67-67

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DEPARTMENT OF ENERGY,
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PAPER 67-67

A METHOD FOR PREDICTING SOIL EROSION IN THE ROCKY MOUNTAIN FOREST RESERVE, ALBERTA

(Report and 21 figures)

N. W. Rutter

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ABSTRACT

A method of soil erosion prediction was formulated for the non-geologist in order to forecast water erosion hazards in potential logging areas of the Rocky Mountain Forest Reserve, Alberta. By using the material presented, a worker should be able to establish qualitatively the gross erosion hazard of exposed soil through airphoto interpretation and field reconnaissance. The steps involve determining the type and lithology of soils (as used in the engineering sense), and their erosion hazard based upon internal and external factors.

Infiltration rate, grain size characteristics, carbonate cement content, and the binding strength of silt and clay are the important inherent soil properties to evaluate. On the basis of these properties the least erodible soils include glacial outwash, alluvial fan and flood plain deposits, talus, and carbonate-cemented till with a high percentage of gravel-sized material. The most erodible soils are lake, pond, and muskeg deposits, and soil derived from the underlying bedrock and till containing a high percentage of silt and clay. Soils of intermediate erodibility are certain varieties of till and colluvium.

The rating of soils based on inherent factors, is evaluated with important external factors which include slope-angle and precipitation. It is concluded that soils in the Forest Reserve offer a low overall erosion risk compared to areas where erosion is a problem. Only exposed soils with high silt and clay content on steep slopes offer any extensive erosion problems.

A METHOD FOR PREDICTING SOIL EROSION IN THE ROCKY MOUNTAIN FOREST RESERVE, ALBERTA

INTRODUCTION

At present there is no standard of soil erodibility. Many investigators have made notable contributions to certain aspects of erosion relating to their specialty. However, no one to the writer's knowledge, has attempted to bring together all important factors and to evaluate them and develop a scheme of soil erosion prediction applicable to a certain area or terrain. In a glaciated area, such as the Rocky Mountain Forest Reserve, the glacial geologist is in a good position to attempt this because a knowledge of the distribution, origin, and physical and chemical properties of glacial deposits is paramount in understanding the nature and cause of soil erosion.

This report presents a method whereby a non-geologist, particularly a forest manager, can identify soil types (the term is used in the engineering sense and thus includes all unconsolidated material over bedrock) in the Rocky Mountain Forest Reserve from a study of aerial photographs and field reconnaissance and from this study, predict the degree of potential soil erosion if timber is removed. Photographs, other than air photographs, were taken by the author prior to his joining the Geological Survey staff. For some of these, negatives are no longer available.

ACKNOWLEDGMENTS

The writer wishes to express his appreciation to the Canada Department of Forestry and Rural Development for supporting the field operations of this project (East Slopes-Alberta-Watershed Research Program). Many individuals aided the writer during the study. Especially helpful were discussions held with W. W. Jeffery, University of British Columbia (formerly with the Canada Department of Forestry); L. A. Bayrock, Research Council of Alberta; and C. Stanton, Canada Department of Forestry and Rural Development.

EROSION AND EROSION FACTORS

Soil erosion is the movement of soil by water across exposed land. The least conspicuous type is sheet erosion which removes thin layers of material rather evenly. Rill erosion, the result of increased runoff, produces small incisions but under more severe conditions, concentrated runoff will cut gullies or follow existing rills resulting in the formation of deep chasms. Generally, the erosion rate increases after the cut passes through the more absorptive, organically-charged upper soil that has undergone physical, chemical, and biological change.

Erosion by mass-wasting, forming slump blocks and landslides caused by shear failure, or plastic flow resulting in earth- and mud-flows is not considered in this report. Although present in a few areas these features are not widespread, and are not necessarily caused by a decrease of vegetative cover.

Manuscript received October 12, 1967

The most important factors in erodibility studies are field characteristics, precipitation characteristics, and soil properties.

FIELD CHARACTERISTICS

Vegetation is the most important erosion control. It reduces erosion losses by; (a) minimizing the mechanical dispersion action of beating rain; (b) decreasing the velocity of runoff and hence decreasing the transporting power of water; (c) decreasing the quantity of runoff; (d) decreasing the turbulence of runoff and hence lessening the abrasive action of sediment-loaded water; and (e) by actually filtering out or holding in place large water-stable aggregates (Yoder 1936, pp. 346-347).

Tests conducted in northern California by André and Anderson (1961, p. 3355) showed that grass cover is associated with the least erodible soils, forest cover with more erodible soils, and brush cover with the most erodible soils. Complete removal of the vegetation mat will result in erosion of any soil-type although other factors control the rate.

Steepness of slope is a major factor affecting the rate of erosion. The available force or shear stress provided by the water, is, among other things, a function of slope. Water velocity is about doubled when the slope (expressed as a percentage) is quadrupled. Doubling the velocity of water increases its erosive or cutting capacity four times and increases the size of particle it can roll or push along 64 times (Toogood and Newton 1955, p. 5). Some field data confirm that erosion on a given slope increases as the steepness increases, reaching a maximum at 40°, and thereafter decreasing to zero as the steepness approaches 90° (Leopold et al. 1964, p. 359). There is no indication however, that the rate of increase in actual soil loss is related to increase of slope by any fixed law (Bennett 1955, p. 83).

As water flows down a slope there is an initial belt of little or no erosion. This can be measured quantitatively by using Horton's equation (Leopold et al. 1964, p. 358):

$$Xc = \frac{65}{qrn} \left(Re \frac{\tan^{0.3} \alpha}{\sin \alpha} \right)^{5/3}$$

Where q_r = runoff intensity

R_e = resistance

α = slope angle

n = roughness factor

The rate of erosion frequently increases with length of slope because a greater volume of water accumulates on long slopes thereby increasing the velocity. However, rainfall intensity, soil properties, vegetation cover, or slope steepness may change with slope length diminishing any effect the added length may have. Most data indicate that slope steepness is much more important than length in the net soil loss.

PRECIPITATION CHARACTERISTICS

Erosion takes place when the force provided by rain splash or flow exceeds the resistance of the soil. Rain impact can dislodge particles and pulverize material. If conditions are right, runoff will remove soil by suspension and erode new material by hydraulic action. On some surfaces, rain impact may help seal the surface thus decreasing infiltration increasing runoff, and promoting erosion.

Rainfall intensity is more important in erosion than the total amount of rainfall. A certain amount of rain falling in a few minutes will cause more runoff and movement of soil than if the same amount of precipitation occurs over a period of a few hours.

The infiltration rate of the soil is the principal factor governing the importance of rainfall intensity. It is defined as the speed with which water can be absorbed into the soil. If the infiltration rate is high, all available water can be absorbed into the soil, thus preventing erosion. The muddier the surface water, the lower the infiltration rate (Bennett 1955, p. 109).

Runoff from melting snow can cause erosion, although it is not as important a factor as rainfall intensity in the Rocky Mountain Forest Reserve because the soil is usually frozen and the rock particles are bound together. The dislodgement of small-grained material caused by the initial impact of falling rain, is also absent. In the area of the Forest Reserve, Chinook winds from the west and southwest frequently bring temperatures above the freezing point during the coldest months, causing short periods of extensive melting and runoff.

SOIL PROPERTIES

Texture, structure and chemistry of the soil affect its erodibility. Basically, there are two concepts to consider: (1) the inherent erodibility of the soil in its response to a particular rate of runoff and (2) the influence the soil exerts on the rate of runoff.

(1) Inherent Erodibility: Erosion of soil particles involves two distinct steps: (a) the dislodging of the particle and (b) the water transport of the dislodged particle.

(a) The dislodging of the particle.

The ease with which particles are separated from each other is a function of the binding strength of the soil. Other factors being equal, the greater the binding strength, the lower the erodibility. Cementing agents such as calcium carbonate, iron and manganese oxides, organic matter and colloids are important 'binders'. Clay minerals are important because of their chemistry, which involves water absorption and expansion properties, and the kind and amount of soluble salts present. Non-clay minerals, usually in the silt-size class or larger are less effective binding agents. There is a tendency for grains to interlock, but this property in the overall erodibility of a soil is not very important.

Experiments have been carried out by several workers in order to formulate an index of erosion by considering binding characteristics. Middleton (1930) used the dispersion ratio. This is expressed as the ratio of the total weight of suspended silt and clay to the total silt and clay obtained by mechanical analysis. Thus, the higher the ratio, the greater the erodibility. Dispersion ratio is closely related to the amount and kinds of cations present in the soil according to Wallis and Steven (1961). André and Anderson (1961) experimented with dispersion and surface aggregation ratios. The surface aggregation ratio is the amount of surface 'requiring' binding, to the amount of binding clay present. They found that in both cases, the higher the ratio, the greater the erodibility.

Woodburn and Kozachyn (1956, p. 752) suggest that in general, splash erosion from artificial rain is high when a soil has a high sand content with little or no water-stable aggregate. Water-stable aggregate is defined as the percentage of a sample of material which remains in a sieve of a particular mesh during a process of wet sieving. Water-stable aggregate with binding materials such as silt and clay in sufficient quantities, showed the least splash erosion.

(b) The water transport of the dislodged particle.

In order to transport a particle once it is dislodged, a force greater than the resistance of the particle is necessary. The larger the particle the greater the runoff required to accomplish erosion. This was clearly shown in a study where the removal of stones 2 inches in diameter from soil, resulted in the loss of twice as much soil as was lost from a comparable area where the stones were not removed (Bennett 1955, p. 93).

Clay and colloids may form aggregates that require much more force to remove than the individual particles. Thus, predicting the erodibility from grain-size analysis may lead to erroneous results.

(2) Control of Runoff: The water capacity and rate of infiltration of a soil are major influences on the amount of runoff that will take place on its surface. The infiltration rate increases as the coarseness of the texture increases, decreasing the chance of runoff and erosion. Sorting and particle shape exert some influence on the rate but not enough to consider in the present study.

Binding agents such as clay and calcium carbonate retard infiltration greatly, as does latent or inherent moisture in the soil. A soil may reach its saturation point at a faster rate than normal due to subsurface soils with low infiltration rates that hinder percolation.

Infiltration rates of certain soils may be increased by organic matter that can absorb large amounts of water relatively rapidly, burrowing animals that form passages and cause soil loss by casting, binding material that aggregates into small pellets, and soil that is loose and friable.

DESCRIPTION OF THE STUDY AREA

LOCATION

The Rocky Mountain Forest Reserve of Alberta lies in the eastern watershed of the Canadian Rocky Mountain section of the North American Cordillera. The Reserve has an area of over 9,000 square miles, extending northwestward from Waterton National Park for about 280 miles to the Cardinal and Brazeau Rivers (Figs. 1 and 2). In the south, the width is about 18 miles, increasing northward to about 75 miles. The area is within 49° and 53° N and 113° and 118° W.

BEDROCK GEOLOGY AND PHYSIOGRAPHY

The Front Ranges and Foothills physiographic regions of the Canadian Rocky Mountains are represented in the Reserve. North of the Bow River, the central and eastern part of the Reserve lies in the Foothills region and contains belts of northwest-trending valleys and subdued ridges. These are developed in relatively weak rocks, mainly shale, siltstone and sandstone of Mesozoic (principally Cretaceous) age. Local relief reaches about 1,000 feet. The rocks are folded and thrust faulted with the beds and fault planes dipping mostly to the southwest.

The western part of the Reserve north of the Bow River lies in the Front Ranges region which consists of northwest-trending mountains with some elevations over 10,000 feet. The rocks are mainly resistant Palaeozoic limestone, dolomite, quartzite, and minor chert and shale, folded and faulted in the same manner as those in the central and eastern part. Inliers of similar material found toward the east in the Foothills region, form resistant mountains with elevations of about 7,000 feet.

South of Bow River the Front Ranges occupy most of the area of the Reserve. Palaeozoic rocks similar to those described above are present to about Castle River. In the eastern part of the Reserve and between valleys of resistant Palaeozoic rocks, weak Mesozoic shale, siltstone, and sandstone are found. In the Crowsnest area, Cretaceous volcanics form discontinuous patches interbedded with sedimentary rocks. South from about Castle River, the lithology of the Front Ranges consists principally of Precambrian argillite and quartzite with some carbonate, shale and basalt.

The major rivers of the Forest Reserve, such as the North Saskatchewan, Brazeau, and Red Deer, flow eastward across the regional strike of the bedrock. Intermediate-sized tributary streams follow valleys between the northwest-trending ridges and mountains. Draining into the intermediate-sized streams are both perennial and intermittent tributary creeks.

FIELD WORK

To predict potential erosion of soils in the Rocky Mountain Forest Reserve it was necessary to have background knowledge of the glacial history of the region and the surficial deposits present. This was gained by mapping and studying in detail parts

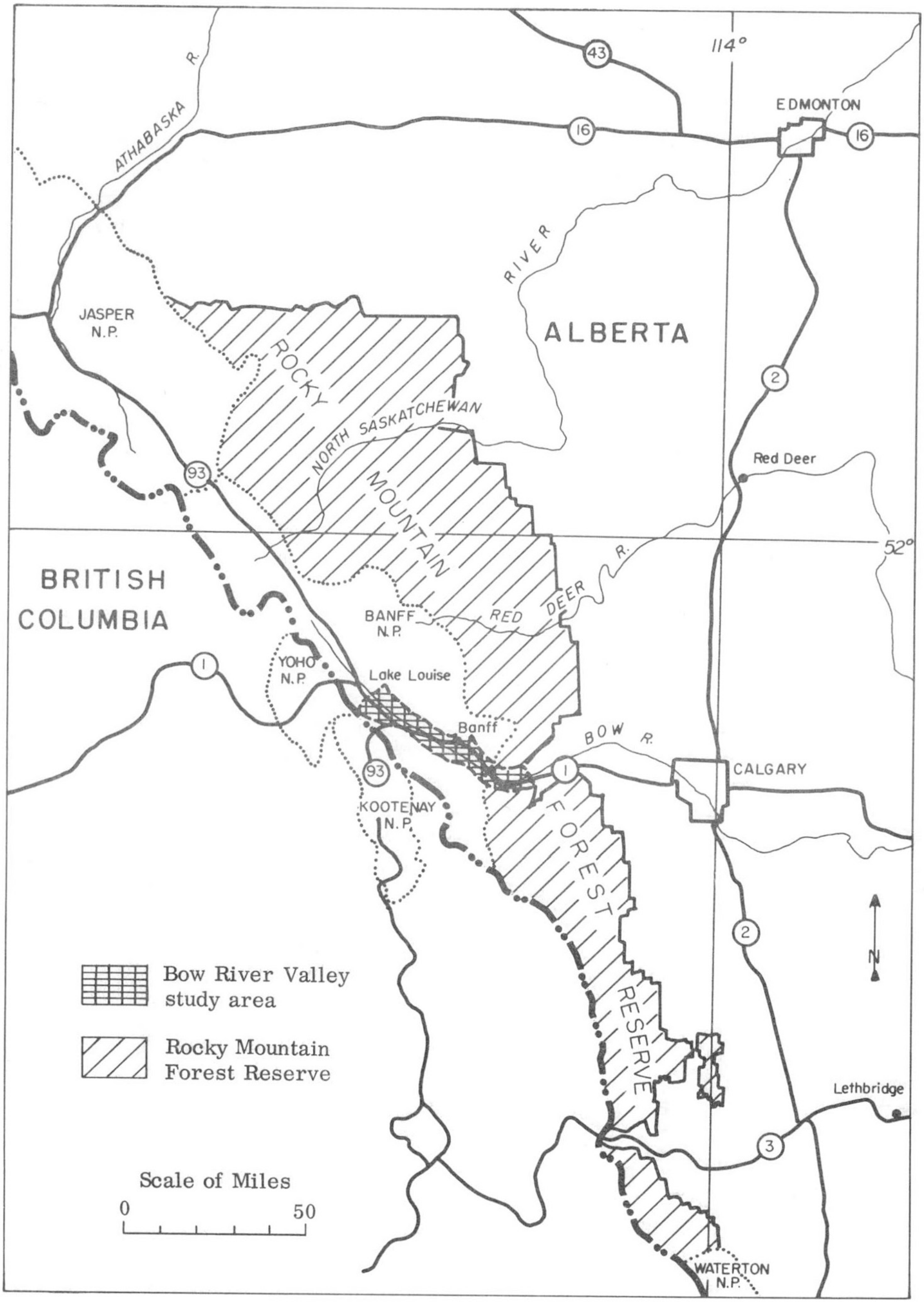

Figure 1. Index map, southwestern Alberta.

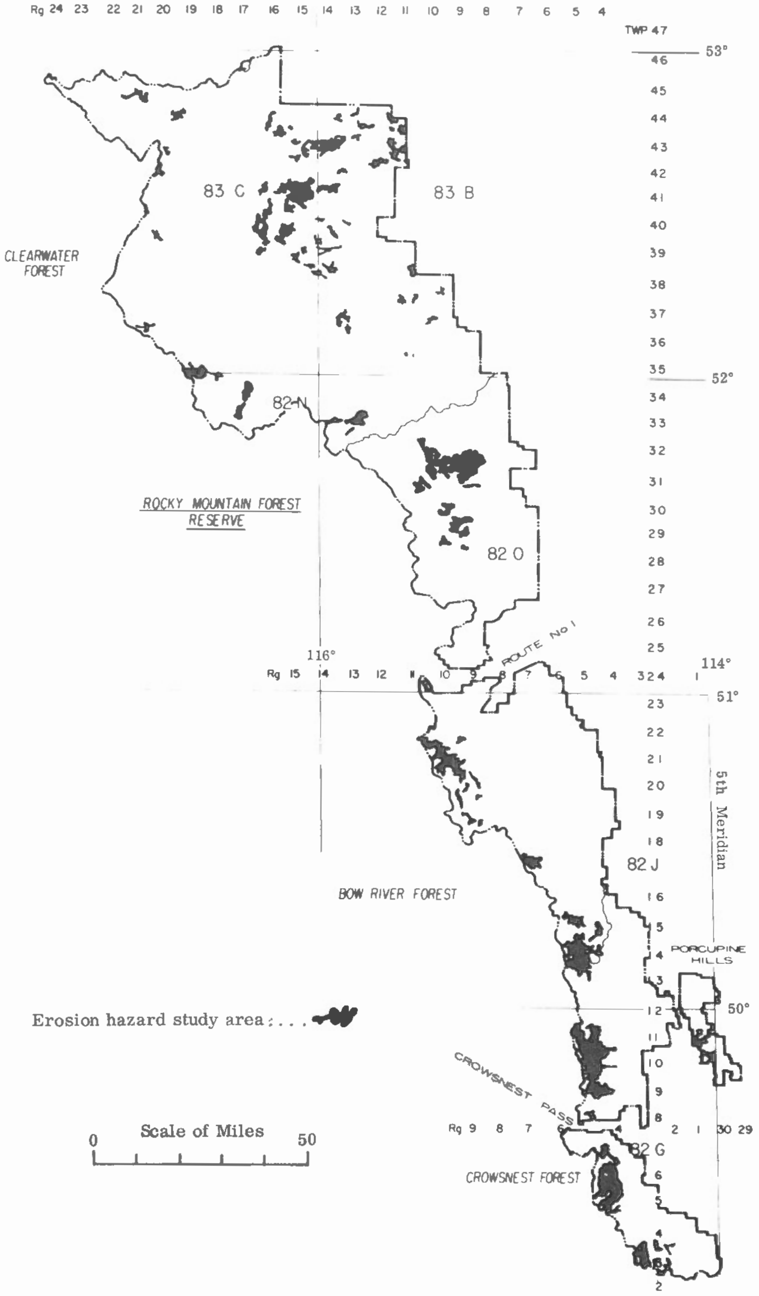

Figure 2. Erosion hazard study areas on the Rocky Mountain Forest Reserve, Alberta.

of Banff National Park area during the summer of 1963 and part of 1964 (Rutter 1965a, b; 1966a, b). After this study, surficial deposits were identified in the Forest Reserve by interpreting aerial photographs of widely separated spruce-fir areas of immediate interest to the forest community (Fig. 2). The interpretations were then checked in the field during the last part of the 1964 season, the lithology of the deposits determined, and erosion factors evaluated.

The great number of factors to consider in erosion, and the limited published data available on factors affecting erosion, prohibits quantitative determination of erosion hazards in the Forest Reserve. The writer qualitatively evaluated the key inherent erosion factors of the soil-types and then determined the overall erosion hazard of soils in their natural settings by considering external factors. Inherent erosion factors considered include infiltration rate, grain-size characteristics, carbonate cement content, and binding strength of silt and clay. External factors evaluated were vegetation, slope, and precipitation.

The method of study enabled the writer to determine soil types and erosion potential from air-photo interpretation and a reconnaissance check in the field of areas other than those of immediate interest to the forest community.

RESULTS

DESCRIPTION OF SURFICIAL DEPOSITS AND EROSION CHARACTERISTICS

TILL

Widespread glaciation from the main ranges of the Rockies has left morainal material on at least the lower ridges and valleys of the Forest Reserve. Generally, the moraines consist of till a few feet thick. The till is undisturbed in valley bottom sites, but slope washing and masking by colluvium have resulted in some modification of the till sheet on gentle valley slopes. The net effect of the modification is the incorporation of bedrock colluvium from above, the removal of some of the finer material, and an overall thinning of the deposit on the upper slopes. In the summit areas of ridges or on steep slopes till is scarce and is found only in occasional patches bordered by bedrock or colluvium.

The major river valleys that cut across the regional trend of the Front Ranges and Foothills contain till deposits commonly more than 50 feet thick. These major valleys were the principal paths of many glacial advances that flowed from the Main Ranges charged with coarse and resistant material common to the Main Ranges area.

Till deposits of the Forest Reserve have distinctive topographic expression only when they are in the form of drumlins. Drumlins are restricted to or near the major outlet valleys such as those of the Red Deer and North Saskatchewan Rivers. Elsewhere, till parallels the contours of the bedrock topography, with few kettles or other distinguishing features usually associated with till. Generally, till can be assumed to be present unless morphological features common to other deposits are present along valley slopes or on the valley floor. Till has been subdivided by the writer into three categories based on criteria relevant to erosion potential: Low Erosion Till, Moderate Erosion Till, and High Erosion Till.

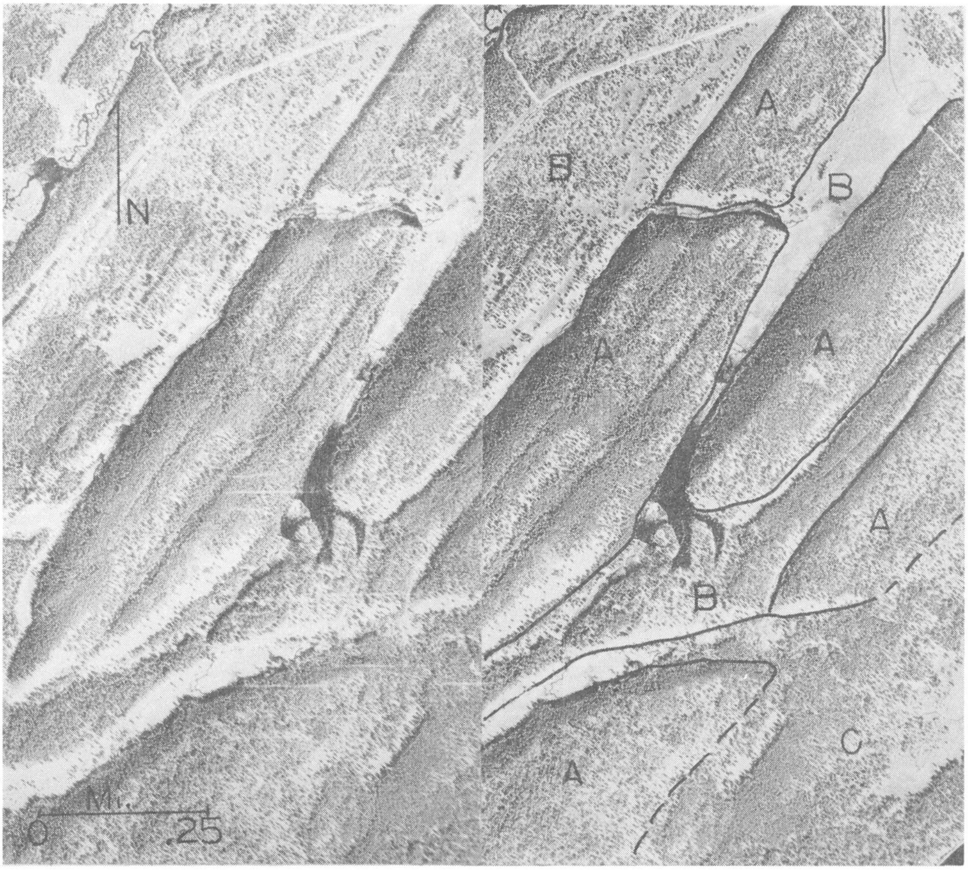

Figure 3. Stereo-pair of photographs of soils north of the North Saskatchewan River near Nordegg. Tp. 40, Rge. 16; 52° 25'N, 116° 15'W. A. Northeast-trending drumlins consisting of Low Erosion Till. B. Glacial outwash, some Low Erosion Till. In places modification by recent stream erosion and sedimentation. C. Recent alluvium. (Alberta Government photographs 1388-5218-4634-113, 114).

Low Erosion Till

Low Erosion Till occurs in valleys, adjacent to the major mountain ranges which are composed dominantly of Palaeozoic carbonate and clastic rocks, and along the major outlet valleys which were paths of confined glaciers from the Main Ranges. Low Erosion Till is unmodified to slightly modified, and contains over 20 per cent gravel-sized material (> 2 mm) consisting mostly of limestone, dolomite, chert and quartzite (Figs. 3, 4, 5, and 6.) The fine fraction (< .074 mm) contains a high percentage of $CaCO_3$ (< 20%) and a low percentage of clay minerals. A low infiltration rate, high binding strength due to $CaCO_3$ cement, and strength added from the high percentage of coarse material, gives Low Erosion Till a relatively low inherent erosion hazard value (Table I).

TABLE I

Relative Erodibility of Soils found in the Rocky Mountain Forest Reserve considering only their inherent properties

Soil	Infiltration Rate	Grain Size Characteristics	Carbonate Cement	Binding Strength of Silt and Clay	Erosion Hazard
Low Erosion till	low	> 20% gravel sized	high	high	low
Moderate Erosion Till	low	> 20% gravel sized	low to absent	high	moderate
High Erosion Till	low	< 20% gravel sized	low to absent	high	high
Modified Low Erosion Till	low to moderate	> 20% gravel sized	high	moderate	low to moderate
Modified Moderate Erosion Till	low to moderate	> 20% gravel sized	low to absent	moderate	moderate
Modified High Erosion Till	low	< 20% gravel sized	low to absent	high	high
Glacial Outwash	high	> 20% gravel sized	low	low	low
Alluvial Fan Deposits	high	> 20% gravel sized	low	low	low
Recent Flood Plain Deposits	high	> 20% gravel sized	low	low	low
Talus	high	> 20% gravel sized	low	low	low
Colluvium	moderate	> 20% gravel sized	variable	variable	low to moderate
Lake, Pond, Muskeg Deposits	low	mostly clay and silt	variable	high	high
Soil possibly derived from underlying bedrock	low	mostly clay, silt and sand	low to absent	high	high

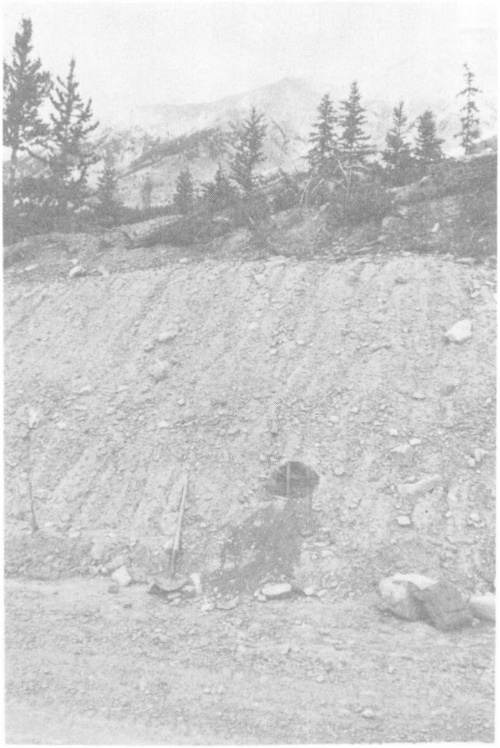

Figure 4.
Low Erosion Till along Smith-Dorrien Road. Tp. 22, Rge. 10; 50° 51'N, 115° 21' W.

Moderate Erosion Till

Deposits of Moderate Erosion Till are widespread south of Crowsnest Pass, where resistant clastics and weak shale outcrop. Therefore, the overlying till contains a matrix of shale particles and inclusions of the resistant rocks. North of Crowsnest Pass, Moderate Erosion Till occurs where there is a high percentage of sandstone and siltstone outcropping in an otherwise shale terrain or, as in the Nordegg area, where pre-glacial gravels are incorporated into till.

Moderate Erosion Till is unmodified or slightly modified and contains over 20 per cent gravel-sized material consisting mostly of varying amounts and combinations of sandstone, siltstone, argillite, volcanics, quartzite, and some carbonates (Figs. 7, 8, and 9). The fine fraction contains a high percentage of clay minerals and less than 20 per cent $CaCO_3$, with most deposits having less than 5 per cent. Clay gives the deposit moderate binding strength and a low infiltration rate, and is rated as a relatively moderate erosion hazard.

High Erosion Till

High Erosion Till is found overlying bedrock consisting mainly of shale with only minor resistant clastics and thus would occur in parts of the Foothills region where the topography is subdued with gentle slopes (Fig. 10). Some material classified as soil possibly derived from underlying bedrock (see below) may actually be High Erosion Till.

High Erosion Till is unmodified or slightly modified with less than 20 per cent gravel-sized material. The fine fraction contains a high percentage of clay minerals and up to 20 per cent $CaCO_3$ with most deposits containing less than 5 per cent. The binding strength is moderate owing to the clay content, whereas the infiltration rate is low. The lack of coarse material, $CaCO_3$ cement, and a low infiltration rate result in a relatively high erosion rating for this soil category.

Modified Low-, Moderate- and High Erosion Till

When any of the three tills described above are on or at the base of steep slopes, they are commonly greatly modified by slope washing and masked by colluvium and three categories of modified till can be distinguished. The deposits have commonly lost some of their finer material which causes an increase in infiltration rate and a decrease in binding strength (Fig. 11). The only change in erosion hazard that these modifications make compared with unmodified till is that Modified Low Erosion Till may have a relatively moderate instead of relatively low erosion hazard because of loss of $CaCO_3$ cement. The morphological expression of modified till is the same as that of unmodified till (Fig. 10).

Figure 5.
Typical outcrop of Low Erosion Till. Resistant spurs cemented by reprecipitated $CaCO_3$.

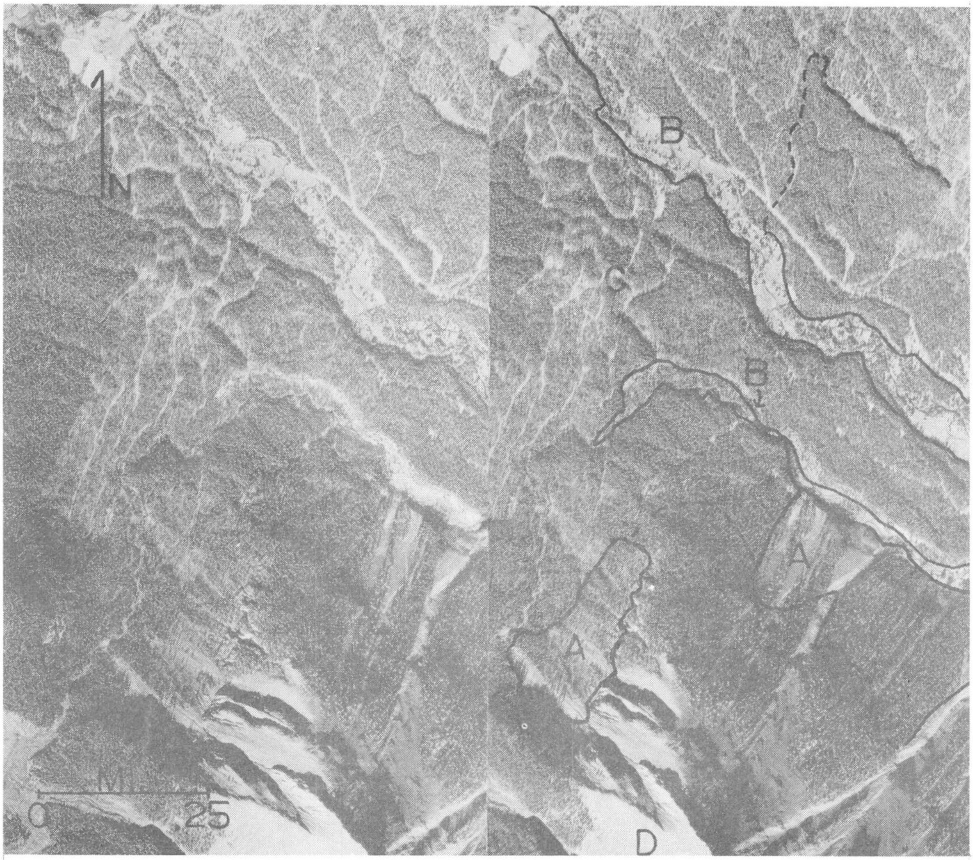

Figure 6. Stereo-pair of photographs of soils in part of the Smith-Dorrien Creek valley. A. Talus slopes. B. Recent alluvial flood plain deposits. C. Low Erosion Till, some modified. D. Bedrock. Tp. 21, Rge. 10; 50° 45' N, 115° 18' W. (Alberta Government photographs 1388-5034-4865A-57, 58).

GLACIAL OUTWASH

Ice-contact and non-ice-contact fluvial deposits, consisting mainly of gravel of various lithologies with minor sand, silt, and clay lenses, are included in this category. Thick and extensive deposits of non-ice-contact outwash are generally restricted to major valleys that cut across the regional strike of the bedrock. They form deposits commonly over 50 feet thick with flat surfaces and arranged in sinuous paths along valley bottoms (Fig. 12). In places, the existing river has eroded through the deposits giving rise to steep cliffs. In drumlinized areas, such as in the vicinity of the North Saskatchewan River near Nordegg, non-ice-contact outwash forms a

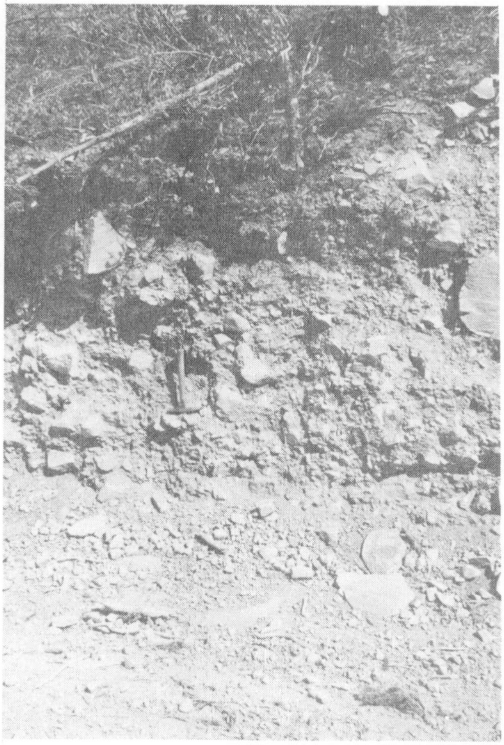

Figure 7.
Moderate Erosion Till located along Coleman Forestry Road. Tp. 14, Rge. 5; 50° 12'N, 114° 33'W.

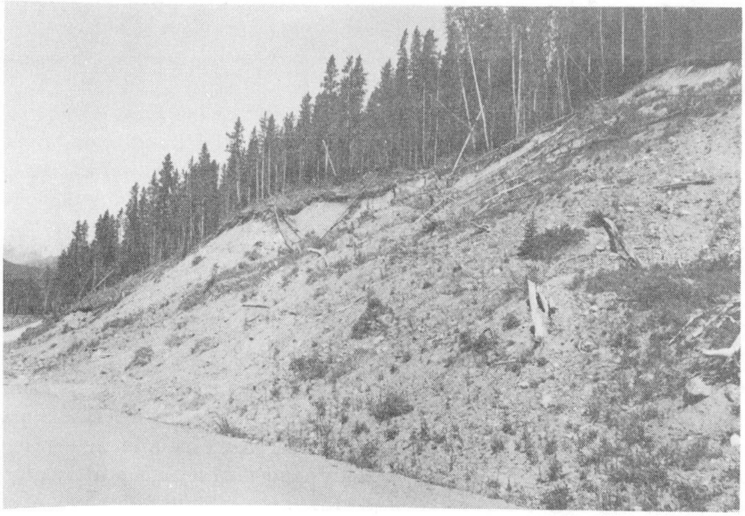

Figure 8. Moderate Erosion Till located near Salter Creek. Outcrop over 30 feet thick. Tp. 15, Rge. 5; 50° 17'N, 114° 33'W.

Figure 9. Stereo-pair of photographs of soils in part of the Castle River valley. A. Recent alluvial flood plain deposits. B. Alluvial fan. C. Moderate Erosion Till, some modified. Tp. 3, Rge. 2; 40° 15'N, 114° 15'W. (Alberta Government photographs 1388-4911-4805-138, 140).

network around the drumlins (Fig. 3). Ice-contact outwash is less common, forming typical stagnant ice features such as kames, eskers, and possible crevasse fillings (Figs. 13 and 14).

Gravel in ice-contact deposits is usually poorly sorted, with strata dipping at various angles in a multitude of directions, whereas in non-ice-contact deposits the gravel is usually moderately to well-sorted and flat-lying. Grain-size and roundness vary considerably but generally the constituents are in the pebble-size range and are subrounded. Erosion hazard is relatively low because of a high infiltration rate due to the deficiency in fine-grained material (Fig. 15).

Figure 10. Stereo-pair of photographs of terrain covered by thin deposits of High Erosion Till and Modified High Erosion Till. A. Topography is bedrock controlled. B. Recent flood plain deposits. Tp. 31, Rge. 10; 51° 42'N, 115° 21'W. (Alberta Government photographs 1388-5130-4629-89, 90).

ALLUVIAL FAN AND FLOOD PLAIN DEPOSITS

Fans studied in the Forest Reserve are modern, and therefore, because of their distinctive fan-shape are easily identified (Figs. 5, 9, 12). They are composed essentially of pebble- to boulder-sized gravel, generally poorly sorted with subangular inclusions (Fig. 16). The infiltration rate is high. Most fans are at the mouths of high-gradient streams and thus they reflect the lithology of the major mountain ranges. The erosion hazard is relatively low due mainly to the high infiltration rate.

Most of the major rivers of the Forest Reserve have well-developed flood plains. Where streams meander widely, the flood plain is particularly extensive.

Figure 11.
Modified Moderate Erosion Till located south of Odlum Creek. Over 80 per cent material pebble-sized or larger. Tp. 17, Rge. 7; 50° 29'N, 114° 54' W.

Modern flood plains can be readily identified by their flat-surfaced, sinuous expression parallel to, and at about the same level as the associated river or stream (Figs. 6, 9, 10 and 17).

Most flood plains consist of gravel; beds of sand, silt, and clay are uncommon. The rock type comprising the gravel depends on the area that is being drained. The gravel is generally pebble-sized, moderately well sorted, with a high infiltration rate resulting in a relatively low erosion hazard.

TALUS

Talus slopes in the Forest Reserve consist of angular rubble deposited as steep, semiconical deposits at the base of the steepest slopes and are associated with mountains composed of resistant Precambrian and Palaeozoic clastics and carbonates (Figs. 6 and 18). The slope of the deposit is generally at the angle of repose, that is 28° - 33°. Most of the constituents are pebble-size or larger and angular in shape. The deposits have high infiltration rates resulting in relatively low erosion hazards.

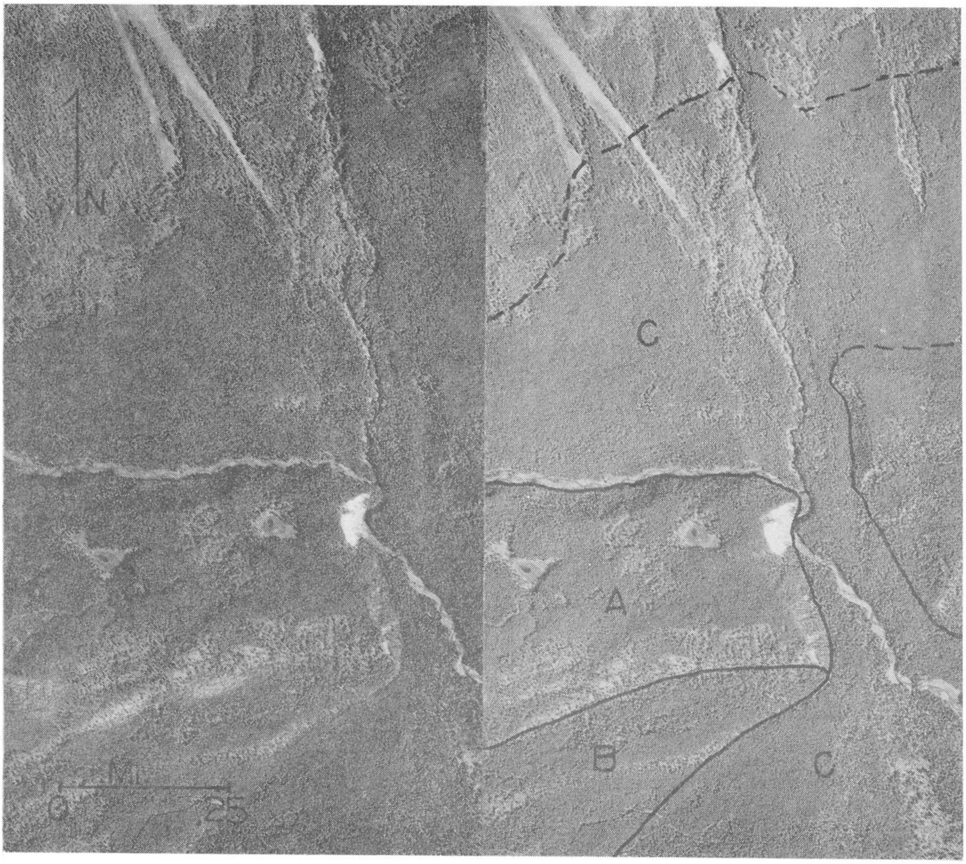

Figure 12. Stereo-pair of photographs of soils in part of the North Saskatchewan River valley. A. Non-ice-contact glacial outwash. B. Outwash that may or may not be glacially derived. C. Alluvium, some in the form of a fan. Tp. 35, Rge. 19; 52° 01'N, 116° 38'W. (Alberta Government photographs 1388-5200-4840-74, 75).

COLLUVIUM

Colluvium consists of a variety of deposits that do not fit the categories discussed above. The deposits are principally the result of mass-wasting, and include bedrock rubble heaped into a variety of shapes at the base of slopes. They are of minor importance in erosion hazard studies of the Reserve because of their limited size and distribution. Generally, colluvium has a low to moderate relative erosion hazard because of its high infiltration rate.

Figure 13. Kames, eskers and possible crevasse fillings located between Kananaskis and Seebe. Bow River in northern part of area, Route 1 in southern part. Area is outside of the Forest Reserve. (Alta. Govt. photo).

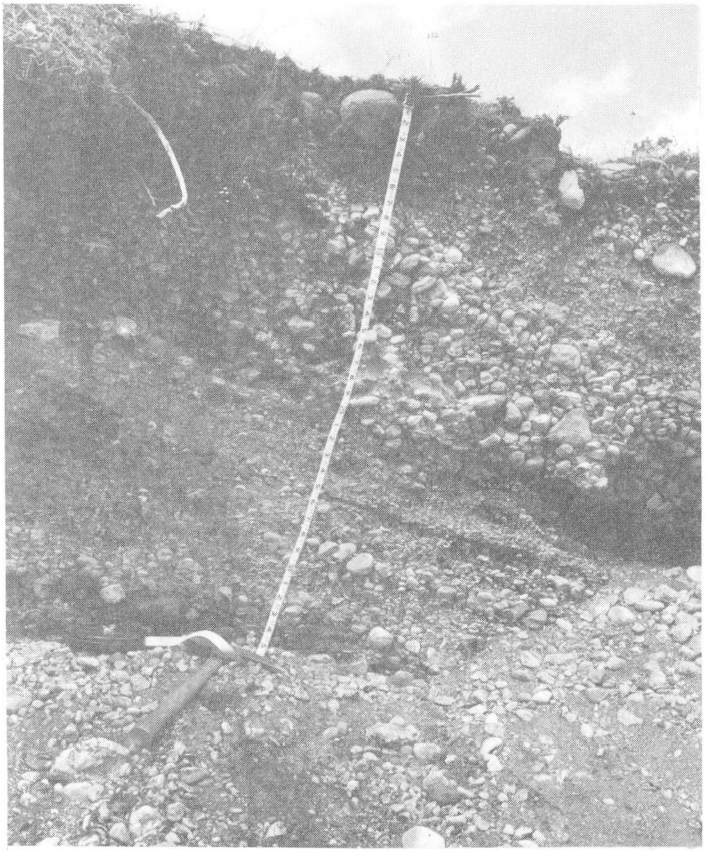

Figure 14. Typical kame deposits, located near Loder's Lime Ltd., north of Route 1A, outside the Forest Reserve. 51° 04'N, 115° 07'W.

LAKE, POND, AND MUSKEG DEPOSITS

Enclosed depressions with flat surfaces covered by swamp grass, stunted trees, or black spruce are usually the best indicators of modern lake, pond and muskeg deposits. They are of minor importance as an erosion hazard because of their limited distribution.

In the northeastern part of the Forest Reserve (not visited by the writer) wide areas may be either till and/or glacial lake deposits. These are identified by broad swells of low relief that may be the result of later glacial erosion (Fig. 17).

Deposits in this category are generally composed of well-sorted sand, silt, and clay-sized material. Small grain size, little $CaCO_3$ cement, and a low infiltration rate result in a relatively high erosion hazard.

Figure 15.
Typical non-ice-contact glacial outwash found in many of the major east-west outlet valleys in the Forest Reserve.

SOIL POSSIBLY DERIVED FROM UNDERLYING BEDROCK

Thin (5-foot-thick) deposits of soil that appear to contain nothing but locally derived material occur in some parts of the area of subdued ridges and valleys. No erratics from outside the immediate area are found. The soils consist of fine-grained material with less than 20 per cent sand or siltstone inclusions of gravel size. This soil is either a weathering product of underlying bedrock or High Erosion Till. As the erosion properties and topographic expression of both are essentially the same, it is not necessary to separate them into distinct units.

EVALUATION OF EXTERNAL EROSION FACTORS

VEGETATION

Vegetation is the most important factor in controlling erosion. In areas of the Forest Reserve where no timber clearing or allied activities have taken place, the forest cover and mat are sufficient to stop large-scale erosion. In logging operations, the forest mat plus some trees remain over much of the harvested area. Complete exposure of soil to erosion is confined mostly to skid trails, roads, and loading areas. The proportion of the total area exposed to erosion varies with the

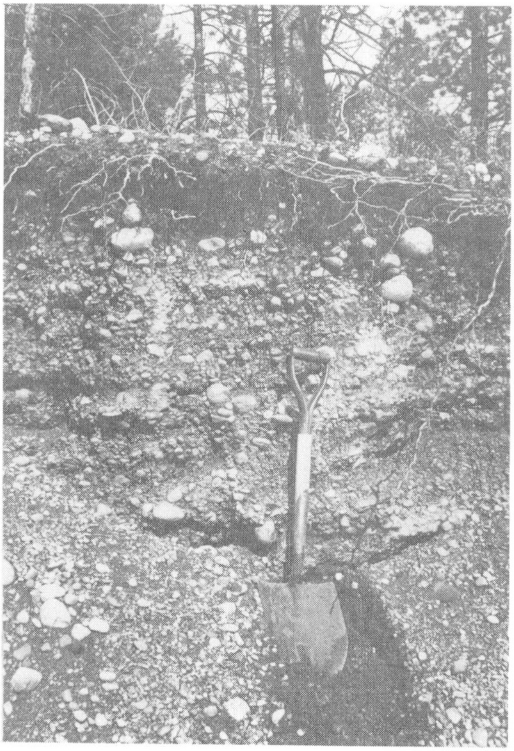

Figure 16.
Typical alluvial fan deposits found at the mouths of high gradient streams throughout the Forest Reserve.

harvesting method, and the care taken to preserve the vegetation mat. Therefore, predicting the amount of soil that will be exposed after a logging operation is difficult. The solution is to assume that a considerable percentage of soil will be exposed, and to eliminate consideration of vegetation in evaluating external erosion factors.

SLOPE

Variations in slope can cause considerable differences in erosion potential even though other erosion factors are constant. Forested areas occur on a variety of terrain varying from essentially flat abandoned floodplains to talus slopes inclined up to 33°. However, most of the Forest Reserve area consists of subdued ridges with slopes between 5° and 20°. It is not uncommon to find a relatively stable soil on a steep slope eroding at a greater rate than a relatively unstable soil on a gentle slope. For the present study the steepness of slope is classified into three categories:

steep slope	> 20°
moderate slope	5° to 20°
gentle to no slope	< 5°

Each natural slope according to its category is then evaluated with other erosion factors and the erosion potential of an area predicted. In the Forest Reserve,

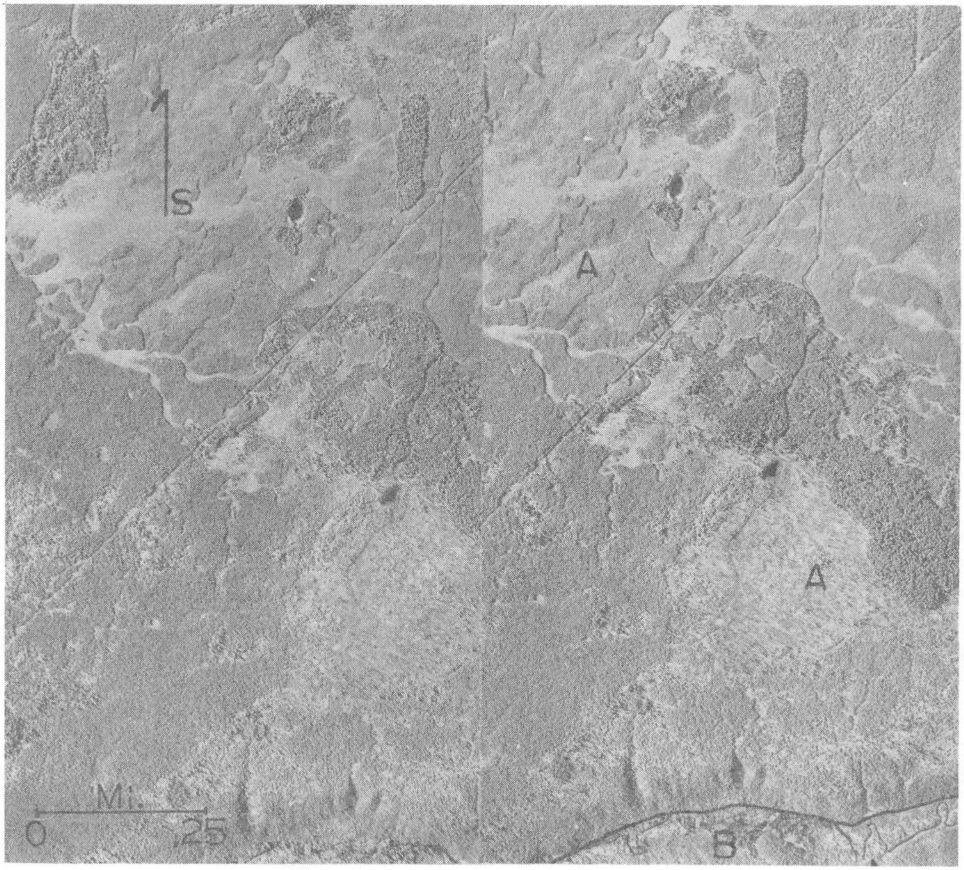

Figure 17. Stereo-pair of photographs of terrain typical of the northeast part of the Forest Reserve, covered usually with fine-grained sediments, most likely glacial lake deposits or till with few inclusions (A). B. Recent alluvial flood plain deposits. Tp. 42, Rge. 14; 52° 36'N, 115° 56' W.

variations in length of slope will not appreciably change the overall erosion potential caused by the slope steepness.

PRECIPITATION

Alberta's annual, daily, and hourly rainfall is relatively low. Storms yield little intense precipitation when compared to records of many United States weather stations where erosion problems are great.

Annual precipitation in the Rocky Mountain Forest Reserve varies between about 20 and 30 or more inches, increasing westward (Fig. 19). From May 1 to September 30, when precipitation is mostly in the form of rain, mean precipitation varies between about 11 and 16 inches (McKay 1963). Twenty-four hour rainfall

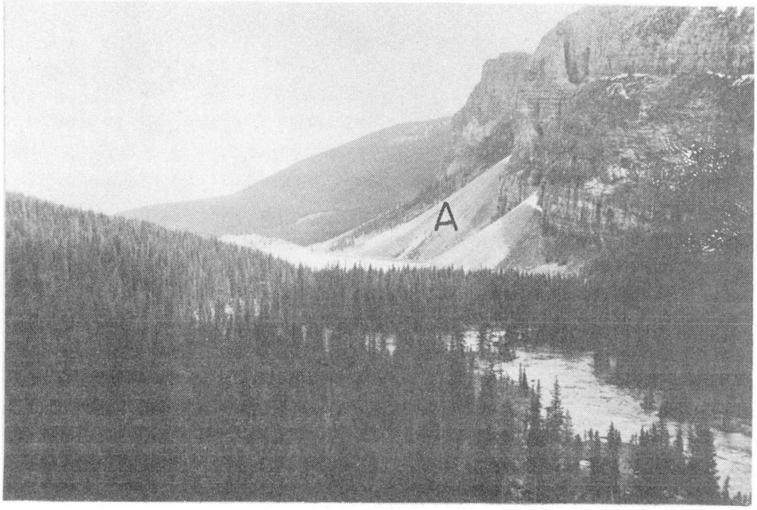

Figure 18. Typical active talus slopes found at the base of steep slopes throughout the Forest Reserve. Photograph taken at Moraine Lake in Banff National Park .

records for June, July and August, the months with the most rain, recorded over a number of years at various Alberta stations show that 71.6 per cent of the heaviest storms yielded 1.0 inch or less and 88.8 per cent 1.5 inches or less (Toogood and Newton 1955, p. 14). Figure 20 illustrates the maximum one-day rainfall recorded in Alberta in a 10-year period. One hour rainfall intensities in Alberta indicate that only once in fifteen years can about two inches of rain in one hour be expected.

EROSION PREDICTION

As the amount and intensity of rainfall in Alberta is relatively low, therefore if an area is vegetation-free, it follows that the slope remains as the single important external factor that governs relative soil erosion hazard of specific areas in the Reserve. The combined effect of inherent soil erodibility and slope is shown in Figure 21. High, moderate, and low erosion risks shown in the graph are relative values for an area of generally low erosion determined by rainfall intensity. Therefore, further qualification is warranted to establish absolute values.

High Erosion Risk – Moderately high risk of erosion during intense rain and runoff. This category includes among other things, till with a high percentage of clay and silt located on steep slopes. Timber harvesting operations should be avoided. If undertaken, conservation measures should be employed to retain as much forest and grass cover as possible.

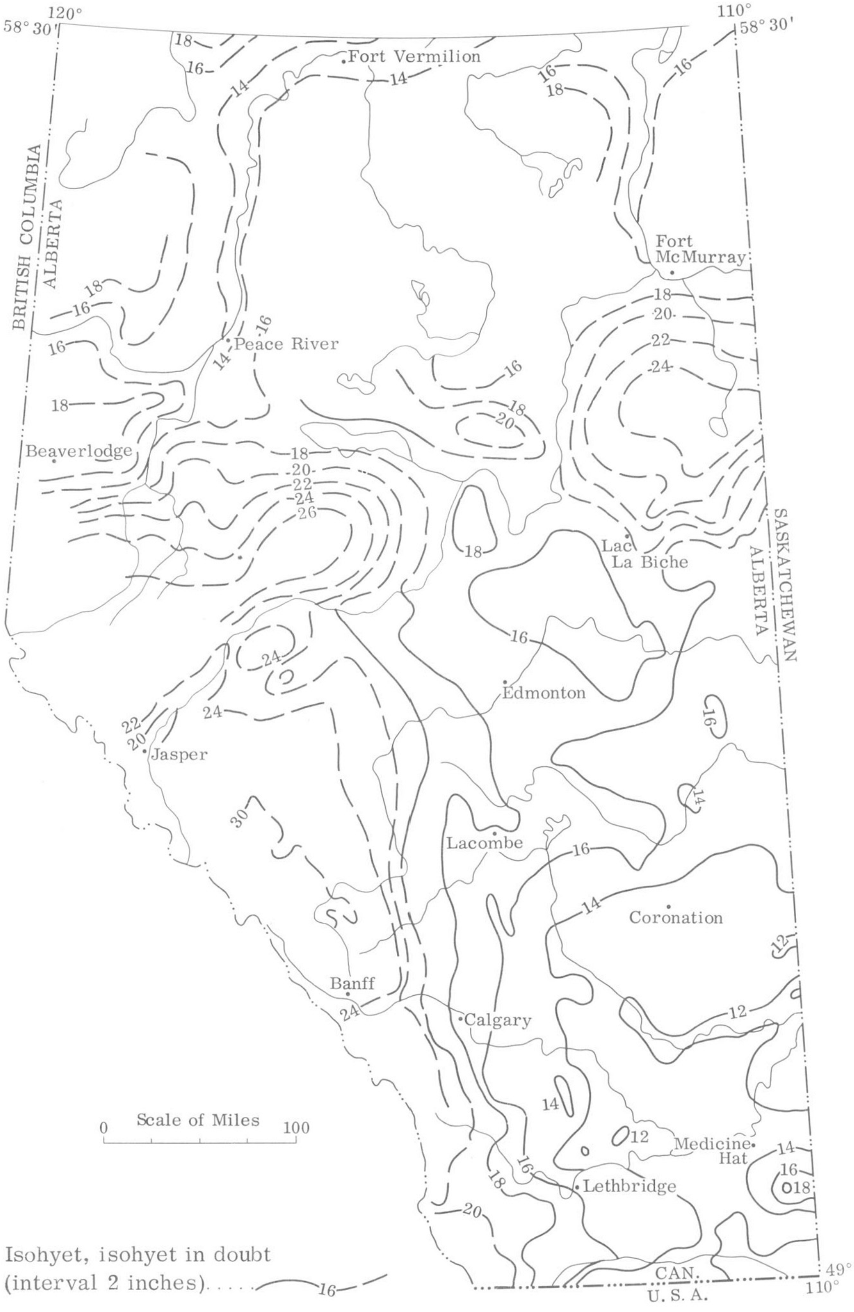

Figure 19. Annual precipitation in Alberta based on period 1921-1950, chiefly on data published by Dept. of Transport (after McKay 1963)

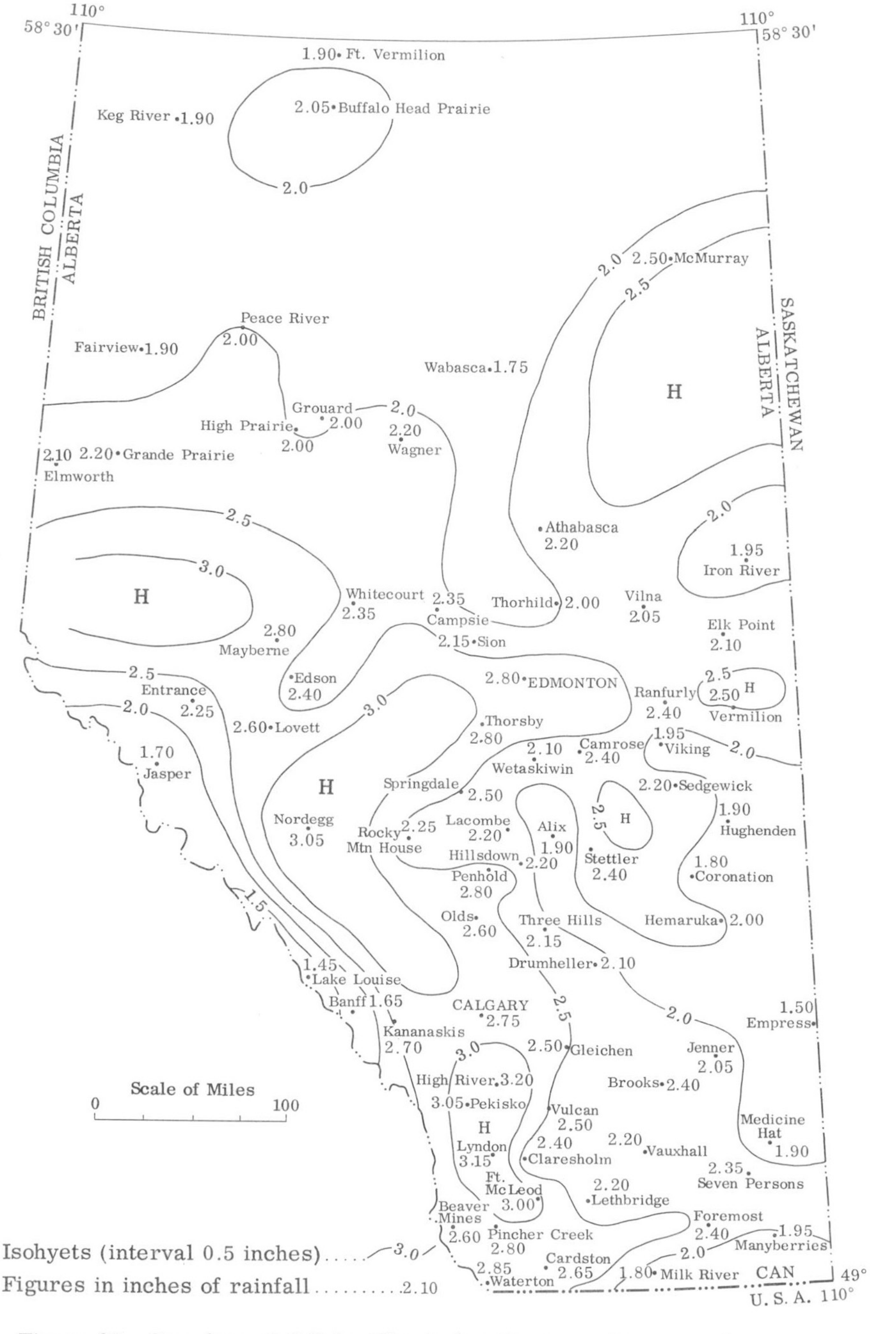

Figure 20. One-day rainfall in Alberta for 10 year return period, season May-August (after Starr, 1963)

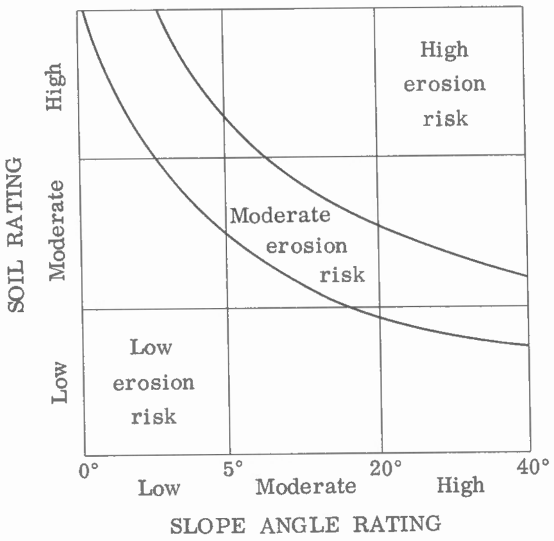

Figure 21. Erosion hazard of soils by comparing soil rating and slope angle rating. Influence of precipitation not considered. Divisions arbitrary, based on observations and published data.

Moderate Erosion Risk – Moderate to low erosion risk depending on factors involved. A till with a high percentage of silt and clay located on a gentle slope has a moderate chance of erosion during intense rains and runoff. Moderate erosion risk areas can be harvested with little danger of wholesale erosion taking place before vegetation again is established.

Low Erosion Risk – Little erosion risk even during the most intense rains and runoff. A gently sloping glacial outwash plain with a high percentage of gravel is an example of a low erosion risk.

The following procedure will enable a worker to predict the erosion hazard of a pre-selected area of the Forest Reserve.

1. Determine the type of deposits present in a selected area by characteristic morphology seen on air photographs. Use photographs in text as a guide.
2. Establish the general lithology of the soil by determining its geographic and geological setting. A field check will be necessary.
3. Determine the erosion hazard of the particular soil from Table I.
4. From topographic maps calculate the necessary slope angles of the selected area.

5. Establish the relative erosion hazard of an area by comparing slope steepness with the soil erosion ratings based on inherent factors on Figure 21.

6. By referring to the definitions of the categories of Figure 21 above, the absolute erosion hazard of a certain soil in its natural setting can be obtained.

DISCUSSION

The extensive area of the Forest Reserve and the limited time devoted to field work necessitated a reconnaissance study of erosion hazard. The writer has used absolute data when possible but has relied heavily upon experience and judgement in selecting and evaluating pertinent erosion factors. The qualitative method employed is probably the only practical way of developing a workable scheme in erosion evaluation. Often, quantitative work cannot take into account all necessary factors, usually because not all factors can be evaluated quantitatively, and thus, fails when the results are applied to a test.

A problem inherent in categorizing soils or the relative importance of erosion factors is that there are always exceptions and omissions. For example, a soil observed in the field may not fit the description of any presented in the suggested scheme because it is transitional. An external erosion factor that is not important in most cases may be important occasionally, for example, the length of slope or exposure direction. Moreover the method of harvesting timber may change the erosion prediction. Thus, although roads and skid trails are constructed with gentler slopes than the natural terrain, and therefore, on the basis of slope alone would appear to be less a hazard than the natural slope, they serve to concentrate runoff into restrictive channels where erosion may be great.

The worker must detect these unusual cases and evaluate them. The more experience and training an investigator has with the physical and biological environment of the Forest Reserve and in earth science, the easier and more accurate his predictions will be. However, the method outlined above is sufficient and accurate enough for the majority of cases of erosion prediction.

SUMMARY AND CONCLUSIONS

Most surficial deposits in the Rocky Mountain Reserve are glacially derived. They consist mainly of till with some outwash and lake deposits. Modern deposits such as talus, alluvial fans and flood plains are common. With the exception of till, most deposits have characteristic morphology and can be easily identified.

Four inherent soil properties are most important when determining relative erosion hazards of soils. These are infiltration rate, grain size characteristics (deposit strength), carbonate cement content, and the binding strength of silt and clay. The most erodible soils are tills that contain high percentages of clay and low percentages of coarse material and $CaCO_3$; lake, pond and muskeg deposits; and, soil possibly derived from underlying bedrock. Least erodible soils include tills that contain high percentages of coarse material and $CaCO_3$; glacial outwash; alluvial fan and flood plain deposits; and, talus.

External factors important in predicting the erosion of a soil in a natural setting are vegetation, slope steepness, and rainfall intensity. If a vegetation mat remains after timber extraction, a negligible amount of erosion will take place and it is the exposed areas that are of interest in such cases. Thus rainfall intensity and slope steepness are the principal factors to evaluate. Statistics indicate that the Forest Reserve has relatively low rainfall intensity compared to areas where erosion problems are great. Thus, the overall erosion hazard in the Forest Reserve is low. Variations of slope steepness evaluated with various soil erosion ratings based upon inherent factors, indicate that all types of soils on most slopes have a low to moderate erosion risk, with only the most erodible soils on steep slopes offering a moderately high erosion hazard.

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APPENDIX

GLOSSARY

Alluvium - Detrital deposits resulting from the activity of modern rivers, thus sediments laid down in river beds, flood plains, lakes, estuaries and fans.

Alluvial fan - A fan-shaped deposit of alluvium made by a stream where it runs into a low gradient plain or stream.

Basalt - An extensive, fine-grained, dark coloured, igneous rock composed primarily of calcic plagioclase and pyroxene, with or without olivine.

Cenozoic - The latest of the four eras into which geologic time, as recorded by the stratified rocks of the earth's crust, is divided.

Clastic rocks - Consisting of fragments of rocks or of organic structures that have been moved individually from their places of origin.

Colluvium - A general term applied to loose and incoherent deposits, usually at the foot of a slope or cliff, deposited chiefly by gravity.

Consequent - A type of stream that follows a course that is a direct consequent of the original slope of the surface on which it developed.

Cretaceous - The third and latest of the periods included in the Mesozoic era. Also, the system of strata deposited in the Cretaceous period.

Crevasse filling - A short ridge left after deglaciation and composed of ice-contact stratified drift which was deposited in an ice crevasse.

Drift - Used here to include all rock material, such as till, gravel, sand, and clay transported by a glacier and deposited by or from the ice or by or in water derived from the melting of the ice.

Drumlin - A streamlined hill or ridge of drift whose long axis parallels the direction of flow of a former glacier.

Esker - Sinuous ridge of assorted and somewhat stratified sand and gravel left after deglaciation and believed to represent fillings of subglacial, englacial or superglacial stream channels.

Mesozoic - One of the eras of geologic time, following the Palaeozoic and succeeded by the Cenozoic era, comprising the Triassic, Jurassic, and Cretaceous periods.

Moraine - An accumulation of drift having initial constructional topography, built within a glaciated region chiefly by the direct action of glacier ice or glacial meltwater.

Obsequent - A stream that flows in a direction opposite to that of the dip of the strata or the tilt of the surface.

Palaeozoic - The era of geologic time before the Mesozoic era. The beginning of the Palaeozoic was formerly supposed to mark the appearance of life on the earth, but that is now known to be incorrect: rocks formed during this era.

Precambrian - All rocks formed and deposited before the Palaeozoic.

Shale - A laminated, fissile sediment in which the constituent particles are predominantly clay-sized.

Subsequent - A stream that flows along belts of more easily erodible rocks. They are therefore, mostly parallel to the strike of the bedrock.

Talus - A collection of fallen, disintegrated material which has formed a slope at the foot of a steeper declivity.

Till - Unsorted, non-stratified sediment carried or deposited by a glacier.