Sensitive Ecosystems Inventory: Kelowna, 2007

Volume 2: Terrestrial Ecosystem, Terrain, Terrain Stability, and Soil Erosion Potential Mapping, and Expanded Legend

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THE REAL ESTATE FOUNDATION OF BRITISH COLUMBIA

City of Kelowna

BRITISH COLUMBIA

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This project has adapted material from the reports for the Bella Vista – Goose Lake Range Sensitive Ecosystems Inventory[8] (SEI), Coldstream Vernon SEI[9], Vernon Commonage SEI[10], Lake Country SEI[11] and Central Okanagan SEI[12].

We would like to thank the many landowners that gave us permission to access their lands for field sampling.

Todd Cashin reviewed the draft version of this report.

[1] The mission of the Real Estate Foundation is to support sustainable real estate and land use practices for the benefit of British Columbians.
[2] City of Kelowna
[3] Iverson & MacKenzie Biological Consulting Ltd.
[4] Polar Geoscience Ltd.
[5] Makonis Consulting Ltd.
[6] Working on behalf of Timberline Forest Inventory Consultants Ltd. at that time
[7] Baseline Geomatics Inc.
[8] Iverson and Shypitka 2003
[9] Iverson and Uunila 2008
[10] Iverson and Uunila 2005
[11] Iverson and Uunila 2006
[12] Iverson et al. 2004

Introduction

This report presents detailed information on terrain and ecosystems in the City of Kelowna in the central portion of the Okanagan Valley. It is the second volume in a series of two volumes.

Volume 2, this report, provides detailed information on terrestrial ecosystem mapping (TEM) methods and gives descriptions of each of the ecosystems that occur within the sensitive ecosystems or other important ecosystems categories described in Volume 1. Appendix B of Volume 1 provides tables that can be used to cross-reference between sensitive and other important ecosystems units and terrestrial ecosystem map units in this report.

This report describes the natural setting of the study area and details methods, results and recommendations for bioterrain, terrain stability and soil erosion potential mapping and ecosystem mapping. It is intended for use by professionals that require more detailed ecological and terrain information.

Volume 1[13] is intended for people and organizations that need information to help conserve and protect remaining sensitive and important ecosystems in the Kelowna area and other similar areas. It is also intended to provide information and advice to the City of Kelowna, landowners, and developers on how to minimize and avoid possible degradation of sensitive ecosystems due to land use and development activities.

[13] Iverson 2008b

Table of Contents

List of Figures

List of Tables

1 Study Area

The study area (Figure 1) lies within the central Okanagan Valley of south-central British Columbia. The boundaries of the study area follow the boundaries of the City of Kelowna. The study area was mapped in two separate pieces: the South Slopes area was updated from the Central Okanagan SEI and the remainder of the City of Kelowna was newly mapped. The area covers 21,445 ha (the City of Kelowna excluding Okanagan Lake) and includes private land and regional parks, and crown land.

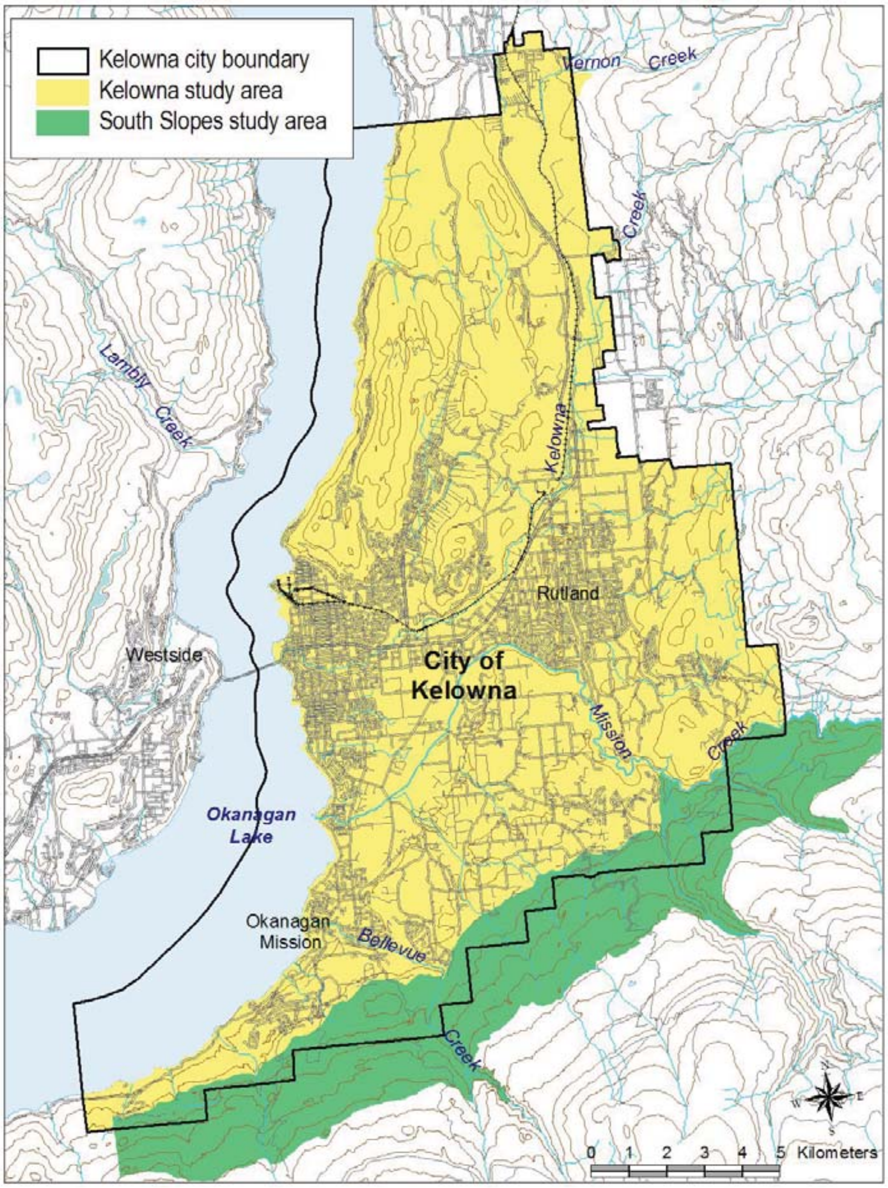

Figure 1. Kelowna SEI study area boundary is shown in black (boundary of the City of Kelowna). The newly mapped portion of the City of Kelowna is shown in yellow and the updated South Slopes portion of the study area is shown in green.

1.1 Landscape Setting

The Okanagan Valley is a major valley of the Interior Plateau. It is situated in the Thompson Plateau, a low relief upland area that represents a Late Tertiary erosion surface. Uplift, faulting and erosion created the major valleys in the Thompson Plateau, including the Okanagan Valley. Okanagan Lake occupies the main trench and Duck, Kalamalka, and Wood Lakes occupy a parallel valley to the east. Okanagan Lake drains to the south into the Okanagan River through Osoyoos Lake and into the United States. The Okanagan drainage is a tributary of the Columbia River. The valley generally lies north-south in the study area.

Bedrock Geology

The slopes of the study area are underlain by a variety of bedrock types of various ages. Characteristics of bedrock, such as structure (i.e. strength, joint spacing, and presence of bedding) and mineral composition impact slope stability, potential for wildlife habitat and nutrient regime[14]. These characteristics influence the shape and size of clasts and matrix texture of colluvium and till. The following describes the bedrock in the study area by geographic location from north to south[15].

The northern edge is underlain by middle Jurassic-aged, intrusive bedrock of the Okanagan Plutonic Suite, including granodiorite and granite. Well-jointed, granitic rocks break into large blocks and boulders and can produce bouldery tills. On weathering, the rock breaks down into sand and minor silt and consequently, areas of granitic bedrock tend to produce till with a silty sand matrix. These rock types tend to produce poor nutrient regimes.

The west-facing slopes in the McKinley Landing area are underlain by Carboniferous to Permian-aged volcaniclastic rocks of the Harper Ranch Group. The core of the study area is underlain by Eocene-aged volcanic rocks of the Penticton Group. An impressive exposure of layered lava flows can be seen on the south face of Layercake Mountain. Bedrock derived from volcanic flows gives rise to cliffs, ledges and rubbly talus. Volcanic rocks break down into rubble and blocks which weather into silt and clay. Widely scattered weathered tuff layers are locally present. These consist largely of clay, and in combination with clay from weathered lavas, produce a noticeably clay-enriched till. Non-siliceous volcanic rock (i.e. basalt) tends to give rise to medium nutrient regimes. Like intrusive bedrock, rock with higher silica content (i.e. rhyolite) gives rise to poor nutrient regimes.

The Mission and Crawford Estates areas of Kelowna are underlain by Eocene-aged sedimentary rocks of the Penticton Group, including mudstone, siltstone, shale, and fine clastic sedimentary rocks. Fine-grained sedimentary bedrock breaks down into silt and clay and, where bedded, the rock tends to fracture along bedding planes to produce slab-shaped clasts. These rock types are relatively nutrient rich.

The eastern and southern perimeter of the City of Kelowna is underlain by Proterozoic to Paleozoic-aged metamorphic rocks of the Shuswap Assemblage. These are the oldest rocks in the study area and are paragneiss; gneiss that is formed by the severe metamorphosis of sedimentary rock. This group also includes zones of less metamorphosed sedimentary rock such as schist, amphibolite and quartzite. Field observations revealed that the Monashee Group rocks

[14] EBA Engineering Consultants Ltd., 1998
[15] Sources: Templeman-Kluit ,1989; Glombick et al., 2004; and The Map Place, 2008

form ledges, overhangs, fissures and blocky talus that have important wildlife habitat values. Metamorphic rock that is largely granular in texture, for example gneiss, tends to break down into sand and coarse silt, resulting in silty sand till. The relatively massive inner core gneiss tends to break into large blocks. Finer-grained metamorphic bedrock of sedimentary origin (i.e. schist, argillite, greenstone, and limestone) tends to break down into silt and fine sand and consequently result in a sandy silt matrix till. Many of the rocks include variable amounts of mica and chlorite. These tend to break into pebble-sized rubble and flaggy slabs and consequently, boulders and blocks generally are uncommon. Highly foliated and weak bedrock such as phyllite can be unstable at gentler slopes than stronger rock types and does not provide a solid foundation for surface structures. Many metasedimentary rock types tend to be nutrient-rich.

Landscape Evolution[16]

The present physiography dates back two hundred million years ago (early Jurassic) when plate tectonics welded the former Pacific Ocean to the margin of the North American continent. This created ridges of metamorphic and plutonic bedrock orientated in a north-south direction. About 50 million years ago (early Tertiary), plate tectonics caused uplift of the area accompanied by extensive volcanism. A long period of relative stability followed, during which erosion and deposition formed a low-relief landscape with gentle slopes and low hills. During late Tertiary, the area was subject to uplift again, followed by a renewed period of down cutting, and stream valleys incised deeply into the old erosion surface.

Both the upland surface and the steep-sided valleys were completely buried by ice during the Pleistocene glaciation. However, glaciers effected only relatively minor modifications to the older topography. Most of the surficial materials date from the last glaciation.

At the beginning of the last major glacial episode (Fraser Glaciation), ice accumulated in the high mountains and then gradually spread to valleys and lowlands. About 14,500 years ago, when the Cordilleran Ice Sheet was thickest and most extensive at the climax of Fraser Glaciation, ice flowed generally southward across the study area[17]. The rounded ridge tops suggest that the entire area was completely overridden by ice at this time, depositing till at the base of the ice sheet.

Deglaciation occurred between about 14,000 and 11,000 years ago. Deglaciation took place by downwasting so that the uplands emerged from beneath the ice while tongues of ice remained in the valley bottoms[18]. Stagnant ice in the valley bottoms impounded temporary glacial lakes in the Okanagan Valley (Glacial Lake Penticton). Downwasting ice often forms characteristic subglacial and ice-marginal landforms on gentle surfaces, such as, eskers, kames, and meltwater channels.

During post-glacial times, processes have re-worked some glacial sediments and weathered bedrock to redistribute them as colluvium (moved by gravity) and fluvial (moved by water) sediments. Some streams and rivers that have graded to the present day lake level have downcut into glacial deposits creating terraces, benches, and steep-sided scarps. Eolian sediments have been transported by wind and deposited on the gentler slopes throughout the study area. Fine-grained sediments have accumulated in depressions due to slope wash.

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[16] adapted from Iverson et al. 2004
[17] Fulton 1965
[18] Fulton 1969

Soils[19]

Soil forms the interface between surficial materials (parent materials) and the ecosystems they support. Ecosystems influence the formation of soils and soil affects what types of plants grow at a given site and the productivity of that site. Soil is defined as "naturally occurring, unconsolidated mineral or organic material at least 10cm thick that occurs at the earth's surface and is capable of supporting plant growth"[20]. Factors affecting soil formation include: parent material, climate, biota, (including the vegetation, wildlife and organisms in the soil), topography (for example: slope, aspect, and slope morphology), and time.

The following descriptions of soil types are derived from Wittneben (1986). Further descriptions of soil horizons and soil taxonomy can be found in The Canadian System of Soils Classification[21]. The following paragraphs describe the major soil groups present in the study area. Soils were not mapped in this project but soil information was collected as part of the field data at ground inspection sites (see Field Sampling, page 11).

Chernozemic soils (brown and dark brown chernozems) have developed in the semi-arid lower valley grassland and open forest communities. These are characterized by the formation of an organic rich (Ah) upper mineral horizon. The Ah horizon forms from the accumulation of organic material primarily from the roots of grasses.

Brunisolic soils occurred throughout the study area. They were common under forested communities on moister and cooler aspects. These soils were present on moderately- to rapidly-drained surficial materials that are medium- to coarse-textured. These are soils that have poorly developed horizons. They have characteristics of other soils groups but have not developed sufficiently to meet the criteria to belong to other orders. They are often found in a complex with other soil types including chernozems, luvisols, and gleysols.

Luvisolic soils are present on moderately- to rapidly-drained clay-rich parent materials such as muddy glaciolacustrine deposits and finer textured tills. These soils are characterized by the movement of clay particles from the upper horizons to a lower horizon of accumulation (Bt). Luvisols occurred under both forested and grassland communities in the Interior Douglas-fir and Ponderosa Pine Zones.

Organic soils develop under wet conditions where decomposition rates are relatively slow and a net accumulation of organic material (peat) occurs. Most organic soils are poor- to very poorly-drained and are saturated for prolonged periods of time. Organic soils occur under wetland communities in depressions, along lake margins and on floodplains.

Gleysolic soils develop under moist to wet conditions usually in depressions, toe slopes, and on valley bottoms. They are mineral soils formed under periodic or sustained reducing conditions caused by water saturation, and result in gleyed colours (grey, blue, and green). Gleysolic soils are imperfectly to very poorly drained and occur under wet forests and wetland communities.

Regosolic soils are under-developed soils that lack defined horizons. Regosols were common on floodplains and talus slopes throughout study area. They develop on recent parent materials such as landslide and river deposits; recently exposed materials such as landslide scarps and eroded

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[19] This section is adapted from Iverson et al. 2004
[20] Soil Classification Working Group 1998
[21] Soil Classification Working Group 1998

banks; or under conditions that suppress soil formation, for example, extremely dry conditions (very rapidly drained, coarse textured soils on southerly aspects). Regosols are often associated with non-vegetated or early successional plant communities.

Solonetzic soils occur on saline parent materials in semiarid to subhumid regions of the B.C. interior. No solonetzic soils were recorded during fieldwork; however, they likely occurred in small non-vegetated or sparsely vegetated pockets in depressions and toe slope positions. These soils are often used as salt licks by wildlife and thus have high wildlife values. They occur in association with chernozemic soils and to a lesser degree with gleysolic and luvisolic soils.

Climate

The study area is located within the northern portion of a dry climatic system resulting in warm, dry conditions[22]. The Coast and Cascade Mountains create a rain shadow effect in the interior of British Columbia, reducing summer and winter precipitation. In summers, hot dry air moves in from the Great Basin to the south.

Within British Columbia, the climate of this region has resulted in semi-arid steppe vegetation. Together with unique geological and landscape features, this has resulted in a diverse and unique assemblage of species in the Okanagan Valley.

Ecoregional and Biogeoclimatic Classification

The study area is located within the Southern Interior Ecoprovince, the northern extension of the Columbia Basin that extends south to Oregon[23]. Situated within the southernmost region of the Interior Plateau of British Columbia, the region lies west of the Columbia Mountains and east of the Coast and Cascade Mountains within the North Okanagan Basin Ecosection (NOB), a wide trench formed by parallel fault lines and further carved out by multiple glaciations.

The Ministry of Forests biogeoclimatic ecosystem classification is a system of classifying vegetation based on climatic and topographic patterns[24]. Two biogeoclimatic variants are represented within the study area: the Okanagan Very Dry Hot Interior Douglas-fir Variant (IDFxh1) and the Okanagan Very Dry Hot Ponderosa Pine Variant (PPxh1). Figure 2 shows the locations of the subzones within the study area.

The **IDFxh1** is the driest variant of the Interior Douglas-fir zone; it has a long growing season with warm, dry summers, and summer drought. Winters are cool with low to moderate snowfall. Most portions of the IDFxh1 are dominated by mixed open forests of Douglas-fir and ponderosa pine; the study area also has extensive areas of grasslands. The IDFxh1 occurs along the south-eastern portion of the study area at higher elevations.

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[22] Demarchi 1996

[23] The ecoregional classification system was developed and adapted by the Ministry of Environment, Lands & Parks, Wildlife Branch, to provide a systematic view of the small scale ecological relationships within British Columbia. See Demarchi 1996 for further information.

[24] The Biogeoclimatic Ecosystem Classification system was developed by the Ministry of Forests to provide a basis for natural resource management, particularly forest management and range management. See Pojar et al. 1987 for further information.

The **PPxh1** is the driest forested zone in British Columbia[25]. Occurring only at lower elevations in the southern valleys of British Columbia, it is at the northern extent of a much larger range that runs south through eastern Washington and Oregon. Cool winters with low snowfall and hot dry summers with growing-season moisture deficits result in a mosaic of open forests and grasslands. The PPxh1 covers the majority of the City of Kelowna.

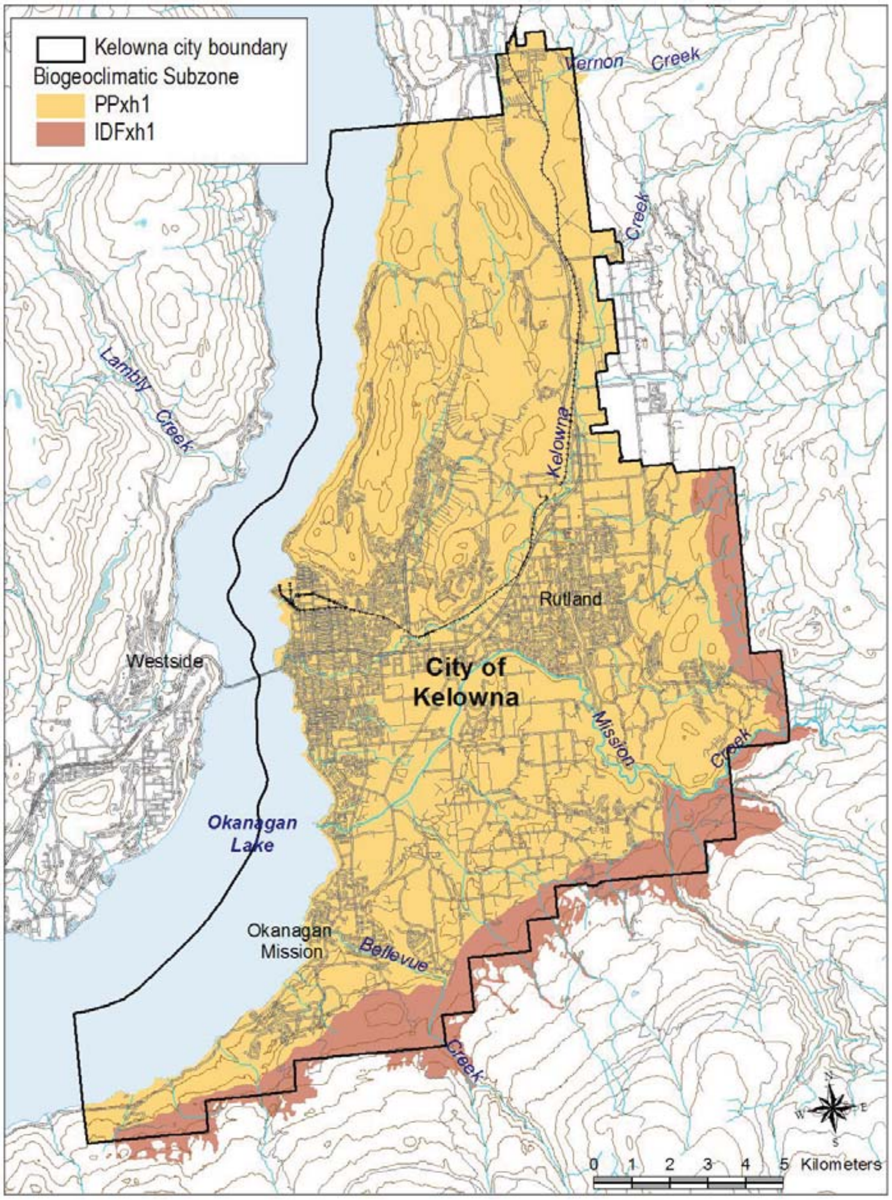

Figure 2. Biogeoclimatic subzones present in the study area.

[25] Lloyd et al. 1990

1.2 Ecology and Disturbance Processes

Historically, frequent low-intensity surface fires maintained grasslands and open Douglas-fir and ponderosa pine forests. Fires were likely ignited by both lightning and First Nations peoples. First Nations people used fire to improve wildlife habitat, root crops (for example, mariposa lily and balsamroot) and likely to fireproof their villages[26]. Most native grassland plants are well adapted to fire through perennating buds or seeds just at or below the ground surface where fire temperatures are cooler[27]. Figure 3 shows a prescribed fire similar to many historical fires.

Figure 3. Understory fire similar to how most historical fires burned.

Frequent fire maintained forest understories dominated by bunchgrasses and shrubs and promoted nutrient cycling. Most grasses, forbs, shrubs and mature trees survived most fires, but small trees likely often died[28]. Historically, forests were mostly very open with grassy, shrubby understories. Moister sites were more productive and likely more closed and shrubby. Fires also contribute to nutrient cycling, releasing nutrients that are otherwise very slowly released through decay processes.

The exclusion of most fires (dating back to the time of intensive grazing in the late 1800's) has lead to striking changes in these ecosystems. Some areas that were formerly grasslands have been encroached upon by trees and are now dominated by trees (Figure 4).

Tree densities are now much higher in forests (Figure 5). Dense forests with accumulated fuels have lead to declines in grass and shrub productivity, increasing susceptibility to insect and disease outbreaks, and a shift from frequent low-severity fires to larger, more intense crown fires[29] such as the Okanagan Mountain fire in the summer of 2003.

Moisture is very limiting in these dry forest ecosystems and available moisture is critical for the survival of ponderosa pine seedlings. Ponderosa pine seedlings, with a deeper taproot, are better able to survive moisture depletion than Douglas-fir seedlings.

Historically, the principal grazing animals were likely primarily deer and elk[30]. Domestic cattle grazing began in the late 1800's and many of the grasslands in the study area have reduced cover of the more grazing-sensitive species such as bluebunch wheatgrass, Idaho fescue, and rough fescue and have more cover of grazing-resistant native grasses such as Columbian needlegrass, junegrass and Sandberg's bluegrass[31]. Some grasslands have been overtaken by invasive alien plants such as knapweed, sulphur cinquefoil and cheatgrass, an annual brome grass. Pockets of late seral and climax grasslands occur primarily on steeper slopes in the study area.

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[26] Blackstock and McAllister 2004; Turner 1994; Pokotylo and Froese 1983; Daubenmire 1969
[27] Daubenmire 1969
[28] Agee 1993
[29] Moore et al. 1999; Fule et al. 1997; Daigle 1996; Filmon 2004
[30] Tisdale 1947
[31] Dormaar et al.1989; McLean and Wikeen 1985; Daubenmire 1940

Figure 4. Encroachment of young ponderosa pine trees onto a grassland ecosystem. With time, this will become a dense forest with few grasslands species.

Figure 5. Ingrown stand resulting from fire exclusion. In this stand, there are likely about 100 times more trees than there were historically.

1.3 Human History

The semi-arid climate of the central Okanagan, with its hot summers and mild winters, has long attracted human habitation. Archaeological evidence indicates that humans have been present in the Okanagan valley for at least 6000 years. The valley provided water, wildlife for hunting, fish, roots, berries, herbs, and other foods and medicines for First Nations peoples[32].

Following the discovery of gold in British Columbia, ranchers from western Oregon came and settled in the dry interior valleys of B.C. Cattle were turned loose on the unfenced range and by the late 1870's most grasslands had deteriorated due to overgrazing[33].

Early forest harvesting was localized but became industrial and more widespread by the mid-1900's[34]. We observed that all accessible areas of the study area had been selectively harvested, leaving very few large, old trees.

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[32] Cannings and Durance 1998; Thomson 2000
[33] Blackstock and McAllister 2004; Mather 1996
[34] Cannings and Durance 1998

2 Methods and Limitations

2.1 Terrain Mapping

Terrain mapping is a classification system used to describe the surficial material (the loose materials on top of bedrock) and their textures, surface expressions (the three dimensional shape of the surficial materials), and geomorphological processes (the active mechanism that continue to shape the landscape) in a given area.

A terrain map is a map of surficial materials; it shows the surficial material type and thickness combined with surface expression or landform type (and geomorphological processes if applicable). Each surficial material type is classified based on its genesis. It has its own characteristics of deposition and therefore physical properties such as texture and consolidation.

Terrain maps are the basis for many kinds of land use planning, including terrain stability, ecosystem mapping, planning of urban roads and development, assessment of geological hazards, and aggregate mining. Terrain mapping with an ecological emphasis is called bioterrain mapping. Bioterrain mapping forms the basis of terrestrial ecosystem mapping (TEM) by delineating polygons with similar ecological conditions such as soil moisture, aspect, and vegetation characteristics.

Terrain mapping is based on air photo interpretation, which is then ground-truthed in the field. For this project, terrain mapping followed the standard British Columbia procedures for terrain classification[35], mapping methods[36], terrain stability mapping[37] (five-class system) and bioterrain mapping methodology[38].

Project terrain mapping was more detailed than is typical as criteria for both bioterrain and terrain stability mapping were used during polygon delineation. Delineation was based on the following:

- terrain type;
- material depths;
- drainage;
- slope breaks;
- slope position;
- aspect: cool (from 285 to 135°) and warm (from 135 to 285°);
- geomorphological processes;
- surface expression and slope morphology (e.g., concave or convex);
- terrain stability class;
- soil erosion potential class;
- vegetation changes;
- riparian zones and corridors; and

[35] Howes and Kenk 1997
[36] Resources Inventory Committee 1996
[37] Ministry of Forests 1999
[38] Resources Inventory Committee 1998

- any other ecologically significant areas such as cliffs, talus slopes, and ponds or wetlands.

The bioterrain pre-fieldwork mapping was completed by Anthony Collett, P.Geo. of Timberline Forest Inventory Consultants Ltd. in 2005 under a separate contract with the Ministry of Water, Land and Air Protection (WLAP)[39]. Terrain units were delineated using a (Digital image Analytical Photogrammetry (DiAP) Viewer and workstation using 1:10,000 scale, 2003, colour digital imagery. Each polygon was labelled with a terrain symbol and drainage class. Existing bioterrain mapping completed for project areas adjacent to Kelowna was obtained from the City of Kelowna, and B.C. Ministries of WLAP and Sustainable Resource Management, and used for edge matching to the Kelowna area. Integrated Mapping Technologies of Vancouver, B.C., converted the spatial files into a format for viewing on a DiAP Viewer.

Under the current contract with the City of Kelowna, Polly Uunila, P.Geo. of Polar Geoscience Ltd. field checked the bioterrain polygons and completed the post-fieldwork editing of the bioterrain mapping using a DiAP Viewer. At the request of the City of Kelowna, slope range (in percent), terrain stability class and soil erosion potential class were added to each polygon.

Field Sampling

Polly Uunila, P.Geo., a terrain specialist spent a total of 15 days collecting terrain information, including 7 days sampling with an ecosystem specialist.

Two types of sample plots were used to identify and assess ecosystems and terrain: ground inspections, and visual inspections (Appendix A: Field Plot Forms). Field sampling procedures for ground inspections are outlined in *Field Manual for Describing Terrestrial Ecosystems*[40]. We followed guidelines from the *Standard for Terrestrial Ecosystem Mapping* in British Columbia[41] for visual inspection data collection. Additional plot data from the original field sampling for the South Slopes in 2001, including one detailed ecological plot, was also used for the mapping in that area (terrain data were collected by D. Spaeth Filatow, P.Geo.).

Additional information regarding terrain stability and erosion potential was collected by Polly Uunila, P.Geo. and included terrain stability and erosion potential classes, signs of instability or erosion, and any other pertinent information regarding stability and erosion potential classes. P. Uunila spent an extra five days in the field to focus on refining the criteria for terrain stability and soil erosion potential.

The location of all ground inspection plots, and visual inspections were either recorded by GPS or marked on hard copy orthophotos (Figure 6). Site locations were digitally captured and are shown on the terrestrial ecosystem map.

Sampling statistics are presented below.

Table 1. Number of field plots with terrain data.

FS882	Ground Inspections	Visuals	TOTAL
1	74	268	343

[39] Collett and Uunila 2005

[40] B.C. Ministry of Environment, Lands and Parks and B.C. Ministry of Forests 1998

[41] Resources Inventory Committee 1998

Table 2. Field Checking Statistics for terrain mapping.

Total Area	Total Number of Polygons	Total Number of Field Sites	Percentage Polygons Field Checked	Field Checks per 100 ha
21,628 ha	3837	343	9 %	1.6

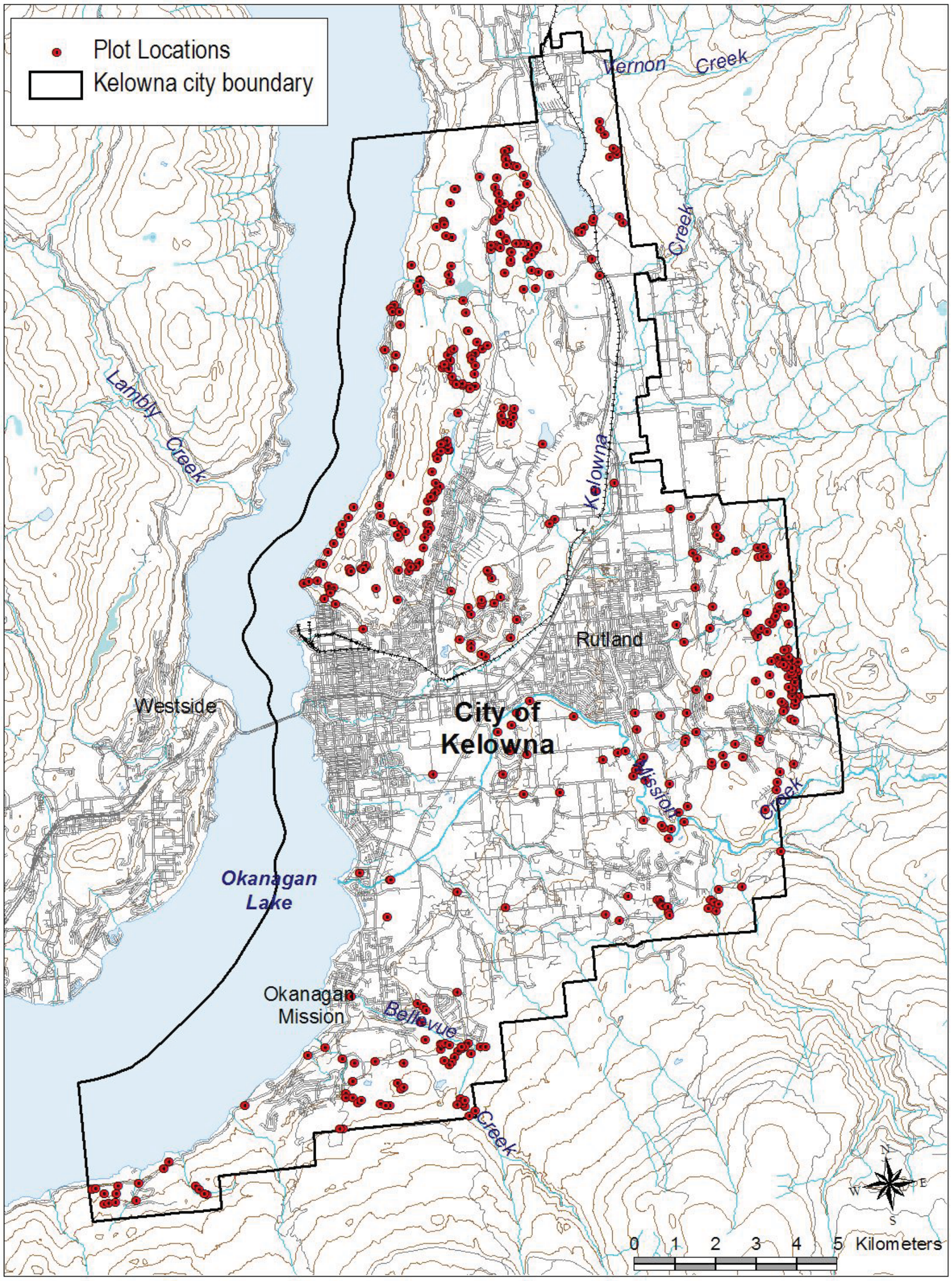

Figure 6. Location of all field plots for the Kelowna SEI study area.

Final Terrain Mapping

Following field work, revisions were made to the pre-typed polygon boundaries using a DiAP Viewer with digital 1:10,000 scale imagery from 2006. At this stage, many of the polygon boundaries were adjusted and new ones added to account for additions of terrain stability and soil erosion potential classes to each polygon. Where possible, the purpose of the changes was to delineate polygons of internally uniform terrain stability class while maintaining an emphasis on important ecological elements, such as surficial material, aspect and drainage. For polygons where this was not possible, the most conservative terrain stability class and soil erosion potential class was assigned to the polygon. A major disadvantage to using a DiAP Viewer is that polygon labels cannot be seen at the same time as viewing the polygons on screen, thus every bioterrain label was redone. While viewing the polygons on-screen, P. Uunila dictated terrain symbols into a dictaphone. P. Uunila then entered the polygon data into the provincial standard MS Excel database.

South Slopes Bioterrain Mapping

A narrow strip of bioterrain mapping completed by Deepa Spaeth Filatow, P.Geo. for the Regional District of the Central Okanagan in 2004 covers the southern edge of the current City of Kelowna project area (part of the South Slopes portion of the Central Okanagan TEM and SEI). Limited field checking was completed in this area under the current contract. The new mapping was edge matched to the work completed in 2004 to provide seamless coverage. The original polygon boundaries and terrain symbols were not altered. Under the current project, the following changes were made to the 2004 database in order to be consistent with the methods and match the criteria used for the interpretations used for the new mapping (please note that the changes are based on the information provided in the databases only; the air photos were not consulted during this analysis):

- soil drainage classes were changed from one class for each component to reflecting the polygon as a whole;
- terrain stability and soil erosion potential classes were changed from one class for each component to one class per polygon. The criteria used to assign classes are based on the same criteria used on the new mapping, and where more that one class is present in a polygon, the most conservative class was assigned.

2.2 Terrestrial Ecosystem Mapping

This project has used the provincially recognised Terrestrial Ecosystem Mapping standard[42] to map ecosystems in the study area.

Mapping at a scale of 1:20,000 and survey intensity level four was completed according to the methods in *Standard for Terrestrial Ecosystem Mapping in British Columbia*[43].

In addition to the required map attributes, the following map attributes were also recorded for each polygon:

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[42] Resources Inventory Committee 1998
[43] Resources Inventory Committee 1998

- structural stage modifiers for shrub ecosystems
- stand composition modifiers (e.g., coniferous, mixed or broadleaf stand),
- seral association for grassland ecosystems,
- disturbance class and subclass,
- quality of the ecosystem (Qual) for sensitive and other important ecosystems,
- viability of the ecosystem (Viab) for sensitive and other important ecosystems,
- slope range,
- terrain stability class, and
- soil erosion potential class

Field Sampling

A field-sampling plan was developed using 1:10,000 orthophotos from 2006 with the following objectives in mind:

- verify the presence, quality, and condition of sensitive ecosystems
- identify other ecosystems
- verify terrain labels including terrain stability and erosion potential
- verify ecosystems in at least 10% of the polygons and terrain information in at least 20% of the polygons
- gather detailed data for unclassified ecosystems

Landowners were contacted by the City of Kelowna prior to fieldwork and many landowners granted us access to sample on their lands. Field sampling took place in August, September and October 2007. A team of two scientists conducted field sampling: a plant ecologist (Kristi Iverson, R.P.Bio. completed the majority of the field work and John Grods, R.P. Bio. completed one day of field work), and a terrain specialist (Polly Uunila, P.Geo.). A total of 10 days were spent collecting ecological information.

Two types of sample plots were used to identify and assess ecosystems and terrain: ground inspections, and visual inspections (Appendix A: Field Plot Forms). Field sampling procedures for ground inspections are outlined in *Field Manual for Describing Terrestrial Ecosystems*[44]. We followed guidelines from the *Standard for Terrestrial Ecosystem Mapping* in British Columbia[45] for visual inspection data collection. Additionally, we collected the pertinent information from a site conservation evaluation form developed by the B.C. Conservation Data Centre to evaluate the condition and ecological integrity of all sensitive ecosystems as per the Standard for Mapping Ecosystems at Risk in British Columbia[46]. Additional plot data from the original field sampling for the South Slopes in 2001, including one detailed ecological plot, was also used for the mapping in that area (ecological and terrain data were collected by K. Iverson and D. Spaeth Filatow, P.Geo.).

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[44] B.C. Ministry of Environment, Lands and Parks and B.C. Ministry of Forests 1998
[45] Resources Inventory Committee 1998
[46] Ministry of Environment Ecosystems Branch 2006

Additional information regarding terrain stability and erosion potential was collected by Polly Uunila, P.Geo. and included terrain stability and erosion potential classes, signs of instability or erosion, and any other pertinent information regarding stability and erosion potential classes. P. Uunila spent an extra five days in the field to focus on refining the criteria for terrain stability and soil erosion potential.

The location of all ground inspection plots, and visual inspections were either recorded by GPS or marked on hard copy orthophotos. Site locations were digitally captured and are shown on the terrestrial ecosystem map. See Figure 6 above for plot locations.

Forested and grassland ecosystems were identified using existing site series described in *A Field Guide for Site Identification and Interpretation for the Kamloops Forest Region*[47]. Most non-forested units such as wetlands and rock outcrops and grassland seral associations were adopted from previous projects: the Lake Country SEI[48], Vernon Commonage SEI[49], Bella Vista – Goose Lake Range SEI[50] and the Central Okanagan SEI[51]. These units were originally described based on field data and units were developed in conjunction with Dennis Lloyd, the Ministry of Forests and Range's Regional Ecologist in Kamloops. Additional wetland units mapped were adopted from the provincial wetland classification[52].

Ground inspections were used to sample sensitive ecosystems and representative examples of site series. Visuals were primarily used to verify ecosystem units, structural stages, or terrain. Plot sampling statistics are presented below.

Table 3. Sites visited with ecological data.

FS882	Ground Inspections	Visuals	TOTAL
1	40	207	248

Table 4. Field Checking Statistics for TEM.

Total Area	Total Number of Polygons	Total Number of Field Sites	Percentage Polygons Field Checked	Field Checks per 100 ha
21,628 ha	3837	248	6.5 %	1.2

Expanded Legend Development

The expanded legend describes the terrain, soils, and vegetation of each ecosystem mapped in the study area. The expanded legend also provides technical mapping information for each ecosystem unit: the map code, the ecosystem name, the site series number (if applicable), a listing of the assumed modifiers for each unit, and the modifier combinations that were mapped.

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[47] Lloyd et al. 1990
[48] Iverson and Uunila 2005
[49] Iverson and Uunila 2006
[50] Iverson and Shypitka 2003
[51] Iverson et al. 2004
[52] MacKenzie and Moran 2004

Site Series and Site Unit Mapping

Following field work, revisions were made to the pre-typed polygon boundaries using a DiAP Viewer with digital 1:10,000 scale imagery from 2006. In addition to the polygons added during terrain mapping, new polygons were added to account for sensitive ecosystems. A major disadvantage to using a DiAP Viewer is that terrain labels cannot be seen at the same time as viewing the polygons on screen, thus there was limited use of the bioterrain map labels. While viewing the polygons on-screen, K. Iverson dictated ecosystem symbols into a dictaphone. K. Iverson then entered the polygon data into the provincial standard MS Excel database.

Ecosystem units were mapped according to the *Standard for Terrestrial Ecosystem Mapping in British Columbia*[53]. Site series were identified according to Lloyd et al. (1990). Two-letter codes have been assigned to all site series in the master list available at: ftp://ftp.env.gov.bc.ca/dist/wis/tem/mapcodes_jan2003.xls[54]. For ecosystems not included in current site series classifications, new ecosystem units were previously approved by the Ministry of Forests' Regional Ecologist and new wetland units follow the four alphanumeric codes assigned in the provincial classification. Sparsely vegetated, non-vegetated and anthropogenic units follow the two-letter codes and descriptions in Table 3.1 of the *Standard for Terrestrial Ecosystem Mapping in British Columbia*[53].

Core polygon attributes collected for all polygons are shown below in Table 5. A sample terrestrial ecosystem map label is shown below in Figure 7. Site modifiers were also used to describe ecosystems. Up to two site modifiers may be present with each ecosystem unit. Site modifiers represent different site conditions than those of the typical situation, as defined in the master list, for each site series. Each site series has a set of assumed site modifiers under the typical situation. Where a site series is mapped in its typical situation, site modifiers are not included in the map label.

The site series code and site modifier(s) are followed by a structural stage designation (one through seven). Stand composition modifiers indicate the dominant composition of the overstory trees (broadleaf, coniferous or mixed) and were mapped for all forested ecosystems. Seral associations were mapped for grassland ecosystems.

Definitions and descriptions for all site modifiers, structural stage, structural stage modifier, and stand composition modifiers can be found in the *Standard for Terrestrial Ecosystem Mapping in British Columbia*[55].

Up to three ecosystems units were mapped for each polygon. The percentage of each ecosystem unit present is indicated by deciles ranging from 1 to 10 (1=10%; 10=100%).

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53 Resources Inventory Committee 1998
54 Resources Inventory Committee 2000a
55 Resources Inventory Committee 1998

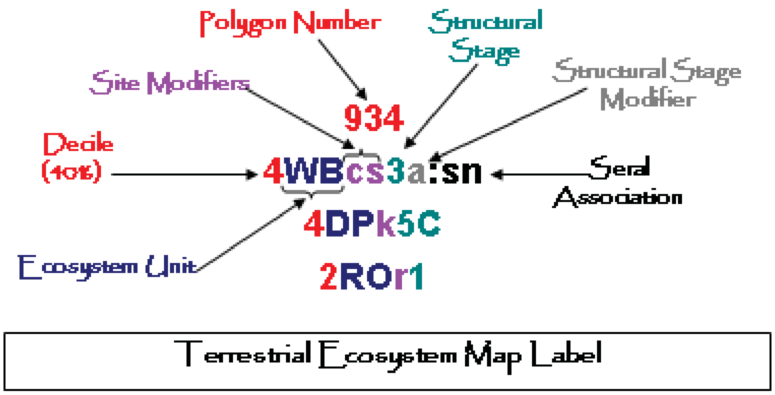

Figure 7. Example of a terrestrial ecosystem map label.

South Slopes Terrestrial Ecosystem Mapping

A narrow strip of TEM completed by Kristi Iverson for the Regional District of the Central Okanagan (RDCO) in 2004 covers the southern edge of the current City of Kelowna project area. The entire South Slopes project area including both the City of Kelowna and RDCO was updated to reflect changes following the 2003 wildfire and changes resulting from residential development. Using a DiAP Viewer and 1:10,000 scale digital imagery from 2006, polygon attributes were updated for polygons within the perimeter of the wildfire. Any areas with recent urban or industrial developments within the South Slopes project boundaries were also updated.

Ecosystems are permanent entities unless the soil has been removed or significantly altered. Thus, structural stage, disturbance class and subclass, and condition and viability were the primary attributes that were updated in the database. New polygons were delineated and ecosystem units were changed in areas that had undergone residential or industrial development.

Table 5. Core attributes collected for all polygons.

Project- or Mapsheet-Specific Attributes - repeated for all polygons

Project name
Ecosystem mapper
Terrain mapper
Survey intensity level

Polygon-Specific Attributes - unique for each polygon

Record one of each of the following elements or classes per polygon:

Mapsheet number
Polygon number
Data source
Ecosection unit
Biogeoclimatic unit (zone and subzone; variant and phase required if present)
Geomorphological processes (when present)
Soil drainages

Record up to three ecosystem and/or terrain units per polygon:

Ecosystem attributes

- Decile
- Site series
- Site modifier(s)
- Structural stage

Terrain attributes

- Decile
- Terrain texture (optional but done where possible; recorded separately for each component)
- Surficial material (recorded one for each component; sometimes included a surficial subtype)
- Qualifiers (when present, recorded one for each component)
- Geomorphological processes when present
- Soil drainage classes
- Surface expression (recorded up to three for each component)

Data Management

Non-spatial information includes field plot data and polygon attribute data. Spatial data includes polygon boundaries and locations of field verification sites.

Field Plot Data

Data from field plots were entered into a digital database using Resources Inventory Committee standard software (VENUS Version 5). Both manual and electronic quality assurance were completed for the VENUS database. This database was used to sort data into ecosystem units and develop the expanded legend. The range of environmental conditions, terrain units, and vegetation communities over which ecosystem units were distributed is described in the expanded legend (Appendix C: Expanded Legend).

Non-spatial Data

We captured the core set of polygon attributes required to meet the provincially accepted *Standard for Terrestrial Ecosystem Mapping (TEM) - Digital Data Capture in British Columbia*[56] (Table 5). Data were recorded on a dictaphone while viewing polygons with a DiAP Viewer and the data were subsequently entered into a standard Excel database. Table 6 lists the optional attributes we also applied in this project. We also applied two "user-defined" polygon attributes for all occurrences of sensitive ecosystems: condition and viability and seven user-defined polygon attributes: slope range (slope_1, slope_2, slope_sep, slope_3, slope_4), terrain stability class (Ss_1) and soil erosion potential class (Ep_1). We ran quality assurance error checking routines to ensure the attribute database was free of errors.

Table 6. List of Optional Attributes

Attribute
Stand Appearance
Seral Association (for grasslands only)
Disturbance Class and Subclass

Spatial Digital Data

Ecosystems were represented visually on maps and the digital data required to produce this representation were maintained according to standards outlined in the TEM Digital Data Capture Standards[57]. The Terrain Resource Information Management (TRIM) was used as the mapping base. The linework mapped by the bioterrain and ecosystem specialist was captured through digitizing while using a DiAP Viewer. Standard quality assurance routines were applied to ensure accurate mapping.

2.3 Terrain stability

Terrain stability mapping identifies relative stability using a polygon-based five class rating system ranging from class I (stable) to class V (unstable) (Table 7). Terrain stability classes indicate a polygon's susceptibility to the initiation of mass movement (gravity induced) processes including landslides, debris flows, rotational slumps, earthflows, and rock slides. Terrain stability maps are used to plan development including forestry, roads, and urban development.

Objectives

The objective of the terrain stability theme was to provide a map, based on the bioterrain information, which will identify areas prone to instability on a regional planning scale. This map will aid in locating building development, roads, green space and other land uses while reducing slope failures caused by human development and the impact of naturally occurring slope failure on

[56] Resources Inventory Committee 2000b
[57] Resources Inventory Committee 2000b

development. ***The use of terrain stability maps does not preclude the need for on-site field inspections***.

Methods

Terrain stability is evaluated by air photo interpretation. Each terrain component was evaluated using the 5 class rating system (**I**, stable to **V**, unstable). Conventional terrain stability mapping assigns one rating for the entire polygon and, where there is a complex of terrain types in one polygon, the polygon is rated according to the terrain with the highest class (i.e., least stable).

Table 7. Definitions and management implications for terrain stability classes.[58]

Stability Class	Interpretation
I	• No significant stability problems exist.
II	• There is a low likelihood of landslides following disturbance or development. • Minor slumping is expected along road cuts and excavations.
III	• Stability problems can develop. • Follow BMP to reduce the likelihood of causing slope failure. • Minor slumping is expected along road cuts and excavations. There is a low likelihood of landslide initiation following disturbance or road construction. • Assessment by qualified geotechnical professional recommended.
IV	• Expected to contain areas with a moderate likelihood of landslide initiation following development, disturbance or road construction. • These areas should be avoided. Use caution when planning intensive land use above or below these areas. • Assessment by qualified geotechnical professional recommended.
V	• Expected to contain areas with a high likelihood of landslide initiation. Signs of existing instability present. • Avoid these areas. Do not plan intensive land use above or below these areas. • Assessment by qualified geotechnical professional recommended.

[58] Adapted from Ministry of Forests 1999

Table 8 outlines the criteria used as a guideline for evaluating terrain stability.

Table 8. Guidelines for assessment of terrain stability classes. Numerical ranges in the table refer to the dominant range of slopes in percent. See Appendix B for definitions of texture and surficial material type.

Dominant texture	Typical surficial material	Terrain Stability Class				
		I	**II**	**III**	**IV**	**V**
fine s, z, zs, sz, c, m	LG, C1	<10 %	10-25 %	25-40 %	>35%	all materials and landforms that are unstable, including rockfall; polygons with: -F"k, -F"m, -F"u, -R"s, -R"r, -R"d, -R"b
sdm, dsm	M	<15 %	15-30 %	30-45 %	>45 %	
dzs, zds, sg,	M, F, FG, C	<20 %	20-40 %	40-50 %	>50 %	
a, x	C	<25 %	25-50 %	50 -60 %	>60 %	
resistant bedrock	R	<25 %	25-50 %	50-70 %	>70 %	

Criteria are based chiefly on slope steepness, material type, texture, and the presence of geomorphological processes. The criteria were used as general guide with adjustments being made, as necessary, for specific conditions such as soil drainage and slope morphology. The mapper also considers local knowledge, field data, reports and mapping from this study area and in relevant adjacent studies. Each terrain polygon was rated individually in order to permit additional local factors to be taken into account when necessary. These additional local factors include:

- ***Slope smoothness/irregularity***: A slope morphology that includes irregular, near-surface bedrock may be rated as more stable than a similar slope with smooth underlying bedrock, because bedrock irregularities can reduce the likelihood of a landslide in surficial materials. The irregular bedrock acts to pin surficial materials in place, thus the potential for instability is less than on a slope of similar overall steepness but with a smoother profile.
- ***Drainage***: In general, wet slopes are more unstable than dry slopes. Wet slopes may be prone to slope failures through a reduction in normal stress due to high pore water pressure in the soil. Where imperfectly-drained areas are mapped on slopes with gradients that occur within the upper end of a slope steepness class range, the polygon may be rated one terrain stability class higher. Where rapidly drained areas are mapped on slopes with gradients that occur on the lower end of a slope steepness range, the polygon may be rated one stability class lower.
- ***Slope position***: In general, lower slopes and concavities are relatively wet because they receive moisture from a large area upslope; thus they may be classified as a terrain stability class higher than a similar slope that is located in a shedding slope position.

2.4 Soil Erosion Potential

Soil Erosion Potential ratings are based on the soil's susceptibility to erosion when vegetation, humus, and other protective layers are removed, not on the polygon's current condition. For this study, erosion was defined as the particle-by-particle removal of soil by running water. Polygons were not rated for wind erosion as different factors contribute to surface erosion by wind.

Erosion occurs where soil is exposed to surface runoff. Areas where soil is commonly exposed and disturbed include: landslide scars, landscaping sites, road cuts, construction sites, excavation sites, areas subject to heavy traffic (for example: foot, bike, motorized vehicles, and heavy machinery), landings, trails, dirt roads, and severe burns (e.g. portions of the Okanagan Mountain Park fire in the South Slopes area). Surface runoff occurs in natural and artificial streams, where water is diverted or concentrated, over relatively impermeable surfaces, in seepage areas, during snow melt, and as a result of storm events. Combinations of the above can intensify surface runoff. Water can be diverted, accelerated, or concentrated by topography, ditch lines, storm sewer lines, irrigation, landscaping, gutters, drainage pipes, leaky structures, and artificial surfaces.

Objectives

The objective of the soil erosion potential theme was to provide a preliminary mapping tool, based on the bioterrain mapping, which identifies areas prone to surface erosion on a regional planning scale. This tool can be used to prevent or reduce soil erosion by identifying areas of very high erosion potential that should be avoided and by applying remedial and preventative measures in moderate to high-risk areas. ***The use of soil erosion potential maps does not preclude on-site field inspection.***

Methods

Soil erosion potential mapping was based on a five-class rating scheme ranging from very low (VL) where no problems of erosion were expected to very high (VH) (Table 9). Ratings were typically assigned through air photo interpretation. Where a single polygon could have more than one rating, the highest value (most conservative) was used (average value is not appropriate).

Table 9. Definitions and management implications for soil erosion potential classes.

Class	Rating	Definition and Implications
VL	Very low	• No erosion or very minor erosion. • No significant erosion problems expected.
L	Low	• Minor erosion.
M	Moderate	• Erosion problems should be anticipated. • Expect moderate erosion where exposed soils are subject to surface runoff. • Assessment by qualified sediment and erosion control professional recommended.

Class	Rating	Definition and Implications
H	High	• Major erosion problems should be anticipated. • Expect significant erosion where exposed soils are subject to surface runoff. • Disturbed soils are a potential source of sediment. • Assessment by qualified sediment and erosion control professional recommended.
VH	Very high	• Severe surface erosion problems should be anticipated. • Surface erosion is active in these areas and they are existing sources of sediment. • Severe surface and gully erosion problems can occur if water is channelled into these areas. • Runoff from these areas can carry significant amounts of sediment into streams. • Assessment by qualified sediment and erosion control professional recommended.

Criteria for assessing soil erosion potential were based on soil texture, material thickness and slope gradient (Table 10).

Table 10. Guidelines for assessment of soil erosion potential. See Appendix B for definitions of texture and surfical material type.

SURFICIAL MATERIAL CHARACTERISTICS		DOMINANT GRADIENT RANGE (%) 0 – 40%	30 – 60%	> 50%	>40%
Dominant texture Decreasing erodibility	Typical surficial material	smooth, irregular, benched, terraced slopes	moderate to moderately steep slopes	single gullies and scarps	dissected slopes (-V[59])
fine s, z, c, m	LG, E, C1	H	H, VH	VH	VH
coarse s, ds, gs, sdm, sdz	FG, C, M, F	M	H	H, VH	VH
dzs, zds	M	L	M	H	VH
sg, sd, sr, sx	F, FG, C, M	L	L, M	M	H, VH
x, a	C	VL	VL	L	L
resistant bedrock	R	VL	VL	VL	VL
organics (some wetlands)	O	VL	-	-	-

The criteria were used as a general guide and adjustments were made, as necessary, for specific conditions such as slope position and geomorphic processes. Each terrain polygon was rated individually to permit additional local factors to be taken into account. These local factors included:

[59] see Description of Geological Processes: Gully Erosion (-V) page 3

- ***Soil drainage:*** Polygons with imperfectly drained soils (seepage present) were rated one class higher;
- ***Slope position***: Lower slopes and concavities tend to be more susceptible to erosion because they generally receive more moisture compared to a middle slope. As a result a polygon may have been rated one class higher if it was a receiving site. In contrast, upper slopes are generally less susceptible to erosion as they receive less water as compared to a middle slope and may be rated one class lower;
- ***Slope morphology***: An irregular slope is generally less susceptible to erosion than a smooth slope. A polygon may have been rated one class lower if a slope was irregular enough to inhibit some erosion potential; and
- ***Geomorphic Processes***: If a polygon contained an active geomorphic process that is deemed to increase the erosion, such as gullying or slope failure, the soil erosion potential class may have be rated one class higher.

2.5 Hazardous Conditions Classification

For this project, a Hazardous Condition Map was produced which combines the ratings for Soil Erosion Pontential and Terrain Stability Classes into a simplified classification of low, moderate and high. The two lowest classes for Soil Erosion (classes L and VL) and Terrain Stability (classes I and II) are grouped into a **low** Hazardous Conditions class. Moderate ratings (Soil Erosion class M and Terrain Stability class III) become Hazardous Conditions class **moderate** and the two highest rating for Soil Erosion (classes H and VH) and Terrain Stability (classes IV and V) are grouped into the **high** Hazardous Conditions class (see Table 11 below). The Hazardous Conditions class assigned was based on highest rating of Soil Erosion Potential or Terrain Stability Class in the polygon. For example, a polygon with Terrain Stability Class IV and Soil Erosion Potential of L was assigned Hazardous Conditions class High.

Table 11. Hazardous Conditions Class definitions.

Hazardous Conditions Class	Soil Erosion Potential Class	Terrain Stability Class
Low	VL L	I II
Moderate	M	III
High	H VH	IV V

3 Mapping Limitations

3.1 TEM & SEI Mapping Limitations

The SEI and TEM information is intended for use in alerting local and regional decision-makers of the presence of important ecosystems and ecological features. ***The SEI and TEM do not replace the need for on-site assessments of areas where land use changes are proposed or contemplated***.

The accuracy of polygon boundaries is limited by the scale (1:10,000 for most of the City and 1:15,000 for the South Slopes) and date (2006 imagery for all polygon attributes) of the aerial photographs on which the sites are delineated. ***Data should not be enlarged beyond the scale of the photos as this may result in unacceptable distortion and faulty registration with other data sets.***

Given the continuing land-uses within the study area, including human settlement and agricultural development, attributes of some polygons will change with time.

One of the primary limitations of aerial photograph interpretations is the limited ability to see disturbances such as grazing and invasive plants. The mapper applies information based on extrapolation from adjacent areas or current land use, and based on the tone and texture seen on the aerial photographs. Some grasslands may have been incorrectly assigned to a seral association.

There is limited ability to delineate polygons around small sensitive features or ecosystems. In most cases, these ecosystems are captured as a small component of a larger polygon dominated by another ecosystem. Many polygons are a complex of ecosystems and sensitive ecosystems may only occupy a portion of that polygon.

Field verification was limited by access. Not all private land owners granted permission to sample on their property.

3.2 Terrain Mapping Limitations (including terrain stability and soil erosion potential mapping)

Bioterrain, terrain stability and soil erosion potential mapping does not replace the need for on-site assessments for areas of proposed development. The accuracy of polygon boundaries is limited by the scale (1:10,000) and dates (2003 and 2006) of the aerial photographs on which the polygons are delineated. The information and analyses contained in this report are based on observations of land-surface conditions and the current understanding of terrain stability and soil erosion potential. The following factors have not been taken into account by this study: subsurface conditions not detectable by airphoto interpretations or surface observations (subsurface hydrologic conditions, for example), events whose time of occurrence and severity cannot be predicted (storm events, for example), management practices, and land-use.

Additional factors affecting the accuracy of the terrain mapping and the reliability of the air photo interpretation are described below in Table 12.

Table 12. The factors affecting the reliability of terrain mapping.

Factors	Notes on this study
Skill and experience of the mapper	Pre-typing completed by experienced terrain mapper, Anthony Collett, P.Geo. Final typing, terrain stability and soil erosion potential interpretations and project completion by Polly Uunila, P.Geo. experienced terrain mapper and a former resident of Coldstream, who has completed several terrain mapping projects in the Okanagan. This is the first time P. Uunila has used a DiAP Viewer. South slopes mapped by Deepa Spaeth Filatow, P.Geo., experienced terrain mapper and resident of Kelowna.
Number of mappers	Three mappers were involved in various stages of the project.
Continuity	Majority of the study area: project started by one mapper and completed by another. Mapping completed on a DiAP Viewer with high quality digital imagery. South Slopes completed by another mapper on 1:15,000 scale air photos. Placement of linework using the DiAP Viewer may be more precise than on the air photos.
Quality control	Spot checked by Kristi Iverson
Vegetation cover	In general, the vast areas of grasslands and open forest allowed the mapper a good view of landform features while mapping.
Complexity of the landscape	Variable. The rock controlled portion of the landscape is predictable and fairly straight forward. The thick fill in the valley bottom and lower slopes is complex.
Quality and scale of the airphotos	Majority of study area: The imagery is high quality and appropriate for the scale of the final mapping. The imagery on the west-facing slopes above Okanagan Lake from Knox Mountain to the McKinley Landing area was distorted and in shadow. It was difficult to confirm pre-typing polygon boundary placement and to assign terrain, terrain stability and soil erosion potential attributes to many of the polygons on this hill slope. Pre-typing completed on 2003 digital imagery and final typing completed on 2006 digital imagery. South Slopes: Good quality imagery but taken pre-fire (from 1996). Colour photos. Photo scale is smaller than the scale of the final mapping.
Terrain Survey Intensity Level (TSIL)	TSIL D[60] is normal for TEM but is low for Soil Erosion Potential and Terrain Stability themes.
Interpretative criteria for Soil Erosion Potential and Slope Stability	Inadequate field data from this study but good data was available from comparable studies done in adjacent areas.

[60] TSIL D is defined as 1-20% of polygons inspected; 9% of polygons were inspected in this project.

Factors	Notes on this study
Quality of the topographic base	Generally good. During the pre-typing, A Collett noted that the surface file, derived from a TRIM digital elevation model (DEM), is not very accurate at the base of deeply incised meltwater channels and river canyons (e.g. Mission Creek canyon). Linework in these areas may not be precisely placed or lines may 'float' above the ground surface when viewed on a DiAP Viewer. During the current contract, P. Uunila noted that the images appeared "flat" in small areas at many of the seams of the surfaces.
Linework	The pre-typing was completed on 2003 imagery and the final mapping was completed on 2006 imagery. P. Uunila noted that in some locations (usually steep terrain) there appears to be small shifts in line placement, i.e. the polygon boundary is not on the slope break when viewing the 2003 linework on 2006 imagery.
Database and editing	The database is free of terrain coding errors. It is not possible to conduct an edit of the terrain labels because "labelled air photos" cannot be created in DiAP as with conventional terrain mapping using hard copy air photos. It is likely that errors are uncommon.

Additional limitations specific to Soil Erosion Potential and Terrain Stability ratings are as follows:

1. Soil Erosion Potential and Terrain Stability ratings are based on a method developed primarily for forestry applications. In an urban setting, artificial surfaces make runoff and delivery of sediments into waterways more prevalent. Caution should be exercised even in areas with low soil erosion potential ratings, and areas rated moderate to very high should be treated as sensitive. Polygons with Terrain Stability classes **III** through **V** should be considered sensitive and caution should still be taken with drainage in class **I** and **II** polygons.
2. Because Soil Erosion Potential and Terrain Stability classes were added after the pre-typing was completed, polygons may include areas of more than one class. One class (the most conservative one) is assigned to each polygon. In contrast, there may be inclusions in the polygon that are too small to isolate for the scale of mapping (typically less than 10% of the polygon) that are more susceptible to erosion or unstable than the assigned interpretive class. For example, a short steep slope within a gently sloping polygon will have higher erosion potential than the indicated Soil Erosion Potential rating for the polygon. In another example, some surficial materials may contain inclusions of finer textured material that are more susceptible to erosion. For example, coarse textured, inter-bedded sands and gravels may contain beds of very fine sand and silt, which are more susceptible to erosion.
3. This study has been conducted at TSIL D (most studies that incorporate Soil Erosion Potential and Terrain Stability are TSIL C-A[61]). The field survey did not focus on M-VH and

[61] TSIL A is defined as 75-100% of polygons field inspected, TSIL B is defined as 50-75% of polygons field inspected, TSIL C is defined as 20-50% of polygons field inspected, and TSIL D is defined as 0-20% of polygons field inspected; 9% of polygons were inspected in this project.

III-V rated polygons, as is the norm (apart from drainage and texture). However, information from several studies completed by P. Uunila in the area was used to establish the criteria for this study.

4. In order to meet the project objectives the mapper incorporated criteria for bioterrain, terrain stability and soil erosion potential into the mapping. This has resulted in a high level of detail (small average polygon size) and utility.

5. Hazardous areas include the initiation, transport and runout zones of slope mass movement. It should be noted that Terrain Stability classes flag only the initiation zones of slides (as denoted by class V), however runout zones can be any terrain stability class. The runout, transport and deposition zones of slope mass movement can be identified by the geomorphological portion process of the terrain symbol. Thus, geomorpological process should be used in combination with terrain stability class to find the hazardous locations within the study area.

4 Results

4.1 Terrestrial Ecosystem Mapping Results

Table 13 and Table 14 below list the ecosystems mapped in the study area for each subzone, the area they covered, the percentage of the subzone, and the percentage of the study area land base. Appendix C: Expanded Legend provides a complete description of each ecosystem.

Table 13. Ecosystem Units mapped in the IDFxh1, their area, their percent of the IDFxh1 land base in the study area, and their percent of the study area land base.

IDFxh1				
Ecosystem Unit Code/ Number	Ecosystem Unit Name	Area (hectares)	% of IDFxh1	% of study area
AS /98	At – Snowberry – Kentucky bluegrass	26.9	1.3	0.1
BM /00	Bulrush Marsh	0.6	0.03	0.003
BN /96	Kentucky bluegrass – Stiff needlegrass	16.4	0.8	0.08
BR /00	Baltic Rush Marsh-Meadow	3.4	0.2	0.02
CD /00	ActFd –Common Snowberry – Red-osier Dogwood Riparian	10.4	0.5	0.05
CF /00	Cultivated Field	111.5	5.3	0.5
CG /00	Reed Canarygrass Marsh	6.2	0.3	0.03
CL /00	Cliff	4.9	0.2	0.02
CS /00	Common Spikerush Marsh	0.2	0.01	0.001
CT /00	Cattail Marsh	0.5	0.02	0.002
CW /00	Choke cherry – Bluebunch wheatgrass rocky bluff	860.9	41.0	4.0
DP /01	FdPy – Pinegrass	99.9	4.8	0.5
DS /07	FdPy – Snowberry – Spirea	110.9	5.3	0.5
DW /03	FdPy – Bluebunch wheatgrass – Pinegrass	5.1	0.2	0.02
ES /00	Exposed Soil	11.5	0.6	0.05
FC /00	Rough Fescue – Cladina	2.8	0.1	0.01
FO /00	FdPy –Saskatoon – Mock orange	150.9	7.2	0.7
FW /91	Idaho fescue – Bluebunch wheatgrass	20.1	1.0	0.09
GP /00	Gravel Pit	1.5	0.07	0.007
OW /00	Shallow Open Water	50.6	2.4	0.2
PB /02	FdPy – Bluebunch wheatgrass – Balsamroot	4.1	0.2	0.02
PD /00	Pond	7.4	0.4	0.03
RF /97	Prairie Rose – Idaho fescue	0.9	0.04	0.004
RI /00	River	3.9	0.2	0.02
RO /00	Rock Outcrop	14.8	0.7	0.07
RS /00	Western redcedar / Douglas-fir – False Solomon's Seal	61.7	2.9	0.3
RW /00	Rural	15.9	0.8	0.07
RZ /00	Road Surface	2.1	0.1	0.01
SA /00	Antelope brush – Selaginella	7.9	0.4	0.04
SB /00	Selaginella – Bluebunch wheatgrass rock outcrop	19.5	0.9	0.09
SD /08	SxwFd – Douglas maple – Dogwood	1.9	0.09	0.009
SO /00	Saskatoon – Mock orange Talus	148.3	7.1	0.7
SP /04	FdPy – Snowbrush – Pinegrass	3.1	0.2	0.01
TA /00	Talus	51.7	2.5	0.2
UR /00	Urban/Suburban	1.5	0.07	0.007
WA /92	Big sage – Bluebunch wheatgrass – Balsamroot	258.4	12.3	1.2

IDFxh1				
Ecosystem Unit Code/ Number	Ecosystem Unit Name	Area (hectares)	% of IDFxh1	% of study area
WB /93	Bluebunch wheatgrass – Balsamroot	0.5	0.02	0.002
WS /09	Willow – Sedge Wetland	26.9	1.3	0.1
Ws01 /00	Mountain alder – Skunk cabbage – Lady fern swamp	0.6	0.03	0.003
TOTAL		**2098.6**	**100**	**9.7**

Table 14. Ecosystem Units mapped in the PPxh1, their area, and their percent of the PPxh1 land base in the study area, and their percent of the study area land base.

PPxh1				
Ecosystem Unit Code/ Number	Ecosystem Unit Name	Area (hectares)	% of PPxh1	% of study area
AK /00	Alkaline pond	24.0	0.1	0.1
AS /00	At – Snowberry – Kentucky bluegrass	33.1	0.2	0.2
BE /00	Beach	5.6	0.03	0.03
BM /00	Bulrush Marsh	12.3	0.06	0.06
BR /00	Baltic Rush Marsh-Meadow	1.9	0.01	0.009
CB /00	Cutbank	33.8	0.2	0.2
CD /00	ActFd –Common Snowberry – Red-osier Dogwood Riparian	237.8	1.2	1.1
CF /00	Cultivated Field	2991.3	15.3	13.8
CG /00	Reed Canarygrass Marsh	3.6	0.02	0.02
CL /00	Cliff	2.3	0.01	0.01
CN /00	Canal	17.0	0.09	0.08
CO /00	Cultivated Orchard	2496.4	12.8	11.5
CT /00	Cattail Marsh	48.1	0.2	0.2
CV /00	Cultivated Vineyard	33.5	0.2	0.2
CW /00	Choke cherry – Bluebunch wheatgrass rocky bluff	14.2	0.07	0.07
DM /08	Fd – Water birch - Douglas maple	68.3	0.4	0.3
DS /07	FdPy – Snowberry – Spirea	110.7	0.6	0.5
ES /00	Exposed Soil	85.0	0.4	0.4
FB /00	Rough fescue – Bluebunch wheatgrass	363.0	1.9	1.7
FC /00	Rough Fescue – Cladina	6.1	0.03	0.03
FO /00	FdPy –Saskatoon – Mock orange	124.1	0.6	0.6
GC /00	Golf Course	496.9	2.6	2.3
GP /00	Gravel Pit	192.7	1.0	0.9
Gs01	Alkali Saltgrass Wet Meadow	8.8	0.04	0.04
Gs02	Nuttall's alkaligrass – Foxtail barley Wet Meadow	0.3	0.001	0.001
Gs03	Field Sedge Wet Meadow	18.8	0.1	0.09
GW /00	Giant Wildrye	0.3	0.001	0.001
LA /00	Lake	163.1	0.8	0.8
MI /00	Mine	1.5	0.008	0.007
OW /00	Shallow Open Water	113.0	0.6	0.5
PC /04	Py – Bluebunch wheatgrass – Cheatgrass	1288.2	6.6	6.0
PD /00	Pond	1.3	0.007	0.006
PF /05	Py – Bluebunch wheatgrass – Rough fescue	654.3	3.4	3.0
PT /02	Py – Red three-awn	519.4	2.7	2.4
PW /01	Py – Bluebunch wheatgrass – Idaho fescue	904.3	4.6	4.2
RE /00	Reservoir	25.9	0.1	0.1
RI /00	River	3.4	0.02	0.02

PPxh1				
Ecosystem Unit Code/ Number	Ecosystem Unit Name	Area (hectares)	% of PPxh1	% of study area
RN /00	Railway	1.5	0.008	0.007
RO /00	Rock Outcrop	4.9	0.02	0.02
RS /00	Western redcedar / Douglas-fir – False Solomon's Seal	8.2	0.04	0.04
RW /00	Rural	1752.0	9.0	8.1
RZ /00	Road Surface	76.5	0.4	0.4
SA /00	Antelope brush – Selaginella	73.6	0.4	0.3
SB /00	Selaginella – Bluebunch wheatgrass rock outcrop	121.1	0.6	0.6
SO /00	Saskatoon – Mock orange Talus	76.6	0.4	0.4
SP /06	FdPy – Snowberry – Pinegrass	161.6	0.8	0.7
SR /00	Snowberry – Rose – Kentucky Bluegrass	12.9	0.07	0.06
TA /00	Talus	11.4	0.06	0.05
UR /00	Urban/Suburban	5461.6	28.0	25.3
WB /00	Bluebunch wheatgrass – Balsamroot	661.6	3.4	3.1
WS /00	Willow – Sedge Wetland	1.1	0.006	0.005
Ws01	Mountain alder – Skunk cabbage – Lady fern swamp	0.2	0.001	0.001
TOTAL		**19 529.2**	**100**	**90.3**

4.2 Terrain Results

In general, the landscape and surficial geology is quite variable and complex. The following geomorphological processes were mapped in the City of Kelowna:

- slumps in bedrock
- slump-earthflow
- slumps in surficial materials
- rockfall
- debris slides

This includes active processes that were evident on the 2006, 1:10,000 scale digital imagery and field observations. Additional geomorphological processes may be present but were not mapped for the following possible reasons:

- the features are too small to be visible on the imagery
- the features are in shadows or under forest cover
- the events have occurred since 2006

The following gives brief and general descriptions of the distribution of surficial geology, terrain stability, and soil erosion potential from the valley bottom to higher slopes within the City of Kelowna municipal boundaries.

Valley bottom: The valley bottom consists largely of fluvial (fan and floodplain) deposits, glaciolacustrine and glaciofluvial sediments. Much of the low-lying areas between Wood Lake and the Okanagan Mission, with the exception of the Glenmore area, consist of modern floodplain and fans. These are formed by all of the major creeks including Scotty, Mission, Kelowna, KLO, and

Bellevue Creeks, as well as smaller creeks including Whelan, Brandt, Rumohr and Priest Creeks. Large deposits of glaciolacustrine sediments are found in the Glenmore area and south of the airport. Thin stretches of beach (lacustrine) discontinuously line the shores on Okanagan Lake and Duck Lake.

Stability issues in this area include potential slumping in glaciolacustrine sediments. The soils more susceptible to erosion included fluvial silts and sands, lacustrine and glaciolacustrine sediments.

Lower slopes: The lower slopes contain areas of thick sediments including glaciofluvial, till, glaciolacustrine and undifferentiated sediments. Landforms tend to be sloping benches dissected by gullies created by post-glacial streams and erosion. Terraces of glaciolacustrine sediments at elevations lower than about 500 m[62] are located along the lower slopes between East Kelowna and the Okanagan Mission and along the south edge of Dilworth and Knox Mountains. Scattered outcrops of glaciolacustrine sediments are located along the Okanagan lakeshore from Knox Mountain to the McKinley Landing area and along Lakeshore Drive in the Mission. Vast areas of glaciofluvial sediments cover much of the remaining lower slopes. Outcrops of bedrock covered by little or no colluvium are scattered throughout these slopes. Veneers of eolian sediments are found discontinuously on the gentler surfaces

Stability issues in this area include, debris slides in gullies dissecting thick sediments, slumping in glaciolacustrine sediments, and rockfall. The soils more susceptible to erosion included fluvial and glaciofluvial silts and sands, eolian silts and sands, and glaciolacustrine sediments. Slopes containing gullies incised through thick surficial materials are areas with high potential for erosion.

Mid to Upper slopes: Gentle to moderately steep slopes are largely covered by blankets and veneers of till with scattered bedrock outcrops and associated colluvium and weathered bedrock. Moderately steep to steep slopes are largely bedrock outcrops discontinuously covered by thin till and colluvium. Talus slopes flank bedrock cliffs.

Single gullies and rockfall comprise the largest amount of potentially unstable and unstable terrain within this area. In general, open slopes steeper than about 50 % and dissected slopes steeper than about 45 % are assigned terrain stability class IV. Steeper bedrock-controlled slopes with a partial veneer of surficial materials are rated as terrain stability class IV. The soils more susceptible to erosion included moderately steep to steep slopes of till. Slopes containing gullies incised through thick surficial materials are areas of high potential for erosion. The following recommendations are standard for avoidance of problems during development in areas that are prone to erosion or instability[63]:

- Use Best Management Practices, for example as outlined in the document *Best Management Practices for Erosion and Sediment Control-Upland Works*[64] . In and adjacent to riparian zones, it is particularly critical to avoid disturbances of erodable soils. Best Management Practices as outlined in *Best Management Practices for Erosion and Sediment Control-Instream Works*[65] should be followed as well as all legal requirements outlined in the *Fisheries Act* and the provincial *Water Act*.

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[62] Nasmith 1962
[63] adapted from Iverson et al. 2004
[64] City of Kelowna 1998b
[65] City of Kelowna 1998a

- Conscientious drainage planning is essential during road construction. Local drainage patterns have slowly been created since deglaciation. This process took thousands of years to evolve, and is in a sensitive equilibrium with the volume of water discharge. All natural drainage patterns, even minor ephemeral channels should be maintained. This is also important upslope of steeper areas as redirected drainage will affect the steep slopes below. Natural drainage patterns should be maintained through comprehensive stormwater planning that maintains natural water flow patterns by using stormwater source control strategies that return 90% of the precipitation to their natural drainage pathways.
- Sloughing of cut banks along roads may develop due to emergence of shallow subsurface water. Design road patterns to minimize cut and fills, and armour ditches with rock or vegetation where erosion is likely to occur. Ditches should be inspected regularly and cleaned or otherwise maintained when necessary.
- Ensure that culvert size is adequate and that the discharge points are properly armoured if necessary to reduce local erosion. Seeding together with geotextiles and armouring with rock are effective for controlling erosion.
- Minimize areas of soil disturbance for each development site or phase construction so that site clearing is minimized at any given time.
- Grass seeding may be an effective means of reducing erosion potential on bare surfaces such as cut banks and other disturbed areas. These areas could be lined with material such as weed-free straw to control erosion until grass becomes established. Grass seed used must be weed-free.
- Road construction should be avoided during wet weather and when the ground is wet due to snowmelt.
- Bare, compacted surfaces, even on gentle slopes, are particularly vulnerable to erosion by running water. Minimize disturbance of soils by having equipment use designated trails. Avoid leaving tracks aligned in the downhill direction that will channel runoff water and increase erosion. On steeper areas, these trails may require armouring to prevent surface erosion. Trails that are not part of the permanent road network should be scarified and rehabilitated and planted with native vegetation species adapted to the specific site.
- On steep slopes, construction should be minimized, but where unavoidable, all appropriate measures should be used to prevent soil and site degradation.
- Qualified registered professionals should evaluate the risk of a debris flow/torrent impacting development on the fan.
- Areas down slope of unstable glaciolacustrine scarps are also areas that could be impacted by landslide runout. Stability of glaciolacustrine scarps can be affected by over-irrigation, redirection of water (ditches and watercourses) onto the scarp, and addition of weight at the edge of the scarp (i.e., buildings, pools, trees, fill etc.). The force of the wind on tall trees and buildings can increase the forces that contribute to rotational slumps in thick glaciolacustrine materials.
- Glaciolacustrine materials are also susceptible to piping and collapse. It is recommended that qualified registered professionals investigate ground conditions in areas of thick glaciolacustrine material even in class **I** and **II** terrain.

- Where development is planned within or near polygons containing terrain stability classes **III, IV** and **V**, on-site inspections is required by a qualified registered professional, such as a Geotechnical Engineer, to determine more precisely the nature and extent of the unstable areas.
- Where development is planned within polygons containing soil erosion potential **M, H** and **VH**, on-site inspections is required by a qualified registered professional.
- Class **V** terrain is unstable and should be avoided.

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