



**TERRAIN CLASSIFICATION AND
TERRAIN STABILITY MAPPING
ALBREDA AND MESSITER PROJECT AREAS**

for:

**BC Timber Sales
Kamloops Business Area**

by:

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Bryan Tasaka was responsible for project management and project coordination. Kyle Skidmore built the databases. Scott Weston, M.Sc., P.Geo., provided senior review and in-house quality control. Chartwell Consultants Ltd. of North Vancouver, BC completed the monorestitution and map production.

SUMMARY

This report accompanies maps produced for a terrain stability mapping project completed by Madrone Environmental Services Ltd. for two areas referred to as Albreda and Messiter, located near Blue River in central eastern British Columbia. Mapping of the Albreda and Messiter project areas was completed under contract to BC Timber Sales – Kamloops Business Area.

Approximately 23 400-hectares were mapped for this project. The main objective of the project was to identify areas prone to geologic and geomorphic hazards, specifically landslides and surface erosion. A six-class terrain stability classification system was used, in which Class V is unstable and Class I is stable.

This report includes a description of the physical environment of the areas, mapping procedures, surficial materials present, terrain hazards identified, classification systems used, and management concerns. The maps and this report may be used to assist in development planning through the identification of unstable and potentially unstable terrain prior to road construction and timber harvesting in an area, and through the identification of the location of surficial materials and their properties that may or may not be desirable for development activities.



TERRAIN CLASSIFICATION AND TERRAIN STABILITY MAPPING ALBREDA AND MESSITER PROJECT AREAS

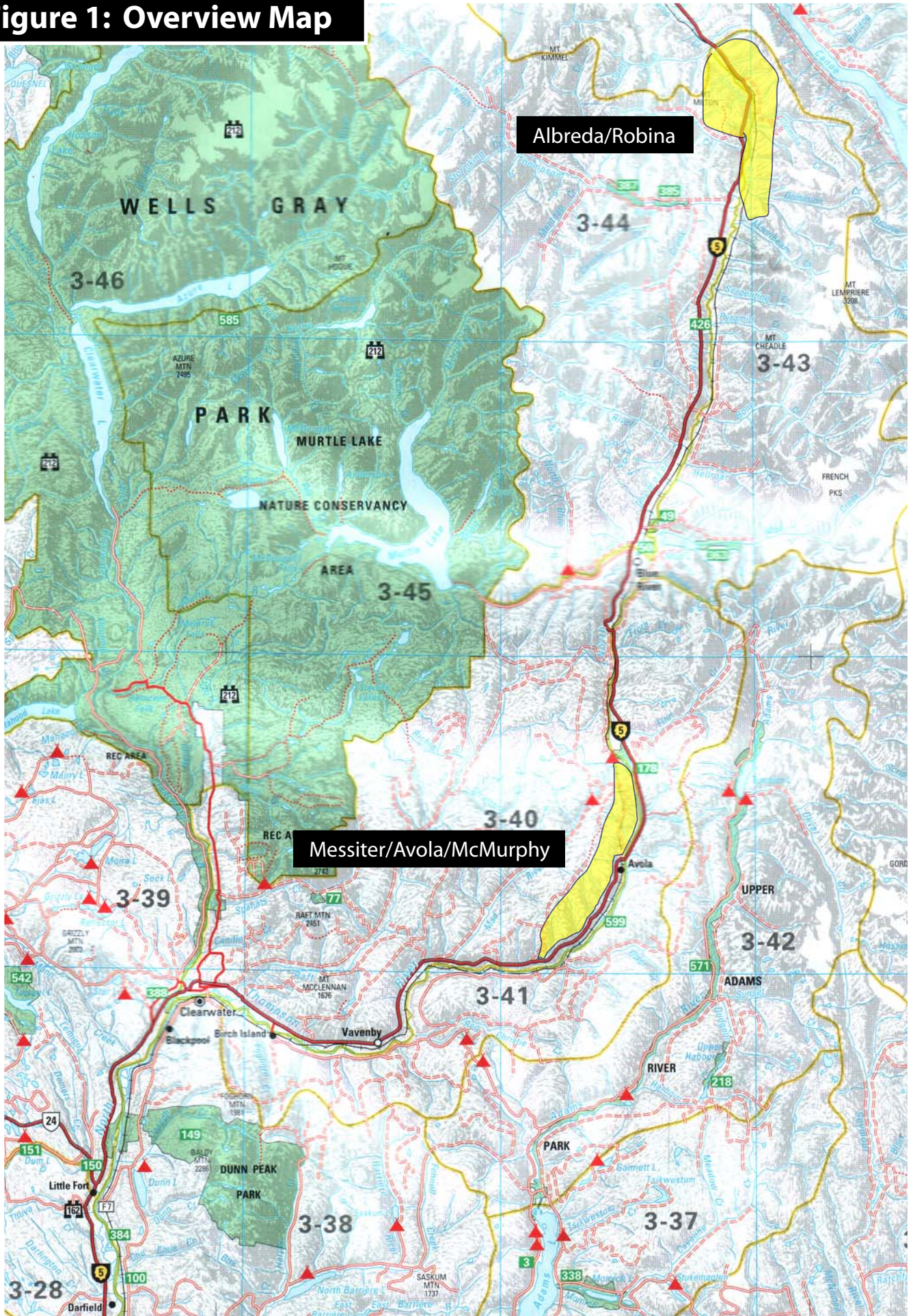
1.0 INTRODUCTION

In the fall of 2006, Madrone Environmental Services Ltd. (Madrone) was retained by BC Timber Sales – Kamloops Business Area to complete detailed terrain mapping and terrain stability mapping of the Albreda project area, located north of Blue River, and of the Messiter project area, located south of Blue River (Figure 1).

The objectives of the project are as follows:

- To complete terrain mapping and terrain stability mapping at a scale of 1:20,000, Terrain Survey Intensity Level C, for operable areas within the defined project area boundary.
- To collect sufficient data from disturbed areas in or near the project area to develop or refine criteria for terrain stability and soil erosion potential interpretations.
- To collect data about the characteristics of surficial materials and slope processes relevant to forest management.

Figure 1: Overview Map



- To prepare a terrain stability map showing ratings (classes) for terrain stability, soil erosion potential, and potential sediment delivery from surface erosion sources.
- To provide digital files in both MicroStation and ArcInfo formats with Resources Inventory Standards Committee standard databases.
- To prepare a report describing mapping methods, reliability of mapping, the physical environment of the area, surficial geology, and criteria used to define terrain stability, soil erosion potential, and potential sediment delivery from surface erosion sources.

The project results are presented as terrain maps and terrain stability maps at a scale of 1:20 000 and in MicroStation and ArcInfo formats. The maps are based on air photo interpretation together with field checking at Terrain Survey Intensity Level C in operable timbered areas. The maps can be used to plan general road and cutblock locations, to identify surficial material properties and material locations (such as construction aggregate) for use in development activities, and to indicate where more intensive watershed management is necessary. They should not be used for making site-specific decisions concerning logging or other development activities.

2.0 METHODS

Terrain mapping and the assessment of terrain stability, soil erosion potential, and potential sediment delivery from surface erosion sources has three stages:

1. Air photo interpretation and the delineation of terrain unit polygons (i.e., ‘pre-typing’).
2. Field checking to confirm or modify labels and line work completed during Stage 1.
3. Air photo correction, review, and monorestitution.

Terrain stability mapping methodology follows the *Guidelines and Standards for Terrain Mapping in British Columbia* (Resources Inventory Committee 1996) and *Mapping and Assessing Terrain Stability Guidebook* (BC Ministry of Forests 1999). The terrain classification used follows see *Terrain Classification Systems for British Columbia* (Howes and Kenk 1997).

2.1 Air Photo Interpretation

The first stage of mapping involved pre-typing, or the interpretation of color, air photos taken in 2000 at a scale of approximately 1:17 000. Full stereo coverage was obtained for the project areas. Air photos were organized by flight line, north arrows and project area boundaries were delineated on the photos, coordination points were identified, and “boxing” of the edges was completed to allow matching between adjacent photos and flight lines. Only every second photo was used for pre-typing.

Terrain polygons were delineated on the air photos with ink pens. Interpreting the terrain from air photos is an acquired skill, which relies on the interpreter’s experience with the area and knowledge of glacial, hillslope, and fluvial geomorphology. A three-dimensional view of the ground is used to interpret slope gradient, shape, position relative to the landscape, cover textures, and evidence of slope processes such as landslides, gulying, snow avalanche, and fan deposition. Lines are drawn around areas of relatively homogeneous terrain creating polygons that represent visible slope facets, distinct landforms or areas exhibiting certain processes such as gulying or snow avalanching. The minimum size of the polygons was 1 cm² or about 4-ha on a 1:20 000-scale map.

An attempt is made to delineate “pure” map units containing only one terrain unit; however, in some cases, polygons include a mixture of terrain types. For example, a colluvial veneer (*Cv*) can often be mapped with steep bedrock outcrops (*Rs*). At this map scale it is not practical to map most individual outcrops, so these two terrain types were mapped as a complex (e.g., *Cv/Rs*). In some cases, complexes of three units may appear. Where polygons contain complexes, the terrain stability of the most hazardous component is presented.



Each polygon was assigned a terrain label following Howes & Kenk (1997) and a label for soil drainage (Table 1). Soil drainage class refers to the speed and extent to which water is removed from a soil in relation to additions.

Based on the pre-typing, areas were identified for field checking. These include landscape features of typically high terrain hazards, steep slopes, landslides, seepage zones, and areas where there was uncertainty in the terrain label.

Table 1. Soil Drainage Classification

Code	Definition
r	rapidly drained
w	well drained
m	moderately well drained
i	imperfectly drained
p	poorly drained
v	very poorly drained

2.2 Field Checks

The second stage of mapping involved the field inspection of a sample of polygons. Guidelines for Terrain Survey Intensity Level C (BC Ministry of Forests 1999) were followed, with the intent of ground checking 20% to 50% of the polygons.

Traverses were planned so that a maximum area of unstable or potentially unstable terrain was inspected. Along each traverse, information was gathered through the examination of materials in shallow soil pits, natural cuts in stream banks, gullies, exposures from windthrown trees, landslide scars, or road cuts (Photo 1). For each polygon inspected, one of three types of plots was made: detailed, reconnaissance, or visual. Information collected for all types of plots was recorded on terrain field cards. The location of all field checks was recorded on the air photos and is identified on the terrain maps and terrain stability maps.

For a *detailed* plot, information for several terrain attributes was collected, including surficial material, texture, slope gradient, slope shape and position, soil drainage, vegetative cover, bedrock type and presence of outcrops, active geomorphic processes, and evidence of instability.



Photo 1. Road cuts are a valuable resource for observing the material below the surface.

Evidence of instability may include recent or historic landslide scars; tension cracks; or leaning, jackstrawed, fallen, or scarred trees. Interpretations of terrain stability and soil erosion potential were made and a rating for each of these was assigned. Seepage, an important factor in terrain stability, was assessed by the presence of hydrophytic vegetation such as devil's club (*Oplopanax horridus*) and lady fern (*Athyrium filixfemina*). Soil creep was assessed by the degree of tree-stem deformation (that was caused by creeping soil but not snow or other external factors) and the presence of fresh colluvium on the ground surface.

Information gathered for a *reconnaissance* plot includes surficial material, soil drainage, slope gradient, terrain stability, and soil erosion potential. *Visual* plots were recorded when nearby polygons were viewed from a vantage point. In most cases, information recorded for these plots was limited to surficial material and an interpretation of terrain stability. In general, visual plots were used for obvious terrain features (i.e., easily identifiable across a valley or from a helicopter) and include floodplains, bedrock outcrops, and colluvial cones.

The foot traverses for each project area were supplemented with a low-level helicopter traverse. During these flights inaccessible areas (e.g., lack of landing spots, treacherous slopes) were inspected and oblique photographs were taken of slopes not traversed. Landslides not inspected on the ground were viewed and initiation zone surficial materials were identified as best as possible.

Field work for the project was based out of Blue River, BC, and completed October 21-27, 2006. At that time, three mapping teams completed 14 ground traverses and two truck traverses. Access to the area was by two trucks and by helicopter. Dense morning fog on several days created logistical challenges.

Both the Albreda and Messiter project areas have been extensively developed, and there is a widespread network of roads traversing lower, mid, and upper slopes. Much of the area was accessed solely by truck, and several of the ground traverses involved a morning helicopter drop off and an afternoon truck pick up. Nearly all terrain polygons dissected by a road were inspected.









Traverse maps (Figure 2, Albreda and Figure 3, Messiter) show the spatial distribution of the ground traverses, as well as the mapped Class IV and V terrain. The traverses were evenly distributed throughout the project areas, and most of the potentially unstable or unstable terrain was inspected. Sampling intensity was low for valley bottom areas, for alpine areas, and for terrain dominated by bedrock outcrops. Sampling intensity was moderate to high in all other areas. After close review of the air photos with the completion of each traverse, it was determined that the terrain inspected along each traverse was representative of the surrounding terrain.

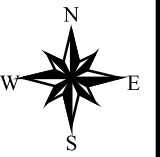
Figure 2

TERRAIN STABILITY MAP

Albreda / Robina Watershed

Terrain Stability Class

-  Class I
-  Class II
-  Class III
-  Class IV-R
-  Class IV
-  Class V
-  Study Area Boundary
-  Ground Traverse



1 0 1 2 Kilometers

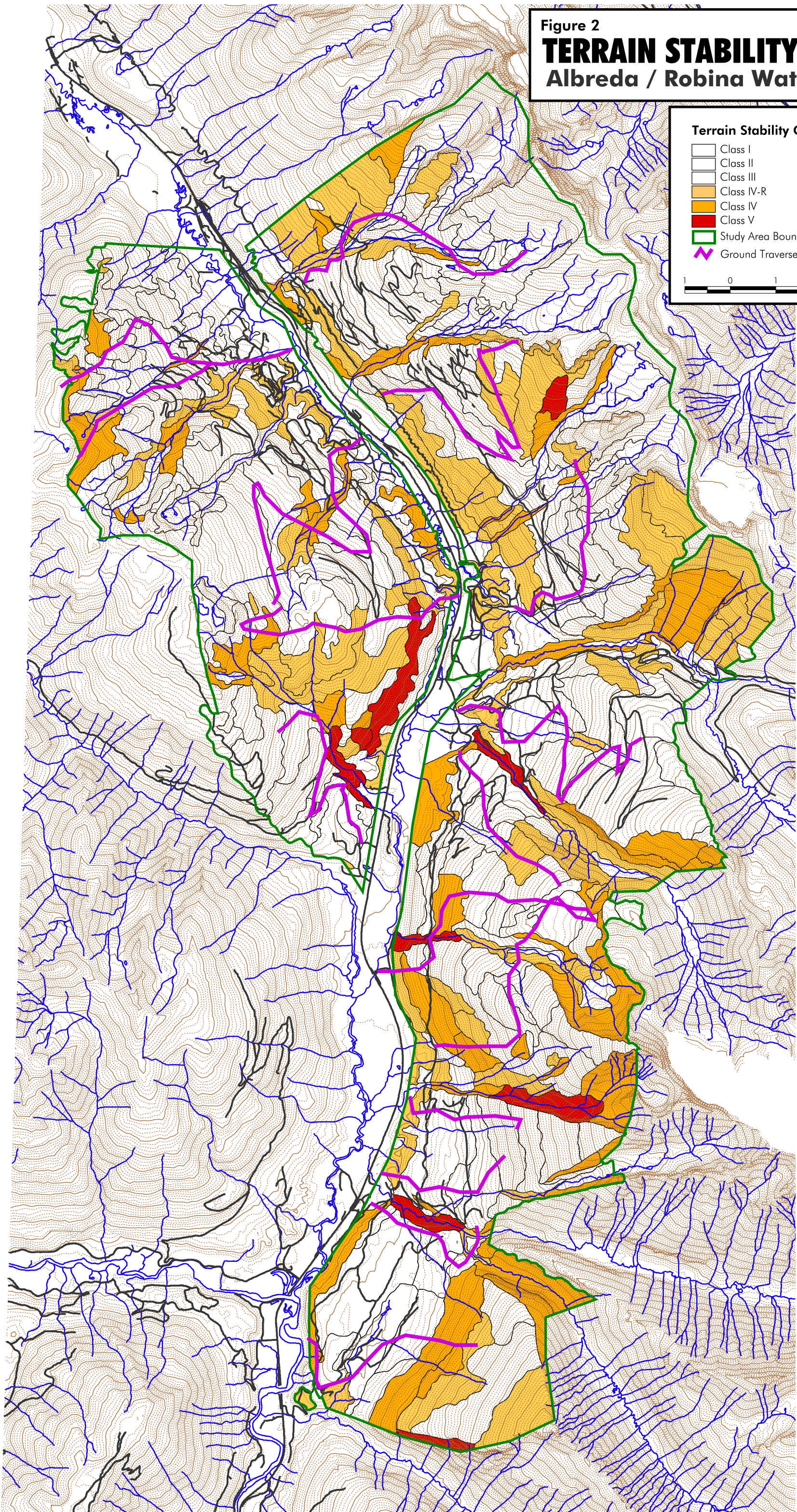










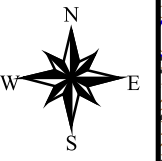
Figure 3

TERRAIN STABILITY MAP

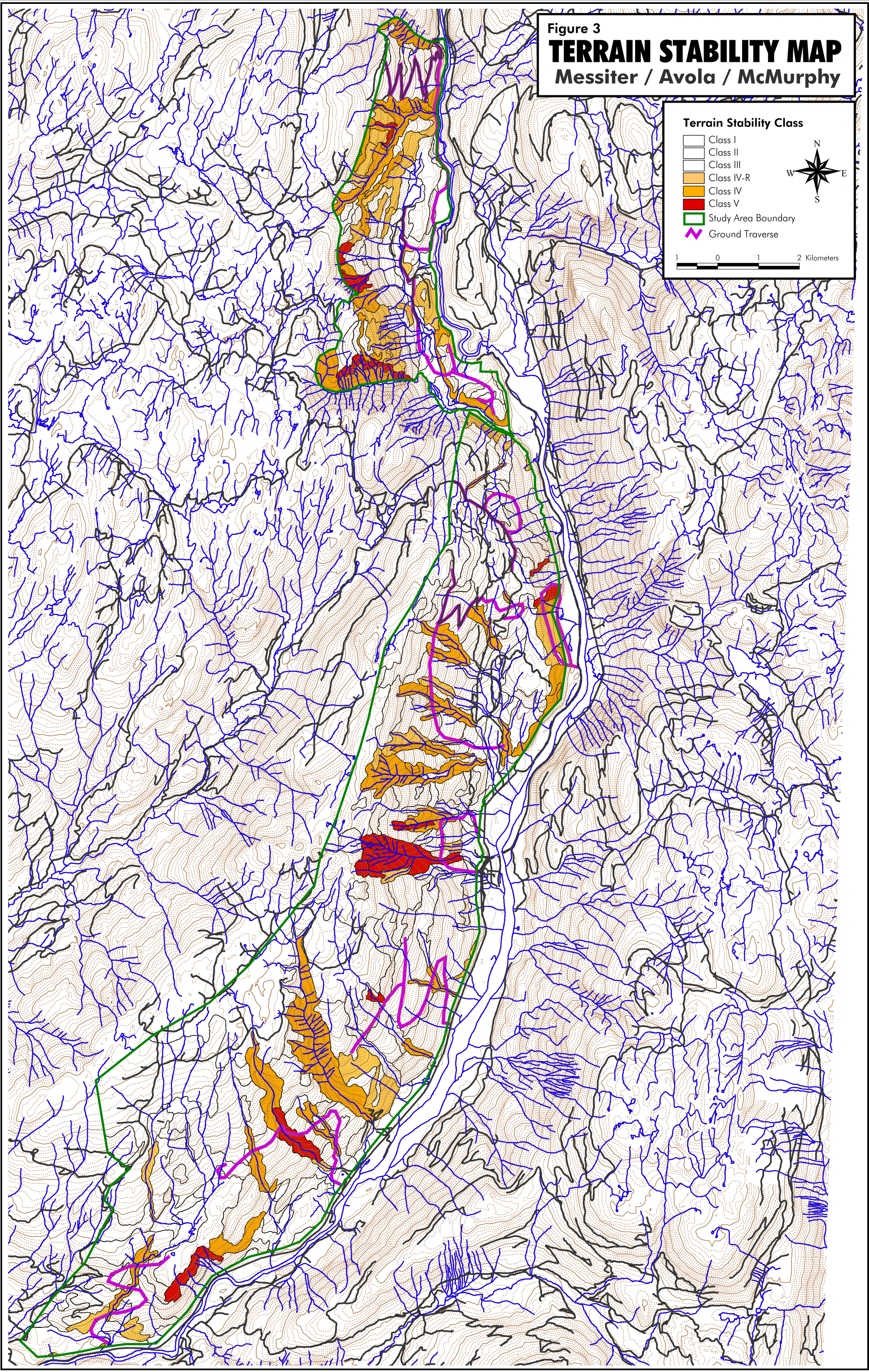
Messiter / Avola / McMurphy

Terrain Stability Class

-  Class I
-  Class II
-  Class III
-  Class IV-R
-  Class IV
-  Class V
-  Study Area Boundary
-  Ground Traverse



1 0 1 2 Kilometers



2.3 Air Photo Interpretation, Correction, Review, and Monorestitution

The final stage of mapping involved completing the labels for each polygon, and adding, modifying, or deleting polygons and the associated label based on observations made during the fieldwork. During this stage, slope range (in percent), and the interpretations of terrain stability, soil erosion potential, and potential sediment delivery from surface erosion sources were added to complete each polygon label. In addition, terrain labels and line work were corrected where necessary and information was added based on the field observations. In complex terrain, two slope ranges may be assigned. Terrain stability, soil erosion potential, and potential sediment delivery from surface erosion sources ratings are interpretations based on observations made. Details of these interpretations are described in Section 6.

With the line work and labels finalized, the mapping was reviewed by Scott Weston, M.Sc., P.Geo. Following the review, the edited line work was digitized using monorestitution software. This is a computerized process in which distortion and tilt in the photos are digitally corrected and line work is transferred to a 1:20 000-scale TRIM base. The final product is a planimetrically correct map showing the location of the polygon line work. In addition, polygon labels were entered into a standardized terrain database, which was linked to the digital maps for the final digital product of labeled terrain maps and terrain stability maps. A final step was to complete a final edit of the labeled polygons by comparing the work on the air photos to the terrain and terrain stability maps.

2.4 Reliability

The terrain maps are presented at a scale of 1:20 000 and are based on air photos with an average scale of 1:17 000. The air photo scale is suitable for the map scale produced, as polygon size and density represents the complexity of the landscape. The mapping of surficial materials is based on experience in air photo interpretation, field observations, and knowledge of geomorphic processes and the Quaternary history of the area. Many of the slopes in the project areas are covered with dense vegetation and are mantled by a complex of materials. Identification of the surficial material, along with deposit depth and material distribution, was based on evidence from the surface, shallow soil pits, soil exposed by windthrow, streams and riverbanks, gully sidewalls, and landslide scars. No subsurface drilling or boring was done.

3.0 PHYSICAL ENVIRONMENT

3.1 Regional Setting, Physiography, and Geology

3.1.1 Albreda

The Albreda project area is located approximately 54 km north of Blue River and 27 km south of Valemount, within the Monashee Mountain Range of the greater Columbia Mountains. The project area is divided by the Albreda River, which flows south into the North Thompson River, with the confluence at the southern end of the project area. The area is bound by the Malton Range of the Monashee Mountains to the northeast, the community of Albreda to the northwest, Mount Milton and adjoining ridgelines to the southwest, and Moonbeam Creek, a tributary of the North Thompson River, to the south.

The Albreda River valley is characterized by a broad U-shaped, glacially-carved valley and sidewalls heavily dissected by deep gullies and valleys (Photo 2). The valleys were intensely glaciated, leaving behind steep sidewalls and deep morainal deposits in the valley bottoms (Holland 1976). The high mountains are mostly massive sharp peaks separated by deep steep-sided valleys (Photo 3). Peaks above 2400 m were above the Pleistocene ice sheet and were subjected to intense cirque glaciation. The resulting jagged peaks are prominent along the northeast boundary of the project area, within the Malton Range (Photo 4).

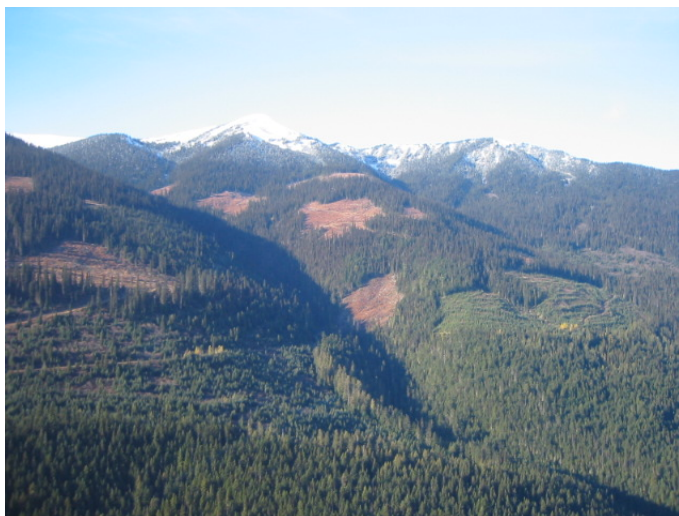


Photo 2. West side of Albreda project area, where valley sidewalls are dissected by deep gullies.



Photo 3. Significant peak of the Malton Range in the northeast portion of the Albreda project area.



Photo 4. Malton Range and east side of Albreda project area.

The Monashee Mountains are underlain by sedimentary and metamorphic rocks, predominantly gneissic rocks of the Shuswap terrain, by Paleozoic and Mesozoic sedimentary and volcanic rocks, and by batholiths and stocks of Lower Cretaceous and younger age. The east side of the Albreda River valley is dominated by the Malton Gneiss Complex (characterized by Lower Proterozoic granitic orthogneiss, mafic orthogneiss, and paragneiss), with the Miette Group – Lower Division (characterized by Upper Proterozoic conglomerate and mylonitic quartzite) along the Malton peaks. The west side of the valley is dominated by rocks of the Kaza Group – Lower Division (characterized by Upper Proterozoic pelitic schist and psammite, minor amphibolite, marble, and calc-silicates), but includes bands of the Horsethief Creek Group – Upper Proterozoic Semipelite-Amphibolite Unit (psammite, pelitic schist, amphibolite, and marble) and Upper Proterozoic Lower Pelite Unit (pelitic schist, psammite, and amphibolite) (Massey et. al. 2006).

Elevations in the project area range from 760 m above sea level on the valley bottom near the confluence of the Albreda and North Thompson Rivers to 2700 m asl in the northern-most corner of the project area, amongst the jagged peaks of the Monashee Mountains.

3.1.2 Messiter

The Messiter project area is located approximately 160 km north-northeast of Kamloops, 54 km northeast of Clearwater, and 27 km south of Blue River, within the Shuswap Highland of the greater Interior Plateau. The Shuswap Highland is characterized by gentle - or moderate-sloping plateau areas dissected by the North Thompson River. The valley sides are typically steep because of glacial erosion, and the total relief in a given area may be great. The effects of glaciation in the region were to reduce the upland relief while steepening and deepening the valleys (Holland 1976).

The project area encompasses terrain located on the west and northwest side of the North Thompson River. Much of the terrain slopes directly down to the North Thompson River, with floodplain and terraces breaking the slope in some places. The southern portion of the project area is dominated by broad, gentle to moderate terrain on the upper slopes, typical of the Shuswap Highland (Photo 5). The project area is bound by the North Thompson River to the east and south, Hornet Creek and massive upland areas to the west, and Cayuse Creek to the north.





Photo 5. Moderate sloping, undulating terrain typical of the southern portion of Messiter project area.

The bedrock geology in the area is dominated by rocks of the Proterozoic to Pelozoic Shuswap Assemblage, including undivided quartzofeldspathic gneiss, biotite-quartz schist, amphibolite, quartzite, marble, calc-silicate, and local pegmatite.

Elevations in the project area range from 575 m asl along at the North Thompson River on the southern end of the project area to approximately 1860 m asl along the ridge line west and upslope of the town of Avola.

3.2 Climate

The nearest climate stations to the project areas are located near Blue River, 54 km from the Albreda project area and 27 km from Messiter. From 1929 to 1985, there was a climate station at Blue River North, situated at 689 m asl. The current climate station, with date collection commencing in 1969, is located in a similar area but at 679 m asl. Both of these climate stations are located a significant distance from the project areas and at a much lower elevation than that typical of the project areas. Therefore, climate data from these stations cannot be considered representative of either of the project areas. Simply, a generalization can be made that the two project areas likely experience cold, wet winters with significant levels of snowfall, and hot, dry summers.

General climate characteristics can be predicted by entering the project area's latitude, longitude, and elevation in a climate model. The results of the model are summarized in Table 2.

Table 2. Projected climatic data for project areas.

Project area	Latitude	Longitude	Elevation (m asl)	Avg winter temperature	Avg summer temperature	Annual precipitation
Albreda	52°35'30"	119°05'30"	1700	-10°C	+10°C	965 mm
Messiter	51°47'30"	119°20'30"	1200	-8°C	+12°C	900 mm

From climate modeling website, <http://genetics.forestry.ubc.ca/cfgc/ClimateBC/Default.aspx>, accessed on February 22, 2007.

3.3 Hydrology

Both Albreda and Messiter project areas include large creeks and rivers draining the surrounding terrain. As a consequence of scattered mountainous topography and heavy annual snowpack, the hydrologic regime of these watercourses is snowmelt dominated. The maximum daily and instantaneous flows typically occur in late spring or early summer, particularly in the larger rivers and creeks. The range of elevation in the Albreda project area is such that a significant snowpack likely persists into July, and this ensures that flows are maintained throughout the summer in the larger creeks and rivers. Peak instantaneous flows are usually associated with the sudden onset of high temperatures that accelerate melting of the snowpack and are typically combined with spring or summer rainstorms falling on the melting snowpack. Flows are more seasonally varied in some smaller creeks lacking the high elevation snowmelt contribution (but still experience a snowmelt peak flow). In some years, a smaller peak flow may occur during late October or early November as a result of rain-on-snow events. These short-term flood flows are significant in entraining sediment. The first large flows of the year entrain much of the sediment stored in tributary creeks and gullies (Photo 6). Sediment load usually peaks following this.



Photo 6. Stream clogged with woody debris and sediment wedges in Messiter project area.

3.4 Biogeoclimatic Zones

3.4.1 Albreda

The Albreda project area includes four different biogeoclimatic zones: Interior Cedar Hemlock along the lower and mid slopes, Sub Boreal Spruce along the lower slopes in the northern portion of the project area and the mid slopes, Engelmann Spruce-Subalpine Fir along the upper slopes, and Alpine Tundra on the upper slopes (Ministry of Forests and Range 2006).

Interior Cedar Hemlock is dominated by western red cedar (*Thuja plicata*) and western hemlock, (*Tsuga heterophylla*) but Ponderosa pine (*Pinus ponderosa*), Douglas fir (*Pseudotsuga menziesii*), western larch (*Larix occidentalis*), lodgepole pine (*Pinus contorta*), western white pine (*Pinus monticola*), trembling aspen (*Populus tremuloides*), and paper birch (*Betula papyrifera*) all may be present within the zone. The zone has long, warm summers and cool, wet winters.

Sub-Boreal Spruce zone dominates the landscape of B.C.'s central interior and occurs up to approximately 1300 m asl. Coniferous forests dominate the landscape with hybrid white spruce (*Picea glauca x engelmannii*) and subalpine fir (*Abies lasiocarpa*) as the dominant climax species. Lodgepole pine and trembling aspen pioneer the extensive seral stands.

The zone has severe, snowy winters; relatively warm, moist, short summers; and moderate annual precipitation. Gentle, rolling plateaus typical of large portions of the project area dominate this zone.

The Engelmann Spruce-Subalpine Fir biogeoclimatic zone is a subalpine zone in mountainous terrain at high elevations. It includes continuous forest cover at its lower and mid elevations and subalpine parkland at its upper elevations. Engelmann spruce (*Picea engelmannii*) and subalpine fir are the dominant climax species with spruce usually dominating the canopy of mature stands. Lodgepole pine is a widespread seral species after fire.

Alpine Tundra occupies the upper slopes of the Albreda project area. The zone is treeless and vegetation is scarce. Precipitation dominates this zone and falls mostly as snow.

3.4.2 Messiter

The Messiter project area falls within two biogeoclimatic zones: Interior Cedar Hemlock on the lower slopes and Engelmann Spruce-Subalpine Fir on the upper slopes (Ministry of Forests and Range 2006). As in the Albreda project area, the Interior Cedar Hemlock zone is dominated by the conifers of western red cedar and western hemlock, with several different species present in places. The Engelmann Spruce-Subalpine Fir biogeoclimatic zone dominates the upper slopes of the project area.

4.0 SURFICIAL MATERIALS

Anthropogenic (A)

Anthropogenic materials have been mapped in 6 polygons in the Messiter project area, all near the town of Avola and in fields adjacent to Highway 5. In these areas, the nature of the surficial materials, including compaction and structure, is different from the original deposits and thus is designated as having been modified by humans.



Colluvium (C)

Colluvium is defined as material in which gravity is the dominant process in transport and deposition. Colluvial landforms can be landslide deposits, talus slopes (Photo 7), and mantles deposited over morainal blankets. Colluvium occurs on some of the steeper slopes throughout the region and at the base of bedrock outcrops where slow or rapid downslope movements are dominant processes. It is present as blankets or veneers (*Cb*, *Cv*). On slopes between 50% and 80% colluvium may be complexed with morainal deposits (*Cv/Mw* or *Mw/Cw*). Colluvium commonly consists of sub-angular to angular rubble or blocks loosely set in a matrix of silty sand. This material is generally moderately well to well drained depending on the texture of the matrix. Coarse-textured colluvium or talus may be rapidly drained. Active colluvial slopes are often subject to intermittent rockfall or rock slide deposition, which in places can represent a hazard to forest workers. Colluvial fans and cones are also present in the project area. These are common at the mouth of gullies where there is an abrupt slope gradient change between the gully channel and the adjacent valley bottom. The aggradation of these fans and cones would primarily be a result of rapid mass movements, such as debris flows.



Photo 7. Stable talus slope in Albreda project area.

Colluvial deposits are common in both the Albreda and Messiter project areas. Specifically, in Albreda, colluvium has been mapped in 177 Polygons out of a total of 417 (42% of the Polygons). In Messiter, colluvium has been mapped in 105 Polygons out of 306 (34% of the Polygons).

Weathered Bedrock (D)

Weathered bedrock has been mapped in 34 Polygons (8% of the total) in Albreda and only 5 Polygons (nearly 2% of the total) in Messiter. This surficial material is a result of highly fractured and jointed bedrock present along ridge tops that has weathered but has not been removed by any geomorphic agent (e.g., water, gravity). This material is not common but is thick enough within a polygon (less than 1 m deep) for identification. The material typically consists of unconsolidated rubble or blocks and is well to rapidly drained.

Fluvial (F)

Fluvial deposits are common along the North Thompson River, the Albreda River, the valley bottoms of most of the larger creeks in both project areas, and at the mouths of the creeks. These deposits have been mapped in 15 Polygons (3% of the total) in Albreda and 13 Polygons (4% of the total) in Messiter.

In the mid and lower reaches of the main valleys there are well-developed floodplains (*Fp*) consisting primarily of sandy gravels, including boulders. In general, coarser sediments are in the upper valleys and the average clast size decreases downstream. The exception to this is at the confluences with the tributaries, large gullies, and creeks. These side valleys supply sediment continuously, and those that are subject to debris flows periodically supply a large volume of sediment of all sizes. Since deglaciation, the creeks and rivers have eroded the glacial sediments in the upper valleys and deposited these in the mid and lower valleys, burying other glacial deposits. The fluvial sediments are highly permeable, and the depth of most of the deposits is estimated to range from 2 m to greater than 10 m.

Within the floodplains there are sections that periodically flood, and a significant amount of sediment is transported downstream. These deposits are considered to be active (*F^Ap*). Many polygons in the valley bottoms are a combination of fluvial and morainal materials (e.g., *Mj/Fj*, *Fj/Mb*), as the two materials grade into one another with indistinct boundaries.



Glaciofluvial (FG)

Glaciofluvial materials were deposited by glacial meltwater either directly in front of, or in contact with, ice. In the Albreda and Messiter project areas, these deposits are moderately well to highly-sorted sandy gravels as well as sands and silts several meters deep (Photo 8). The material is non-cohesive and subject to ravel on steep slopes, and the poor cohesion renders it susceptible to erosion. The deposits are moderately well to well drained. In places, polygons delineating the material separate a terrace plain (*FGpt.Mjp*) from the steep terrace scarp (*Msk.FGsk*). Deposits are complexed with morainal deposits and fluvial sediments in many of the polygons.



Photo 8. Bedding planes of silt and sand in a massive glaciofluvial deposit in the Albreda project area.

In places, post-glacial incision and gullying through the deposits has resulted in oversteepened banks (*FGks/Mks-V*) that are susceptible to failure, chronic ravelling, and erosion.

Glaciofluvial materials deposited by large glacial meltwater rivers in the Albreda project area are common on the lower valley slopes. These deposits are tens of meters thick (Photo 9) and are commonly capped with a terrace surface.



Photo 9. Glaciofluvial gravel deposit more than 20 m deep. Located in southeast corner of Albreda project area.

This material type has been mapped in 82 Polygons in Albreda (nearly 20% of the total) and in 9 Polygons in Messiter (3% of the total).

Moraine (M)

Morainal material, also known as till, is the dominant surficial material in both project areas. It has been mapped in 277 Polygons in Albreda (66% of the total) and in 234 Polygons in Messiter (76% of the total). Till deposits are extensive throughout the region. Many of the polygons delineating till deposits are complexed with other materials such as colluvium (*Mb/Cv*) or with bedrock exposures (*Mv/Rk*).

In general, till deposits are absent on the steeper slopes (greater than 70%) and blanket (*Mb*) the lower and mid slopes. Deeper deposits (*Mj*, *Ma*) are present primarily in the valley bottoms. The deposits are dissected by major and minor creeks, and in places stream erosion has resulted in oversteepened banks (*Ms*) susceptible to failure. Till is relatively compact and resistant to erosion in an undisturbed state.

Upon disturbance (e.g., in road construction or in slope failure), it loses much of its original strength. The surface expression of the thinner deposits (*Mv*) is a reflection of the profile of the underlying bedrock. Much of the terrain at higher elevations is bedrock controlled with numerous outcrops and bedrock hummocks. The till deposits in these areas typically mantle (*Mw*) the underlying irregular bedrock with a till veneer (less than 1 m deep) on the steeper slopes, adjacent to a deep pocket (1-3 m deep) of till in the troughs. The surface expression coincides with the irregularity of the bedrock.

Since the time of deposition during glaciation, the upper meter of the material has weathered. The weathered till has a sandy (*s*), silty sandy (*zs*), or sandy silty (*sz*) matrix texture and is fairly permeable. The unweathered material typically has a silty sandy texture and is generally highly consolidated and impermeable. The coarse fragments in both the weathered and unweathered zones are variable in size, and occupy 30% to 80% of the material volume. The clast roundness ranges from sub-angular to round.

Organics (O)

Organics are limited in extent in the two project areas. Organics have been mapped in 2% of the polygons in Albreda and 4% of the polygons in Messiter. The material is associated with bogs and wetlands and is present on gentle slopes. The mapped areas are imperfectly to very poorly drained, and typically the material has accumulated over another surficial material. Organics have been mapped as homogenous units or as a complex with morainal or fluvial deposits.

Bedrock Exposure (R)

Bedrock outcrops and rock covered by a thin mantle (up to 10 cm thick) of unconsolidated organic material have been mapped throughout both project areas (Photo 10). In Albreda, 96 Polygons, or 23% of the total, have been mapped with some degree of bedrock exposure. In Messiter, 94 Polygons, or 31% of the total, have been mapped as encompassing bedrock. There are few areas where bedrock is the only component of a terrain unit, and bedrock polygons often contain colluvium and/or lesser amounts of till and weathered bedrock. On a few scattered slopes, the bedrock is uniform and the surface expression is related to the slope gradient (*Rs*, *Rk*, *Ra*), but in more places the bedrock is irregular and expressed as hummocks (*Rh*) or undulations (*Ru*).





Photo 10. Bedrock exposure typical of Messiter project area.

5.0 GEOMORPHIC PROCESSES

Snow Avalanches (-A)

Snow avalanches have not been mapped in the Messiter project area and only in 30 Polygons in Albreda. This process occurs on the steep slopes of the eastern portion of the project area (Photo 11). The geomorphic process label is included in the polygons where the avalanches initiate as well as in the downslope polygons that are affected by the events. Snow avalanches play an important role in transporting entrained debris to the valley bottom.



Photo 11. Avalanche tracks originating in alpine area of northeastern portion of Albreda project area.

Channeled by Meltwater (-E)

Large and small meltwater channels incised during periods of deglaciation have been mapped in 4 Polygons in the Albreda project area. The channels are incised in glaciofluvial and morainal deposits. The smaller channels have narrow ridges, shallow troughs, and moderately steep sidewalls. The larger channels are incised tens of meters and have steep sidewalls and a wide, flat trough. This process has not been mapped in the Messiter area.

Surface Seepage (-L)

Areas of surface seepage have been mapped in 14 Polygons in Albreda; none in Messiter. Materials affected by these imperfectly to moderately well-drained conditions include till, colluvium, and organics. Many of these areas support shrubs and deciduous trees, including red alder (*Alnus rubra*), devil's club (*Oplopanax horridus*), and skunk cabbage (*Lysichiton americanum*), and the slope gradient ranges from gentle to steep (Photo 12). These areas are often associated with avalanche tracks or the base of long slopes. In most places, the poor drainage is a result of the presence of fine particles (silt and clay) in the matrix of the material. These areas may be susceptible to soil erosion and large-scale slow or rapid mass movement events.



Photo 12. Seepage area characterized by dense shrubs.

Meandering Channel (-M)

The Albreda River channel has been mapped as meandering in one polygon. In this area, there is a regular and repeated pattern of bends. This is typical of the Albreda River along those reaches of the river.

Rapid Mass Movement (-R)

Rapid mass movements occur frequently in both Messiter and Albreda project areas. This process has been mapped in 78 Polygons in Albreda (19% of the total) and in 59 Polygons in Messiter (also 19% of the total).

Processes that have been identified include debris flows, debris slides, rock slides, and rockfall.

Debris Flows (-R"d) and Debris Slides (-R"s)

Debris flows and debris slides are scattered throughout both Albreda and Messiter project areas but are typically associated with the sidewalls along the many creeks and rivers. Many of these slope failures have directly deposited material in sensitive fish-bearing creeks and rivers, while many have indirectly contributed sediment to these watercourses. Much of the terrain that is subject to these types of rapid mass movements is subject to more than one process. The terrain labels are typically a complex of two or three processes, particularly in gullied terrain, where in places it is difficult to make a distinction between a debris slide and a debris flow. After an event has occurred within smaller gullies, it is sometimes difficult to determine if the surficial material slid down the gully or if it was saturated and flowed downstream. The initiation point of a debris flow is not always easily identified, particularly for those areas with air photo interpretation only. As a result, the label for a number of the polygons subject to rapid mass movements has a complex of subclasses.

Typical initiation zones for natural failures include steep bedrock slopes with veneers of colluvium or till, stream banks, or gully sidewalls composed of deep till deposits or colluvium undercut by fluvial action. Gully sidewall failures are more common than open-slope failures. Debris slides or slumps within gully systems commonly deposit in the channel and are later transported downstream. The volume of most of the debris slides is estimated to range from 50 m³ to 1000 m³.

The debris flows in the project areas have initiated on mid or upper slopes in till or colluvium and flowed into creeks or gullies. Many of the larger gully systems are inherently unstable and debris flows may occur relatively frequently, flushing out any material that may have accumulated between events. The volume of the debris flows is estimated to range from 1000 m³ to 10,000 m³, depending on several factors, including distance traveled to the deposition zone and the amount of material entrained in the transport zone.

For both debris slides and debris flows, the geomorphic process label is included in the polygons where the slope failure was triggered (e.g., -R"s) (Photo 13), as well as the downslope polygons that were affected by the event (e.g., -Rs). In most places, an on-site symbol on the map is used to delineate the extent of the failure.



Photo 13. Initiation zone of debris slide that initiated in deep surficial material.

Rock Slides (-R"r) and Rockfall (-R"b)

Rockfall occurs throughout the steep, mountainous terrain of the Albreda project area and less often in Messiter. Much of the terrain in the project areas is bedrock controlled with minimal surficial materials, and the bedrock in the area is highly fractured and jointed. Erosion from bluffs and along gully sidewalls is common. The average rockfall event is small and travels a short distance.

Much of the rockfall occurs within gully systems where the material accumulates in the channel and is eventually transported downstream during episodes of high discharge or debris flows. Rockfall accumulation in the form of cones or aprons at the base of bedrock outcrops and bluffs is less common.

Rock slides occur less frequently than rockfall in the area but are, nonetheless, a significant geomorphic process for transporting material downslope.

The distinction between the two processes is that rockfall involves falling, bouncing, and rolling of dislodged bedrock pieces, and rock slides involve the sliding of the pieces. For both types of events, the geomorphic process label is included in the polygons where the failures were initiated (e.g., -R”r or -R”b), as well as the downslope polygons that were affected by them (e.g., -Rr or -Rb).

Gully Erosion (-V)

There are numerous gullies throughout the region (Photo 14), and gully erosion has been mapped in 59 Polygons in Albreda (14% of the total) and in 49 Polygons in Messiter (16% of the total). Gullies are a significant conduit for transporting material downslope and are important to sediment supplies in the valley bottoms. In many places, the gullies are incised in bedrock. On the lower slopes and in places where the surficial materials are deep, gullies are incised tens of meters in surficial material.



Photo 14. Large gully system in Messiter project area.

Along these reaches the sidewalls are composed of steep surficial material that is susceptible to debris slides. Many of the larger gullies are deep bedrock ravines that are incised more than 50 m and are located along fault lines.

Rapid mass movements are a common occurrence in the gullies in this region and include debris slides, rockfall, and rock slides. In addition, there is evidence that snow avalanches are commonly channelized through some of the gully systems in the area.

Inactive gullying (-V^h)

This has been mapped in one polygon in Albreda and in five polygons in Messiter. This activity qualifier is used for those gullies which were eroded during different hydrologic conditions and as a result, gullying is no longer an active process in that area (i.e., no water flows through the system anymore).

6.0 TERRAIN INTERPRETATIONS

6.1 Terrain Stability

The assessment of terrain stability hazards and the assignment of a terrain stability rating for a given polygon follow the guidelines outlined in the *Mapping and Assessing Terrain Stability Guidebook* (Ministry of Forests 1999). Using field observations, experience with similar terrain in logged and roaded areas, and terrain attributes of a given area, a six-class terrain stability classification was developed for the project area. The criteria developed to define each class are summarized in Table 3.

Terrain attributes influencing the terrain stability rating include surficial material, texture, deposit thickness, slope shape and gradient, presence and form of bedrock outcrops, geomorphic processes, vegetation type, and presence of active or historic instability. During the fieldwork, the initiation zones of several natural and logging-related landslides in the project areas were ground checked, and this information was used to develop the terrain stability criteria.

Each polygon is assigned a terrain stability class. For polygons with a complex of more than one material, the terrain stability hazard rating of the most unstable terrain unit is presented.

Terrain stability classes represent the probability that areas of unstable ground will exist within a polygon with that probability increasing from Class I to Class V. Since polygons are rarely completely uniform, Class III polygons may contain small areas of unstable ground, Class IV polygons typically contain significant areas of stable terrain, and Class V polygons often contain some stable ground.

Class V polygons exhibit active or historic instability. It is believed that development in the form of road construction or timber harvesting will promote or initiate further instability. All polygons mapped in both the Albreda and Messiter project areas include an active geomorphic process and most polygons have multiple processes affecting the terrain. The processes include rapid mass movements and gully erosion. Surficial materials include till, glaciofluvial sediments, colluvium, and weathered bedrock. The slope gradient of the Class V polygons ranges from 40% to 150%, with many of these polygons falling between 70% and 100%. Many unstable slopes have a gradient range of 60% to 80% and consist of deep deposits of till and glaciofluvial sediments. In most cases these are oversteepened surficial material deposits created by stream erosion and undercutting (i.e., erosional slopes). This type of terrain, particularly along streams and creeks, has been subject to many rapid mass movements in the project areas. In contrast, extremely steep (80% to 120%) slopes in competent bedrock with little or no overlying surficial material are relatively stable.

Class IV polygons have similar terrain characteristics to those of Class V, but evidence of instability is generally lacking. Terrain units in Class IV should be treated with a similar level of caution as those in Class V, as their potential instability renders them sensitive to disturbance. The designation of Class IV does not preclude road construction or timber harvesting in the entire polygon. If roads must traverse the polygon, alignments must be carefully placed to minimize the crossing of unstable areas, and special construction techniques will likely be required on some or all road segments.

Class IV_R polygons have terrain characteristics similar to Class III but standard road construction (i.e., balanced cut-and-fill) across the terrain may promote or initiate significant instability along large sections of a road. Surficial materials present in Class IV_R terrain in the Albreda and Messiter project areas include till, glaciofluvial sediments, colluvium, and weathered bedrock.



The typical slope gradient range is 45% to 70%. Geomorphic processes occur in approximately half of the Class IV_R polygons and include gullying, rockfall, rock slides, and debris slides. If road construction is planned across this terrain, a detailed terrain stability field assessment should be conducted and alternative construction techniques (e.g., full-bench construction with end-hauling, engineered fillslopes) can be recommended.

Class III polygons should be interpreted as containing some potentially unstable terrain. In general, these polygons are less problematic than those of Class IV_R, Class IV, or Class V, as Class III polygons have lower inherent instability. Evidence of actual or historical instability is lacking. This stability class is not restricted to any one type of surficial material, soil drainage, slope morphology or position and includes a wide variety of attributes. Active geomorphic processes in these polygons are limited to surface seepage, snow avalanching, rock slides, and rockfall with limited gully erosion. Slope gradients commonly range from 35% to 70%. The designation of Class III does not preclude road construction or timber harvesting in most areas within the polygon but does indicate that increased levels of attention in planning, engineering, and maintenance are necessary, relative to Class I and Class II terrain. Slope failures can occur in Class III terrain, and attention to specific road location is warranted. Inadequate or failed drainage systems on roads can initiate landslides on Class III terrain.

Class II and **Class I** polygons have a relatively low inherent instability and display no evidence of historic or active slope failures. Class II and Class I polygons have a relatively low inherent instability and display no evidence of historic or active slope failures. Planning and engineering do not require special precautions, except those consistent with sound watershed management.

The number of polygons mapped by terrain class is summarized for the Albreda and Messiter project areas in Table 4.

Table 3. Terrain Stability Classification

Terrain Stability Class	Likelihood of Landslide Initiation	Examples of Terrain Attributes	Management Implications
I	Negligible	<p>Well-drained slopes and coarse-textured material on up to 30% slopes.</p> <p>Fine-textured material on < 10% slopes.</p> <p>Floodplains, fans, organics, wetlands.</p>	<p>No significant stability problems expected.</p>
II	Very Low	<p>Well-drained, morainal, colluvial, and glaciofluvial deposits on slopes up to 40%.</p> <p>Imperfect to moderately drained lower and mid-slope with morainal or fine-textured colluvial deposits on slopes up to 40%.</p> <p>Upland plateau areas and bedrock-controlled ridges with organics, till, colluvium, or weathered bedrock on slopes up to 60%.</p>	<p>No significant stability problems expected.</p> <p>Minor slumping expected along road cuts.</p> <p>Regular road inspections should occur and periodic maintenance may be required.</p>
III	Low	<p>Wet or fine-textured morainal deposits on 30% to 45% slopes.</p> <p>Gullied and moderately well-drained morainal deposits on slopes between 30% and 50%.</p> <p>Well-drained morainal and glaciofluvial deposits with slopes between 40% and 60%.</p> <p>Well-drained morainal and/or colluvial deposits complexed with minor bedrock outcrops on slopes up to 65%.</p> <p>Irregular, hummocky, bedrock-controlled terrain with varying drainage and slope gradients up to 75%.</p>	<p>Minor problems of instability should be expected. No natural slope failures are present.</p> <p>Some road-induced instability or erosion may occur. Minor slumping expected along road cuts.</p> <p>Regular road inspections should occur and periodic maintenance may be required. Effective drainage should be maintained.</p> <p>Road construction and/or harvesting may cause sidewall sloughing in gullied terrain.</p> <p>Detailed terrain stability field assessment by a qualified terrain stability specialist is usually not required, but sensitive microsites may require review.</p>

Table 3. Terrain Stability Classification (continued)

Terrain Stability Class	Likelihood of Landslide Initiation	Examples of Terrain Attributes	Management Implications
IV _R	<p>Moderate to High for road-induced landslides</p> <p>Low for harvesting</p>	<p>Wet or fine-textured morainal deposits on 45% to 60% slopes.</p> <p>Moderately well-drained morainal, glaciofluvial deposits, and fine-textured colluvium on 50% to 70% slopes.</p> <p>Well-drained, uniform morainal and glaciofluvial deposits and fine-textured colluvium on 55% to 70% slopes.</p> <p>Well-drained, shallow morainal and/or colluvial deposits complexed with minor bedrock outcrops on slopes up to 75%.</p>	<p>Similar to Class III terrain if harvesting only.</p> <p>Similar to Class IV terrain with conventional road construction.</p> <p>Special construction techniques, regular inspection and maintenance, and permanent deactivation are often recommended.</p> <p>Detailed terrain stability field assessment by qualified terrain stability specialist is required for development of roads and excavated trails.</p>
IV	Moderate to High	<p>Historic or small-scale instability may be present.</p> <p>Wet or fine-textured morainal deposits with > 60% slopes.</p> <p>Wet gully sidewalls with > 55% slopes.</p> <p>Moderately well-drained till, glaciofluvial scarps, and fine-textured colluvium on > 70% slopes.</p> <p>Well to rapidly drained, coarse-textured colluvium on slopes > 75%.</p> <p>Well-drained, uniform morainal and glaciofluvial deposits and fine-textured colluvium on > 70% slopes. Little evidence of small-scale instability.</p> <p>Well-drained, shallow morainal and/or colluvial deposits complexed with minor bedrock outcrops on slopes > 75%.</p>	<p>Wet season construction and harvesting will significantly increase the potential for logging-related landslides.</p> <p>Special road construction techniques, regular inspection and maintenance, and permanent deactivation are usually recommended.</p> <p>Detailed terrain stability field assessment by qualified terrain stability specialist is required prior to development.</p>

Table 3. Terrain Stability Classification (continued)

Terrain Stability Class	Likelihood of Landslide Initiation	Examples of Terrain Attributes	Management Implications
V	High to Very High	<p>Areas where active or recurrent terrain instability is present.</p> <p>High scarps of thick till or complex stratigraphy with recurrent failures or evidence of significant soil creep.</p> <p>Gullied terrain incised in deep till with evidence of instability on sidewalls.</p> <p>Actively eroding or failing scarps of fans and terraces; often undercut by lateral fluvial erosion.</p> <p>Steep-sided gullies or very wet slopes where small-scale instability or surface disturbance is significant.</p>	<p>This type of terrain should normally be avoided during forestry development.</p> <p>Special road construction techniques, regular inspection and maintenance, and permanent deactivation are usually necessary.</p> <p>On-site supervision of road construction is often required. Detailed terrain stability field assessment by qualified terrain stability specialist is required prior to development.</p>

Modified from *Mapping and Assessing Terrain Stability Guidebook* (Ministry of Forests 1999) and *Guidelines and Standards for Terrain Mapping in British Columbia* (Resources Inventory Committee, January 1996).

Table 4. Summary of Polygons Mapped By Terrain Class

Terrain Stability Class	ALBRED A		MESSITER	
	# of polygons	% of total	# of polygons	% of total
I	17	4	23	8
II	106	25	99	32
III	149	36	89	29
IV	56	13	47	15
IV _R	75	18	35	11
V	8	2	13	4

6.2 Soil Erosion Potential

As for terrain stability, soil erosion potential has been rated for each polygon. The assessment of soil erosion potential and the assignment of a rating for a given polygon follow the guidelines outlined in the *Mapping and Assessing Terrain Stability Guidebook* (Ministry of Forests 1999). Soil erosion is defined as the detachment, entrainment, and transport of individual sediment particles by water or wind.

Using field observations, experience with similar terrain in logged and roaded areas, and terrain attributes of a given area, a five-class soil erosion potential classification was developed for the project area. The criteria developed to define each class are summarized in Table 5. For the assignment of soil erosion potential rating it is assumed that the forest floor has been removed and bare soil is exposed. The classes range from VL (very low) to VH (very high). The soil erosion potential class provides only the probability that exposed mineral soil will erode; it does not provide a measure of the likelihood that sediment produced will enter a stream network.

Soil erosion is a function of surface cover, mineral soil type and texture, slope gradient, slope length and shape, and rainfall intensity. Silts and fine sands are the textures deemed most susceptible to erosion because of the ease of particle detachment under the entraining influence of water or wind. Clay-rich soils resist detachment because of cohesive forces acting between particles. Long, steep, uniform slopes are most at risk because surface runoff will gain high velocities and high entraining powers.



Broken slopes with numerous surface irregularities are less prone to erosion as runoff is interrupted. An area subject to concentrated seepage or runoff during high rainfall renders all exposed mineral soil highly subject to erosion.

Surface cover is an extremely influential factor controlling surface erosion. For example, road construction surfaces where there is minimal or no surface cover, such as fillslopes, cutbanks, ditches, or the running surfaces of roads, are highly susceptible to erosion. In addition, poor deflection in cable yarding, or disturbance in skidder or feller-buncher operations may result in extensive exposure and subsequent erosion of mineral soil. A reasonable standard of care for controlling erosion is necessary at all stages of logging operations.

The number of polygons mapped by soil erosion potential is summarized for the Albreda and Messiter project areas in Table 6.

Table 5. Soil Erosion Potential Classification

Soil Erosion Potential	Typical Slope Range	Dominant Texture	Soil Drainage	Other Factors	Management Implications
Very Low (VL)	< 10%	Blocks, rubble, silt, mud	Very poor to imperfect, rapid	Flat or very short slopes	Low concern for sediment production.
Low (L)	5% to 40%	Blocks, rubble, silt, mud, coarse sand, gravel	Poor to rapid	Short slopes, small catchment area	Erosion limited to channels and stream banks. Expect minor erosion of fines from ditch lines and disturbed soils. Exercise care not to channelize water onto sensitive sites.
Moderate (M)	30% to 70% on M and C, 0% to 40% on F and FG	Rubble, silt, mud, coarse sand, gravel	Imperfect to well	Moderate to long slopes with small to medium catchment area	Expect some problems with disturbed sediments. Plan additional measures to reduce sediment production where entry into stream network is likely.

Table 5. Soil Erosion Potential Classification (continued)

Soil Erosion Potential	Typical Slope Range	Dominant Texture	Soil Drainage	Other Factors	Management Implications
High (H)	> 70% on M, > 80% on C, 40% to 70% on F and FG	Silt, sand	Moderate to well	Long slopes, large catchment area, some gullying	Water management is critical. Care should be taken to prevent soil erosion. Mitigative measures should be employed during road construction. <u>Detailed site inspection by terrain or soils specialist is recommended.</u>
Very High (VH)	> 70% on F and FG, > 80% on M	Silt, sand	Moderate to well	Long slopes, large catchment area, active gullying, active geomorphic processes	Site disturbance should be avoided. Severe surface and gully erosion problems exist. No water should be channelized onto these sensitive sites. Disturbed sites should be rehabilitated immediately. <u>Detailed site inspection by terrain or soils specialist is recommended.</u>

Modified from *Mapping and Assessing Terrain Stability Guidebook* (Ministry of Forests 1999) and *Guidelines and Standards for Terrain Mapping in British Columbia* (Resources Inventory Committee, January 1996).

Table 6. Summary of Polygons Mapped By Soil Erosion Potential

Soil Erosion Potential	ALBRED A		MESSITER	
	# of polygons	% of total	# of polygons	% of total
VL	0	0	5	2
L	159	38	150	49
M	164	39	100	33
H	69	16	50	16
VH	19	5	1	<1

6.3 Potential Sediment Delivery from Surface Erosion Sources

The potential for sediment delivery from a surface erosion source has been rated for many of the polygons. This rating represents the likelihood that sediment from an erosion source in a given polygon will be entrained, transported, and delivered to a watercourse. Following the guidelines outlined in the *Mapping and Assessing Terrain Stability Guidebook* (Ministry of Forests 1999), this interpretation is made for only those polygons that have a high (H) or very high (VH) soil erosion potential.

A five-class system was used to rate the potential for sediment delivery from a surface erosion source, ranging from very low (vl) to very high (vh). The criteria used to define each class are summarized in Table 7.

During the initial air photo interpretation, the potential for sediment delivery from surface erosion sources was mapped on the air photos as a three-class system, with ratings of 1 for low, 2 for moderate, and 3 for high. During the building of the databases, polygons were reassessed and the classification presented in Table 7 was adapted. However, the air photos were not modified. Therefore, the five-class system in Table 7 is included in the final digital files but not reflected on the air photos.

In the Albreda project area, 88 Polygons had a soil erosion potential of high or very high and were therefore rated for PSDSES. In the Messiter project area, 51 Polygons had a soil erosion potential of high or very high and were rated for PSDSES. The distribution of these ratings is summarized in Table 8.

Table 7. Potential Sediment Delivery from Surface Erosion Sources Classification

Risk of sediment delivery to streams	Proximity of stream channel to polygon		
	No stream channel in or adjacent to polygon	Minor stream* channel in or adjacent to polygon	Major stream** channel in or adjacent to polygon
Very Low (vl)	Gentle to steep slope		
Low (l)		Gentle slope	
Moderate (m)		Moderate slope	Gentle slope
High (h)		Steep slope	Moderate slope
Very High (vh)			Steep slope
	Slope steepness downslope from polygon to stream channel		

* Minor streams are those perennial streams with channel widths that are less than or equal to 1.5m, or any ephemeral stream

** Major streams are perennial streams with channel widths that are greater than 1.5m.

From *Mapping and Assessing Terrain Stability Guidebook* (Ministry of Forests 1999).

Table 8. Summary of Polygons Mapped for PSDSES

potential for sediment delivery from a surface erosion source	Albreda		Messiter	
	# of polygons	% of total	# of polygons	% of total
vl	3	3	4	8
l	13	15	2	4
m	35	40	1	2
h	35	40	33	65
vh	2	2	11	22



7.0 MANAGEMENT CONCERNS AND RECOMMENDATIONS

Terrain instability poses a risk to water quality, fish habitat, site productivity, and visual quality, and logging and related activities can affect the stability of a hillslope in several ways:

- Road construction can increase landsliding by diverting and concentrating water flows.
- Ground-based harvesting can lead to diverted flows and the saturation of areas of a hillslope that do not otherwise receive as much water. This in turn can lead to landslides.
- Where cut-and-fill road construction crosses steep slopes, roads can create unstable fillslopes subject to failure when they saturate or when incorporated stumps and logs collapse.
- Cutslopes can undercut soil mantles above the slope, leading to debris slides (Photo 15).



Photo 15. Large cutslope failure in deep glaciofluvial deposits, located in the northeastern portion of the Albreda project area.

- Timber harvesting can reduce the shear strength of the surface mantle of soil through the loss of root strength as tree roots rot.
- Timber harvesting may result in locally increased blowdown that could divert flows onto otherwise stable hillslopes.
- Timber harvesting may increase soil erosion and the subsequent transport of sediment downstream.

Timber harvesting can alter the forest hydrology and lead to increased runoff in streams and increased soil moisture, which will impact the landscape in a number of ways, including the initiation of landslides and increased channel scour.

There are a number of measures that can be taken to minimize the effect of logging on terrain stability. The most effective measure is to avoid areas of high risk (i.e., consideration of both hazard and consequence). The primary objective of this mapping exercise is to allow areas of high hazard to be identified in the planning stages and thus be avoided.

The occurrence of Class IV_R, Class IV, and Class V terrain has been discussed in Section 6.1. Terrain with these stability ratings should be closely inspected prior to any development. Development on Class V terrain should be avoided where possible. Terrain within Class IV polygons is not all inherently unstable, but is likely to contain smaller areas that are. Thus it may be possible to develop a portion of Class IV terrain, still avoiding the unstable components within the polygon. An on-site terrain stability field assessment by a qualified professional is required to ensure that such components will not be affected by the development and that the road design will not result in unstable fillslopes.

In general, it is not necessary to avoid Class III polygons in harvesting and road construction plans. However, a risk management approach is still necessary. Class III polygons may contain small areas of potential instability. Where the consequence of slope failure is significant, for example, above a steep gully leading down to a creek, extra care in hazard evaluation and monitoring of operations is warranted.

Besides avoidance of sensitive areas, there are other methods of minimizing or eliminating the effect of road construction and logging on terrain stability, and these are described below.



7.1 Road Construction

- Proper planning, construction (including supervision), and deactivation of logging roads and skid roads can minimize water diversion or concentration problems. Planning includes the placement, spacing, and sizing of culverts.
- Full-bench construction, coupled with appropriate sidecast treatment, such as full or partial end-haul, will reduce the hazard of fillslope failures on roads built on hillslopes greater than 60% to 70% (depending on terrain and material).
- Cutslope instability can be prevented by avoiding road construction across steep slopes with deep deposits.
- Proper watershed management measures in road construction and maintenance will minimize the amount of sediment produced along roads. Careful water management is especially necessary during construction, when the potential for generating sediment is greatest.

Appropriate drainage structures are necessary when pioneered roads cross watercourses. Near watercourses, sediment-laden water from ditches should not be allowed direct access to free-flowing streams. Where a high or very high soil erosion potential has been mapped, extra care is needed to protect soils from erosion.

7.2 Timber Harvesting

- The loss of root strength after clearcutting an area is a temporary effect that diminishes as the forest regenerates. Prompt regeneration of fast-growing stock will reduce the window of vulnerability and reduce the likelihood that slope failures will occur resulting from root strength loss. However, a period of at least 30 years will pass before the slope approaches its previous stability, and landslides will still occur if the slope remains otherwise unstable.
- Maximizing deflection of cables and minimizing ground lead during yarding will minimize surface scour and prevent the creation of ruts where surface water can channelize.

8.0 LIMITATIONS

This mapping is based on air photo interpretation with limited field checking. The terrain unit boundaries should not be considered to be precise. If logging or road construction encroaches on Terrain Stability Class IV_R, IV, or V terrain or terrain with a Very High (VH) Soil Erosion Potential, a detailed field check is warranted. The mapping is intended to assist in planning but does not take the place of site-specific work.

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9.0 REFERENCES

Atmospheric Environment Service. 1993. *Canadian Climate Normals, 1961 To 1990*. British Columbia. Can. Climate Prog. Ottawa. 134 pp.

British Columbia Ministry of Forests. 1999. *Mapping and Assessing Terrain Stability Guidebook*. Forest Practices Code. Victoria, BC.

British Columbia Ministry of Forests and Range. 2006. *Biogeoclimatic Zones of British Columbia*. Victoria, B.C.

Holland, SS. 1976. *Landforms of British Columbia: A Physiographic Outline*. B.C. Department of Mines and Petroleum Resources, Bulletin 48, Victoria, B.C.

Howes, DR and E. Kenk. 1997. *Terrain Classification System for British Columbia (Revised Edition)*. Min. Environment Manual 10. Victoria, BC.

Massey, NWD, MacIntyre, DG, Desjardins, PJ, and RT Cooney. 2006. *Digital Geology Map of British Columbia, Tile Nn11 Mid Rockies and Tile Nm11 Southeast BC*. BC Ministry of Energy and Mines, Geofile 2005-6.

Resources Inventory Committee. 1996. *Guidelines and Standards to Terrain Mapping in British Columbia*. Surficial Geology Task Group, Earth Sciences Task Force, Victoria, BC.

10.0 TERRAIN PHOTO INVENTORY

10.1 Albreda

30BCC00096, No. 131-137

30BCC00096, No. 118-126

30BCC00096, No. 049-057

30BCC00096, No. 031-039

30BCC00101, No. 180-186

30BCC00101, No. 160-164

30BCC00095, No. 166-170

30BCC00095, No. 189-192

30BCC00101, No. 103-106

10.2 Messiter

30BCC00011, No. 176-178

30BCC00022, No. 001-003

30BCC00092, No. 109-111

30BCC00092, No. 154-157

30BCC00092, No. 198-200

30BCC00093, No. 021-023

30BCC00049, No. 190-193

30BCC00050, No. 018-022

30BCC00050, No. 122-125

30BCC00050, No. 168-172

30BCC00055, No. 048-053

30BCC00049, No. 088-094

30BCC00023, No. 100-104

30BCC00023, No. 048-051

