflecting the presence of prairie vegetation. Most are strongly calcareous to the surface, probably a result of a combination of low precipitation, desiccating winds, and recharge by calcareous aeolian material. At the bottom of the fans, close to river level, the sola are dark brown to black in color and from 4 to 20 inches thick. Headward on the fans under forest vegetation, the sola are thinner, concomitant with depth of loess (2 to 6 inches), browner in color and may have lower carbonate content in the upper 1 inch. The dark organic-rich horizons are considered non-chernozemic and the soils are classed as Regosols with some of the forested types approaching Eutric Brunisols. Regosols and Gleysols are present in the floodplains.

LAND SYSTEM I[1]

These generally east-west trending portions of the valley have similar geology to I except that low angle fans are not present and terraces are more common.

The vegetation consists of a pine-buffaloberry forest at the west end of the area with a somewhat open pine-aspen tree cover in the Windy Point region.

The soils are similar to the forested areas of I with soil development consisting essentially of the incorporation of organic material and a darkening of the surface. These soils are generally calcareous to the surface. Included in this System are some fans at higher elevations which have Degraded Eutric Brunisol soils.

Land Unit Ia (3,300 acres, 3%)

Included in this unit is the area known as the Kootenay Plains which includes the lower portion of the Two O'Clock Creek fan and the Whiterabbit Creek fan. The unit occurs within 30 feet of river level and has slopes of less than 5%. The surface material is a relatively thick (16 to 40 inches) deposit of fine sand and silt of alluvial or aeolian origin.

The vegetation is dominated by grasses with accessory sage, wormwood and flax. Trees, mainly aspen and spruce, occur along stream channels or where subsurface water is readily available.

Soils have dark brown to black Ahk horizons with a relatively high humus content. The organic matter decreases with depth so that by 4 to 12 inches the Ahk grades to a Ck horizon. Buried horizons are common, particularly close to the river. The surface horizons have a very weak structure and are very friable with a poorly developed organic-mineral association (moder type). Also, the bulk densities are about 0.8 gm/cc. The Ah horizons are therefore considered to be nonchernozemic and the soils are classed as Cumulic and Orthic Regosols. They are generally well drained and are strongly calcareous to the surface.

Land Unit Ib (5,400 acres, 5%)

This unit takes in the majority of the intermediate slope (5 to 10%) fans in the Land System. The fans have elevations generally within 300 feet of river level and are composed of coarse gravelly or cobbly alluvium with common sand lenses. The constant shifting of the parent stream results in an undulating microrelief and accounts in part for the variability in thickness, from 0 to 8 inches, of the silty aeolian mantle.

A prairie type of vegetation exists on the lower half of the fans. It is composed of grasses with

[4] Percentages do not include System IV - Rocklands.

[5] All vegetation has been removed from this system north of the Kootenay Plains in preparation for the Bighorn Dam.

accessory shrubs and herbs such as junipers, cinquefoil, silver willow and rose, and some scattered aspen. Towards the heads of the fans a general forest cover of aspen prevails with buffalo berry and grass in the understory (Fig. 9).

The principal feature of the soils is a darkening of the surface horizons to give a brownish Ahk horizon which grades, by 2 to 6 inches, to Ck or IICk horizons. In the forested areas the color is browner than in the open, grassy, locations and the soils may be classed as Eutric Brunisols; whereas the soils in the open areas are classed as Orthic Regosols. The structure is weak and the consistence is soft when dry. The soils are well to rapidly drained and generally calcareous to the surface.

Land Unit Ic (6,200 acres, 6%)

This unit is on the same landform as Ib, but is located in Land System I[1]. The geology is the same although a greater variability in depth of loess may be encountered.

Figure 9—Land Unit Ib located east of Sentinel Mountain. There is an increase in forest cover towards the heads of the fans

A pine forest with a buffalo berry shrub layer is the principal vegetative associate although aspen may be encountered and spruce may dominate at the western extremity of the area. The herb layer is scattered and the moss cover is discontinuous.

The soils are calcareous and generally weakly developed. They vary from those having an Ahk or Bmk, Ck horizon sequence (Eutric Brunisol) to those which have a light colored "eluviated" surface horizon of mainly geological origin (Degraded Eutric Brunisol). Adjacent to the river there is evidence of continuing aeolian deposition and Regosolic soils are common. The soils are well drained and have thin, up to 1 inch, L-H horizons.

In several areas this unit is complexed with Ib and inclusions of terrace units (Ie) are present in the west adjacent to the park.

Land Unit Id (1,600 acres, 2%)

This unit encompasses the low angle (2% slope) fan built by the Cline River and parts of the terraces west of the Kootenay Plains bridge. The underlying material is a well sorted coarse gravel which is covered by 4 to 10 inches of loess.

The vegetation ranges from a grass-herb prairie on the Abraham Flats to a pine forest with buffalo berry, rose, juniper, bearberry, and grass.

The soils are quite thin, depending upon the thickness of overlay, and calcareous. Under the prairie vegetation the soil generally has a thin, up to 1 inch, Ahk and a Bmk developed in the loess over IIBCk and IICk horizons in the gravel (calcareous Orthic Eutric Brunisol). Under the forest cover the sola are slightly thicker and consist of weakly calcareous, often mottled Aej and Bmk horizons. This soil (Degraded Eutric Brunisol) is very similar to that mentioned in Ic.

Land Unit Ie (2,400 acres, 2%)

This unit comprises the relatively flat (less than 2% slope) terraces which occur close to river level in the western part of the area and at the confluences of the Siffleur and Cline Rivers. Moderately well sorted gravels are the principal component of the terraces but they may be covered by up to 3 feet or more of fine sands and silts of both alluvial and aeolian origins. Micro-relief is often quite rough with locally occurring cut and fill features and duned material.

The vegetation on this unit is somewhat sparse and variable. Grasses and shrubs such as juniper prevail but small groves of trees, mainly spruce feeding directly from the water table, occur. An exception is the continuous coniferous forest in the extreme west of the area.

The soils are dominantly orthic Regosols with little, if any, profile development. Geological stratification is the primary feature. In some instances, on relatively higher terraces, soils and vegetation similar to unit Ib are present. The soils are strongly calcareous and are generally well drained but may have a water table within 3 to 6 feet of the surface.

Land Unit If (1,000 acres, 1%)

Included in this unit are the floodplains which can be mapped separately from the river channel. These areas are 1 to 4 feet above high river level and are composed of fine sands and silts overlying gravel at depth.

The dominant tree cover is stunted spruce (Fig. 10). The shrub layer is well developed and includes willow, swamp birch, and cinquefoil. Bearberry, sedges and grasses are also present. The relatively more recent deposits, closer to river level, have less tree and more shrub cover. They are frequently very hummocky with relief variation of 8 to 20 inches.

The thickness of the L-H horizon ranges from 0-6 inches, the depth to water table from 4 to 30 inches and buried horizons may or may not be present. Peat accumulations are absent and the hummocks are characteristically more strongly calcareous than the troughs. The classification of these

soils varies, with depth to water table, from Rego Gleysols to Gleyed Regosols.

Land Unit Ig (6,000 acres, 6%)

This is the main river channel (Fig. 10). The bars in the braided channel are composed of moderately sorted gravels and sand lenses and often sandy cappings. Some of those above high water level are partially vegetated with spruce, shrubs, sedges, and grasses. The soils are Orthic Regosols.

Land Unit Ih (1,100 acres, 1%)

This includes the several small areas of rock outcrops, particularly in the vicinity of the Siffleur confluence. Minor amounts of till, colluvium and alluvium are associated with the rock. The vegetation is sparse and the soils present are comprised of undifferentiated Regosols.

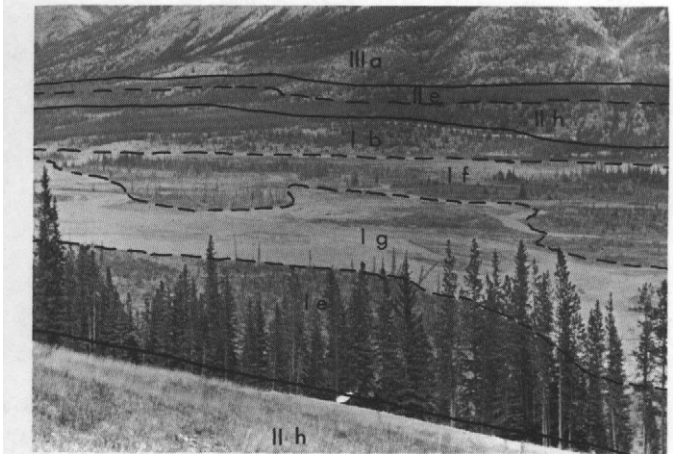

Figure 10—Valley Land Units E of Sentinel Mountain

LAND SYSTEM II

Lateral Benches (and Till Plain) Land System (34,500 acres, 34% of area)

This Land System includes the bench-like features along the valley sides and the somewhat fluted till plain in the Siffleur Wilderness area (Fig. 2). These features are 200 - 300 feet above river level and have elevations of 4500 - 4900 feet AMSL at the upstream end of the area and 4300 - 4600 feet at the downstream end. Also included in this system are the steep (50 - 60% slope) scarps dropping from the benches to the valley center. (Fig. 8).

The topography is undulating to rolling with slopes of 5 to 30%. The east-west portion of the valley, particularly south of the river, has ridges or flutings parallel to the valley wall. Mountain streams emerging from side valleys transect these ridges at about 2 mile intervals. The Siffleur River crosses the southeast part of the system and drops into a bedrock controlled channel about 1½ miles from its confluence with the North Saskatchewan River. Apart from the streams mentioned the drainage is somewhat deranged. Small peaty areas may be encountered in the troughs and undrained depressions but the only open water is Whitegoat Lake about 1½ miles north of the Cline River bridge.

Glacial till, ranging up to 100 feet in thickness, is the major surficial deposit but inclusions of ice-contact and outwash materials are present, particularly in the Whirlpool Point area. Outwash may predominate on the south side of the river near the Park boundary. The till is coarse textured, extremely calcareous, and very compact. This land form is overlain by 4 to 8 inches of silty aeolian material with a high volcanic ash content.

The vegetation consists mainly of a lodgepole pine forest with accessory spruce near the valley walls and with a somewhat scattered but continuour shrub layer composed of buffalo berry with some juniper and rose. Herbs include twinflower, bunchberry, wintergreens, aster, bearberry, and arnica. Grasses (mostly wild rye grass) and mosses may also be present.

Soils in this system are characterized by an Ae, Bm or Bt, IIBCk, IICk horizon sequence with the A and B horizons developed in the loessial overlay, or a till-loess mixture, and the lower horizons in the till. They commonly have a brownish surface layer up to 1 inch thick but this horizon is not considered diagnostic. Gray Luvisol soils with well expressed Ae and Bt horizons predominate. Some Podzolic development is apparent in the more humid sites. Where the environment is influenced by the strong valley winds profile development is markedly reduced. This is most apparent on the outside of the curve in the southeastern part of the area where B horizon development is weaker and the soils are classed as Degraded Eutric Brunisols, some of which have weakly to moderately calcareous sola. The depth of A plus B horizons seldom exceeds 6 - 8 inches and the A horizons in particular have very weak structure and soft consistence. The surface horizons are slightly acid to neutral in reaction and nearly all of the soils are well drained.

Land Unit IIa (1,900 acres, 2%)

This unit is located at the base of northeast facing slopes along Whitegoat Creek and Loudon Creek at elevations of 4900 to 5400 feet AMSL. The underlying material appears to be colluvium from a till source and slopes are from 15 to 20%. A silty aeolian deposit up to 10 inches thick may be present.

The vegetation generally indicates relatively humid site conditions with a pine-spruce tree layer and a shrub layer containing labrador tea, juniper and buffalo berry. The principal herbs are twinflower, bunchberry, wintergreen, and arnica. In the Loudon Creek area grouse berry is also common. Mosses, lichens, and some grass form a continuous ground cover.

The soils are predominantly of a Bisequa Gray Luvisol type (Whitegoat series, Wo.), characterized by an Ae, Bf podzolic sequum overlying an Ae, Bt luvisolic sequum (Fig. 11). The upper sequum varies

from 3 to 6 inches in thickness with the depth to the bottom of the Bt horizons averaging 8 to 12 inches. Calcareous IIBC and IIC horizons in the colluvium underlay the A and B horizons. A common variation is one in which the upper sequum is weakly expressed. These soils are well drained but some poorly drained peaty soils are associated in the unit.

Land Unit IIb (9,800 acres, 10%)

This unit includes the bench areas flanking the river, which on the right side are confined to the extremities of the study area. The predominant surface material is an extremely calcareous gravelly till with a 4 to 8 inch silty aeolian overlay. There are some minor inclusions of ice-contact and outwash material and some colluvium near the valley walls. An area of outwash adjacent to the park on the south side of the river is included.

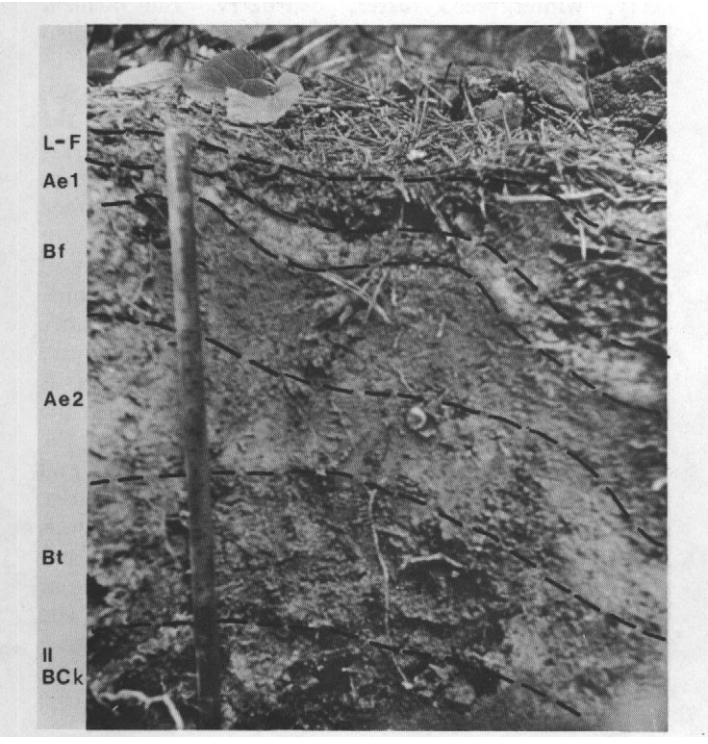

Figure 11—Bisequa Gray Luvisol (Ae1 = 1 inch)

The forest consists mainly of immature lodgepole pine with some spruce in the understory. Buffalo berry with some juniper make up the somewhat scattered shrub layer. Herbs include twinflower, bunchberry, arnica, aster, and wintergreen. Moss cover is continuous and some grass is present.

The principal soil is an Orthic Gray Luvisol (Cline River series, Cr.) with a strong brown, clayey Bt horizon (Fig. 12). The upper solum is developed in the aeolian material with the Ae horizons in particular having a high volcanic ash content. Stones are commonly present, probably as a result of frost action or to soil disturbance at some stage of development. Underlying the Ae and Bt horizons are rather dark colored, loose, gravelly, extremely calcareous horizons about 8 inches thick. These horizons (IIBCk) have a high content of organic remains and appear to result from the action of roots breaking up the surface of the very compact glacial till (IICk). On the east side of Sentinel Mountain in the moister sites near the valley wall, the soils tend to be more strongly degraded. A surface Bm horizon up to 4 inches thick may occur but an Ae1, and Ae2 horizon sequence is more common. Also, deeper L-H horizons and redder, more clayey Bt horizons are usual. Windthrow is an active process and Regosolic soils resulting from this process are common.

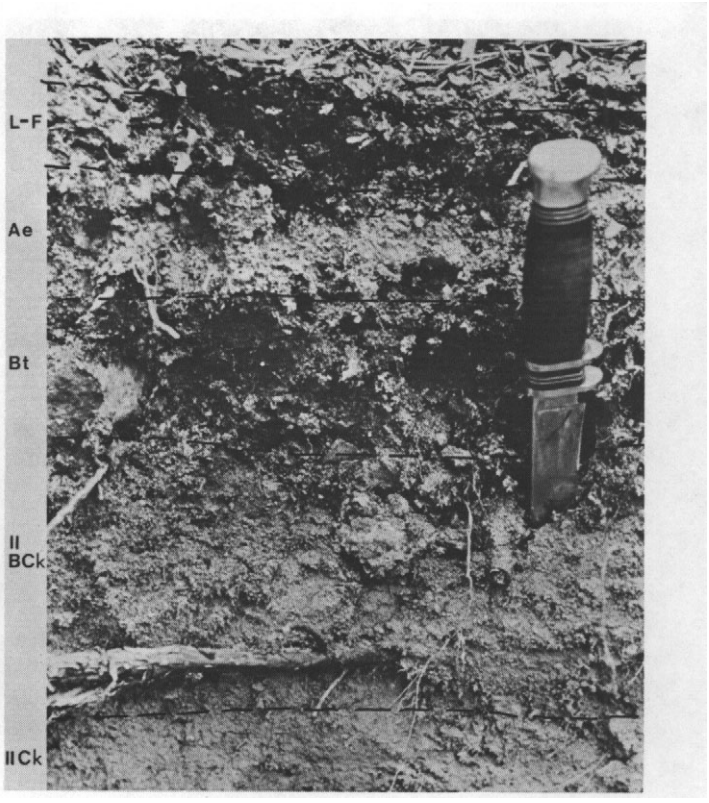

Figure 12—Orthic Gray Luvisol (Bt = 4 inches)

Land Unit IIc (900 acres, 1%)

This unit is the same as IIb with the exception that consolidated bedrock is close to the surface and occasionally outcrops. Soils with rock substrates within 20 inches of the surface are common.

Land Unit IId (8,300 acres, 8%)

This unit is located in the Siffleur Wilderness area and extends westerly along the Saskatchewan River on topography that is somewhat fluted or dissected. There are more poorly drained soils than in IIb but they occupy less than 5% of the area. The surface material is a gravelly sandy loam till with a silty loess mantle.

The vegetation is like that described for IIb.

The dominant soils are classed as Orthic Gray Luvisols but have only weakly expressed Bt horizons. Compared to the Cline River series of IIb, the Bt horizons have less clay (loam versus clay loam), are duller colored, and have less well developed structure. Areas nearer the river have associated Degraded Eutric Brunisols in which the B horizons do not meet the requirements of a Bt. There are some associated Regosols and Gleysols.

Land Unit IIe (7,200 acres, 7%)

This unit encompasses those bench areas directly influenced by the desiccating and other effects of the valley winds. It includes the area centered around the Siffleur River confluence, extending west to Corona Creek and north past the Kootenay Plains. The surficial material is dominantly a gravelly sandy loam till which is extremely calcareous and below the top 8 inches very compact. A silty aeolian capping is continuous and commonly up to 8 - 10 inches or more in thickness. In this unit there is a significant proportion of ice-contact material, particularly in the Whirlpool Point area, and some outwash.

The vegetation is dominated by a lodgepole pine forest which is rather thin in exposed locations near the Siffleur confluence. The scattered shrub layer has buffalo berry with accessory juniper and rose. The herb layer includes twinflower, bearberry, wintergreen, and strawberry but little or no arnica. The moss layer is often absent although sparse grass growth is common (Fig. 13). On the more exposed dry sites lichen crusts may be present.

The soils of this unit are characterized by light colored silty surface horizons which are very weakly structured and soft when dry. These horizons are considered as Ae horizons, which they resemble even though they are essentially of geologic origin and may in fact represent very little eluviation. Pedological development is also weakly expressed in the B horizons, being confined mainly to the development of a brownish color although some weak clay accumulation and structural development occurs. These soils are classed as Degraded Eutric Brunisols. Near the river, particularly in the Siffleur area, carbonates may be present in the B or even A horizons and where there is recent aeolian deposition the soils grade to Regosols. Bordering unit IId there is stronger definition of the B horizons and the soils grade to Orthic Gray Luvisols. The soils are well drained.

Land Unit IIf (900 acres, 1%)

Included here are some small areas at the Cline and Siffleur River confluences. The underlying material is a moderately well sorted outwash covered by 8 to 20 inches or more of silty aeolian deposits.

The vegetation and soils are very similar to those of unit IIe. However, the soils are often calcareous to the surface (calcareous Degraded Eutric Brunisols) and there is a greater percentage of Regosols.

Land Unit IIg (3,400 acres, 3%)

This unit comprises several rather large fans formed at the break in slope from the valley walls to the benches and having slopes of 10 to 40%.

The vegetation is similar to that of the IIb unit with which it is associated except that aspen is often present in the actively aggrading portions.

The soils are generally Regosolic with the commonest form being a somewhat brownish darkened surface horizon (Ahk or Bmk) which grades to a Ck horizon. The lower parts of the fans are very similar to Ic while the upper, steeper portions are of coarser material with signs of more colluvial and alluvial action. Some of the older surfaces may have Degraded Eutric Brunisols or even Orthic Gray Luvisols. The soils are rapidly to well drained but may be kept moist by seepage waters.

Figure 13—Vegetation in Land Unit He. This lodgepole pine—buffalo berry association is common to most of the forested portion of the area

Land Unit IIh (2,100 acres, 2%)

This unit comprises the steep (50 to 75%) slopes dropping from the benches to the valley center. The scarps are somewhat faceted and the surface material is a loose, coarse gravelly colluvium.

The vegetation varies markedly with exposure. On the windward (upstream facing) facets a few stunted pine are generally the only trees, with scattered juniper and cinquefoil making up the shrub layer. Bearberry is common and there are some associated herbs and grasses. Lichens are present

but no moss, with often less than 50% of the soil surface covered. On the leeward facets a pine-buffalo berry-hairy wild rye grass community is present.

The soils of the exposed windward facts have a surface horizon which appears to be a mixture of roots (mostly bearberry) and other weakly humified organic remains with the coarse-textured calcareous mineral fractions. These "Ahk" horizons grade to Ck horizons by 8 to 16 inches and the soils are classed as Regosols (Deors series, De). The soils of the forested, sheltered facets tend towards Degraded Eutric Brunisols with an Ae, Bm, Ck horizon sequence although the instability of the slopes results in much variation and a large percentage of Regosolic soils.

LAND SYSTEM III

Mountain Slopes Land System (39,500 acres, 39%)

This system encompasses the mountain slopes and fans of the valley walls up to the tree line from approximately 4800 to 7000 feet AMSL. The slopes are generally steep (30 to 70%) and the dominant surface material is a rather coarse textured colluvium with some talus,[6] scree and rock outcrops. At breaks in slope and on protected ledges glacial till is often encountered. All of the materials are calcareous, reflecting the dominance of carbonate rocks.

The forest consists mainly of lodgepole pine with Engelmann spruce and alpine fir becoming prominent at higher elevations and on north and east aspects. The buffalo berry and twinflower understory tends to be replaced by grouse berry at about 6000 feet AMSL.

Soil development is controlled by the unstable surface conditions and Regosols are dominant. Luvisolic and Brunisolic soils are also present. The soils are well drained although seepage is common.

Land Unit IIIa (13,600 acres, 13%)

This unit includes the steep (30 to 70%) south and west facing slopes. These are usually dip slopes and the surface material tends to be a rather coarse-textured loose colluvium which overlies till or bedrock at lower elevations but grades to rock and scree slopes. The bedrock component may reach 50% or more in this unit with significant scree areas as well.

The vegetation is usually sparse, reflecting the exposure and the often shallow rooting zone. The tree cover is dominantly pine while the shrub layer consists of scattered buffalo berry and juniper with some cinquefoil in the more exposed sites (Fig. 14). The herb layer contains bearberry, twinflower, legumes, and grasses. The moss layer is discontinuous, commonly absent, and lichens are often present.

Disrupted profiles due to downslope movement of materials are common and 25 to 50% of the area is occupied by Regosols of this type. On the more stable materials and less steeply sloping areas, Gray Luvisols may dominate. Where B horizon development is weak as a result of disruption, or immaturity, or both, Eutric Brunisols occur. The L-H horizons on these soils are generally quite thin, 1 - 2 inches and the shallow scree soils have an AC type of profile very similar to that of the Deors series (Land Unit IIg).

The soils of this unit are rapidly to well drained and generally somewhat dry due to the exposure.

Land Unit IIIb (18,100 acrea, 18%)

This includes the steep (40 to 80%) north and east facing slopes. These are usually back slopes and the dominant surface material is a loose cobbly colluvium with some associated talus but less than 20% exposed rock.

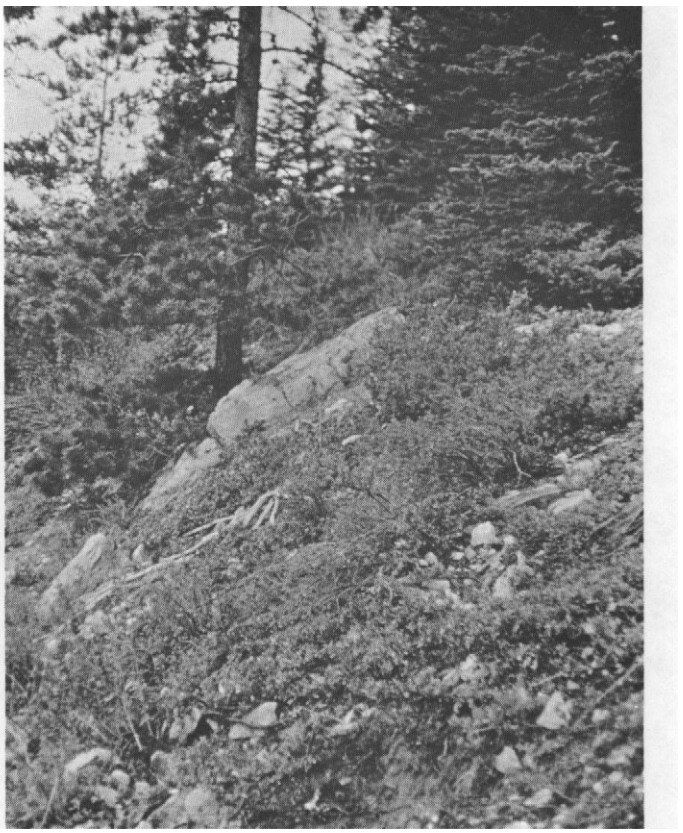

Figure 14—Land Unit IIIa. This is a 60% west facing slope with rock very close to the surface

The vegetation consists of a pine-spruce forest with alpine fir replacing the pine at higher elevations. The shrub layer composed of buffalo berry, labrador tea, and juniper is somewhat scattered. The herb layer includes twinflower, grouse berry, wintergreen, and arnica with some grasses. The moss layer is continuous and up to 4 inches or more thick.

On the more stable sites, soil development proceeds to the Orthic Gray Luvisol stage or even to some bisequa development. The soil genesis in this unit is dominated by mass wasting to the extent that 50 - 75% of the soils have disrupted profiles and must be classed as Regosols. There is a general increase in soil chroma and a decrease in grade of

[6] See Glossary for definition.

structure with elevation. Local small peaty accumulations may be encountered in seepage areas on slopes up to 75%. Although much of the area may be subirrigated by seepage, the soils are well drained and reducing conditions do not exist, apparently a result of the high oxygen content of the waters.

Narrow (15 to 50 feet) snowslide and landslide tracks are fairly common. The material is very coarse cobbly and Dryas is often encountered in the ground cover. The soils are Regosolic and similar to those encountered in the high angle fans (IIId) to which they often grade.

Land Unit IIIc (1,000 acres, 1%)

This encompasses the talus accumulations under the steep, east facing rocklands. The slopes range from 55 to 70% and the material is coarse cobbly at the surface but commonly having more fines (sands) at depth.

The vegetation is extremely varied depending on the activity of talus fall and the moisture balance. The scattered tree layer includes pine, spruce, fir and occasionally aspen. Alder, maple, birch, and willows, as well as buffalo berry, cinquefoil, serviceberry, and rose may also be present. The ground cover is comprised mainly of grasses and some bearberry, small herbs, moss, and lichens.

The principal soil is a Cumulic Regosol with an Ahk, Ck type of profile. The Ahk horizon is essentially an horizon of angular talus cobbles embedded or enveloped in felted mats of organic material and roots. The organic content decreases with depth giving a total solum tickness in the 6 to 12 inch range. Fresh talus on the surface is common. These soils grade to Orthic Regosols common on the more active and less moist sites, to high angle fans (Unit IIId), or to rock.

Land Unit IIId (1,600 acres, 2%)

This unit comprises the "high angle" (>30%) fans which are formed at or above the break from the mountain slope to the benches. These fans have slopes of 30 to 50% and are intermediate between units IIIc and IIg. That is, they are gradational between talus slopes and fans on the benches.

Land Unit IIIe (4,000 acres, 4%)

Included in this unit are those lower mountain slopes which are less steep (20 to 40%) and which are generally more stable than most of this system. The two main areas of this unit are along Whitegoat Creek and on the north side of the river from Whirlpool Point west. The material is dominantly colluvial but is derived from till and generally rests upon till. Some coarse colluvium and rock substrates may also be encountered.

Pine is dominant in the tree layer but spruce (and fir) are common in the understory. The somewhat scattered shrub layer is composed of buffalo berry with some juniper. The principal herbs are twinflower, bunchberry, aster, arnica, and wintergreen. The moss layer is continuous.

The major soil is an Orthic Gray Luvisol very similar to that in unit IIb. The upper mineral portion of the soils (Ae and Bt) have some aeolian admixture with a volcanic ash component, but colluvial processes have mixed it with gravelly till material so that no sharp break in material is apparent. Twenty to 40% of the unit has variously disturbed, less well developed soils dominantly Regosolic in nature. All the soils are well drained.

Land Unit IIIf (1,100 acres, 1%)

This comprises the less steep (10 to 40%) upper mountain slopes from about 5600 to 6900 feet AMSL. This unit was encountered in only one location, above the Two O'Clock Creek fan. The material consists of loose colluvium often underlain by till. A silty aeolian mantle up to 6 inches thick is common on the more stable surfaces.

The pine-spruce tree layer of the lower elevations gives way to spruce-fir at elevations greater than 6000 feet AMSL. Also, the buffalo berry shrub layer almost disappears and the ground cover changes to grouse berry and horsetail with white mountain heather coming in at about 6500 feet. The moss is continuous and up to 4 inches thick.

The soils also change with elevation. At the lower altitude the major soil is an Orthic Gray Luvisol similar to Cline River series but at about 6000 feet development of a podzolic (Ae, Bf) upper sequum is common and the Bisequa Gray Luvisol (Whitegoat series) becomes dominant. With increasing elevation the upper sequum becomes more pronounced while the luvisolic (Ae, Bt) sequum becomes weaker until at about 6500 feet podzolic soils (Sentinel series, Se) are encountered. The medium acid sola are about 10 inches thick and overlie calcareous IIBC and IIC horizons. As the alpine zone is approached there appears to be less horizon development and greater profile disruption. The soils are well drained.

LAND SYSTEM IV

Rocklands Land System

This encompasses the barren rock areas of the mountains. Elevation is generally over 6500 feet ASML and slopes are usually in excess of 60%. The bedrock is mainly composed of bedded and fractured limestones and dolomites with some sandstones and shales outcropping at the higher elevations.

Vegetation is limited to ledges and crevices and to scattered small areas of relatively stable materials. It is comprised of alpine and stunted subalpine species.

The soils, like the vegetation, are of limited occurrence, making up less than 1% of the system. They are in general very shallow, up to 4 inches deep and limited laterally. Often they are simply an organic accumulation with some mineral admixture. The majority of the soils are classed as Lithic Regosols, with some Brunisols.

SOIL FORMATION

Factors of Soil Formation

The major factors recognized in soil development in the project area are parent material, vegetation, climate, and slope. The very high carbonate content of the majority of parent materials severely limits the depth of pedogenic activity. This is apparent from the very shallow nature of the soils which are mainly developed in the less calcareous loess material. The high carbonate content and compactness of the till are indirectly responsible for the development of the singular IIBCk horizons. Tree roots cannot penetrate more than about 8 inches into the till and therefore spread laterally near the surface. The concentration of roots accounts for the high content of poorly humified organic remains. The lack of bindings clays, and the possible partial solution of some of the carbonate cements, allow the till to break into a very loose material.

The principal vegetative changes from forest to grassland and to alpine vegetation relate well with changes in soil character. The "prairie" soils are characterized by dark colored surface horizons with a high humus content, derived from the grass vegetation. Under pine and spruce forest the surface horizons have much less organic matter and are brown in color or appear eluviated. Minor vegetative species often indicate special site characteristics, such as humidity, which are reflected in the soil. For example, the presence of arnica is usually associated with the presence of Bt horizons. However, relationships between soil and gross forest character are not strongly apparent since the vegetation generally reflects fire history rathen than soil conditions and climatic conditions. One anomaly is the occurrence of Gray Luvisols on some of the scree slopes and barren ridge crests where tree cover is extremely sparse. This suggests that the forest was somewhat expanded in the past.

The climatic factors of humidity and temperature are strongly modified by aspect and elevation. Both vegetation and soils reflect the cooler, more humid climate on the north and east facing slopes as compared to the south facing slopes. Lusher undergrowth indicates that humidity and precipitation efficiency also increase with elevation and distance from the center of the valley.

The valley winds are another major climatic factor and exert several important influences. First is the desiccating effect of the wind through its influence on evaporation and transpiration. Second is the effect of valley air currents in determining the direction of minor disturbances such as thunderstorms. Storms following side valleys are seemingly cut off or diverted along the edges when entering the main valley. A third contribution of the wind is its role as an agent of deposition which is important in soil formation in this environment. Burial phenomena are particularly apparent on the lower fans. Not only does loessial deposition continually bury existing soils and alter weathering patterns, but in this area the calcareous nature of the material results in a constant recharge of calcium carbonate which suppresses pedogenic development. The areas of poorly developed soils coincide with areas where the valley winds are most prominent. This appears to be a desiccation effect as site humidity increases with distance from the center of the valley. However, carbonate recharge may also be important. These are important factors in the complexity of wind phenomena, to which may be added physical affects such as the overthrow of trees (Fig. 15) and limitation of vegetation on exposed scarps.

Slope is a very important soil forming factor in mountain areas. Field investigations showed that soils must be stable to achieve maximum morphological expression. In other words, the "climax" soil at any location is directly dependent on the slope and the degree of mass wasting.

Figure 15—Windthrow—a forest process. This phenomena is common on the benches and lower fans

Soil Development in the Project Area

The last major deglaciation probably occurred about 10,000 years B.P. (18, 25). This likely left the principal valley features, the scoured walls and benches, much as they are today. The majority of the fans and some loess were subsequently added. About 6,600 years B.P., a thin layer of volcanic ash from an eruption at Crater Lake in Oregon may have been deposited and retained on the stable surfaces. The next 2,500 years were possibly warmer and drier —the Altithermal period (5, 18). During this period there may have been *in situ* weathering of the surface material, but because of the high carbonate content of the till and/or the low precipitation, eluviation was probably limited. From 4,000 years ago climatic conditions much like the present may have prevailed with higher moisture efficiency and greater weathering near the valley walls and particularly at the base of north and east facing slopes.

The period to 2,500 years B.P. may be thought of as a conditioning period with the leaching of carbonates from the immediate surface and the beginning of primary mineral weathering. About 2,500 years B.P., another series of ash falls occurred originating in British Columbia and Washington (25). These falls totaled 4 to 6 inches in thickness in the study area and were quite uniform over most of the bench areas. There was now a new surface exposed to pedogenic processes. As with the previous cycle, this material weathered more strongly away from the center of the valley and at higher elevations where there is a higher precipitation efficiency—away from the desiccation and lime recharge effects of the winds. The ash material has a low buffering capacity so that chemical (podzolic) weathering was able to proceed more quickly than in the underlying calcareous till. The apparent result was the liberation of ions, particularly iron, which together with silica and aluminum and "neo-clays" were washed into the previously weathered former surface horizons augmenting their clay contents and imparting to them a strong reddish color. These horizons, the result of two weathering cycles, are the present Bt horizons. In the case of maximum weathering a podzol is formed in the upper deposit (Bisequa Gray Luvisol). As site humidity and weathering intensities decrease the soil sequence passes through well developed to weakly developed Gray Luvisols, to Degraded Eutric Brunisols, and in the most arid sites, to the calcareous Degraded Eutric Brunisols. This reflects an extreme range in soil characteristics within the confines of a relatively small area, from soils exhibiting strong pedogenic development to those whose features are dominantly controlled by the lithology of the deposit.

Soil development on the fans of the central valley followed a different course. This landform is continually under the influence of the valley winds and the aridity or continual deposition of calcareous material, or both, result in soils which are calcareous to the surface and weakly differentiated. The presence of free lime and aridity combine to retard weathering processes to the extent that the accumulation of organic matter masks most other effects. This is most pronounced on the well grassed, low angle fans of the Whiterabbit and Two O'Clock Creek areas (Kootenay Plains) where thick, very dark Ah horizons have built up. These areas are very close to river level (less than 30 feet) and so receive more aeolian material than do those areas farther removed from the source. Farther from the river, usually under a light forest cover, there is a thinner loess mantle and less grass growth. Here the soil sola are thinner and browner in color. The fans above the benches are much less stable and the materials show little, if any, signs of soil formation beyond some darkening of the surface.

The lower mountain slopes are characterized by unstable conditions. Glacial debris plastered against the rock combined with scree and other debris is being continually shifted by mass wasting. During stable periods this colluvium develops horizons, but subsequent movement fosters disruption and truncation.

At high elevations the cooler, moister climate, and possibly a less calcareous material, results in a more acid weathering regime and podzolization becomes dominant to the exclusion of the lessivage process (clay illuviation). At the treeline the podzol processes become weaker, probably because of coldness (and possibly saturation without leaching), and Dystric Brunisols result. These in turn give way to turfy soils under the grasses and herbs of the alpine vegetative community.

I LAND CAPABILITY FOR FORESTRY

CLASSIFICATION

Forestry capability classes: based on degree of limitations and characterized by a productive range.

1 no important limitations to the growth of commercial forests
2 slight limitations
3 moderate limitations
4 moderately severe limitations
5 severe limitations
6 very severe limitations
7 limitations preclude the growth of commercial forests

Forestry capability subclasses: denotes kinds of limitations.

C a combination of climatic factors
H low temperatures
U exposure
M soil moisture deficiency
W soil moisture excess
X combination of M and W
R restriction of rooting zone by bedrock
E actively eroding soils
I soils periodically inundated

Tree Specie indicator: for which the ratings are made.

wS White Spruce
eS Englemann Spruce
lP Lodgepole Pine
alF Alpine Fir

DISCUSSION

Soil conditions are only moderate for forest production with limitations present in the extreme calcareousness of the materials, the compactness of the till and the rock substrata on the slopes. Climate is probably the most severe limitation with the central valley areas in particular being quite dry and subject to strong winds.

The majority of the area is presently covered by an immature pine forest approximately 70 years in age. The only commercial development to date has been a logging operation in the Corona Creek area where a 300 year old stand of limited area was harvested. As other areas mature, some logging may be economical but the area does not have a high capability for commercial wood production.

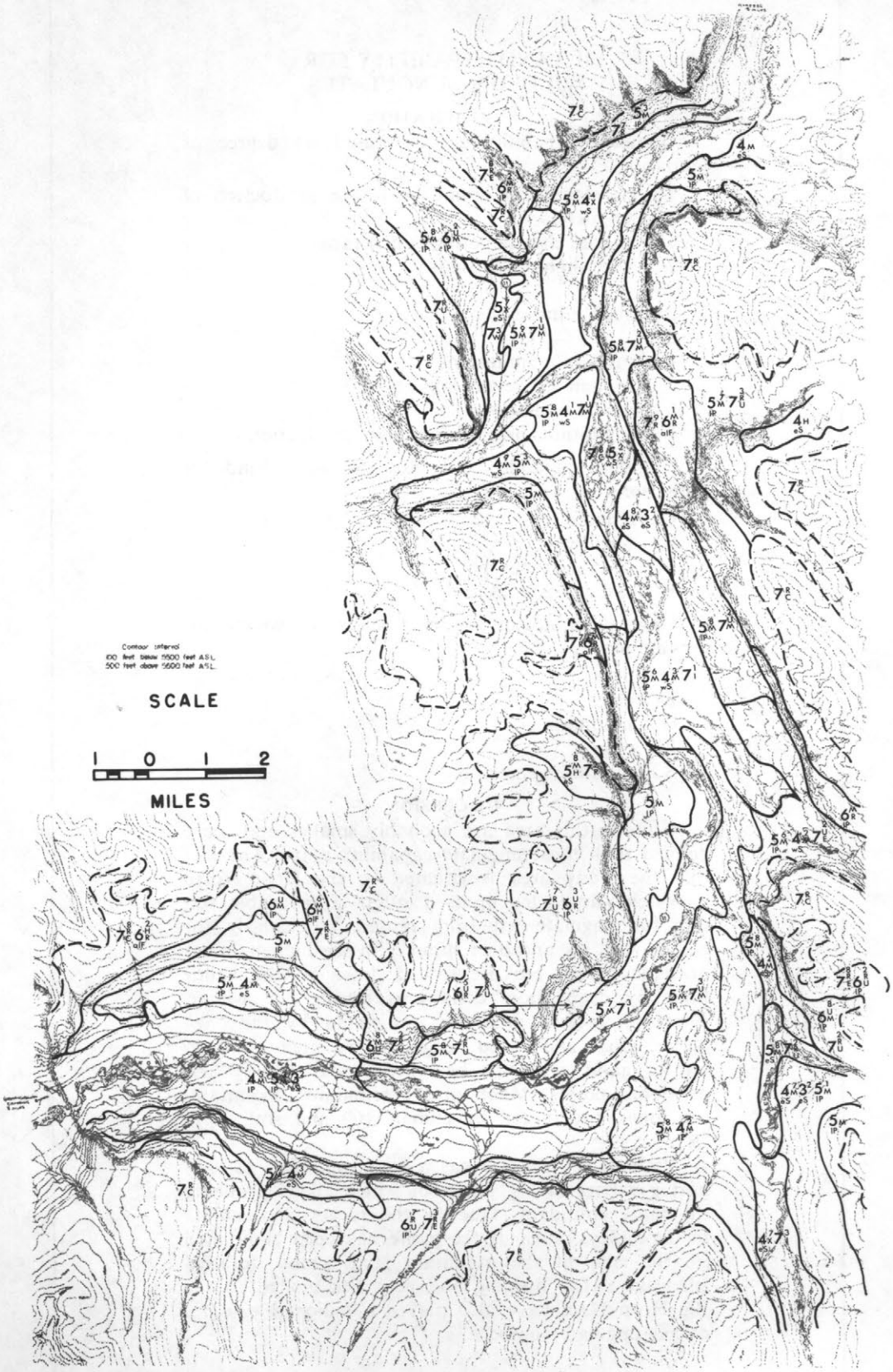

Figure 16—Land capability for forestry

Source: Province of Alberta, Department of Lands and Forests, Alberta Forest Service Branch

II LAND CAPABILITY FOR WILDLIFE—UNGULATES

CLASSIFICATION

Ungulate capability classes: based on degree of limitation.

- 1 no significant limitation to the production of ungulates
- 1W special class denoting winter ranges
- 2 very slight limitations
- 2W
- 3 slight limitations
- 3W
- 4 moderate limitations
- 5 moderately severe limitations
- 6 severe limitations
- 7 limitations preclude ungulate production

Ungulate capability subclasses: denotes kinds of limitations.

- C climate
- F fertility
- M soil moisture
- R soil depth (rock)

Ungulate indicator species: species for which ratings are made.

- D deer
- E elk
- G mountain goat
- M moose
- S mountain sheep

DISCUSSION

Units in this area are probably smaller and more defined than most ungulate capability maps. The fact that the study area is situated in the large North Saskatchewan valley in itself offers a favorable setting for ungulate wintering ranges, particularly for elk. Moose, elk and deer summer in the higher timber or alpine areas but are forced down to the valley floor by deep snow conditions during the winter. These important units are designated by the "W" factor. Goat and sheep ranges in the area are only fair to good, with the best areas near Windy and whirlpool points. Much of the remaining mountainour areas are limited by climate (C) and soil depth (R).

Potentially this area has a high capability to support a variety of big game, of which elk is probably the most abundant. Due to the recent accessibility to the valley, much of the game has been eliminated (in the case of the mountain goat almost totally). Intensive native hunting and activities related to the Big Horn Dam have also played a major role in reducing ungulate numbers.

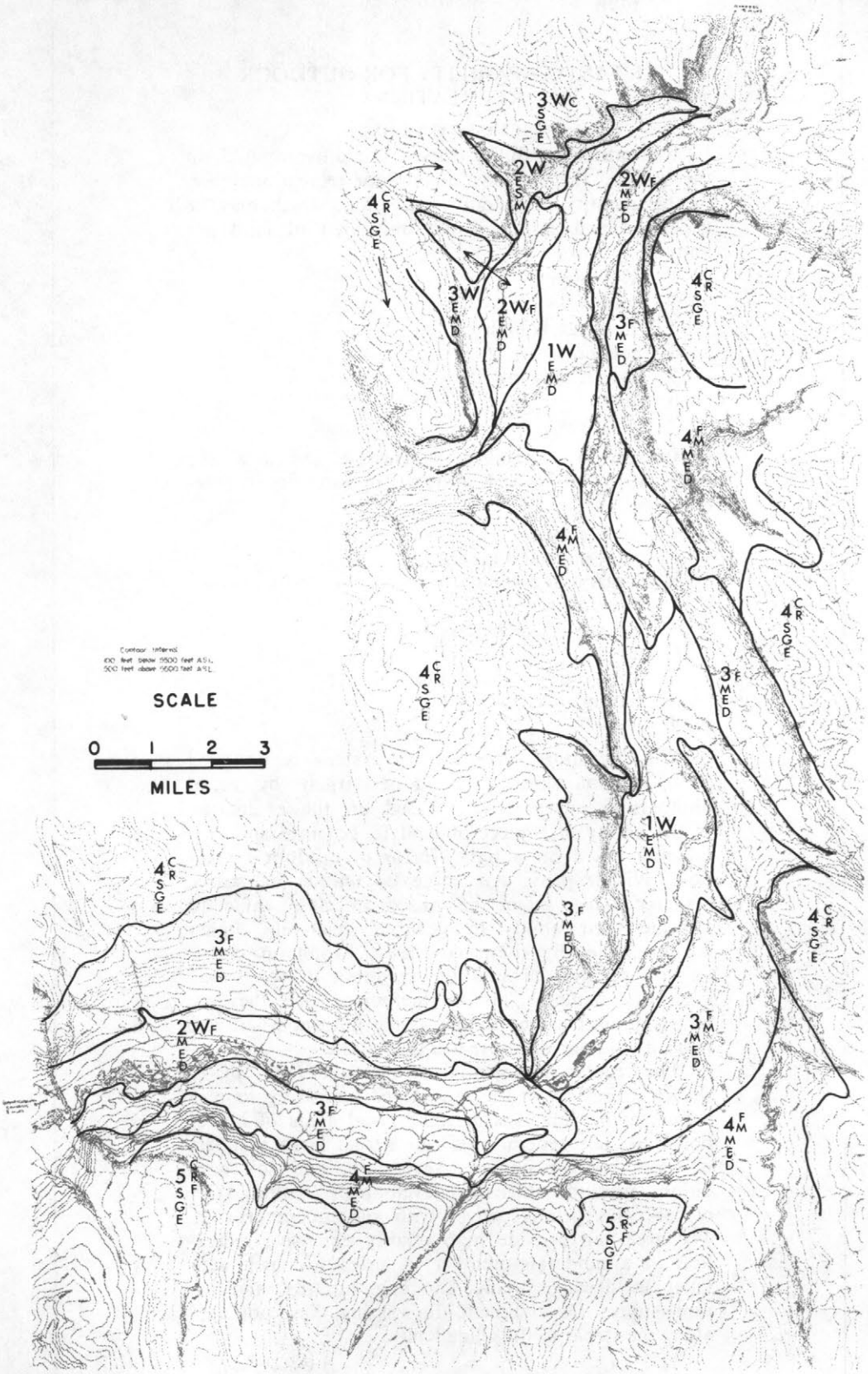

Figure 17—Land capability for wildlife—ungulates

Source: Province of Alberta, Department of Lands and Forests, Fish and Wildlife Division

III LAND CAPABILITY FOR OUTDOOR RECREATION

CLASSIFICATION

Recreation capability classes: are differentiated on the basis of the intensity of outdoor recreational use, or the quantity of outdoor recreation, which may be generated and sustained per unit area of land per annum.

1 very high
2 high
3 moderately high
4 moderate
5 moderately low
6 low
7 very low

Recreation capability subclasses: indicates the kind of features which provide opportunity for recreation.

E vegetation
F waterfalls and rapids
K organized camping
L landforms
M small surface waters
O upland wildlife
Q topographical variation
S skiing areas
V view

DISCUSSION

The recreation classification system is designed as a reconnaissance type, done largely by aerial photograph interpretation, based on the evaluation of the ability of a piece of land to generate and sustain use based on popular forms of outdoor recreation. Within provincial contexts, unique or scarce resource types might be raised in class value to indicate their ability to generate relatively higher use levels locally than nationally. Mountain classification revolves around the crediting of the scenic value of mountains, not to themselves since they are largely unusable, but to the valley bottom where the majority of recreation use will take place.

The recreation potential of the area (Fig. 18) is shown to be low in the mountains increasing to moderate in the valleys with small focal areas of higher potential. The general area can attract large numbers of users but the climate, vegetation, and soil conditions preclude intensive development without risk of loss of vegetative cover with subsequent erosion. The area can provide high quality extensive recreation to a moderate number of users for such activities as viewing, hiking, camping, hunting, and nature study. Development for skiing has potential along the slopes to the Cline River.

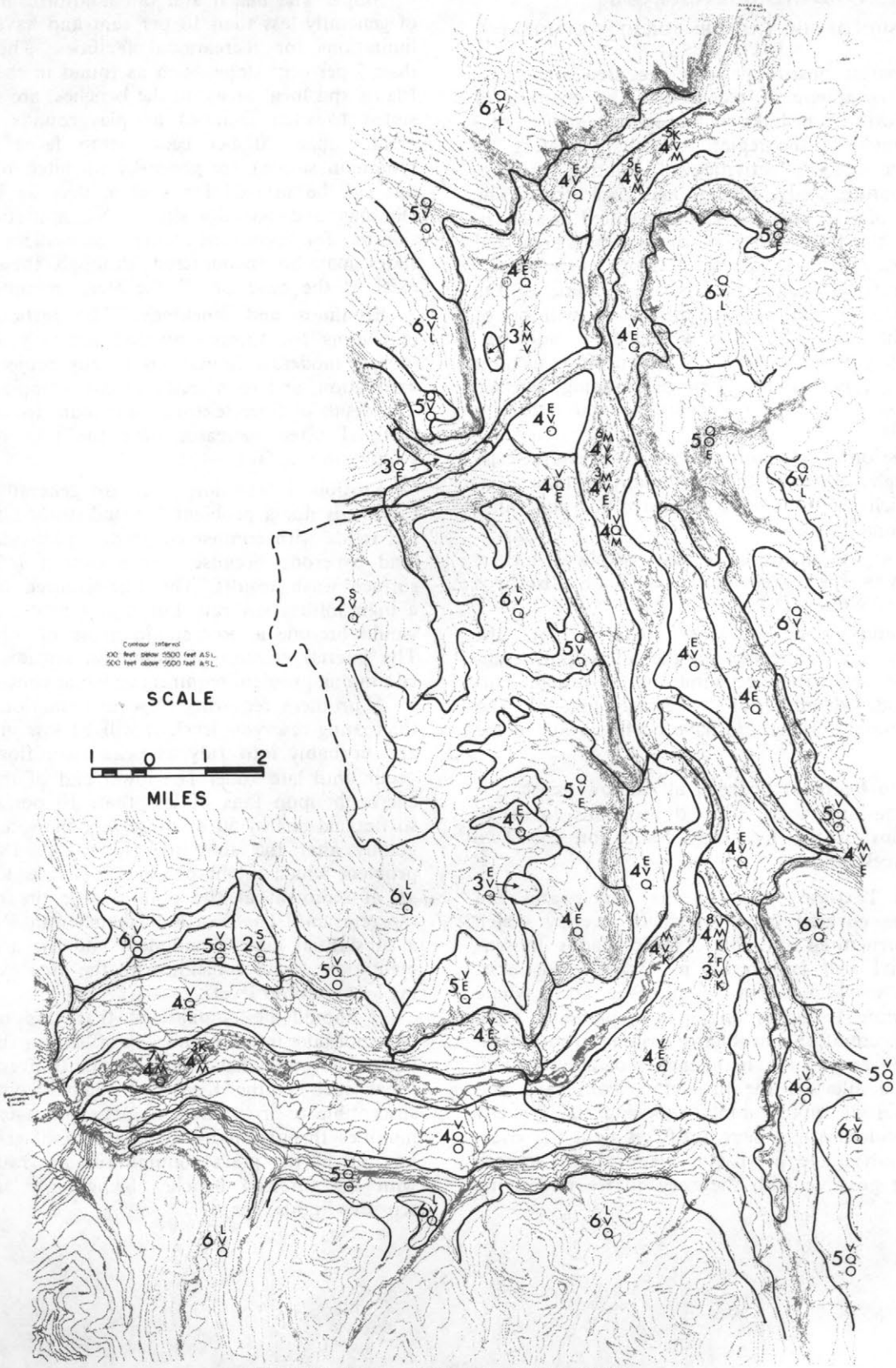

Figure 18—Land capability for outdoor recreation

Source: Province of Alberta, Department of Lands and Forests, Parks Branch

IV LAND USE ASPECTS

DISCUSSION OF SOIL FACTORS FOR RECREATIONAL FACILITIES

The greatest possibilities for the area appear to lie within the sphere of recreation. The creation of the Big Horn Dam Lake will augment the recreational potential of the region to include boating, as well as the present activities of hunting, fishing, camping, nature study, hiking, and pack trips. The completion of Highway No. 11 has resulted in a sharp increase in the flow of traffic through the area and future increases will require the development of camping and possibly commercial facilities. Some of the soils information gathered in this study will be of value in the future planning of the area. Soil features which can be beneficially taken into account are: drainage, pemeability, risk of flooding, surface texture, slope, stoniness or rockiness, and depth to bedrock (13).

A discussion of the more pertinent soil characteristics is complemented by the accompanying map (Fig. 19), in which the soil areas are rated for suitability for recreational facilities.

Drainage: All of the soils have excellent surface drainage with the exception of a small discharge area north of Whitegoat Lake.

Permeability: The outwash materials on the benches are very permeable but the till is quite compact and internal drainage somewhat impeded. This poses a moderate limitation to sewage disposal. The fans are rapidly drained and have no limitation in the regard.

Depth to Bedrock: Bedrock at shallow depth is a severe limitation. Areas affected are soils areas Id and portions of the Kootenay Plains on the Two O'Clock Creek fan.

Surface Texture: Most of the bench and fan surfaces are covered by a silt loam overlay which is poorly structured and soft. Traffic readily loosens this material and can result in extreme dustiness. Safeguards would have to be taken in areas where even moderate traffic is anticipated; planning must take into account the problems ensuing from intensive use. Where possible, maintenance of good ground cover would alleviate the problem. Also, trails and paths can erode quite rapidly exposing the gravelly materials underneath. Where traffic is light the overlay is an advantage in that it results in a smooth surface not possible with the very coarse underlying deposits.

Slope: The bench and fan landforms have slopes of generally less than 10 per cent and have no severe limitations for recreational facilities. Those of less than 5 per cent slope, such as found in the Kootenay Plains and local areas on the benches, are particularly suited to such facilities as playgrounds. Slopes of greater than 20 per cent (scrap faces and lower mountain slopes) are generally unsuited for camping but can be utilized for such outlets as hiking and climbing and possibly skiing. No limitation is considered for positions where snowslides or landslides may be encountered although these locations exist at the base of all the steep mountain slopes.

Stoniness and Rockiness: The surficial deposits (excluding the loessial mantle) are very coarse and impose moderate limitations to any project requiring excavation, and to a lesser extent, camping facilities. The depth of finer textured (silt loam to sandy loam) material often increases near the toes of the less steeply sloping fans.

Erosion: Infiltration rates are generally high and erosion is not a problem for undisturbed soils. Sloping roads with compacted grades, particularly in till, tend to erode because waters cannot infiltrate and surface wash results. The fine-textured overlay has a high infiltration rate but if not protected, erosion would become a problem in areas of intensive use. The laterial erosion of mountain streams is also a continuing problem requiring constant control.

A problem requiring close examination is that of fluctuating reservoir level. It will be low in the spring and probably into July as peak river flow does not occur until late June. The lower end of the lake will encroach upon fans of less than 10 per cent slope, so fluctuations of 50 or more feet in water level will greatly alter the shoreline (note Fig. 18). Another problem which might be encountered is the building up of sediment at the point where the river enters the reservoir. The North Saskatchewan River moves a substantial load of sediment and the area of sedimentation would coincide with the area exposed during low reservoir levels.

It should be emphasized that this brief report does not take into account any influences that a camping public might have upon the natural environment. Areas such as the Kootenay Plains would be very susceptible to irreparable damage of vegetative communities through indiscriminate use of the areas. In fact, all of the grass communities are rather fragile, with the forested benches being only slightly less sensitive in this regard.

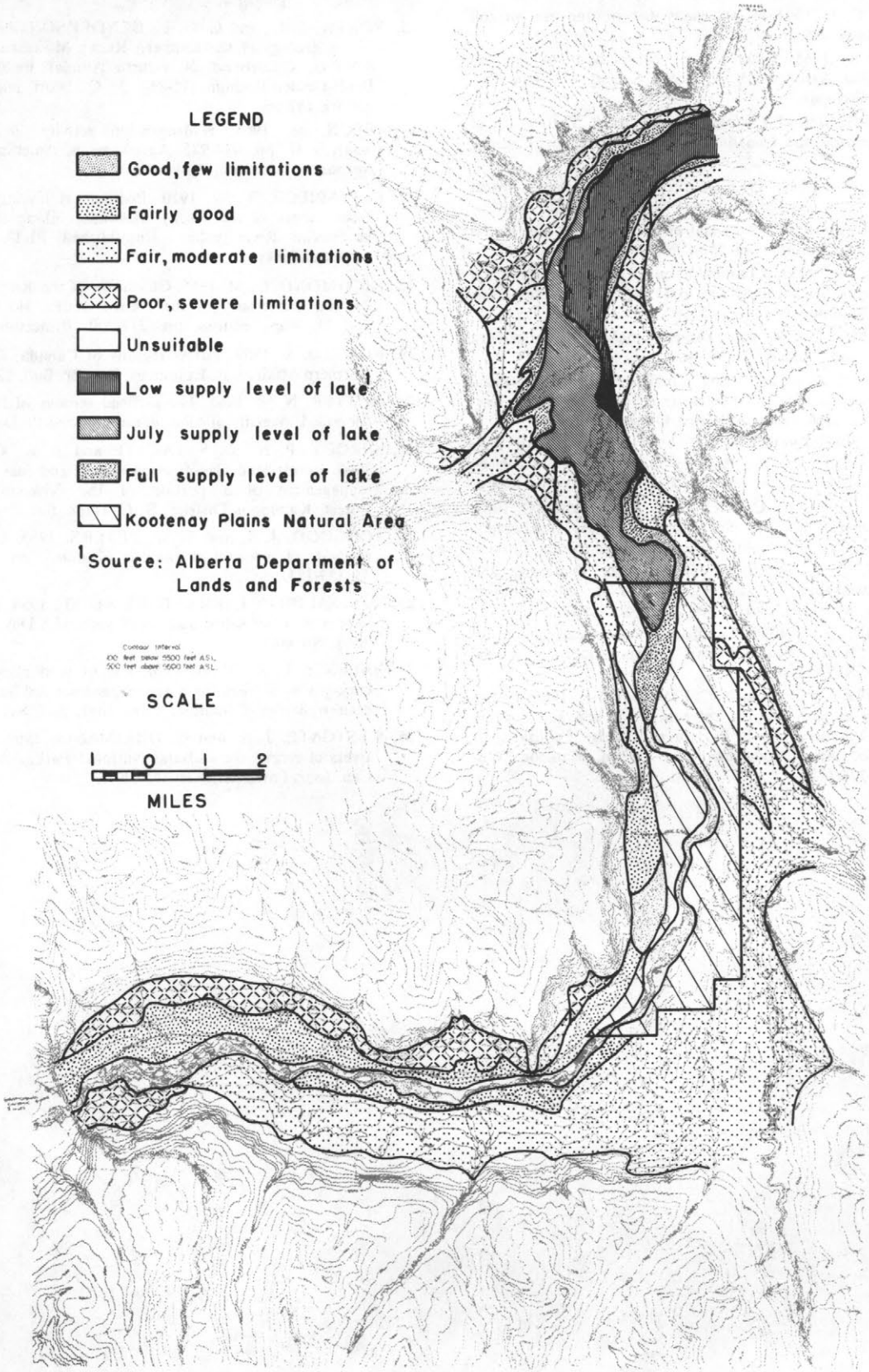

Figure 19—Soil rating map for recreational facilities

REFERENCES

1. BASCOMB, C. L. 1961. A calcimeter for routine use on soil samples. Chem. Ind. Nov. 11: 1826-1827.
2. BLAKE, G. R. 1965. Bulk density. *In* methods of analysis I. pp. 379-380. Agronomy 9, American Society of Agronomy, Madison, Wisconsin.
3. CANADA SOIL SURVEY COMMITTEE. 1970. The system of soil classification for Canada. Queen's Printer for Canada, Ottawa.
4. CORMACK, R. G. H. 1953. A survey of coniferous forest succession in the Eastern Rockies. For. Chron. 29(3): 218-232.
5. HEUSSER, C. J. 1956. Postglacial environments in the Canadian Rocky Mountains. Ecol. Mon. 26(4): 263-302.
6. HORTON, K. W. 1959. Characteristics of subalpine spruce in Alberta. Dept. Northern Affairs and Nat. Res., Forest Res. Div. Tech. Note no. 76: 20 pp.
7. JACKSON, M. L. 1959. Soil chemical analysis. Prentice-Hall Inc., Englewood Cliffs, N. J. 498 pp.
8. LACATE, D. S. Compiler. 1969. Guidelines for bio-physical land classification. Dept. of Fish. and For., Can. For. Serv. Published No. 1264. Queen;s Printer, Ottawa.
9. MANAGEMENT REPORT NO. 2. 1969. Some climatic data for the east slopes of the Rockies in Alberta. Prepared by W. H. Poliquin. Eastern Rockies For. Conservation Board.
10. McKAY, G. A., G. E. CURRY, and A. S. MANN. 1963. Climatic records for the Saskatchewan River headwaters. Prepared by Can. Dept. Agr. P.F.R.A., Engineering Branch.
11. McKEAGUE, J. A. and J. H. DAY. 1966. Dithionite and oxalate extractable Fe and Al as aids in differentiating various classes of soils. Can. J. Soil Sci. 46(1): 13-22.
12. McPHERSON, H. J. 1970. Landforms and glacial history of the upper North Saskatchewan valley, Alberta Canada. Can. Geogr. XIV (1): 10-26.
13. MONTGOMERY, P. H. and F. C. EDMINSTER. 1966. Use of soil surveys in planning for recreation. *In* soil surveys and Land Use Planning. L. J. Bartelli *et al* eds. Published by Soil Sci. Soc. Amer. and Amer. Soc. Agron. Madison, Wisconsin. pp. 104-112.
14. MOSS, E. H. 1959. Flora of Alberta. University of Toronto Press.
15. NORTH, F. K. and G. G. L. HENDERSON. 1954. Summary of the geology of the southern Rocky Mountains of Canada. A.S.P.G. Guidebood of Fourth Annual Field Conference, Banff-Golden-Radium (15-81). J. C. Scott and F. G. Fox editors. 182 pp.
16. PEECH, M. 1965. Hydrogen-ion activity. *In* Methods of Analysis II. pp. 914-925. Agronomy 9, American Society of Agronomy, Madison, Wisconsin.
17. PETTAPIECE, W. W. 1970. Pedological investigations in the front ranges of the Rocky Mountains along the north Saskatchewan River valley. Unpublished Ph.D. thesis, University of Alberta.
18. RICHMOND, G. M. 1965. Glaciation of the Rocky Mountains. *In* The Quaternary of the United States, H. E. Wright Jr. and D. Frey, editors. pp. 217-230. Princeton Univ. Press.
19. ROWE, J. S. 1959. Forest regions of Canada. Department of Northern Affairs Nat. Resources, For. Br. Bull. 123.
20. RUTTER, N. W. 1965. The surficial geology of the Banff area, Alberta. University of Alberta, unpublished Ph.D. thesis.
21. SPROUT, P. N., D. S. LACATE and J. W. C. ARLIDGE. 1966. Forest land classification survey and interpretations for management of a portion of the Niskonlith Provincial Forest, Kamloops District, B. C. Dept. For. Publ. No. 1159.
22. TOOGOOD, J. A. and T. W. PETERS. 1953. Comparison of methods of mechanical analysis of soils. Can. J. Agric. Sci. 33: 159-171.
23. U. S. SALINITY LABORATORY STAFF, 1954. Diagnosis and improvement of saline and alkali soils. U.S.D.A. Agric. Handbook, No. 60.
24. VALENTINE, K. W. G. 1970. Use of land classification conconcepts as a basis for a reconnaissance soil survey in northeastern British Columbia. Can. Jour. Soil Sci. 50(1): 71-77.
25. WESTGATE, J. A. and A. DREIMANIS. 1967. Volcanic ash layers of recent age at Banff National Park, Alberta, Canada. Can. Jour. Earth Sci. 4(1): 155-161.

GLOSSARY

Aeolian deposit—Wind deposit, includes both loess and dunes.

Alluvium—A general term for all deposits of rivers and streams.

Biophysical Land Classification—A classification system for forest land and associated wildlands. It differentiates ecologically -significant segments of the land surface.

Bisequa—Two sequa in one soil; that is, two sequences of an eluvial horizon and its related illuvial horizon.

Bulk density, soil—The mass of dry soil per unit bulk volume. The bulk volume is determined before drying to constant weight at 105C.

Calcareous material—Material containing sufficient calcium carbonate (often with magnesium carbonate) to effervesce visibly when treated with cold 0.1N hydrochloric acid.

Cation exchange capacity—The sum total of exchangeable cations that a soil can adsorb. Expressed in milliquivalents per 100 grams of soil.

Climax—The most advanced type capable of development under, and in dynamic equilibrium with, the prevailing environment.

Cobbles—Coarse fragments between 3 and 10 inches in diameter.

Colluvium—A deposit of rock fragments and soil material accumulated at the base of steep slopes as a result of gravitational action.

Complex—A mapping unit used in detailed and reconnaissance soil surveys where two or more defined soil units are so intimately intermixed geographically that it is impractical, because of the scale used, to separate them.

Consistence—The resistance of a material to deformation or rupture. The degree of cohesion or adhesion of the soil mass.

Creep—Slow mass movement of soil and soil material down relatively steep slopes primarily under the influence of gravity, but facilitated by saturation with water and by alternate freezing and thawing.

Eluvial horizon A soil horizon that has been formed by the process of eluviation.

Fan—(alluvial fan) A fan shaped alluvial deposit of a stream where it encounters a change in slope or at its junction with a main stream.

Floodplain—The land bordering a stream, built up of sediments from overflow of the stream and subject to inundation when the stream is at flood stage.

Glacial till—Unsorted and unstratified materials deposited by glacial ice.

Glaciofluvial deposits—Material moved by glaciers and subsequently sorted and deposited by streams flowing from the melting ice. The deposits are stratified and may occur in the form of outwash plains, deltas, kames, askers, and kame terraces.

Gleysolic—An Order of soils developed under wet conditions and permanent or periodic reduction. These soils have low chromas and/or prominent mottling in some horizon.

Gravel—Coarse fragments up to 3 inches in diameter.

Great Group—The fifth category in the Canadian system of soil classification. It is a taxonomic group of soils having certain morphological features in common that reflect a similar pedogenic environment. (examples are Gray Luvisol and Podzol).

Horizon (soil)—A layer of soil or soil material approximately parallel to the land surface that differs from adjacent genetically related layers in properties such as color, structure, texture, consistency, chemical, biological and mineralogical composition.

Illuvial horizon—A soil layer or horizon in which material carried from an overlying layer has been precipitated from solution or deposited from suspension. The layer of accumulation.

Isohyet—A line on a map indicating equal precipitation.

Land system—Part of the Biophysical Land Classification. An area of land throughout which there is a recurring pattern of landforms, soils and vegetation (mapping scale about 1:125,000).

Land Type—Part of the Biophysical Land Classification. An area of land, on a particular parent material, having a fairly homogeneous combination of soil and chronosequence of vegetation (mapped at scales from 1:20,000 to 1:50,000).

Loess—Material transported and deposited by wind and consisting of predominantly silt-sized particles.

Mass wasting—The downslope movement of materials in response to gravity.

Moder—A mineral-organic humus form characterized by the dominance of a mechanical mixture rather than an intimate association of the constituents.

Parent material—The unconsolidated and more or less chemically weathered mineral or organic matter from which the solum of a soil is developed by pedogenic processes.

Ped—A unit of soil structure such as a prism, block, or granule, formed by natural processes (in contrast with a clod, which is formed artifically).

Permeability, soil—The ease with which gases, liquids, or plant roots penetrate or pass through a bulk mass of soil or a layer of soil.

pH—The negative logarithm of the hydrogen-ion activity of soil. The degree of acidity (or alkalinity) of the soil.

Porosity—The volume percentage of the total bulk not occupied by solid particles.

Profile, soil—A vertical section of the soil through all its horizons and extending into the parent material.

Scarp—An escarpment, cliff, or steep slope of some extent along the margin of a plateau, mesa, terrace, or bench.

Soil Series—The second category (II) in the Canadian Classification System. This is the basic unit of soil classification consisting of soils which are essentially alike in all major profile characteristics except the texture of the surface.

Solum—(plural sola) The upper horizons of a soil in which the parent material has been modified and within which most plant roots are confined. It consists usually of A and B horizons.

Stones—Coarse fragments greater than 10 inches in diameter.

Soil structure—The combination or arrangement of primary soil particles into secondary particles, units, or peds.

Subgroup—The fourth category in the Canadian classification system. (example Orthic Gray Luvisol and Bisequa Gray Luvisol).

Talus—Fragments of rock and other soil material accumulated by gravity at the foot of cliffs or steep slopes.

Texture (soil—The relative proportion of the various particle sizes present.

Till—See Glacial Till.

Volcanic ash—Fine (4mm) pyroclastic material.

Windthrow—The overthrowing of trees by wind action.

APPENDIX A

SOIL DESCRIPTIONS

Humo-Ferric Podzol

Location: W. of Two O'Clock Creek.

Principal map unit: Land Unit IIIf.

Topography: 25% N. E. facing slope.

Elevation[1]: 6,300 ft.

Vegetation: Immature spruce forest with grouse berry, white mountain heather, horsetails, and mosses.

Drainage: Well drained.

Parent Material: Colluvium from till, with a silty mantle.

L-H—3 to 0 inches, needles and moss; medium to strongly acid; abrupt, smooth boundary; 2 to 4 inches thick.

Ae—0 to 1 inch, light brownish gray (10YR 6/2 m[2]); coarse silt loam; weak fine platy; loose; abundant roots; medium to strongly acid; abrupt, wavy boundary; 1 to 2 inches thick.

Bfh—1 to 2 inches, dark brown (10YR 3/3 m); coarse silt loam to loam; weak fine granular; loose to very friable; plentiful roots; medium acid; clear, wavy to broken boundary; 0 to 1 inch thick.

Bf—2 to 5 inches, yellowish red (5YR 4/8 m); silt loam; weak fine granular; loose; plentiful roots; neutral; gradual, wavy boundary; 2 to 4 inches thick.

Bm—5 to 8 inches, strong brown (7.5YR 5/6 m); silt loam, some stones; weak fine granular; loose; few roots; neutral; clear, wavy boundary; 3 to 6 inches thick.

IIBCk—8 to 11 inches, dark brown (10YR 3/3 m); gravelly sandy loam; moderate medium granular; friable; plentiful roots; strongly calcareous; gradual, wavy boundary; 3 to 6 inches thick.

IICk—11 to 14+ inches, grayish brown (2.5Y 5/2 w); stony loam; strongly calcareous.

Bisequa Gray Luvisol (Whitegoat series)

Location: 1 1/2 miles W of Whitegoat Lakes.

Principal map unit: Land Unit IIa.

Topography: 15% slope to N.E.

Elevation: 4,900 ft.

Vegetation: Pine forest with accessory spruce, juniper, wintergreens, twinflowers, bunchberry, grasses, moss and lichens.

Drainage: Well drained.

Parent Material: Colluvium with silty mantle.

L-F—2 to 0 inches, pine needles, some moss; medium acid; abrupt, smooth boundary; 1 to 3 inches thick.

Ael—0 to 1 inch, brown (10YR 5/3 m); light gray (10YR 7/2d); loamy sand to coarse silt loam; single-grained to weak fine platy; soft; abundant roots; slightly acid; abrupt, wavy boundary; 1/2 to 2 inches thick.

Bf—1 to 2 inches, strong brown (7.5YR 4/4 m), reddish yellow (7.5YR 6/6 d); coarse silt loam; weak fine platy; soft; plentiful roots; neutral; gradual, wavy boundary; 1 to 4 inches thick.

Ae2—2 to 5 inches, brown (7.5YR 5/4 m), light yellowish brown (10YR 6/4 d); coarse silt loam; weak fine platy; soft; plentiful roots; neutral, abrupt, smooth boundary; 2 to 4 inches thick.

Bt—5 to 9 inches, strong brown (7.5YR 5/6 m), yellowish brown (10YR 5/6 d); clay; moderate to strong fine granular; hard; few roots; neutral; abrupt, smooth boundary; 3 to 5 inches thick.

IIBCk—9 to 13 inches, dark brown (10YR 3/3 m), brown (10YR 4/3 d); very gravelly sandy loam; weak granular; friable; plentiful roots; very strongly calcareous; gradual, wavy boundary; 4 to 8 inches thick.

IICk—13 to 16+ inches, grayish brown (10YR 5/2 m), light brownish gray (10YR 6.5/2 d); very gravelly loam; massive; slightly hard; very few roots; extremely calcareous.

[1] Elevations are Above Mean Sea Level

[2] Munsell color notation: m-moist; d-dry; w-wet.

Orthic Gray Luvisol (Cline River series)

Location: 1 mile along Whitegoat cut line.

Principal map unit: Land Unit IIb.

Topography: Rolling topography with slopes of 10 to 20%.

Elevation: 4,800 ft.

Vegetation: Pine, buffaloberry, juniper, bearberry, wintergreen, arnica, rose, Indian paintbrush and grasses.

Drainage: Well drained.

Parent Material: 16 inches of loose material over compact till.

L-F—1 to 0 inches, mostly undecomposed pine needles; slightly acid; abrupt, smooth boundary; 1 to 3 inches thick.

Bm—0 to 1/2 inches, brown (10YR 4/3 - 5/4 m), pale brown (10YR 6/3 d); coarse silt loam; single-grained to weak fine granular; soft; abundant roots; slightly acid; clear, wavy boundary; 0 to 2 inches thick.

Ae—1/2 to 3 inches, brown (10YR 5/3 m), light gray to very pale brown (10YR 7/2 - 7/3 d); loan; weak fine platy; soft; plentiful roots; neutral; abrupt, smooth boundary; 2 to 4 inches thick.

Bt—3 to 7 inches, dark brown to brown (7.5YR 4/4 - 5/4 m), strong brown (7.5YR 5/6 d); clay loam; moderate fine granular to fine subangular blocky; slightly hard; few roots, neutral; abrupt, smooth boundary; 3 to 4 inches thick.

IIBCk—7 to 14 inches, dark brown (10YR 3/3 - 4/3 m), grayish brown (10YR 5/2 d); gravelly loam; weak fine granular; friable; plentiful roots; extremely calcareous; gradual, wavy boundary; 7 to 10 inches thick.

IICk—14 to 18+ inches, grayish brown to light brownish gray (10YR 5/2 - 6/2 m), light gray (10YR 7/1 d); gravelly loam; massive or fractured; very hard; very few roots; extremely calcareous.

Orthic Gray Luvisol

Location: 1/2 mile S of river, W of Spreading Creek

Principal map unit: Land Unit IId.

Topography: Fluted or ridged till plain, 5% slope.

Elevation: 4,775 ft.

Vegetation: Pine with some spruce; juniper, buffalo berry; arnica, twinflower, bearberry, violet, wintergreen and grasses.

Drainage: Well drained.

Parent Material: Thin aeolian mantle over till.

L-F—1 to 0 inches, undecomposed needles; slightly acid; abrupt, smooth boundary; 1/2 to 1 inch thick.

Ae—0 to 3 inches, brown (10YR 5/3 m), light gray to very pale brown (10YR 7/2 - 7/3 d); silt loam; weak fine granular; soft; upper 2 cm mottled; abundant roots; neutral; clear, wavy boundary; 3 to 5 inches thick.

Bt—3 to 8 inches, yellowish brown (10YR 5/4 m), pale brown (10YR 6/3 d); loam; weak to moderate, fine granular; friable; plentiful roots; neutral; abrupt, wavy boundary; 3 to 5 inches thick.

IIBCk—8 to 16 inches, brown (10YR 5/3 - 4/3 m); gravelly sandy loam; weak fine granular; friable; few roots; extremely calcareous; gradual, wavy boundary; 7 to 10 inches thick.

IICk—16 to 20+ inches, light brownish gray (10YR 6/2 m); gravelly sandy loam; massive to fractured; hard; very few roots; extremely calcareous.

Degraded Eutric Brunisol

Location: 1 mile E of Siffleur Campground.

Principal map unit: Land Unit IIe.

Topography: On a bedrock controlled bench, less than 5% slope.

Elevation: 4,750 ft.

Vegetation: Pine; buffalo berry, rose, juniper, bearberry and grass with some twinflower, wintergreen and strawberry.

Drainage: Well drained.

Parent Material: Eight inches silty aeolian deposit over till.

L-F—1/2 to 0 inches, pine needles; neutral; abrupt, wavy boundary; 1/2 to 1 inch thick.

Bm—0 to 1 inch, brown (10YR 4/3 - 5/3 m), pale brown (10YR 6/3 d); coarse silt loam; single-grained to weak fine granular; soft; abundant roots; neutral; gradual irregular, boundary; 0 to 2 inches thick.

Ae—1 to 3 inches, brown (10YR 5/3 m), light gray (10YR 7/2 d); silt loam; single-grained to weak fine granular; soft; often has few to common, fine (7.5YR 5/4) mottles; abundant roots; neutral; gradual, wavy boundary; 2 to 4 inches thick.

Btj—3 to 7 inches, yellowish bronw (10YR 5/4 m), light yellowish brown (10YR 6/4 d); loam; weak to moderate fine granular; slightly hard; plentiful roots; neutral, sometimes weakly calcareous at bottom; abrupt, irregular boundary; 2 to 5 inches thick.

IIBCk—7 to 16 inches, brown (10YR 5/3 - 4/3 m); gravelly sandy loam; weak fine granular; friable; few roots; extremely calcareous; gradual, wavy boundary; 7 to 10 inches thick.

IICk—16 to 20+ inches, light brownish gray (10YR 6/2 m); gravelly sandy loam; massive to fractured; hard; very few roots; extremely calcareous.

Degraded Eutric Brunisol to Orthic Regosol

Location:	1/2 mile S along Siffleur cut line
Principal map unit:	Land Unit IIe.
Topography:	Dissected upland, 5% south facing slope.
Elevation:	4,750 ft.
Vegetation:	Sparse pine, scattered juniper and buffalo berry; some grass, lichens.
Drainage:	Well drained.
Parent Material:	Silty deposit over till.

crust—0 to 1 inch, a crust which appears to be a result of recent deposition mixed with lichens; weakly calcareous; clear, smooth boundary; 0 to 1 inches thick.

A—1 to 4 inches, light gray (10YR 7/2 d); coarse silt loam; structureless; soft; few roots; alkaline; gradual, wavy boundary; 2 to 6 inches thick.

Bk—4 to 6 inches, very pale brown (10YR 7/3 d); coarse silt loam to fine sandy loam; structureless to weak fine granular; soft; moderately effervescent; abrupt, wavy boundary; 1/2 to 2 1/2 inches thick.

IIBCk—6 to 14 inches, brown (10YR 5/3 - 4/3 m); gravelly sandy loam; weak fine granular; friable; few roots; extremely calcareous; gradual, wavy boundary; 7 to 10 inches thick.

IICk—14 to 18+ inches, light brownish gray (10YR 6/2 m); gravelly sandy loam; massive to fractured ; hard; very few roots; extremely calcareous.

Orthic Eutric Brunisol

Location:	Abraham Flats
Principal map unit:	Land Unit Id.
Topography:	Low angle fan, less than 2% slope.
Elevation:	4,250 ft.
Vegetation:	Grasses, sages, vetch, bedstraw, crocus, lichens and others.
Drainage:	Well to rapidly drained.
Parent Material:	Thin aeolian deposit over outwash gravels.

Ahk—0 to 1 inch, very dark grayish brown (10YR 3/2 m), dark grayish brown (10YR 4/2 d); coarse silt loam; weak fine granular; soft; moderately calcareous; clear, wavy boundary; 0 to 1 inches thick.

Bmk—1 to 3 inches, brown (7.5YR 5/4 m), light brown to pinkish gray (7.5YR 6/4 - 7/2 d); coarse silt loam; weak fine granular; soft; weakly calcareous; abrupt, wavy boundary; 1 to 3 inches thick.

IIBCk—3 to 10 inches, dark brown (10YR 4/3 - 3/3 m), pale brown (10YR 6/3 d); very gravelly sandy loam; few roots; strongly calcareous; gradual, wavy boundary; 6 to 10 inches thick.

IICk—10+ inches, grayish brown (10YR 5/2 m), light gray (10YR 7/2 d); gravel; strongly calcareous; no roots.

Note: this is an example of the very thin profiles which can be encountered.

Cumulic Regosol

Location:	On Kootenay Plains E of river.
Principal map unit:	Land Unit Ia.
Topography:	Low angle fan, less than 2% slope.
Elevation:	4,400 ft., about 30 ft. above river level.
Vegetation:	Grasses *(Agropyron, Festuca, Poa)*, sages, wormwood and wild flax.
Drainage:	Well drained.
Parent Material:	Alluvium and/or aeolian material over coarser alluvium.

Ahkl—0 to 1 inch, black (10YR 2/1 m), very dark brown (10YR 2/2 d); silt loam; turfy to weak fine granular; very friable; abundant roots; strongly calcareous; gradual, wavy boundary; 0 to 2 inches thick.

Ahk2—1 to 3 inches, very dark brown (10YR 2/2 m), very dark grayish brown (10YR 3/2 d); silt loam; weak fine granular; soft; abundant roots; strongly calcareous; gradual, wavy boundary; 2 to 4 inches thick.

ACk—3 to 5 inches, a gradual transition horizon from the Ah above to the C below characterized principally by diminishing organic content.

Ck—5 to 16 inches, dark grayish brown (10YR 4/2 m), grayish brown (10YR 5/2 d); silt loam; structureless; soft; few roots; very strongly calcareous; buried horizons common; abrupt, smooth boundary; 6 to 16 inches thick.

IICk—16+ inches, sandy alluvium with gravel lenses.

Orthic Regosol

Location:	On the Whitegoat Creek fan.
Principal map unit:	Land Unit Ib.
Topography:	Fan, 8% slope.
Elevation:	4,150 ft.
Vegetation:	Grasses (strips or groves of aspen in more moist locations), some junipers, sages and rose.
Drainage:	Well drained.
Parent Material:	Variable (2 to 6 inches) silty material over coarse fan material.

Ahk—0 to 1 1/2 inches, very dark grayish brown (10YR 3/2 m), dark grayish brown (10YR 4/2 d); coarse silt loam; weak fine granular; soft; a mixture of mineral matter, roots and dark, well humified organic matter; moderately effervescent; gradual, wavy boundary; 1 to 3 inches thick.

ACk—1 1/2 to 3 inches, dark grayish brown (10YR 4/2 m), grayish brown (10YR 5/2 d); similar to the Ahk but less organic matter and fewer roots; moderately effervescent; gradual, wavy boundary; 1 to 3 inches thick.

Ck—3 to 5 inches, dark grayish brown (10YR 4/2 m), light brownish gray (10YR 6/2 d); coarse silt loam; structureless; soft; few roots; strongly effervescent; abrupt, irregular to broken boundary; 0 to 3 inches thick.

IICk—5+ inches, strongly effervescent angular cobby fan material.

A common variant has surface colors of higher chroma (10YR 4/3 - 5/3 d).

Orthic Regosol (Deors series)

Location:	Scarp E of Elliot Peak.
Principal map unit:	Land Unit IIh.
Topography:	Windward scarp face, 50% slope.
Elevation:	4,400 ft.
Vegetation:	Bearberry, some cinquefoil, junipers, grass, milkvetch, lichens. At least 25% of the ground not covered.

Drainage: Well drained.

Parent Material: Gravelly colluvium over gravel.

L-H—1/2 to 0 inches, not always present, a lichen crust; strongly calcareous; abrupt, irregular boundary; 0 to 1/2 inches thick.

Ahk—0 to 8 inches, dark brown (10YR 3/3 - 4/3 m), grayish brown (10YR 5/2 d); gravelly sandy loam; a mixture of roots and organic remains and mineral material; strongly calcareous; diffuse boundary; 4 to 10 inches thick.

ACk—8 to 16 inches, brown (10YR 4/3 - 5/3 m), light brownish gray (10YR 6/3 d); gravelly loamy coarse sand; similar to the Ahk but with less organic matter; strongly calcareous; diffuse boundary; 4 to 10 inches thick.

Ck—16+ inches, grayish brown (10YR 5/2 m), light gray (10YR 7/2 d); very strongly effervescent gravelly material.

Cumulic Regosol

Location: E slope of Elliot Peak.

Principal map unit: Land Unit IIIc.

Topography: Talus slope, 75% slope.

Elevation: 5,000 ft.

Vegetation: Scattered spruce, fir, aspen; alder, maple, birch, willows, buffalo berry, cinquefoil, service berry, rose; grasses, bearberry, mosses and lichens.

Drainage: Well drained; may get moisture from higher slopes.

Parent Material: Talus.

Ck—0 to 3 inches, recent rock debris; calcareous; abrupt, broken boundary; 0 to 6 inches thick.

Ak—3 to 8 inches, essentially an horizon of angular talus cobbles of carbonate rock embedded or enveloped by felted mats of organic matter (F material) and roots; gradual boundary; 2 to 6 inches thick.

ACk—8 to 14 inches, similar to Ak but with decreasing organic matter and often more fine (sandy) material.

—14+ inches, very little organic material; calcareous rubble.

Floodplain Soils

Location: N of Cline River confluence.

Principal map unit: Land Unit If.

Topography: Floodplain with very hummocky (8 to 20 inches micro relief.

Elevation: River level, 4,200 ft.

Vegetation: Some scattered stunted spruce; swamp birch, cinquefoil, willow; bearberry, grasses, sedges and mosses.

Drainage: Imperfect to very poor (water table at 4 to 20 inches).

Parent Material: Stratified overbank fines.

Gleyed Orthic Regosol

(L-F) H—2 to 0 inches, somewhat turfy (some Ah).

Ck—0 to 8 inches, dark grayish brown (10YR 4/2 m); loamy, very fine sand; structureless; strongly effervescent; diffuse boundary.

Ckg—8 to 16+ inches, grayish brown (2.5Y 5/2 wet); stratified effervescent sands.

Rego Gleysol

L-H—6 to 0 inches, variable from turfy to L-H horizons; 0 to 6 inches thick.

Ckg—0 to 8 inches, gray (2.5Y 5/1 wet); loamy, very fine sand (stratified); single-grain effervescent.

Water table at 8 inches.

APPENDIX B

ANALYSES OF SELECTED SOIL SAMPLES

Physical and chemical data for selected soils are given in Table 3. Particle size distribution of the less than 2 mm was done by the pipette method (22). Moisture characteristics were determined by the pressure membrane and pressure plate methods (23). Bulk density was estimated by a rubber balloon method (2). pH was determined on saturated soil paste and on 1:5 soil to 0.01M CaC12 mixtures (16). Total carbon was determined by a dry combustion procedure and organic matter calculated after a correction for inorganic carbon. Total nitrogen was determined by a macro-kjeldahl method (7). CaCO3 equivalent was determined by a manometric procedure (1). Cation exchange capacity and exchangeable cations were determined on neutral normal ammonium acetate extracts with exchangeable hydrogen determined on a barium acetate extract. Free (Fe + Al) was determined by an ammonium oxalate method (11).

Particle Size Distribution

The dominant features are the high silt content of the ashy aeolian overlay and the coarse gravelly nature of the till. The results for the greater than 2 mm fraction are low because fragments larger than 2 - 3 inches were not sampled.

Moisture Retention

A moderate water holding capacity is indicated for the silt-loam surface samples with a rather low capacity for the gravelly subsurface samples.

Bulk Density

The rather low bulk densities of the surface samples are a reflection of the high volcanic ash content and the poor structure.

pH

In general, the soil on the benches have neutral to weakly acid reactions in the upper sola with the upper mountain slope soils being slightly more acidic and the soils on the fans being alkaline.

Organic Matter

Definite increases are apparent in the IIBCk horizons (to 3 - 6%) where root concentrations were noted. On the grassed fans the organic matter content of the surface is quite high (9 - 17%) but decreases regularly with depth.

$CaCO_3$ Equivalent

The carbonate content of the materials in the area (except for the ash) is high, the tills having values of about 45% and the fans and outwash about 25%. These high contents can effect physiological drought and hence somewhat limit root penetration. Also, these carbonates can act as a cementing agent contributing to the extreme compactness of the till.

Exchange Analysis

Ca dominates the exchange complexes.

Free Fe and Al

The soils recognized in the field as podzolic are characterized by significant accumulation of amorphous oxides in the B horizons.

TABLE III—PHYSICAL AND CHEMICAL ANALYSES OF SELECTED SOIL SAMPLES

Horizon	Depth (inches)	Particle size distribution: % >2 mm	% of <2 mm: S	Si	C	Texture*	Moisture retention: 1/3 atm	15 atm	Bulk density gm/cc	pH: H_2O	$CaCl_2$	Organic matter (%)	C:N ratio	$CaCO_3$ equiv.	Exchange Analysis me/100 gm: H	Ca	TEC	Fe & Al %
Humo-Ferric Podzol, west of Two O'clock Creek																		
L-H	3-0					SiL				5.5	4.9	43.0	34		21.0	44.0	70.0	
Ae	0-1					SiL				5.5	5.0	4.3	23		5.8	8.2	15.1	0.32
Bfh	1-2					SiL				5.9	5.5	6.1	24		8.2	13.1	23.1	1.17
Bf	2-5					SiL				6.7	5.6	3.6	20		5.7	9.6	17.7	1.22
Bm	5-8					SiL				6.5	6.0	1.7	26		1.4	8.5	12.3	0.59
IIBCk	8-11					GSL				7.4	7.0	3.3		17				0.55
IICk	11-14+					StL				7.7	7.3			27				
Bisequa Gray Luvisol, (Whitegoat series), 1½ miles W of Whitegoat Lakes																		
L-F	2-0									6.0	5.6	46.0	31		3.0	73.6	79.0	
Ae	0-1	—	27	63	9	SiL				6.6	5.9	4.1	20		2.3	15.0	17.7	0.29
Bf	1-2	—	23	67	10	SiL				7.2	6.2	2.1	15			14.9	15.3	2.11
Ae2	2-5	—	25	62	13	SiL				7.3	6.4	1.6	15			12.3	12.6	
Bt	5-9	28	25	32	43	C				7.0	6.7	2.2	26			20.1	22.0	
IIBCk	9-13	72	40	35	25	GL				7.9	7.2	4.8	20	27				
IICk	13-16+	68	47	36	17	GL				7.9	7.2			34				
Orthic Gray Luvisol (Cline River series), 1 mile along Whitegoat cut line																		
Ae	½-3	11	43	44	13	L	21	5	0.8	7.1	6.6	1.4	15			8.0	8.8	0.17
Bt	3-7	13	40	23	36	CL	23	12		7.3	7.0	2.1	17	2		19.7	22.7	0.41
IIBCk	7-14	33	40	41	19	GL				8.2	7.5	6.1	26	50				
IICk	14-18+	32	48	35	17	GL				8.4	7.7	2.9		45				
Orthic Gray Luvisol, ½ mile S of river, west of Spreading Creek																		
L-F	1-0									6.1		61.0	32		14.5	50.0	69.0	
Ae	0-3	—	27	64	9	SiL	32	11		6.7	6.3	3.3	23		2.0	9.9	13.5	0.13
Bt	3-8	10	40	41	19	L	23	11		7.3	7.0	2.1	23	4		24.4	29.4	0.28
IIBCk	8-16	35	60	30	10	GSL				7.9		3.0	29	50				
IICk	16-20+	43	59	29	12	GSL	16	8		8.1				41				
Degarded Eutric Brunisol, 1 mile E of Siffleur Campground																		
Aej	1-3	—	32	54	14	SiL	28	12		7.1	6.7	3.6	26			19.2	20.5	
Btj	3-7	6	31	51	18	SiL	26	11		7.3	6.9	1.4	16			17.0	19.5	
IIBCk	7-16	38	61	24	15	GSL				7.9	7.5	4.5		42				
IICk	16-20+	35	60	32	8	GSL	14	5		8.1	7.7			41				
Orthic Eutric Brunisol, Abraham Flats																		
Ahk	0-1	—	24	66	10	SiL				8.0		7.4	13	10				
Bmk	1-3	—	32	57	11	SiL				8.1		3.5	12	2				
IIBCk	3-10	80**	53	35	12	VGSL				8.1		9.2	31	27				
IICk	10+	80	80	14	6	VGLS				8.5				21				
Cumulic Regosol, on Kootenay Plains E of river																		
Ahk	0-3	—	26	61	13	SiL	42	28	0.7	7.6	7.3	17.6	13	20				
ACk	3-5	—	30	62	8	SiL	27	11		7.8	7.5	6.2	12	24				
Ck	5-16	—	25	65	10	SiL				8.1	7.7	2.8	15	28				
Orthic Regosol (Deors series), scarp E of Elliot Peak																		
Ahk	0-8	37	63	31	6	GSL	22	10	1.1	8.5	7.8	9.9	29	24				
ACk	8-16	41	82	14	4	GLS	6	2		8.6	8.0	7.1		22				

*Symbols: C, Clay; G, gravelly; L, loam or loamy; S, sand or sandy; Si, silt or silty; St, stony.
**Estimated