

Threat Assessment of Riparian Areas in the Kettle River Watershed

Prepared for

Granby Wilderness Society

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Executive Summary

The riparian zone is the 'ribbon of green' between land and water where lush vegetation prevents erosion, provides habitat, protects water quality, and improves quality of life. Academic studies, watershed plans, and resource management textbooks all speak to the importance of riparian areas for ecosystem health. However, planners and managers often know too little about the condition and impacts on riparian areas to protect riparian ecosystem function amid competing demands on the land base and fragmented jurisdiction over land use and resource protection.

What are the threats to riparian health in the Kettle River Watershed? How do landscape-scale patterns impact riparian ecosystems in different parts of the watershed, and what can society do to respond?

The Granby Wilderness Society undertook this *threat assessment* to understand watershed scale influences on riparian health across the Kettle River Watershed in support of the Regional District of Kootenay Boundary's Kettle River Watershed Management Plan.

The project team examined available literature on influences on riparian health and prepared GIS (Geographic Information System) and field assessment analyses to evaluate conditions in the Kettle River Watershed. The GIS assessment determined land use and status of riparian areas based on third order (small tributary) subwatersheds. For the field study, the team selected subwatersheds with high levels of differing land uses as well as a reference watershed with low levels of active disturbance. The team assessed riparian health and vegetation structure at 90 locations in nine subwatersheds, and evaluated patterns of riparian health and landscape disturbance.

To complement the GIS and field study the team analyzed historical and current air photos for Grand Forks and the rural area around Rock Creek to understand historical changes in floodplains. Visible changes to wetlands, riparian areas, and floodplain forest cover were more apparent in Grand Forks than in Rock Creek, highlighting the large role that urban development plays in altering riparian areas. The team also undertook a retrospective assessment of past riparian restoration projects to evaluate factors contributing to success and failure and develop recommendations for future restoration projects.

The coarse scale assessment found that range and forestry were dominant land uses, with extensive natural and human-influenced disturbances including Mountain Pine Beetle and historical fires. Resource roads made up 3.4% of riparian areas. As linear features with over 10,000 stream crossings, resource roads amplify disturbance related to sedimentation and habitat fragmentation. Developed urban areas have a smaller footprint on riparian areas than other land uses, but disproportionately impact the riparian areas of the grassland ponderosa pine ecosystem, one of the rarest in the province.

The fine scale analysis showed how increasing human activity decreases riparian health. For instance, the Kettle subwatershed (along the valley floor near Midway and Grand Forks) had the most urban land use and the poorest riparian health scores, and remote, high elevation sites had the highest riparian health scores. The team also found the lower elevation plots had the highest cover of invasive species. Plant diversity and forb species richness tended to increase in sites with less human disturbance, lower numbers of invasive species and higher riparian integrity. Sites with higher forest structure diversity had notably higher number of species of forbs and overall plant diversity.

Findings from the assessment and related scientific literature point to this broad characterization of pathways of riparian impacts:

- Insufficient regulation, enforcement, incentives and awareness allow for riparian damage across all land use sectors.
- Road establishment, improper use and maintenance, and insufficient removal and remediation leave lasting impacts of sediment delivery to streams at stream crossings.
- Increasing human activity and infrastructure near and in riparian areas increases damage to riparian structure (vegetation, large woody debris, soils).
- Loss of structure reduces function (shade, in-stream habitat, erosion prevention, biodiversity).
- Loss of function combined with impacts from roads and development at stream crossings creates cascading downstream effects.

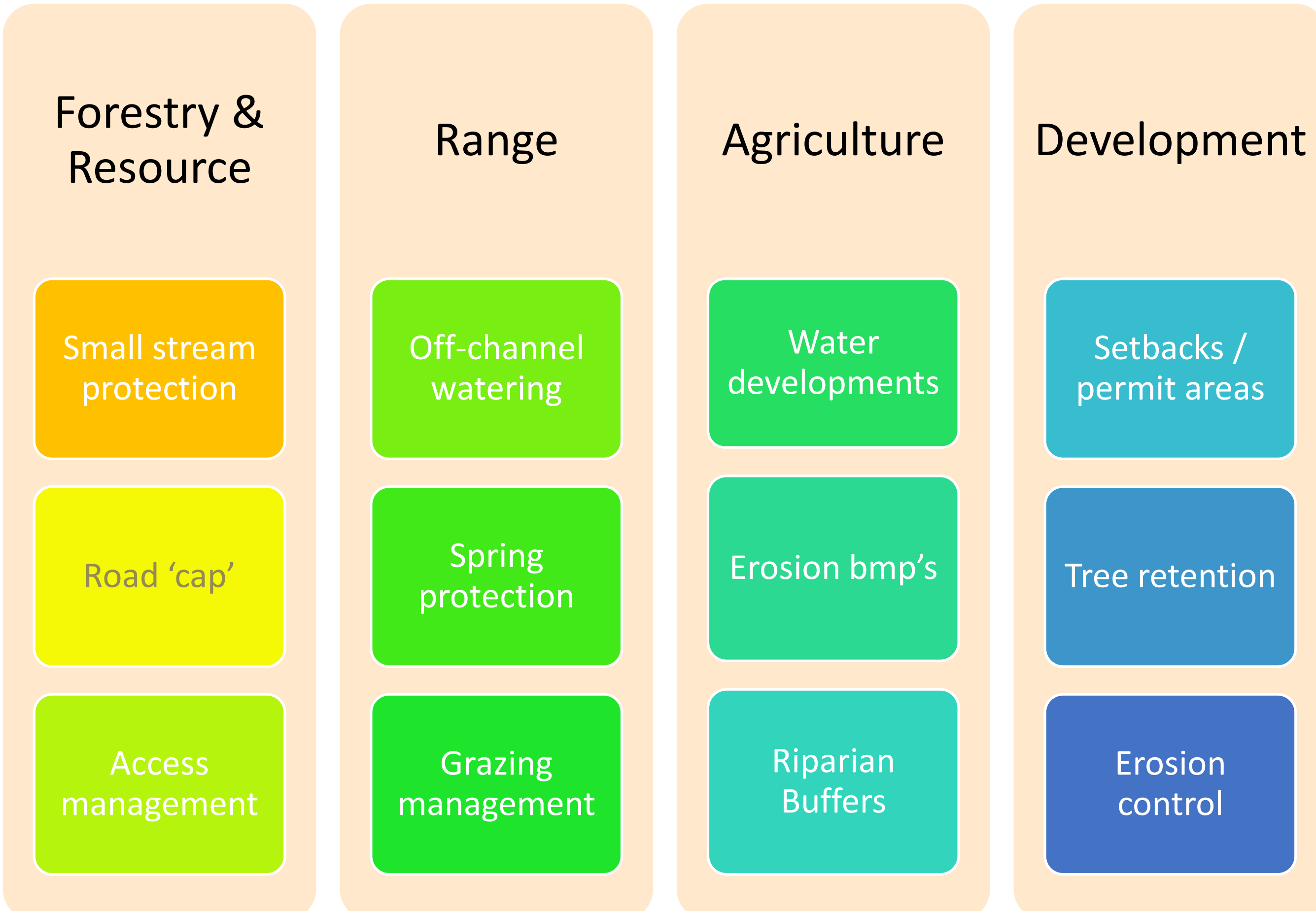
Creating solutions will involve coordinated and parallel action by different levels of government, resource management sectors, agriculture, private landowners, and other agencies. Therefore, the team recommends that policy and decision makers sectors:

- implement policy and regulatory support for protecting riparian and aquatic systems with *clear and consistent* development and management setbacks and buffers that include functional riparian vegetation for all waterbodies;
- implement riparian protection for small stream and non-classified drainages in forest management; and
- develop effective total planning, maintenance and access management for roads and trails within the context of cumulative effects management.

The key recommendation from this report is that each jurisdiction and resource sector develop and implement policy and regulatory support for protecting riparian and aquatic systems with *clear and consistent* development and management setbacks and buffers that include functional riparian vegetation for all waterbodies. The authors recommend that the Board of Directors for the Kettle River Watershed Authority endorse this report, and further that they formally request representatives of **each sector and jurisdiction** with land use and resource management authority to respond with a **commitment and timeline to propose how their sector will develop and implement these setbacks and buffers within their respective management planning frameworks**. Such commitment is required to spur appropriate management decisions and protection of the riparian resource.

These solutions will depend on a broad network of organizations and individuals working together, sharing information, finding resources, and supporting each other in watershed protection. The recommendations are directly integrated into the Kettle River Watershed Management Plan, and will be brought forward for refinement and implementation by the Implementation Advisory Group and associated organizations. This network has already started investing in capacity building and training for restoration practitioners and landowners in the region, strategic funding development and high-profile restoration projects.

Finally, there is a need to prioritize, fund and implement restoration work in riparian areas strategically throughout the watershed, based on the findings of this report and further expert input. Follow-up work with local stakeholders and resource management experts should develop a framework for managing risk, prioritizing restoration work, and selecting sites for future restoration and management projects.



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1 Introduction

1.1 Why Study Riparian Ecosystems?

Riparian ecosystems are the transitional areas where land and water meet and interact (Alberta Environment and Water, 2012). The presence of water influences soils, vegetation and wildlife in riparian areas, which in turn influence adjacent water bodies. These areas function as habitat for wildlife, support aquatic ecosystems, and provide many ecosystem services for society.

Wildlife use riparian areas more than any other habitat. Riparian areas comprise only a small amount of our landmass but have among the highest biodiversity values compared to other ecosystems (Naiman, Decamps, & Pollock, 1993). In western North America, riparian areas constitute less than 1% of the land but provide habitat for more avian species than all other vegetation types combined (Knopf and others, 1988). Riparian areas act as corridors that link habitat patches and provide dispersal and movement corridors for many plants and animals (Gregory, Swanson, McKee, & Cummins, 1991).

Healthy riparian areas provide several important functions for aquatic ecosystems. For instance, they help protect water temperature in water bodies by providing shade. Overhanging vegetation and woody debris provide cover for fish and other aquatic species, and the litter of organic material provides food for microbes and invertebrates, which are the foundation of the aquatic food chain. The benefits of headwater wetlands and small streams (first and second order)[1] cascade downstream to higher-order streams and rivers (Alexander et al., 2015).

If properly managed, ecosystems provide a flow of 'services' that are vital to society, including the production of goods (food), life-support services (water purification), and life-fulfilling conditions (beauty, opportunities for recreation)(E. Nelson et al., 2009). Riparian areas are particularly valuable for the integrity of the aquatic environment, providing the following documented ecosystem services (Hobbs, 1992; Naiman et al., 1993; National Research Council, 2002; The Associated Programme on Flood Management, 2012; Washington State Department of Ecology, 2012):

- filter and reduce sedimentation from upland sources;
- help retain flood waters and protect shorelines;
- moderate water movement and storage;
- recharge groundwater;
- provide shade and forage for livestock and wildlife;
- contribute to sustainable agriculture systems; and
- provide recreational opportunities in addition to the many aesthetic and cultural values around water bodies.

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[1] Stream order describes the placement of a given stream in a hierarchy of tributaries. A headwater stream with no tributaries has a stream order of 1, and when two first order streams join the resulting stream has an order of 2, and so on (Strahler, 1952).

1.2 Threats to Riparian Ecosystems

Researchers and land managers have identified numerous human activities that can threaten riparian area health across the landscape (Obedzinski, Shaw, & Neary, 2001; Wasser, Chasmer, Day, & Taylor, 2015). The distribution and density of these land uses and disturbances and their associated vegetation cover types affect the function of upon the landscape, associated riparian areas, and resulting water quality (Brown & Froemke, 2012).

For example, forestry cut blocks and roads near watercourses create losses in riparian habitat and tree cover that can affect water temperature (Bowler, Mant, Orr, Hannah, & Pullin, 2012), the presence of wildlife (Gyug, 2000), and sedimentation affecting water quality (Rashin, Clishe, Loch, & Bell, 2006). The amount of riparian area in agricultural lands can indicate the potential effects of agricultural run-off (Hall, Leavitt, Quinlan, Dixit, & Smol, 1999). Several authors have documented impacts of livestock in riparian areas (Kauffman, Krueger, & Vavra, 1983) that affect watershed hydrology, stream channel morphology, fish and wildlife and water quality (Belsky, Matzke, & Uselman, 1999). The severity of mountain pine beetle infestations increases sedimentation and hydrological changes that affect streams (Ministry of Forests Lands and Natural Resource Operations, 2014).

All shorelines are vulnerable to development and over-use, and many activities near water harm riparian habitat, plants and soils (Alberta Environment and Water, 2012). These threats include urban development, agriculture and livestock in riparian areas, resource development, recreational pressure, the presence of non-native species, fragmentation of ecosystems, and overarching climate change. Human water use and altered hydrologic regimes affect rivers (Dudgeon et al., 2006), and because channel processes and riparian areas are inherently tied to hydrologic and sediment regimes (Gregory et al., 1991), activities and conditions throughout the watershed will influence riparian areas.

When people damage riparian areas, they not only affect local habitat, but also impact downstream fish, aquatic vegetation, wildlife, landowners and social and economic values. For example, trees, shrubs and native plants have large root systems that buffer moving water during floods. When they are removed and replaced with non-native grasses and other plants with shallow roots, high waters can easily carve into river banks and cause instability. The added sand, gravel and stones from unstable banks in turn provide even more material to streams and rivers, increasing erosion, channel migration and flooding risk downstream. Steeper slopes (greater than 15%) may yield significant sediment when disturbed (Alberta Environment and Water, 2012).

The literature on human impacts on riparian areas indicates that development and resource management have major impacts that compromise the health and function of watersheds. What has been unknown is the impact that human activities are having on the Kettle River Watershed.

1.3 Riparian Ecosystems in the Kettle River Watershed

The Kettle River Watershed has a wide variety of ecosystem and habitat types. Several of the riparian ecosystems are locally rare, such as the river riparian habitat of the Interior Cedar Hemlock biogeoclimatic zone or wetland riparian habitat of the very dry Ponderosa Pine zone, which, which hosts numerous threatened and endangered species. Some of these areas are not only rare in the Kettle River

Watershed but in the whole Province, such as the red listed Black Cottonwood Plant Community (Egan, Cadrin, & Cannings, 1997).

The Kettle River Watershed offers a variety of recreational opportunities, and in many cases, water is at the heart of them. Christina Lake is a popular tourist destination and the Kettle and Granby Rivers are popular fishing destinations. The broad network of resource roads and recreational trails also accesses many streams and lakes.

Because of the scenic beauty offered by rivers, they are idyllic places for trails from a recreational perspective but are not always ideal when considering the ecological integrity of riparian areas. For example, mature and decadent cottonwoods that are ideal nesting trees for such species as the Lewis's Woodpecker become 'danger trees' when they are next to trails and may be topped or removed.

Agriculture, human settlement and industry has concentrated along major streams and rivers where society has taken advantage of the availability of water for irrigation, transporting logs, or disposing of waste. Homes, businesses, and industry interact directly with riparian areas, with too little regard for the important functions that intact riparian areas provide.

Land clearing, cultivation, grazing, and concentrated feeding have systematically reduced the function of riparian areas in all of the valley bottoms, while large-scale forestry and mining has fragmented the land base and concentrated impacts at road and trail crossings of streams across the watershed.

Until now, knowledge of these intersecting impacts on riparian areas in the Kettle River Watershed has been intuitive, drawn from site-specific studies or narrative observations. Planners, conservationists and water resource managers involved in the Kettle River Watershed Management Plan called for greater systematic study of riparian areas to support improved decision-making across resource and land use sectors, and this study provides the first response.

1.4 Project Overview

The goal of this project is to improve the understanding of human impacts on riparian areas in the Kettle River Watershed so that decision-makers, landowners, land managers, and the public are better able to reduce impacts and improve riparian area health and ecosystem services.

The study area is the Canadian portion of the Kettle River Watershed (Figure 1), which has an area of approximately 8150 km^2. The land use is a mix of forestry, protected areas, agriculture, rural and urban development. The population was about 12,000 people in 2011 (Stats Canada, 2011). Tourism and amenity development are important economic drivers, and many residents and visitors report a strong sense of belonging to and stewardship of the land and waters (The KRWMP Stakeholder Advisory Group, 2013).

Human activities throughout the Kettle River Watershed have increased pressures on riparian areas around rivers, streams, lakes and wetlands. However, a lack of information on the health and function of riparian areas and wetlands has hampered management planning (Summit Environmental Consultants, 2012).

The Stakeholder Advisory Group for the Kettle River Watershed Management Plan created the Riparian Working Group to begin filling information gaps. The group developed a study design to examine coarse-scale influences (threats) on site-specific conditions related to riparian area health, with emphasis on putting the widespread impacts of mountain pine beetle disturbance in context of other factors affecting hydrology, road development, sedimentation, and habitat fragmentation. They envisioned that the study would support strategies and actions in the watershed plan relating to aquatic ecosystem health, bank stabilization, and biodiversity (Regional District of Kootenay Boundary, 2014; The KRWMP Stakeholder Advisory Group, 2014).

The project team developed a course scale analysis to understand threats, impacts, conditions and opportunities for mitigation using a Geographic Information System (GIS) to evaluate land use and status across the watershed (**Section 2**), and implemented a field-based assessment (**Section 4**) with supplementary air photo analysis to understand site-specific conditions. We[2] also studied temporal changes in riparian areas and floodplains around Grand Forks and Rock Creek using historical air photos (**Section 3**) and reviewed past restoration projects using interviews and site visits (**Section 5**). Interpretation, synthesis and recommendations are in **Section 6**. Technical appendices on data sources (Appendix I) and the Riparian Model (Appendix II) accompany this report.

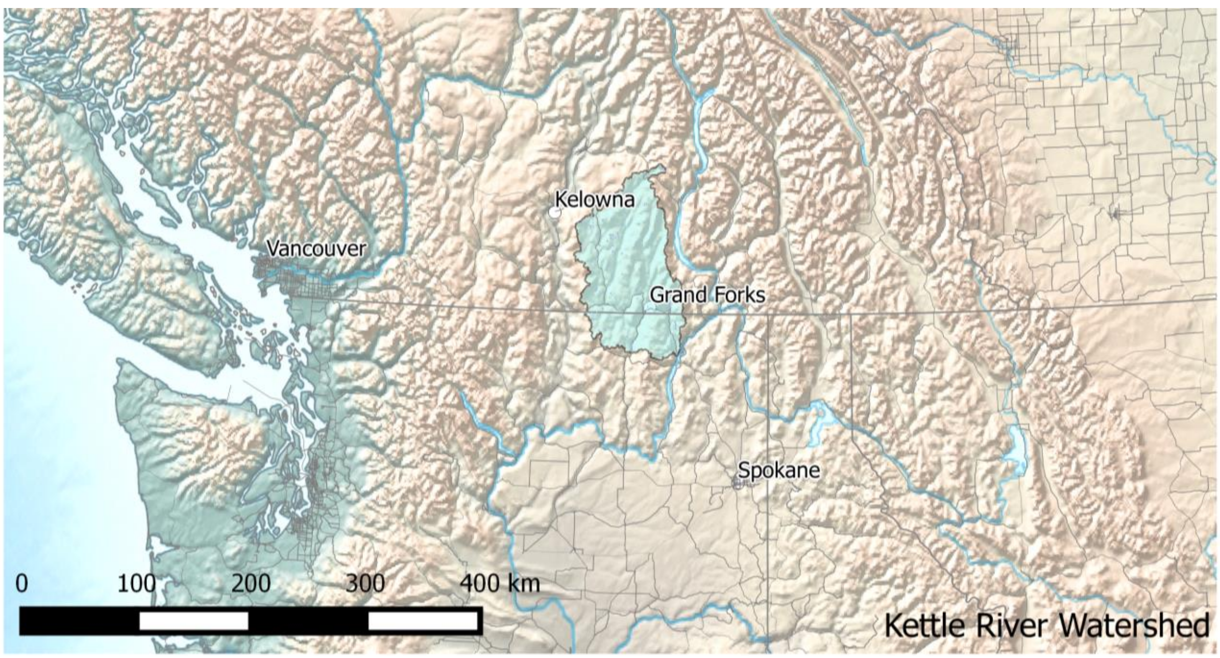

Figure 1. Location of the Kettle River Watershed in the Southern Interior of British Columbia.

[2]The authors sometimes utilize the active voice with personal pronoun 'we' for readability and to distinguish when others contributed results (as in the case of Field Technicians) or external content (Appendix II).

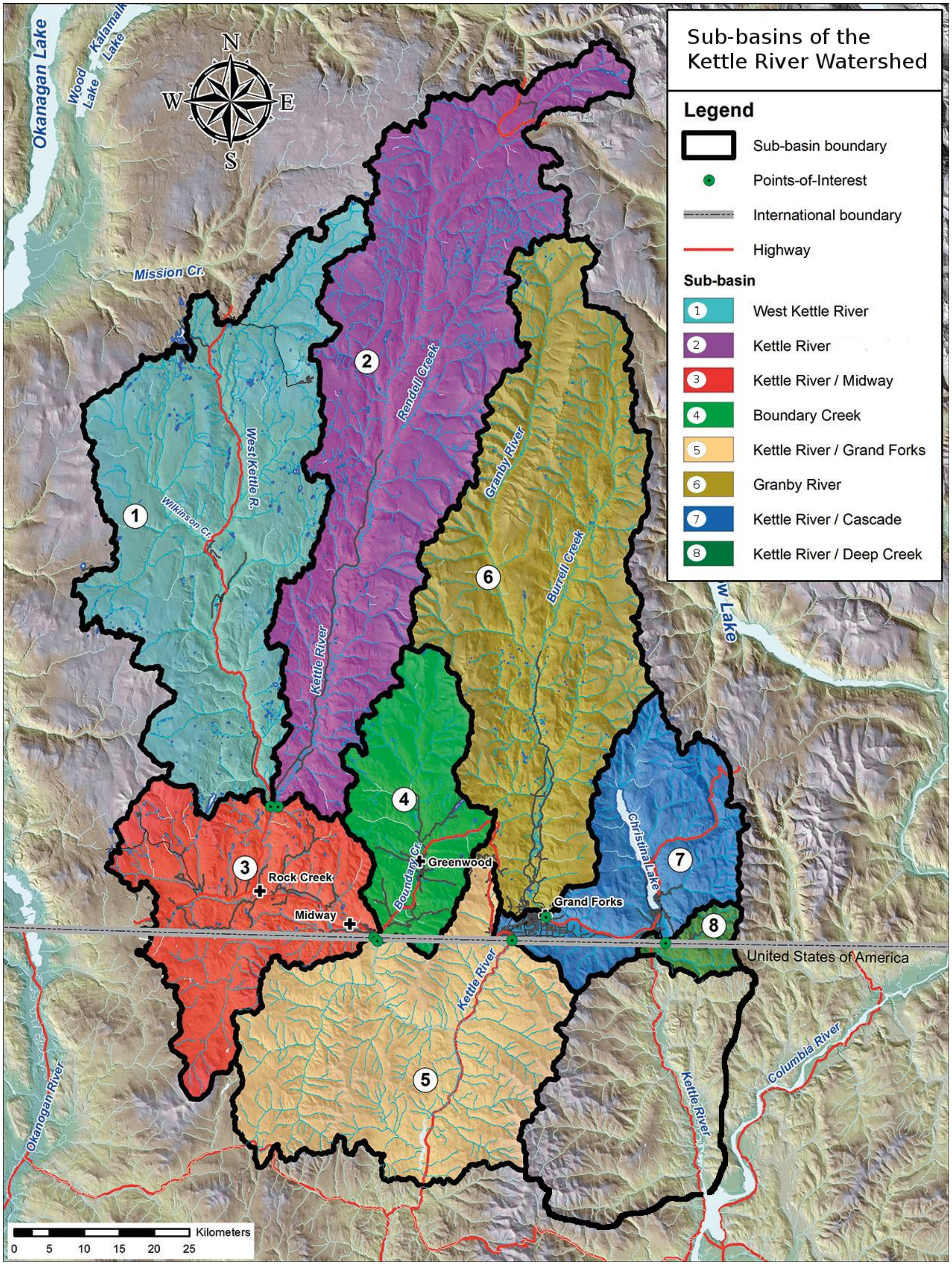

Figure 2. Sixth Order Sub-basins of the Kettle River Watershed.

2 Coarse Scale Analysis

2.1 Methods

To understand coarse-scale influences on riparian health, the team reviewed and compiled data from various data sources and conducted the following analyses:

- Riparian buffer area based on different watershed features
- Riparian area by local government jurisdiction and ownership
- Watershed features by Biogeoclimatic Subzones
- Riparian area within each Land Use/Disturbance Type
- Length and density of roads in riparian buffers and
- Number of stream crossings by roads

To estimate the riparian areas relative to different watershed features we:

- represented riparian areas with a 100 metre buffer on polygon features (rivers, lakes, wetlands and ponds) and line features (streams, orders 1-8)[3] using ArcGIS 10.1. The 100 metre buffer distance is consistent with other protocols for measuring land use impacts in British Columbia (Porter, Casley, Snead, Pickard, & Wieckowski, 2012).
- clipped the resulting buffers to Kettle River watershed boundaries and dissolved them to remove overlapping features.

To determine the amount of riparian area within each land use/disturbance type we accessed data layers from provincial data sources representing different land uses,[4] including: Biogeoclimatic Ecosystem Classification (BEC) subzone (Ministry of Forests Lands and Natural Operations, 2014); Mountain Pine Beetle polygons (1966-2012) from the provincial forest 'pest' dataset; land use and status; forest harvest activities (openings); and roads. The team also evaluated the footprint of recreational areas by examining recreational trails and sites.[5] We then clipped the resulting land base to the 100m riparian buffer

To characterize roads, the team:

- used three different sources to create a single road data layer for analysis since each data source did not provide coverage of all roads. The resource roads database (Appendix III #32) density layer had the most coverage of the layers, so we added roads from the digital roads atlas (#33) layer that fell outside of the resource road layer in a "select by location" query, then added remaining polylines from the forest tenure road layer (#31) to make the final roads layer.

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[3] The freshwater atlas of British Columbia provided data on streams, rivers, wetlands, ponds and (Ministry of Forests and Lands, 2009).

[4] from the provincial GeoBC online database (http://geobc.gov.bc.ca/) or the province's Land and Resource Data Warehouse (http://lrdw.ca/). Data sources and manipulations are detailed in Appendix III.

[5] Not all trails were available digitally and are missing from the analysis such as the trails within the City of Grand Forks and the River Walk trail of Midway.

- classified roads into three different classes: highway (Routes 3, 33, 6, 41 and 385), local roads (all secondary and town roads), and resource roads (remaining roads).
- buffered the roads layer to approximate a road surface footprint based on the identified (digital roads atlas) or assumed (forest tenure or resource road) number of lanes.
- considered each lane to have a width of 5 m for local and resource roads 8 m for highway lanes (Porter et al., 2012), and assigned buffer widths in forest tenure road and resource road spur (one lane) and operational road (2 lane) classes.
- assigned the road layer two additional columns – number of lanes and buffer widths – then created a buffer for the total road width and calculated its area.

Because the team combined different sources of road data with various known and unknown errors, we assumed that spatially represented roads actually exist and that errors introduced by the combination do not affect the overall results. We assume that any resulting errors do not significantly affect our understanding of landscape-level threats, and note that the results should not be used to predict or make prescriptions for site-specific conditions.

We performed several measures to understand the extent and impact of roads in the watershed:

- estimated road density for each 3rd order (1:50,000 scale) watershed and for 100 m riparian buffers by dividing the length of road (km) by the watershed area and riparian buffer area (km^2), respectively.
- calculated road density using the line density function of ArcGIS 10.2. Spatial Analyst (ESRI, 2013), with a 100 m output grid and 1000 m search function.
- calculated the number of road/stream crossings using the ArcGIS 10.2 Spatial Analyst Intersect Tool
- calculated road/stream crossing density by dividing the number of road-stream crossings by the area of the watershed.

2.1.1 Riparian buffer model

The 100 m buffer used to identify threats to riparian areas is a coarse approximation of riparian areas. It can wrongly include some upland sites in high relief valleys and exclude some known riparian areas on valley bottoms. The potential riparian area may be more accurately delineated by incorporating information on terrain, drainage area, soils, vegetation and other information (Theobald, Mueller, & Norman, 2013; Western, Theobald, Merritt, & Norman, 2010).

To improve on the identification of potential riparian areas the BC Ministry of Forests, Lands, and Natural Resource Operations (FLNRO) developed a model (Appendix II Riparian Model). Due to a number of shortcomings, the authors determined the model needs further work and additional data before using in this study. For instance, the model wrongly identified potential riparian areas on many valley-bottom sites, and missed known riparian sites around wetlands. Modellers may be able to improve results by including additional parameters such as soil texture, drainage, and depth to water table, where the data are available, or by using higher resolution terrain data. However, soil data is generally not high enough resolution and higher resolution terrain data was not available during the study. FLRNO staff will continue to work on improvements to the model in future projects or as more data are available (personal communication L. Tedesco).

2.2 Results

2.2.1 Riparian Buffer by Aquatic Feature

The area of riparian buffer varied widely depending on the extent of different water features, with streams representing 95% of all riparian areas (Table 1). The classification of water bodies are from the Freshwater Atlas (Data sources #1-5).

Table 1. The area of riparian buffer each aquatic feature type covers. [6]

Feature	Area (km^2)	Percent
Lakes	82	3%
Ponds	38	1%
Rivers	94	3%
Streams	2645	95%
Wetlands	200	7%
Total Area	2773	100%

2.2.2 Riparian Area by Local Government Jurisdiction and Ownership

The amount of riparian areas varies by aquatic type across different jurisdictions and ownership (Table 2). Electoral Area E has the highest amounts of riparian area for all water features, and a significant amount of lake riparian area falls on private property. Greenwood has only stream riparian while Grand Forks has a variety of water features and associated riparian areas.

Table 2. Amount of riparian area (km^2) by local government jurisdiction and ownership.

	Area C[7]	Area D	Area E	Midway	Greenwood	Grand Forks	Private
Lake	6.66	11.26	49.56	0.00	0.00	0.16	10.11
Ponds	1.68	7.56	25.14	0.00	0.00	0.00	4.36
River	2.43	26.27	45.10	1.17	0.00	1.42	19.45
Streams	166.56	659.74	1368.93	3.35	0.83	1.25	160.61
Wetlands	1.05	17.50	116.40	0.00	0.00	0.19	12.81

2.2.3 Riparian features by Biogeoclimatic Subzones

Most of the Kettle and Granby Rivers is within the Interior Douglas-fir / Kettle Dry Mild (IDF dm 1) BEC zone (Figure 1).[8] The major rivers (West Kettle, Kettle and Granby Rivers) follow the valley bottoms

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[6] percentages add up to greater than 100% because of the overlap between adjacent buffered features such as wetlands and lakes.

[7] Electoral Areas: 'C' / Christina Lake, 'D' / Rural Grand Forks, and 'E' / West Boundary

[8] Full details on BEC zone acronyms and interpretation at http://www.for.gov.bc.ca/hre/becweb/resources/classificationreports/subzones/index.html

while lower order tributaries comprise the largest riparian area at higher elevations, where Montane Spruce Okanagan dry mild (MSdm1) and Engelmann Spruce-Subalpine Fir (ESSF zones) occur.

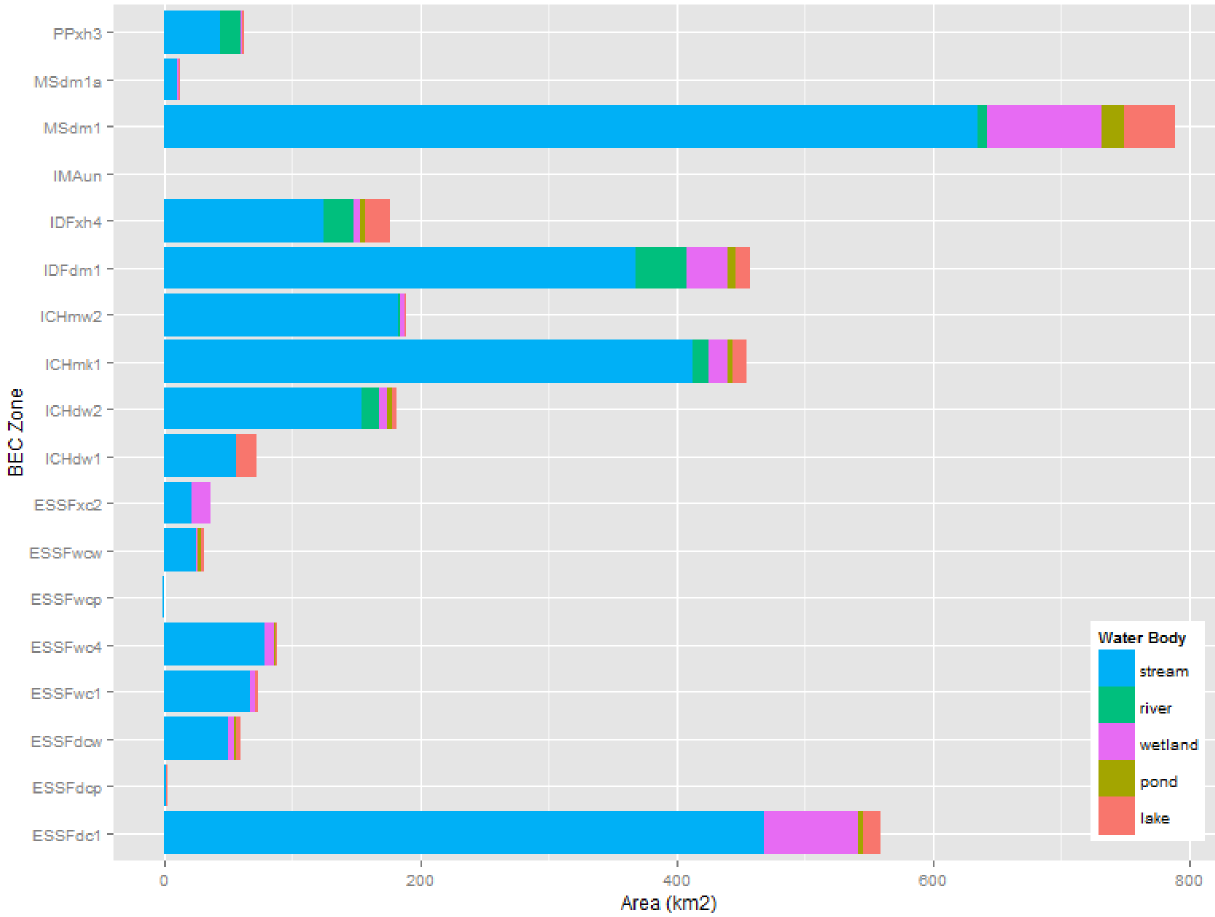

Figure 3. Amount of Riparian Areas (km²) within Biogeoclimatic sub-zones.

2.2.4 Riparian Area by Land Use/Disturbance Type

The amount of riparian area varies across different land use and disturbance types (Table 3). Range tenures were the largest land use across the watershed covering riparian areas,[9] followed by Agricultural Land Reserve lands. Mineral Tenures also encompass a large amount of riparian areas. There are more than 500 mines recorded in the watershed (132 in the riparian buffer), although there is little active mining.

Current and historical logging (all openings) have a significant footprint in riparian areas (Table 3). Forest harvest has occurred extensively throughout the watershed except in protected areas. The location and extent of active logging has varied over time, with larger cut blocks being associated with past severe outbreaks of mountain pine beetle (MPB) such as the West Kettle River and Boundary Creek watersheds (Figure 6).

[9] Both range tenures and active range tenures were reported in order to account for current use and past impacts.

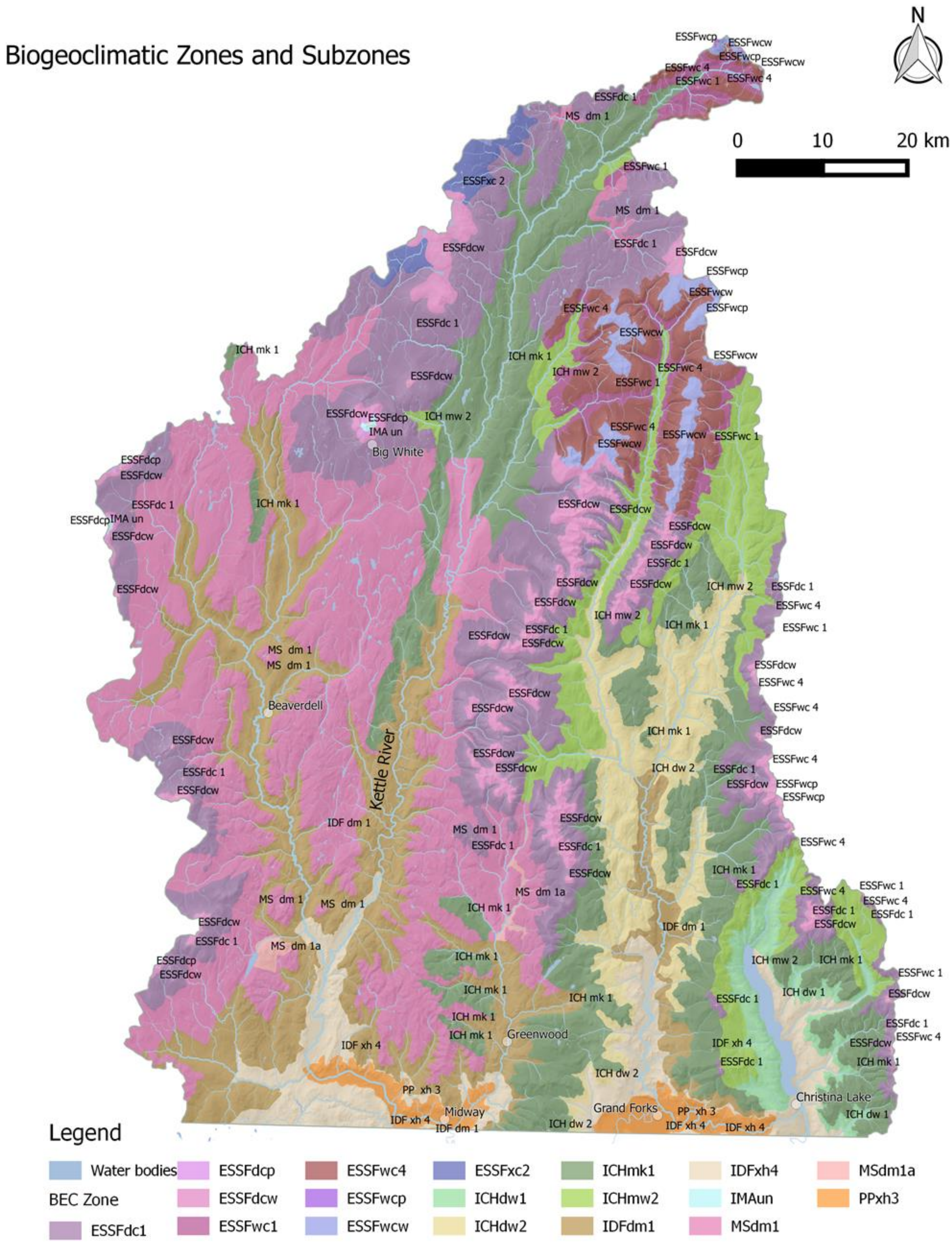

Figure 4 Biogeoclimatic Zones and Subzones.

Table 3. Amount of Riparian Area within Each Land Use/Disturbance Type (i.e. Agriculture refers to land converted into cropland, pastureland, etc. while ALR Agricultural Land Reserve refers to land status governed by the Agricultural Land Commission).

	Lake		Pond		River		Stream		Wetland		Combined	
	km^2	%	km^2	%	km^2	%	km^2	%	km^2	%	km^2	%
Agriculture	1.6	2.0	1.1	2.8	4.6	4.9	27.5	1.0	1.7	3.5	36.2	1.3
ALR	6.3	7.7	3.6	9.5	34.8	37.0	149.3	5.6	6.4	12.8	175.2	6.3
Developed	2.4	2.9	0.6	1.7	4.0	4.3	21.5	0.8	0.9	1.7	26.3	1.0
Historical Fires	25.9	31.5	15.6	41.1	21.2	22.5	896.8	33.9	24.9	49.9	924.9	33.4
Forest Harvest Tenures	21.4	13.2	5.2	2.0	15.6	2.2	691.2	1.2	5.8	79.8	724.7	1.5
Forest Recreation Sites	10.9	26.1	0.8	13.7	2.0	16.6	31.9	26.1	39.8	11.6	42.1	26.1
Historical Logging	12.4	15.2	6.7	17.7	6.1	6.5	577.9	21.9	26.0	52.2	600.7	21.7
Mineral Titles	25.2	30.7	13.4	35.2	29.5	31.4	695.7	26.3	25.4	51.0	732.9	26.4
Mountain Pine Beetle	11.5	14.0	5.4	14.3	8.2	8.7	452.5	17.1	15.5	31.1	468.0	16.9
Protected areas	9.2	11.3	3.8	9.9	10.6	11.3	301.8	11.4	3.6	7.1	311.8	11.3
Range Tenures	67.0	81.8	31.8	83.7	54.4	57.8	2240.1	84.7	89.7	179.7	2332.1	84.1
Range Tenures Active	62.6	76.3	29.6	78.0	47.8	50.8	2041.3	77.2	82.7	165.6	2123.8	76.6
Recreational Trails	0.2	0.2	0.1	0.3	0.5	0.5	6.0	0.2	0.1	0.2	6.5	0.2
Roads	3.2	3.9	1.3	3.4	4.0	4.2	88.4	3.3	3.4	6.8	94.1	3.4

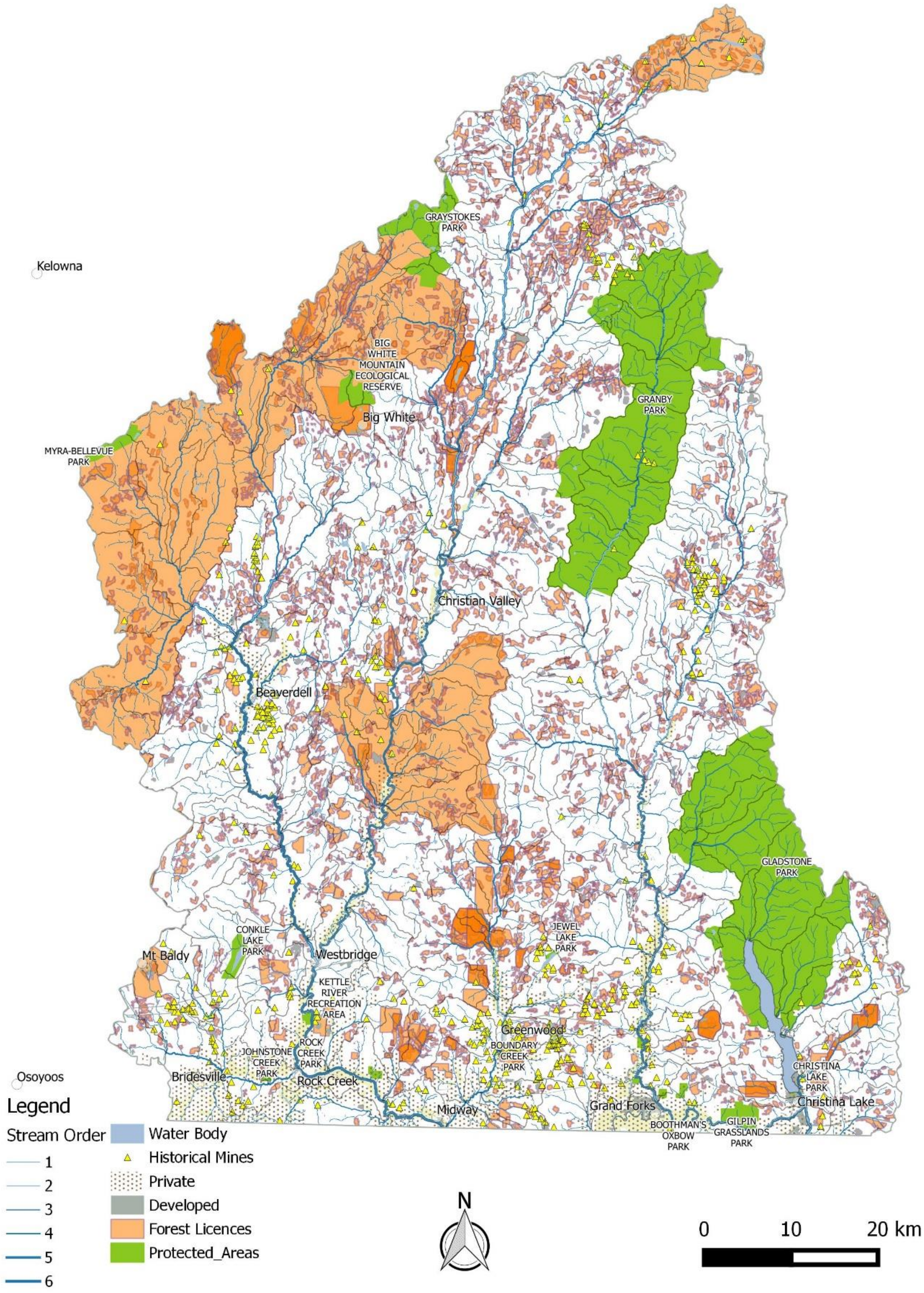

Figure 5. Land Use Tenure and Activity

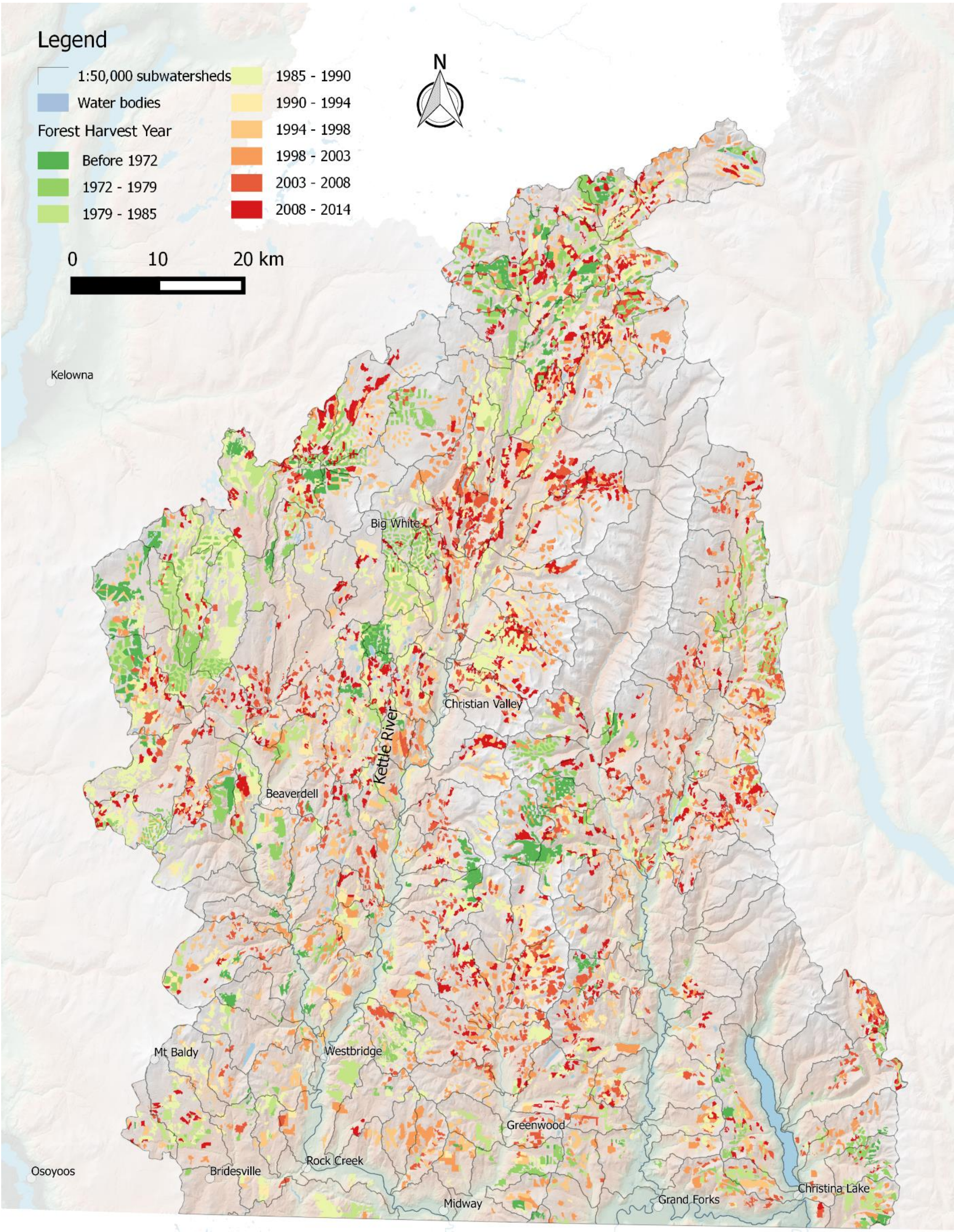

Figure 6. Forest Harvest by Year.

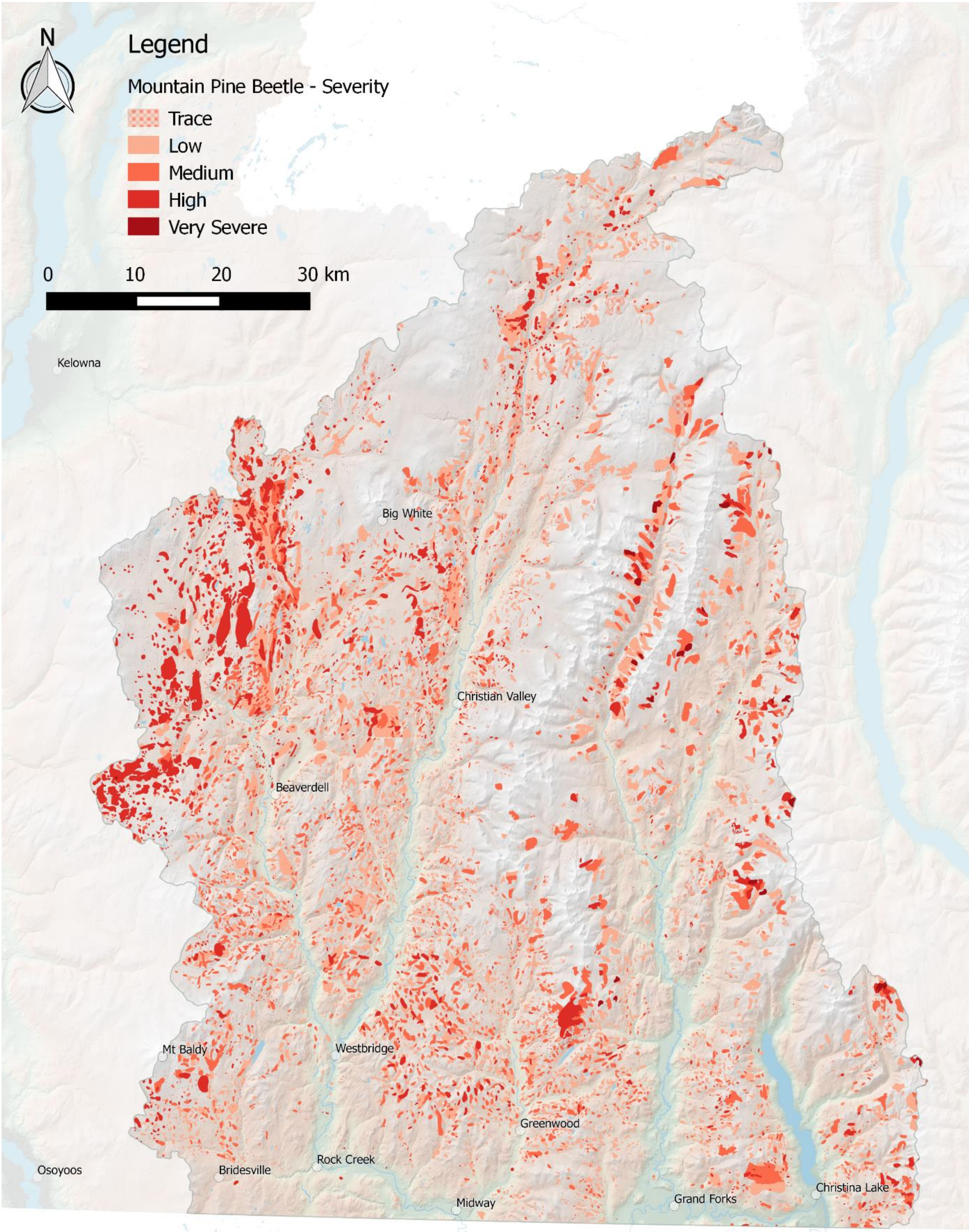

Figure 7. Severity of Mountain Pine Beetle disturbance.

Roads have a significant interaction with riparian areas across the watershed (Table 4):

- The total length of roads is 16,410 km.
- Over 15,000 km of these roads are related to resource management
- 221 km of resource roads within riparian areas are on unstable or potentially unstable terrain.
- 5107 km of resource roads are within stream riparian areas, with an associated density of 1.93 km/km^2
- 407 km of roads are within wetland riparian areas, with an associated density of 2.03 km/km^2.
- The Kettle and Granby Rivers had the highest density of roads within 100 metres, due to the proximity of settlements, farms, and transportation corridors.

Figure 8. Road maintenance can lead to sediment deposition into streams - Knappen Creek Forest Service Road along Burrell Creek.

Table 4. Length and Density of Roads in riparian buffers.

	Length (km)			Density (km/km^2)		
	All Roads	Resource	Local	All Roads	Resource	Local
Lakes	184.05	149.10	34.95	2.24	1.82	0.43
Ponds	74.39	66.16	8.23	1.96	1.74	0.22
Rivers	216.37	133.31	83.06	2.30	1.42	0.88
Streams	5468.76	5107.87	360.89	2.07	1.93	0.14
Wetlands	440.34	407.06	33.28	2.20	2.03	0.17
Total Area	5799.27	5352.45	446.82	2.09	1.93	0.16

There are over 10,940 known road-stream crossings in the watershed (Table 5) including 2811 culverts. Most of these stream crossings are resource roads on first order streams.

Table 5. Road and Stream Crossing Numbers by Stream Order and Road Type.

	Stream Order								
Road Class	1	2	3	4	5	6	7	8	Total
Highway	123	49	22	11	3	4	3	2	217
Local	348	125	73	33	5	6	7	7	604
Resource	7397	1852	593	193	61	15	7	2	10120
Total	7868	2026	688	237	69	25	17	11	10941

The river and associated riparian areas are attractive areas for recreational activities. Of the 240 km of the Trans Canada Trail in the watershed, 47% is within 100 metres of all streams and 16% is within 100 metres of the Kettle River. The local ATV group has mapped 1223 km of trails (mostly on resource roads), of which 41% are within 100 m of a water feature.

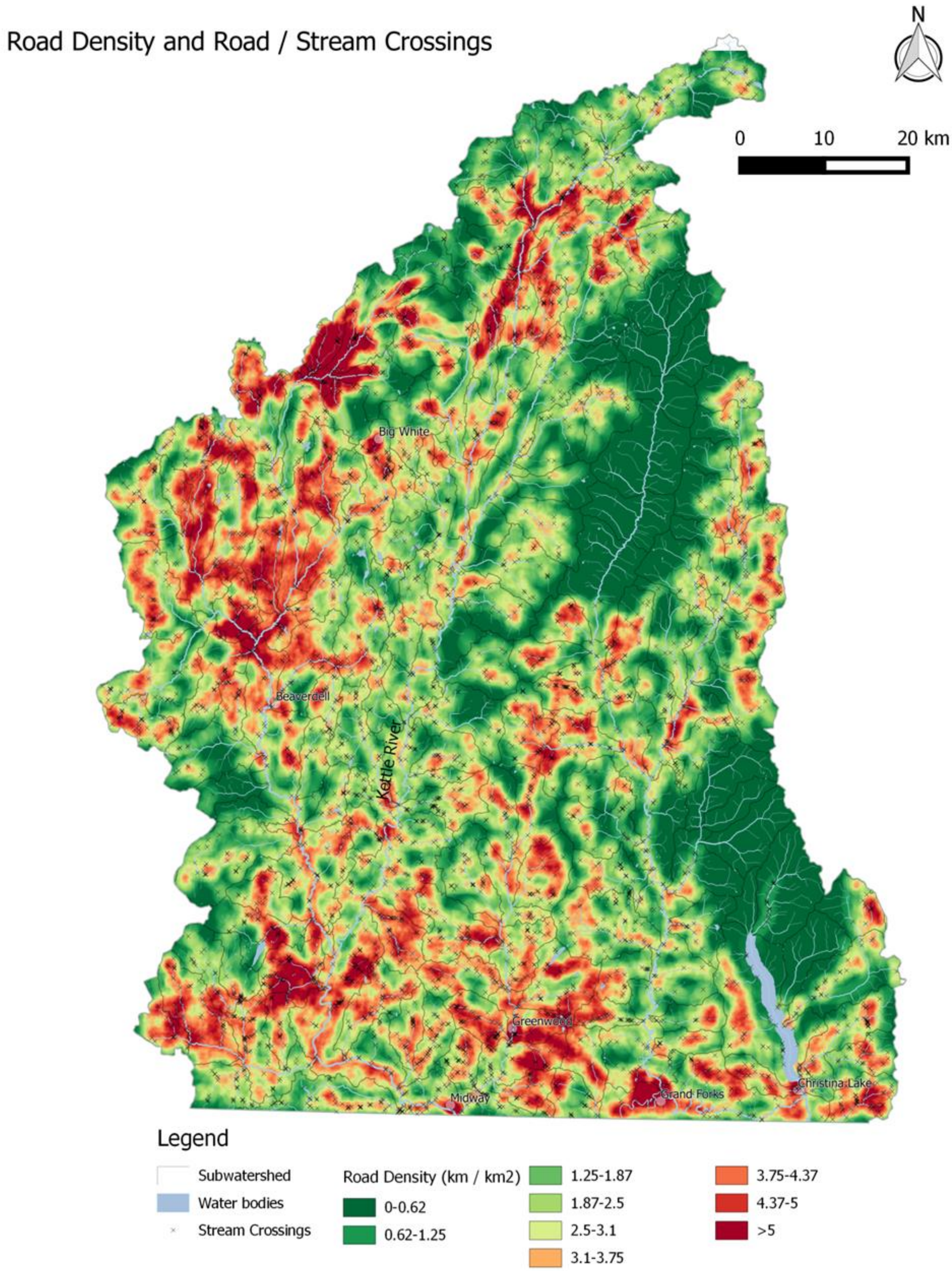

Figure 9. Linear density of roads and occurrence of road/stream crossings.

2.3 Discussion – Coarse Scale

The distribution and density of land uses and disturbances reflect pressures upon the landscape, associated riparian areas, and resulting water quality (Brown & Froemke, 2012). The coarse scale analysis identified and illustrates the location and extent of different land uses types and human disturbances across the Kettle River watershed.

Our analysis found some overlap between forestry harvest openings and MPB disturbance. Pest management strategies for MPB involve the harvest of Lodgepole Pine in salvage operations - across the watershed, 35% of the total area logged also had MPB disturbance. However, management actions for MPB associated with harvest activities has been poorly documented (RESULTS_Openings database).

Fire is a naturally occurring disturbance that has multiple ecosystem benefits but can also affect riparian areas and water quality. Until 2015, there had been no significant fires in the Boundary for decades. Between 2000 and 2014, 11 different fires burnt 1.97 km^2 of riparian area, mostly from one fire. Fire suppression has caused a buildup in fuels resulting in higher risks of high severity fires (Teel & Afford, 2015), which are more likely to burn vegetation in riparian areas. Thus the effect of fire suppression on fire severity is an important consideration when implementing ecosystem restoration (Dwire, Meyer, Sandra, Riegel, & Burton, 2011).

Most urban development occurs in the lower valley bottom of the Kettle River. While their footprint may be small, urban areas tend to have a disproportionate impact on water quality and sediment inputs to stream systems (Alberta Environment and Water, 2012; K. C. Nelson et al., 2009; Wahl, McKellar, & Williams, 1997).

The Trans Canada Trail runs through the Kettle River Watershed, nearly half of which is within the 100 m riparian buffer of streams or rivers. The local ATV group has been also developing trails, of which 41% are within the riparian buffer. Environmental stewardship coupled with trail and recreational planning ensures all values are incorporated into recreational development. Trail managers must consider riparian health, potential for wildlife conflicts and wildlife/danger trees explicitly when designing recreational facilities, parking or access points.

3 Historical comparison of Riparian Areas and Changes Over Time for Selected Sites along the Kettle River

3.1 Background

Historical analysis is an important component of threat assessments because land managers and planners need to understand how humans and natural forces have shaped ecosystems over time in order to mitigate impacts of current activities and develop management and restoration actions (B. Poff, Koestner, Neary, & Henderson, 2011; Western et al., 2010). In addition, historical analysis can identify sites appropriate for providing reference conditions for planning nearby ecological restoration works, where land use and disturbance have been minimal over time (Stein et al., 2010).

The team developed the historical comparison to understand historical changes in selected stretches of riparian area within the Kettle River Watershed. Our specific objectives were to: 1) select stretches of river for which historical aerial photographs were available, 2) digitize land cover for both current and historical photographs, and 3) compare temporal changes in land cover in the riparian area over time.

3.2 Methods

The team identified two sites (Grand Forks and Kettle River Provincial Park to Rock Creek; Figure 10 and Figure 12) to compare land use changes in riparian areas and floodplains. We based our selection on the dominant land use in riparian areas and advice from the Riparian Working Group. We requested copies of the relevant historical air photos from the University of British Columbia Geography, then scanned, georeferenced and projected the photos to the BC Albers coordinate system using the Georeferencing Tool in ESRI ArcGIS.

ArcGIS software includes orthophoto base maps, which we used to digitize the recent status of habitat and land use in riparian areas. The team digitized land cover in ArcMap 10.1 and classified polygons according to Canada's Land Cover Classification Scheme (Natural Resources Canada, 2004). We then clipped the land cover layer to a 50 m analysis buffer, summarized land cover by year and calculated land cover comparisons in Microsoft Excel. Data for individual land cover classes are in Appendix III: Supplemental Results.

3.3 Results

3.3.1 Grand Forks

The dominant land use type for the City of Grand Forks selection is urban development and for the Rock Creek area is agriculture. The oldest air photos the UBC Geography Department could supply was 1938 for Rock Creek and 1951 for Grand Forks.

Figure 10. Aerial photographs used to compare riparian and floodplain changes in Grand Forks, BC, overlaid in Google Earth. The top photo shows recent conditions and the bottom shows 1951 conditions.

The team interpreted land cover classes based on the Canada National Forest Inventory (Natural Resources Canada, 2004), but clumped some classes for analysis: Building and Parking, Roads, Exposed land, All Shrubs, All Herb-Grass, Deciduous Dense, Deciduous Open/Sparse, All Conifer & Mixed Tree, All

Dense & Open Trees, and all Trees.

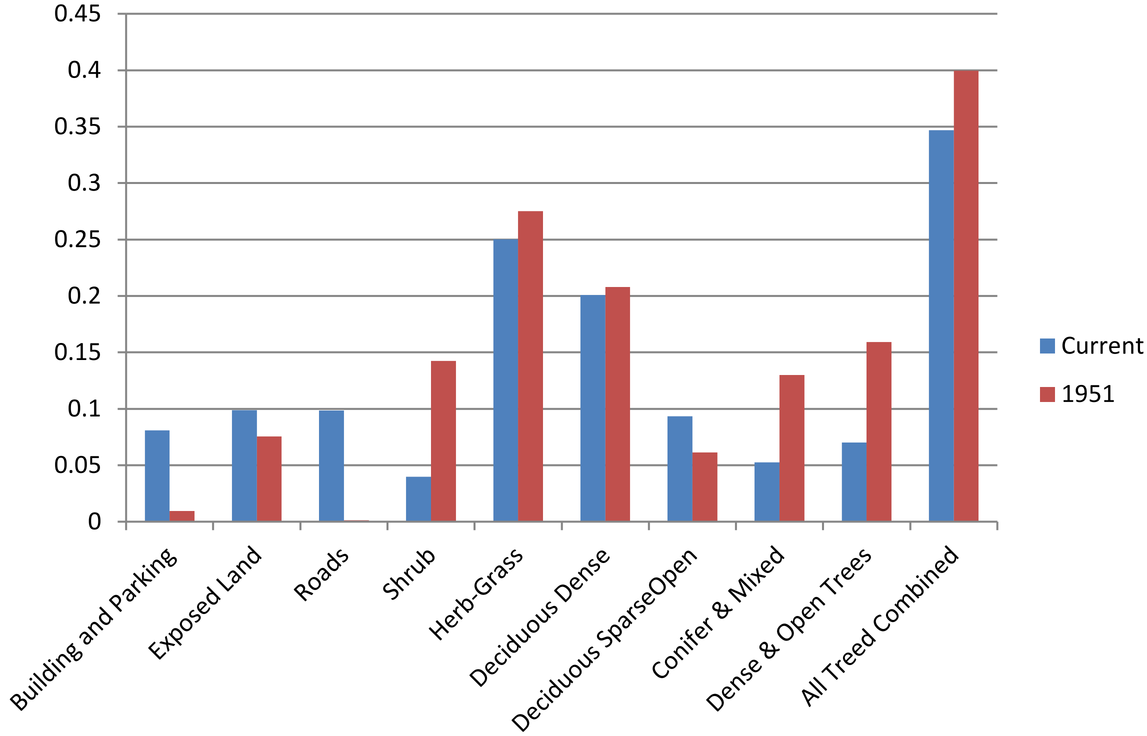

Figure 11. Comparison of land cover classifications between 1951 and Current Conditions within 50 metres of water features in Riparian Areas of the City of Grand Forks area.

Table 6. The amount (km²) of each land cover class within 50 metres of water features within Grand Forks.

	Area in km²		
	Current	1951	% Change
Building and Parking	0.08	0.01	746
Exposed Land	0.10	0.08	30
Roads	0.10	0.00	8328
All Shrub	0.04	0.14	-72
All Herb-Grass	0.25	0.28	-9
Deciduous Dense	0.20	0.21	-3
Deciduous Sparse/Open	0.09	0.06	52
All Conifer & Mixed Tree	0.05	0.13	-60
All Dense & Open Trees	0.07	0.16	-56
All Treed Combined	0.35	0.40	-13

3.3.2 Rock Creek

The team also clumped the land cover classes for the Rock Creek Area to the following classes: Building and Parking, Roads, Exposed land, All Shrubs-Herb-Grass Combined, All Deciduous, All Conifer & Mixed, and All Dense & Open Trees Combined (for data of all individual cover classes see Appendix III).

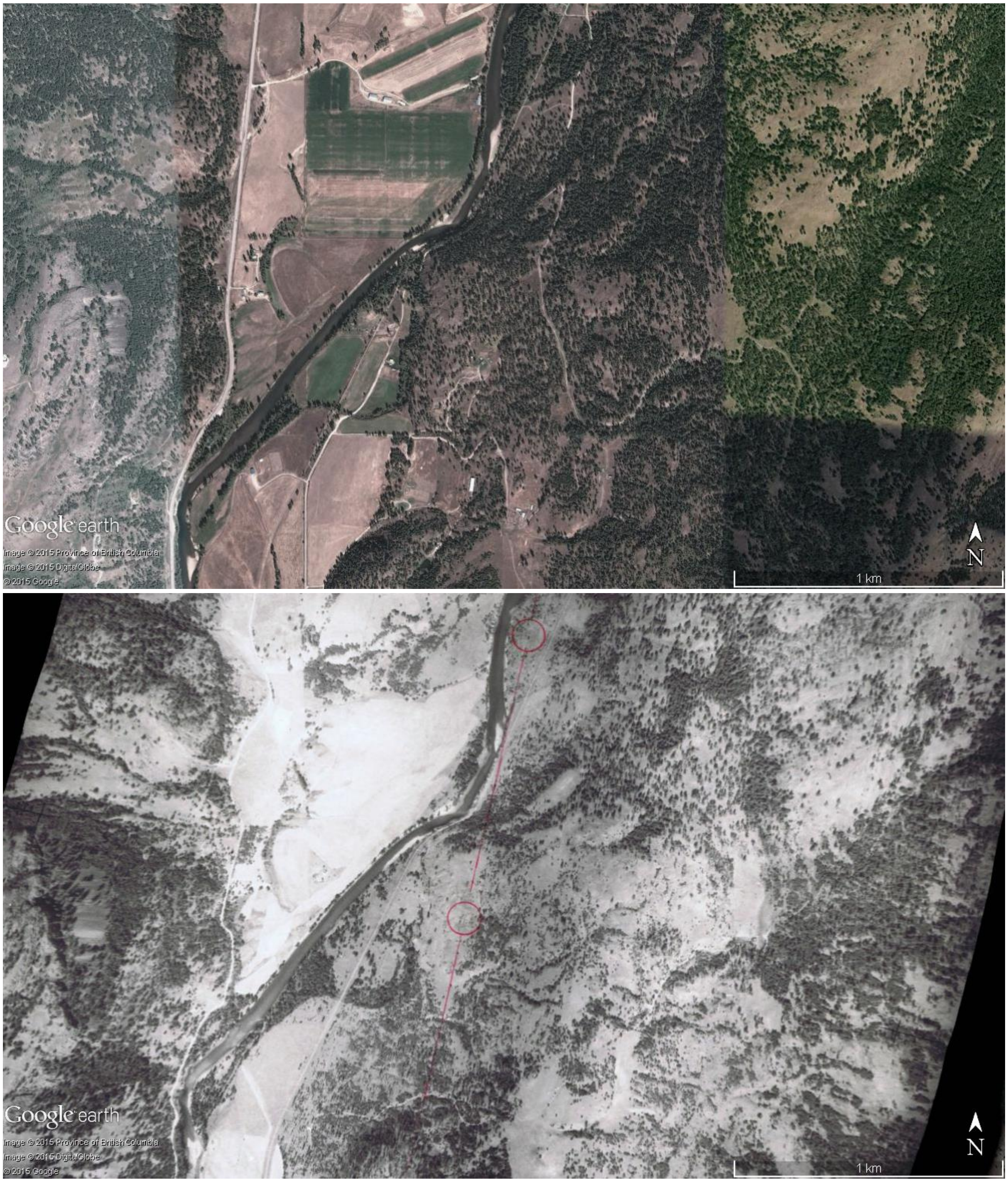

Figure 12. Aerial photographs used to compare riparian and floodplain changes in the Rock Creek Area, overlaid in Google Earth. The top photo shows recent conditions and the bottom shows conditions in 1938.

In 1938, there was no building and parking within the 50 metre riparian area in the Rock Creek area (Figure 13). Roads and exposed lands increased. There was varying results for tree cover; deciduous trees (dense, open, and sparse) were clumped and this class showed an increase in cover between 1938 and current. All tree classes together showed an increase in cover by 23%. The largest change was the increase in exposed land.

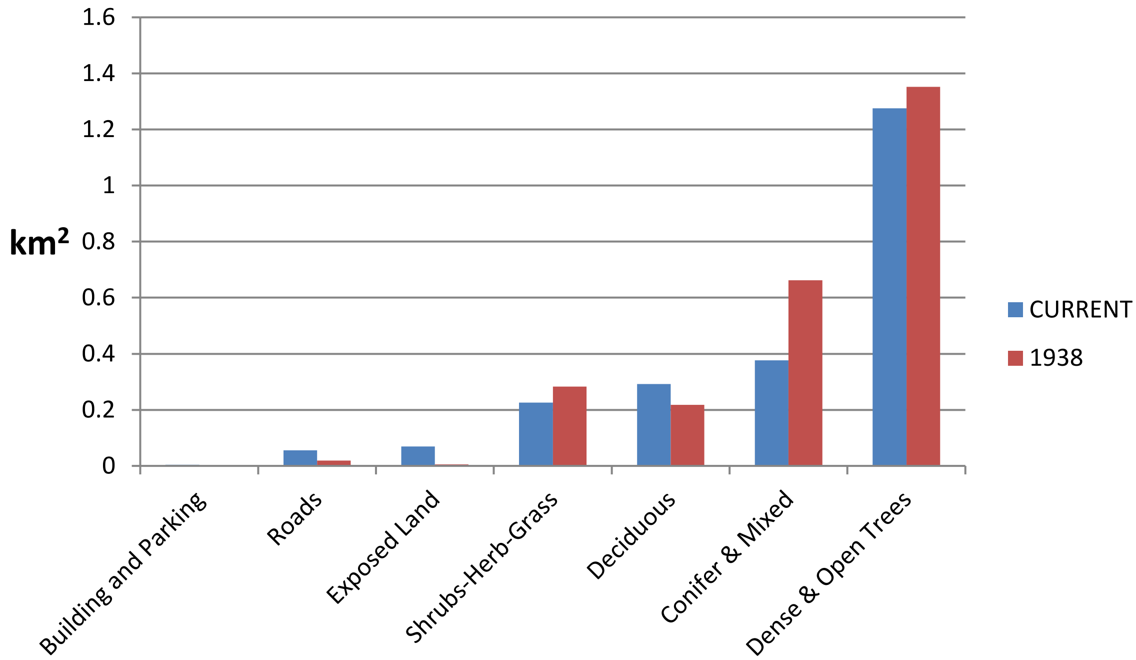

Figure 13. Comparison of land cover classifications between 1951 and Current Conditions within 50 metres of water features in Riparian Areas of the Rock Creek Area north to the Kettle River Provincial Park.

Table 7. The amount (km2) of each land cover class within 50 metres of water features within the Rock Creek Area.

	Current	1938	Percent Increase
Building and Parking	0.005	0.00	NA
Roads	0.06	0.02	188
Exposed Land	0.07	0.01	1222
All Shrubs-Herb-Grass	0.23	0.28	-20
All Deciduous	0.29	0.22	34
All Conifer & Mixed	0.38	0.66	-43
All Dense & Open Trees	1.28	1.35	-6

3.4 Discussion – Historical Comparison

In the last 60 years, there have been major changes in the amount of urban development in Grand Forks within the riparian areas of the Kettle and Granby Rivers. This has caused many impacts to riparian areas, including the loss of wetlands. The Kettle River from Rock Creek to the Kettle River Provincial Park has not seen as many dramatic changes. The small changes seen along the river in this area is likely because the properties have remained as large parcels and agriculture has continued to be the primary land use, as it was in 1938.

The decreasing amount of riparian vegetation so apparent in the Grand Forks area echoes the trend across North America (Obedzinski et al., 2001; Swift, 1984; Wasser et al., 2015; Yeakley, Ozawa, & Hook, 2006). Now many land managers are facing costly restoration projects and need to prioritize areas to restore or conserve as they realize the true value of riparian areas.

Land cover classifications from aerial or satellite images provides a relatively simple and cost effective tool in evaluating land cover changes over time. However, it does not provide any information on the quality of habitat within the different land cover types. Even though the Rock Creek area shows an increase in deciduous tree cover, changes in habitat quality are not well understood.

The Rock Creek area falls within Electoral Area 'E' / West Boundary of the Regional District of Kootenay Boundary where there is no land use planning in place for private lands except the Agricultural Land Reserve.

Official Community Plans and zoning bylaws are the principal means for local governments to guide decisions on planning and land use management, and articulate the long-term vision for the community. Implementing planning for the West Boundary could provide additional measures for protecting riparian areas and wetlands through the Official Community Plan, zoning, environmental development permit areas, and other means (University of Victoria Environmental Law Clinic & Curran, 2007).

Historical comparisons of the Grand Forks showed significant land use changes within the riparian area of the Kettle and Granby Rivers and wetlands within the City. Rock Creek also showed changes but not as dramatic as in Grand Forks.

The City of Grand Forks has a Sustainable Community Plan where section 14.0 discusses Development Permit Areas (DPAs) with appropriate guidelines around wetlands and water quality protection; currently there is one wetland designated as a DPA (see City of Grand Forks SCP). During the summer of 2014, students working under the City of Grand Forks worked with the Granby Wilderness Society to begin mapping wetlands within the City of Grand Forks. These areas may be a consideration for designation of Development Permit Areas or natural area protection in future planning work.

4 Fine Scale Analysis

The purpose of the field assessment was to complement the coarse-scale assessment by characterizing actual riparian conditions (vegetation composition and structure, disturbance and stream bank condition), and place these conditions in context of landscape patterns in the overall watershed.

4.1 Methods

4.1.1 Sampling design

Sampling riparian conditions in such a large area requires trade-offs – if the team had distributed samples randomly across the watershed we would have had less time available for data collection because of travel time and access issues. We estimated that field crews would be able to visit between 90 and 100 sites in the 2014 summer field season if sites were somewhat clustered. Therefore, we selected the eight 3rd order watersheds with the highest levels of different land use impacts (i.e. roads, stream crossings, forestry openings, agricultural land use), as well as a reference watershed, and planned for ten field sites per sub-basin based on the budget for fieldwork (Table 8).

The sample design identified sites from all possible locations along streams, rivers, lakes and wetlands within target sub-basins using a stratified random sample with the R package spsurvey (Kinkaid et al., 2013)(Figure 10). Samples were spread equally among small streams, large streams, lakes and wetlands. For sub-basins with too few sites in one or more of the stream order/water body strata, we set the sampling to 'unequal' to obtain even distribution among remaining strata. The sampling method provided an oversample of 10 additional sites per sub-basin for times when initially selected sites were unreachable or the field crew could not obtain landowner access.

4.1.2 Field data collection

The field crew gathered data between June 16 and August 20, 2014, locating plots using a Garmin 60 CSX handheld GPS in conjunction with the Kootenay and the Okanagan Backroads Mapbook (Ernst & Mussio Ventures Ltd., 2009). Where plots fell on private property, we contacted landowners to obtain permission to access the site. Sometimes landowners did not grant permission or the crew could not reach the site because of terrain steepness or mapped streams did not exist in reality. In these cases, the crew visited the next site in the sampling sequence or from the oversample set as required. Because many of the sites in Boundary Creek and Lynch Creek watersheds were not accessible, we needed to calculate an additional oversample of five sites each.

Once the crew located a site, they averaged the position with GPS and stored it as a waypoint associated with the original sample. They measured slope with a Suunto clinometer in 10-metre increments, and observed animal injury, browse class, and other visual impacts to the riparian area. From the sample location, the crew laid out a 50 m transect perpendicular to the edge of the water body with a Stanley long tape. They took photos on a Fujifilm digital camera in four directions from the plot location, and

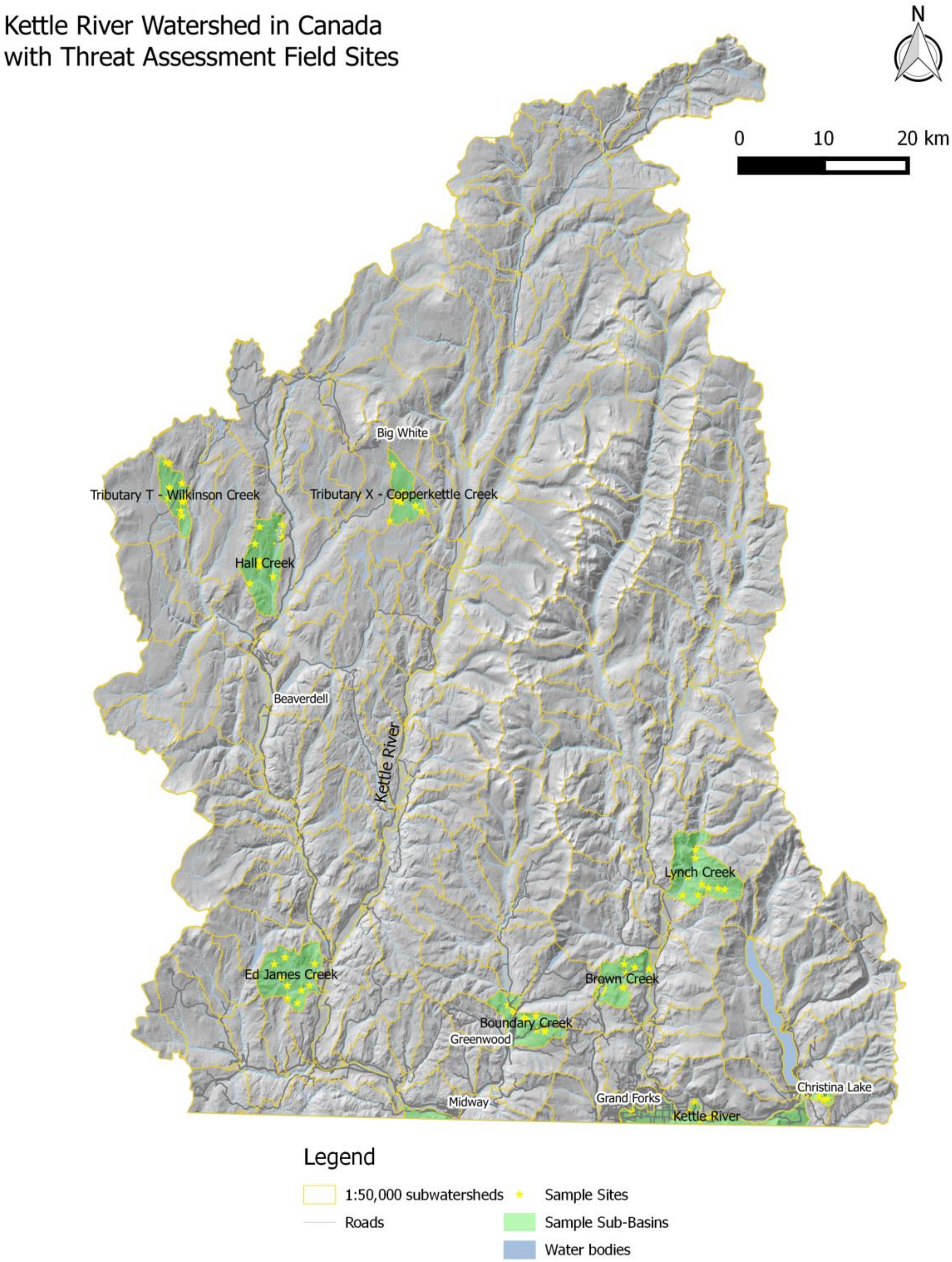

Figure 14. Overview of Sub watershed basins selected for fine scale analysis and plot locations.

took another photo from the end of the transect. They took additional photos of anything of interest around the field site.

The field crew collected vegetation information along the transect in 1x10 metre segments. The field crew did not record individual forbs (non-woody plants) but did record the total number of different forbs found (i.e. forb species richness). The crew also identified species and estimated percent cover for shrubs, trees, and non-native plant species. They counted and categorized every shrub and tree expected to achieve over 2 metres vertical growth (i.e. in the canopy) into structural stages of under 2 metres, 2-10 metres, over 10 metres, decadent, or dead. They recorded amount of coarse woody debris that fell under the transect line in categories of 5-10 cm, 10-30 cm, 30-50 cm, and over 50 cm diameter.

The team reviewed and incorporated key metrics from comparable field methods including the 'Cows and Fish' Riparian Health Assessment (Alberta Riparian Habitat Management Society, 2014), the Slocan Watershed SWAMP methodology (Durand, 2014), and the Provincial Forest and Range Evaluation Program (Tripp, Tschaplinski, Bird, & Hogan, 2006, 2007). Based on this review, the field crew recorded observational data across a 50 m reach on either side of the plot on a "Cows and Fish" riparian health form (Fitch, Adams, & Hale, 2009), and calculated a riparian health score that reflects disturbance, condition of native plants, amount of erosion and exposed soil, and other factors (Table 9).

Table 8. Condition of sample watersheds for selected GIS parameters with summary statistics of all 3rd order (1:50,000 scale) watersheds.[10]

FID	Cond.	Name	Ord.	Mag.	Area (HA)	Road Length	Road Dens.	Stream X Dens	Agri %	Dev'd %	MPB %	Openings Total %	Reference Potential
5838	Ag2_Dvlp1	Kettle River	8	9153	4126	141.7	3.4	1.1	32.2	26.7	1.8	0	64.1
5686	Ag3	Brown Creek	3	27	2918	70.8	2.4	1.6	20.4	0.1	22.9	43.3	52.2
5671	Dvlp2	Christina Creek	5	571	764	13.7	1.8	0.7	0	24.6	22.8	14.9	49.4
5781	MPB3	Hall Creek	4	50	4278	171	4	2.9	0	0	132.3	32.5	141.6
5755	RdD_2	Ed James Creek	5	45	4427	192.7	4.4	2.3	2.4	0	8.1	31.5	21.6
5740	RdD_3	Boundary Creek	6	452	3208	132.8	4.1	1.6	8.7	4.6	31.8	24.9	51.3
5689	Reference1	Lynch Creek	5	256	5099	33.3	0.7	0.6	0	0	10.2	8.1	12.5
5812	RpOpngs1	Copperkettle Creek	3	29	2238	49	2.2	1.9	0	0	32.9	105.4	67
5778	RpOpngs3	Wilkinson Creek Trib.	4	25	2053	63.8	3.1	2	0	0	28.9	116.2	73.4
Summary of all 3rd order watersheds													
null			2	2	0	6	6	7	131	133	1	13	11
min			1	0	764.7	0	0	0	0	0	0	0	0
median			4	65	3998.2	74.8	2	1.3	0	0	26.5	8	116.2
mean			4	493	4421.4	89.1	2	1.4	1.9	0.8	32.6	9.2	33.3
std.dev			1	1289	1815.7	57.7	1	0.7	5	3.4	28.3	7.1	36.8
max			8	9730	9450.2	288.5	6	3.5	32.3	26.7	198.5	41.4	24

10 Watershed order represents the stream order of largest stream in the sub-watershed; magnitude is the number of contributing tributaries; road density is the length of roads (km) per square km); percentages are the portion of each watershed in agriculture, development, mountain pine beetle, and forest harvest openings; reference potential is a combined score of disturbance and land use parameters for selecting reference and sample watersheds: the lower the score, the less disturbance noted.

Figure 15. Looking away from stream along transect at plot 46 in the Christina Creek sub watershed. Field Technician Venessa Langhorn measures plant and structural diversity.

Table 9. Riparian Health Assessment questions and scoring

#	QUESTION	SCORING
1	Vegetative cover of floodplain and streambanks	0-6
2A	Non-native Plant Species: Canopy Cover	0-3
2B	Non-native Plant Species: Density/Distribution	0-3
3	Disturbance-increased undesirable herbaceous species	0-3
4	Preferred tree and shrub establishment and regeneration	0-6
5A	Use of trees and shrubs – preferred trees and shrubs – browse	0-3
5B	Use of trees and shrubs – use other than browse	0-3
6	Standing decadent and dead woody material	0-3
7	Streambank root mass protection	0-6
8	Human-caused bare ground	0-6
9	Streambank structurally altered by human activity	0-6
10	Reach structurally altered by human activity (excl. banks)	0-3
11	Stream Channel Incisement (vertical stability)	0-9
	Total possible score	0-60

Finally, to record the landscape context of field sites, we buffered plot locations by 100 m in QGIS and imported the resulting ~3.1 ha circles into Google Earth to record the proportion of the buffer area covered by roads, gravel pits, buildings, agriculture, or permanent landscaping as observed in the aerial photo.

4.1.3 Data analysis

The team entered all field and air photo data onto an Excel spreadsheet and imported data to the R statistical program (R Core Team, 2015) for summary, data visualization explored relationships between landscape-level influences and site conditions. We prepared scatter plots and correlated individual relationships between several variables and riparian health scores for exploratory purposes using Kendall's rank correlation (McLeod, 2011). Then we examined the relationship of several site and landscape predictor variables to landscape health using a 'conditional inference tree' method (Hothorn, 2015), which enables sifting through a large number of variables to determine what combination of factors best correspond to the differences in response variable, in this case riparian health score.

4.2 Results

Our analysis revealed a variety of different conditions among field sites and subwatersheds relating to vegetation structure, woody debris, and overall riparian health condition.

The number of different forb species (richness) varied between zero at several sites to almost 30, with the lowest overall score for Kettle River sites (Figure 17). Similarly, overall plant diversity index (except for forbs) varied between 0.4 and 2.94, with the lowest overall distribution for Kettle River sites (Figure 18). The greatest cover of non-native plants were found in Boundary Creek, Brown Creek, and Christina Creek field sites, with the lowest in Coppermine, Lynch and Wilkinson sites (Figure 19). Plots with higher cover of non-native plants tended to have lower plant diversity, with a significant negative Kendall's rank correlation tau (-0.22, p=0.006).

4.2.1 Vegetation composition and structure

Figure 16. Riparian conditions at Plot 31 on a 3rd order stream in the Brown Creek sub watershed looking upstream from the beginning of the transect. Healthy riparian vegetation along the bank including a diverse assemblage of forbs stabilizes the channel, and coarse woody debris provides habitat for small minnows and cover for amphibians.

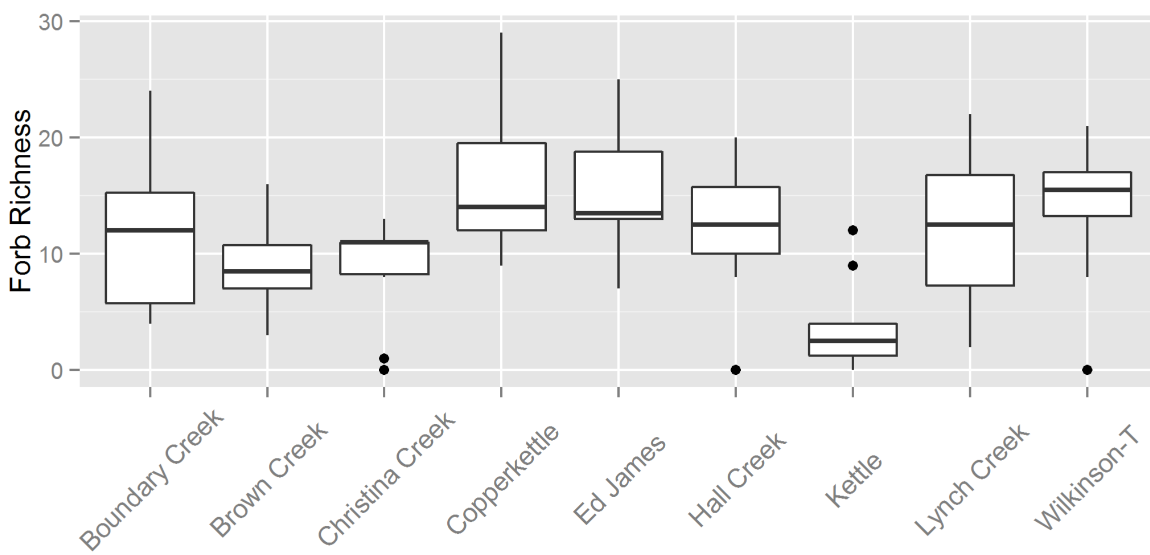

Figure 17. Distribution of forb richness (number of forb species in each plot) across subwatersheds. Upper and lower bounds of rectangle show the 25th and 75th percentiles, respectively, the central line shows the median, and lines ('whiskers') extend to the highest and lowest value that are 1.5 times the inter-quartile range. Data beyond the end of the whiskers are considered outliers and plotted as points.

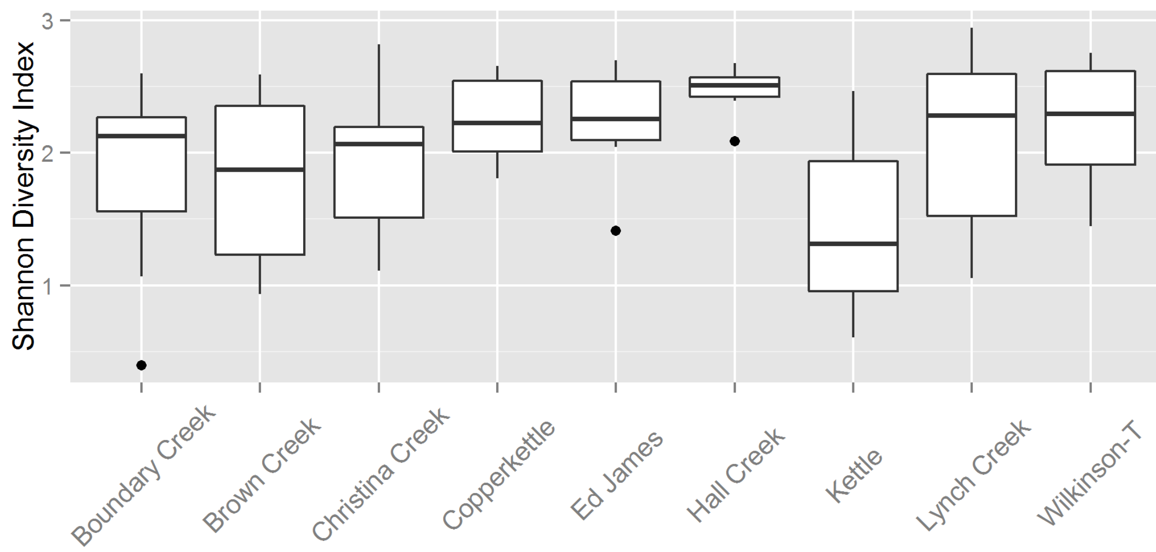

Figure 18. Distribution of vegetation diversity (Shannon index) of field sites across subwatersheds.

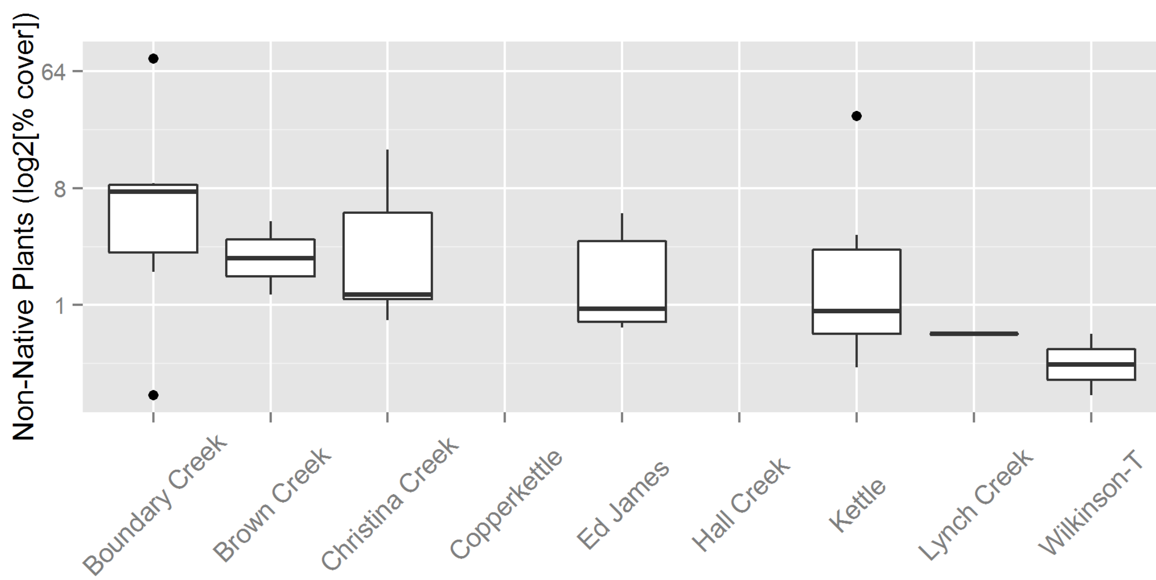

Figure 19. Distribution of percent cover of non-native plant species across subwatersheds, displayed on a binary logarithm y-axis to enable differentiating ranges of values between 0 and 10 as well as higher outlying values.

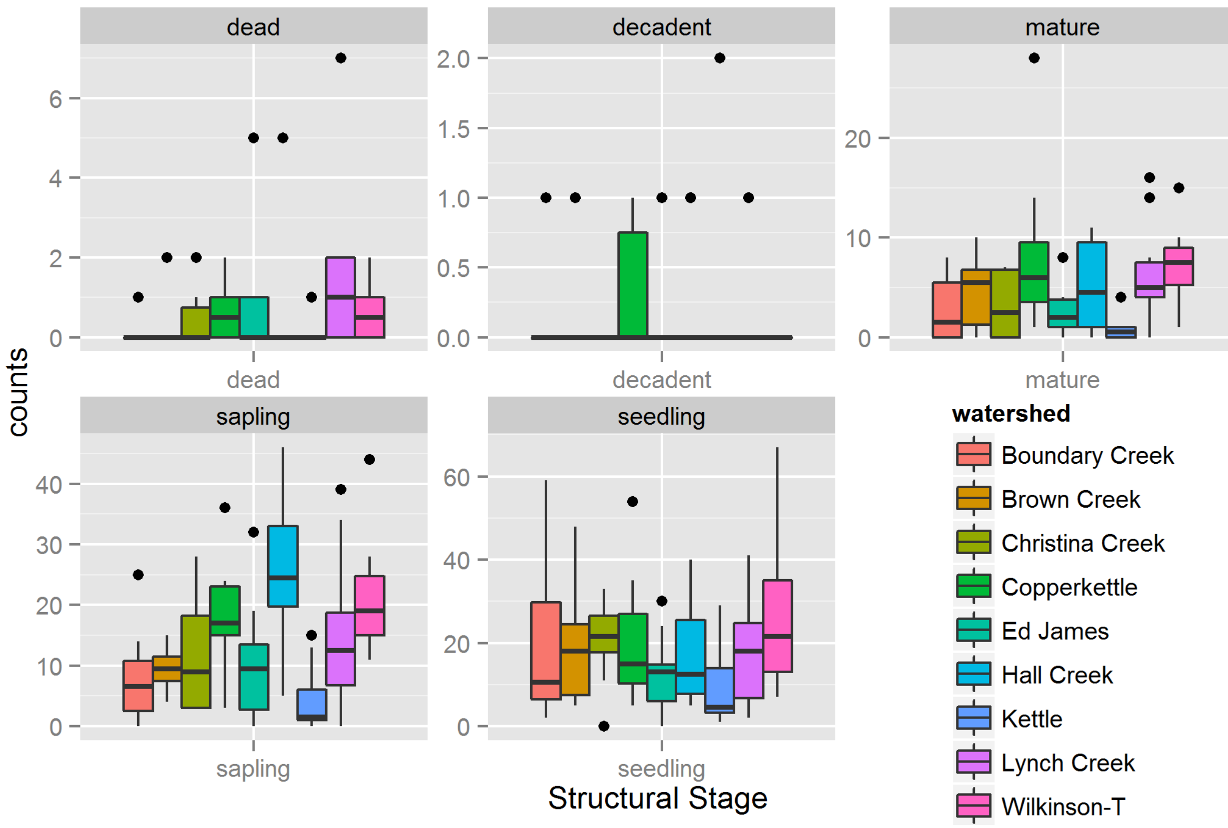

Figure 20. Counts of shrubs and trees across subwatersheds by structural stage.

The numbers of shrubs and trees in different structural classes varied widely across field sites in different watersheds (Figure 20). Kettle River sites had the lowest numbers of seedling, sapling, and mature trees, with very few decadent or dead trees. Conversely, Lynch Creek sites had the highest proportion of dead trees, with moderate numbers of seedling, sapling and mature trees. Wilkinson and Hall Creek sites had the greatest number of seedling and sapling stage trees, respectively. Boundary Creek, Brown Creek, Hall Creek, and Kettle sites had very few trees in the decadent and dead structural stages, indicating a reduction in potential recruitment of large woody debris to streams.

Cover of coarse woody debris (CWD) varied from zero to 13%, and was highest in Brown Creek and Copperkettle tributary sites and lowest in the Kettle and Wilkinson tributary sites (Figure 21). Boundary Creek and Ed James Creek sites varied from low to medium cover of CWD. This pattern mirrors the overall pattern of tree structural stage in Figure 20.

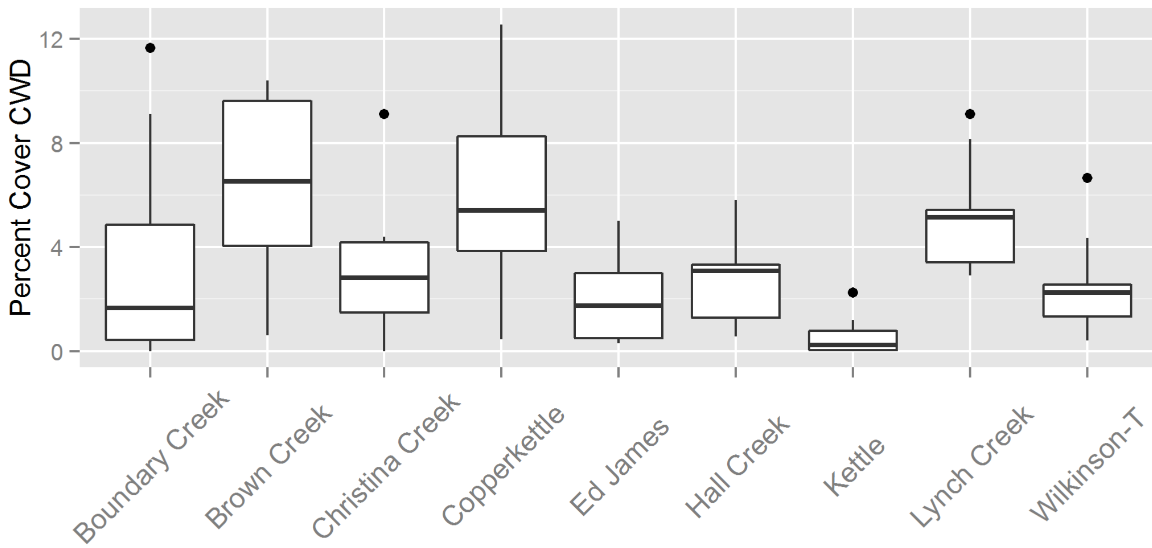

Figure 21. Distribution of percent cover of coarse woody debris across subwatersheds.

Figure 22. The vegetation at Plot 11 on the Kettle River is moderately structurally diverse with some decadent and dead cottonwood trees that are critical nesting habitat for birds. There are few seedlings and saplings for recruitment.

4.2.2 Riparian health

The team observed a wide variation in the health of riparian areas among field sites and sub-basins (Figure 23). The field sites in Lynch, Coppermine and Wilkinson sub-basins consistently had the highest riparian health scores with all but outlier sites considered less than healthy, while the Boundary Creek and Kettle River sites were somewhat or mostly unhealthy, respectively. We found that the lowest scoring components of the riparian health score (Table 9) were stream reach alteration (i.e. diking, channelization, bridges, culverts) (question 10), standing decadent and dead wood (6), and streambank alteration (9). The highest scoring components were non-native plant species (questions 2A, 2B), undesirable herbaceous species (3), and vegetative cover of floodplains and streambanks (1).

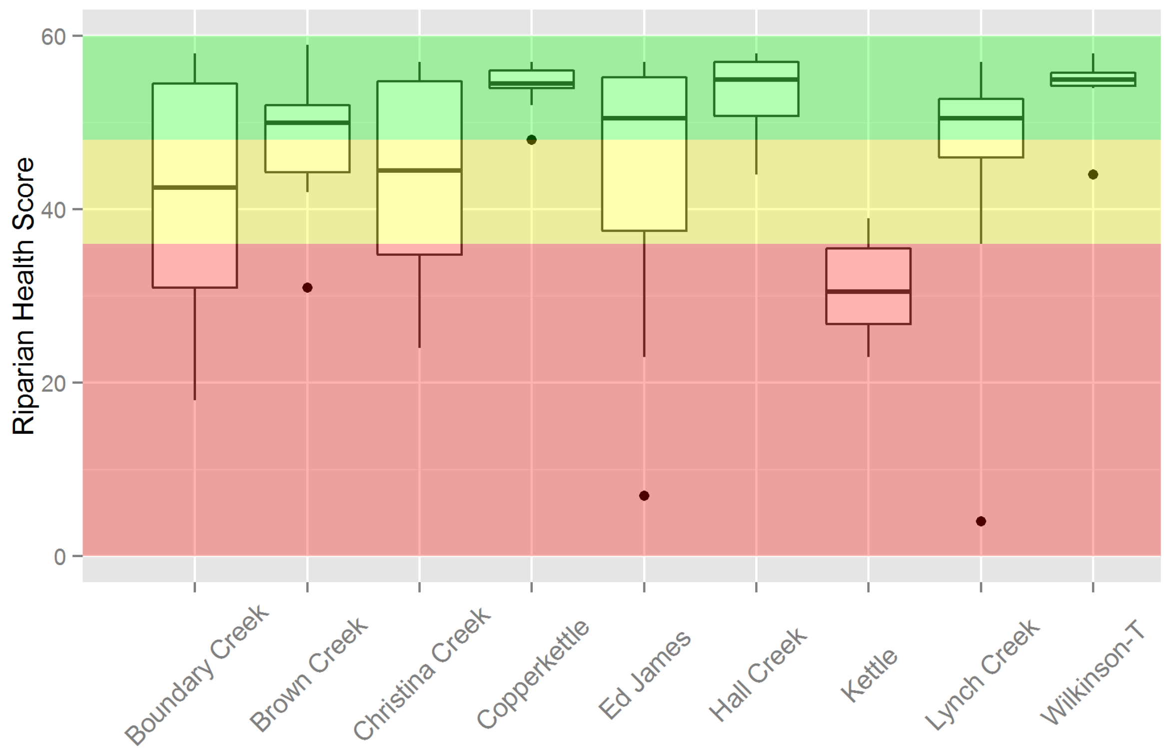

Figure 23. Riparian Health Scores of sites across watersheds. The colour overlay (green, yellow, red) refers to three overall conditions: proper functioning condition / healthy (score of 48-60); functional at risk / healthy with problems (36<48); and non-functional / unhealthy (<36) (Alberta Riparian Habitat Management Society, 2014)**.**

Table 10. Riparian Health Score component questions, mean score and percentage across all field sites (Alberta Riparian Habitat Management Society, 2014)**.**

#	QUESTION	SCORING RANGE	MEAN SCORE	MEAN PERCENTAGE
1	Vegetative cover of floodplain and streambanks	0-6	5.0	83%
2A	Non-native Plant Species: Canopy Cover	0-3	2.6	87%
2B	Non-native Plant Species: Density/Distribution	0-3	2.6	87%
3	Disturbance-increased undesirable herbaceous species	0-3	2.6	87%
4	Preferred tree and shrub establishment and regeneration	0-6	4.8	80%
5A	Use of trees and shrubs – preferred trees and shrubs – browse	0-3	2.3	77%
5B	Use of trees and shrubs – use other than browse	0-3	2.2	73%
6	Standing decadent and dead woody material	0-3	1.9	63%
7	Streambank root mass protection	0-6	4.7	78%
8	Human-caused bare ground	0-6	4.7	78%
9	Streambank structurally altered by human activity	0-6	3.9	65%
10	Stream reach structurally altered by human activity	0-3	1.7	57%
11	Stream Channel Incisement (vertical stability)	0-9	6.9	77%
	Overall range / mean	**0-60**	**44.7**	**75%**

Figure 24. Livestock trampling and heavy browsing have destabilized the bank and removed riparian vegetation in this wetland in the Ed James Creek watershed (Riparian Health Score of 7/60)

Figure 25. Low plant diversity and high percent cover of non-native grasses – riparian health score of 39/60 (Plot 143 on the 6th order stream Boundary Creek in the Boundary Creek sub watershed, looking upstream from the beginning of the transect.)

Figure 26. The riparian area at Plot 4 along the Kettle River at the end of Graham Road is heavily used by dog walkers, picnickers, and people seeking access to water recreation. This plot received a riparian health score of 30/60.

Figure 27. A wetland with a "healthy" and high functioning riparian area in the Hall Creek watershed at plot 66 (health score 58/60).

The amount of human footprint (roads, buildings, landscaping and crops) within 100 m varied widely among field sites. Developed and agricultural sites at lower elevations (Boundary Creek, Kettle sub-basins) have far greater proportions of human footprints than sites at higher elevation and reference sites (Ed James, Lynch Creek)(Figure 29).

Sites with higher human footprint tended to have lower riparian health scores (Figure 30; Kendall's rank correlation tau=-.345, p-value=0.00002). Only two sites with 'healthy' scores (>48/60) had greater than a 25% human footprint.

Figure 28. Looking downstream along a first-order stream in the Hall Creek sub watershed. Riparian health score of 57/60 with diverse forbs, shrubs, and trees.

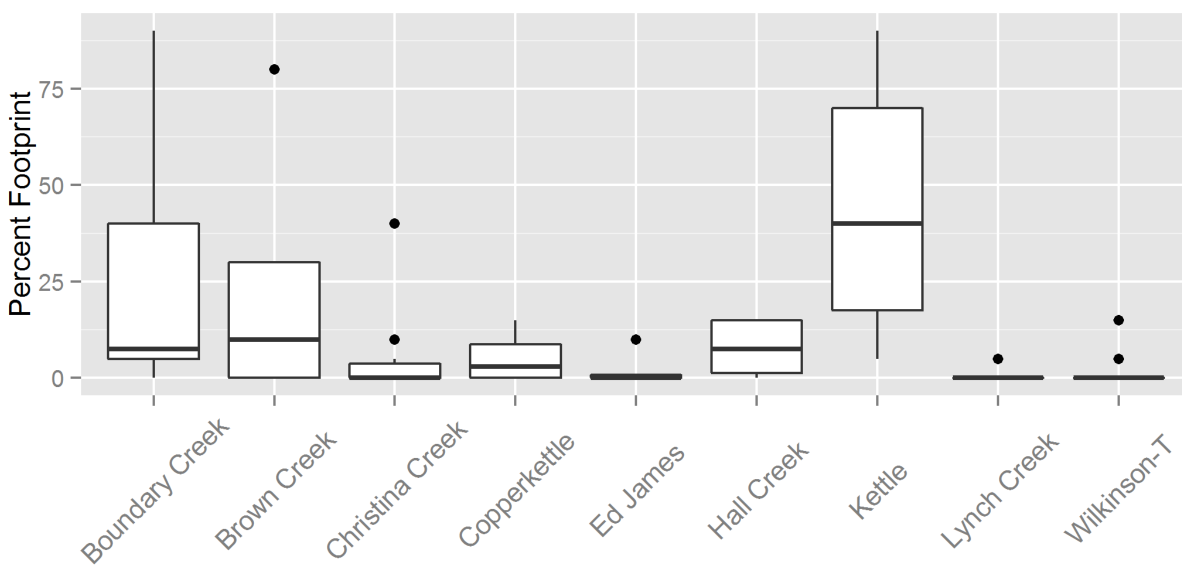

Figure 29. Average human footprint within 100-metre buffer of plots within each sub watershed.

Considering the influence of all available factors[11] using a conditional inference tree, almost all the variation in riparian health score related to proportion of human footprint, elevation, and cover of non-native plants (Figure 31). For instance, sites with greater than 30% human footprint (n=12) had scores between 20 and 33. Sites with less than 30% human footprint tended to have lower health at lower elevations (<=525 m) whereas higher elevation sites with low human footprint had better scores when non-native plant cover was very low (n=62) and lower scores with higher non-native plant cover (n=7). Elevation is likely strongly connected to human impacts as human settlements and farms are generally at lower elevations.

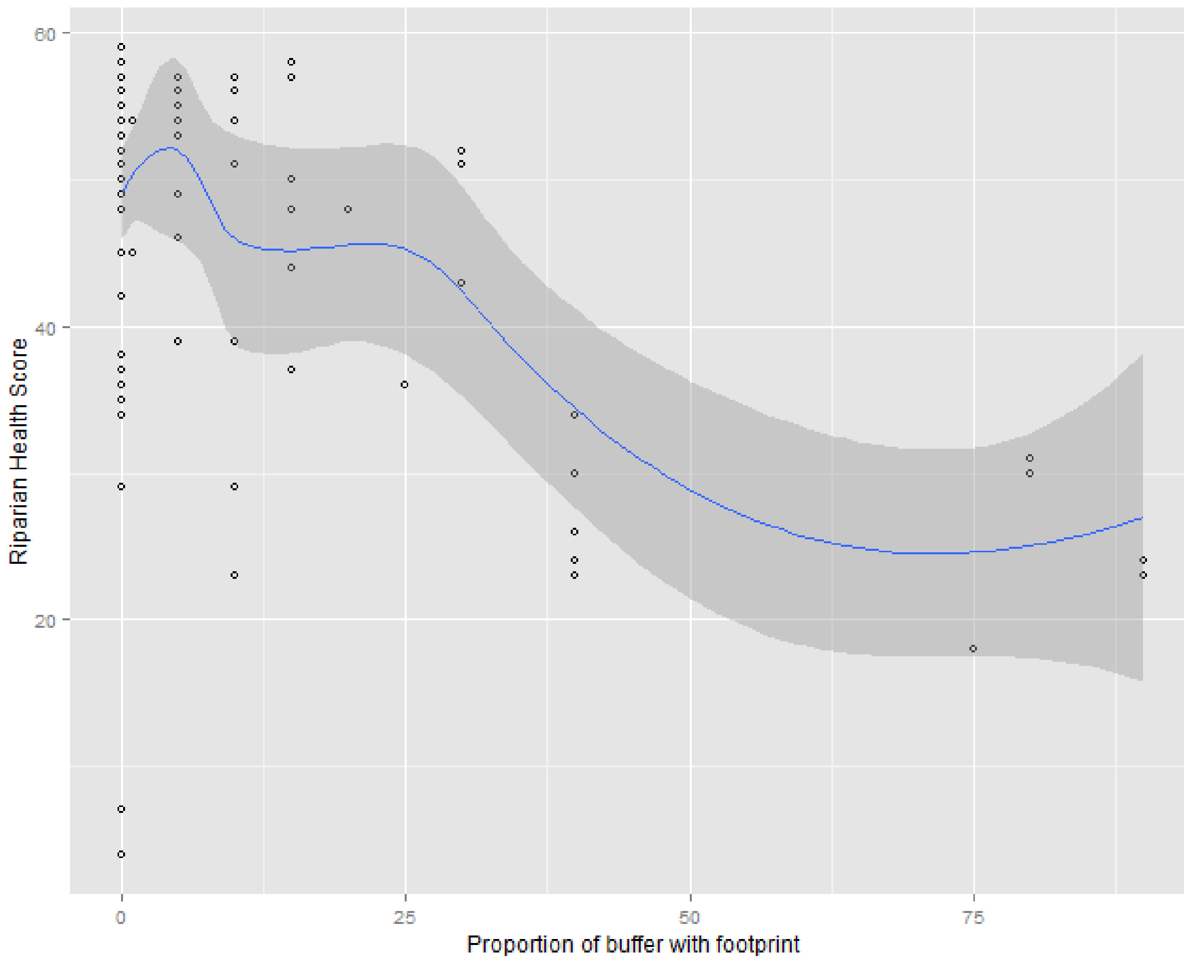

Figure 30. The relationship between riparian health score and proportion of 100 metre buffer with footprint of human activity (Lowess local trend in blue with 95% confidence interval in grey). [12]

[11] Variables considered in conditional inference analysis included width of vegetated buffer, cover of coarse woody debris, proportion of buffer in human footprint, cover of non-native plants, cover of bare ground, amount of browse by ungulates or cattle, type of feature [lake, river, stream, wetland], mesoslope position, elevation, and ownership status.

[12] The two outliers in the lower left of the figure with low scores and zero human footprint were on sites with large amounts of rock talus and bare ground.

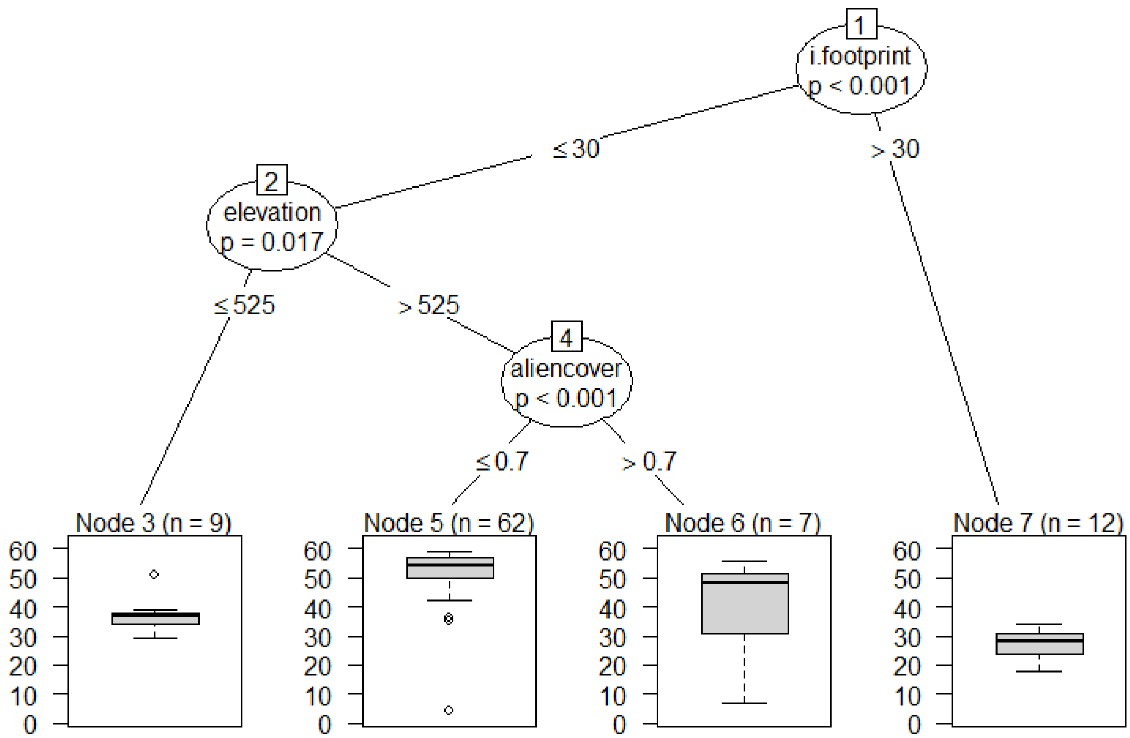

Figure 31. Conditional inference tree influence of landscape and site factors on distribution of riparian health score, shown with the box and whisker plot node. Each circular node marks the break in the continuous data that explains the greatest variation in health scores.

4.3 Discussion – Fine Scale

Our analysis of field conditions revealed a variety of different contexts among field sites and subwatersheds relating to vegetation structure, woody debris, and overall riparian condition.

4.3.1 Species Richness

Riparian areas are consistently higher in plant diversity than associated upland areas because of the higher gradients and edges in light, moisture, soil types, and disturbance caused by being close to water (Naiman et al., 1993; J. S. Richardson & Moore, 2007). For instance, researchers have found higher herbaceous plant diversity near riparian areas on headwater streams (Hagan, Pealer, & Whitman, 2006).

In our findings, forb species richness and plant diversity tended to increase in sites with less human disturbance, lower numbers of invasive species and higher riparian integrity. Sites with higher diversity of forest structure had notably higher number of species of forbs and overall plant diversity.

4.3.2 Forest Structure

Large woody debris is a critical component of riparian and river systems, providing many functions and benefits in headwater streams, medium to large rivers, in estuaries and lakes and even in the ocean (Maser, Tarrant, Trappe, & Franklin, 1998). For instance, woody debris slows the flow of water through stream channels, dissipates energy, stores sediment, and provides important habitat structure for aquatic organisms. Woody debris is retained in aquatic systems for varying lengths of time, and depends on riparian forests with old-growth structure and ongoing regeneration to provide regular inputs falling and flood-swept trees (Beckman & Wohl, 2014b).

In four of the nine sub-watersheds examined, we found few or no dying or dead trees within the riparian area. This reduces recruitment of large woody debris from these sites in the near term. Other studies in the region have highlighted the long-term legacy of past logging practices. For instance, clear-cutting and skidding along streams around a century ago in the Italy-Sutherland Creek drainage left a long-term deficit of large woody debris, in spite of the large amount of slash left in the riparian area. Much of the remaining large woody debris is in the form of short, rotten pieces that lie parallel to the stream channel, with none of the functions normally provided by large woody debris (Green, 2014).

In addition to the contribution of large woody debris and cover, researchers have found that old-growth, multi-story forest structure increases the diversity of in-stream habitat and primary productivity (Stovall, Keeton, & Kraft, 2009). Past and ongoing land management practices (timber harvest, beaver trapping, placer mining, road building, de-snagging) have been found to decrease stream function many decades later (Castro, Pollock, Jordan, Lewallen, & Woodruff, 2015; Green, 2014; E. Wohl, 2014; Ellen Wohl & Beckman, 2014).

Researchers have only recently begun to understand the importance of riparian forests in carbon sequestration and storage. High levels of productivity due to sub-irrigation and deposits of sediment lead to fast accumulation of carbon, and patch dynamics, beaver dams and flood disturbance provide frequent pulses of large woody debris input to create large quantities of slow-decaying waterlogged and buried wood that provides a stable, slow release pool of carbon (Beckman & Wohl, 2014a; Guyette, Cole, Dey, & Muzika, 2002).

Providing greater tree retention in headwater streams and, where appropriate, managing for structural complexity similar to old-growth forests would provide greater habitat diversity and stream productivity than even-aged stands (Beckman & Wohl, 2014a; Stovall et al., 2009; Ellen Wohl & Beckman, 2014). Indeed, the desirable functions of headwater streams are protected and enhanced by ensuring recruitment of large woody debris, preferably by retaining old-growth structures, or when required placing logs across small streams (Beckman & Wohl, 2014b; E. Wohl et al., 2015).

4.3.3 Riparian Health

Our findings are largely consistent with the available literature findings that increasing human use and development decreases riparian health (Alberta Environment and Water, 2012; The KRWMP Stakeholder Advisory Group, 2014). The most meaningful factors in explaining differences in riparian health for our study area were surrounding land use, elevation, and the cover of non-native plants. For instance, sites with greater than 30% human footprint within 100 m all scored poorly for riparian health. For sites with lower human footprint, lower elevation sites scored poor to fair and higher elevation sites scored well unless there was noticeable non-native plant cover.

In the distribution of our sample sites, elevation relates strongly to land use in that lower elevation and valley bottom sites have the longest duration of settlement and development, and most intensive ongoing land use. Population size and development pressures in urban and near-urban areas are a key component; there was a much greater level of disturbance in the Grand Forks and rural area compared to rural Rock Creek in the historical air photo analysis.

This has important implications for rapid risk assessment of riparian areas in future field studies that points to the importance of incorporating landscape-scale metrics such as land use, canopy cover, and occurrence maps of invasive plants when determining risks to riparian systems. For instance, one comparison of several visual assessment tools (Ward et al., 2003) found that stream health increased along with stream canopy cover, though they noted this doesn't hold true for some ecosystems with naturally low shrub cover.

Land use is a tremendously important determinant of riparian health (Alexander et al., 2015; K. C. Nelson et al., 2009; Western et al., 2010). Loss of vegetation, hardening of surfaces, engineering and construction, and ongoing disturbance all cause a loss of riparian function, increase in stream temperature, increase in sediment and pollution transport to streams.

Researchers have found that sites dominated by non-native plants are so much less resilient to disturbance that restoration practitioners need to plan for fundamentally different restoration pathways (D. M. Richardson et al., 2007). Intact, higher elevation systems serve as refugia for native species and prevent downstream dispersal of non-natives (Alexander et al., 2015). Therefore, managers need to prioritize protection of high elevation riparian sites and minimize disturbance to limit the spread of non-native species.

At the same time, occasional natural disturbance by floods and ice flows are important for riparian tree regeneration, fish habitat maintenance, and even water quality (Carlisle, Wolock, & Meador, 2011; Gao, Vogel, Kroll, Poff, & Olden, 2009; Rood, Goater, Mahoney, Pearce, & Smith, 2007; The Nature Conservancy, 2009). In areas where people have dammed and regulated rivers to control floods or ice flows, managers need to consider measures to rehabilitate environmental flows across the natural range of variation. For unregulated rivers such as the Kettle, this speaks to the need to document and understand all aspects of natural river function and disturbance before considering reservoir development (N. L. Poff et al., 2010; Warner, 2013; Watt & The KRWMP Stakeholder Advisory Group, 2014).

When range practices were evaluated In the Kootenay-Boundary by provincial assessors, only two percent of sites sampled had trampling impacts, while in the Thompson-Okanagan eight percent of sites had trampling and excessive grazing impacts (Government of British Columbia, 2015). This is less trampling than our team found in active rangeland sites, so researchers should follow up with a deeper comparison of methods and findings, and if required, reproduce the research with more sample sites.

One difficulty comparing the results of the field assessment with other reports in BC is that we utilized a variation of the Alberta 'Cows and Fish' methodology (Alberta Riparian Habitat Management Society, 2014; Durand, 2014; Mccleary, 2013; Tripp et al., 2007) instead of the Provincial Forest and Range Evaluation (FREP) standard. This provides us with a baseline for future monitoring and studies in this area but caution should be used when making specific comparisons with other areas and other types of studies.

5 Retrospective Assessment of Restoration Work in the Kettle River Watershed

5.1 Background

Ecological restoration is defined by the Society for Ecological Restoration as an "intentional activity that initiates or accelerates the recovery of an ecosystem with respect to its health, integrity and sustainability" (Society for Ecological Restoration, 2004).

Riparian restoration projects have occurred throughout the Kettle River Watershed on an ad-hoc basis on public and private lands when funding and personnel have been available to support them. The team developed the retrospective assessment to learn from past restoration projects to help improve results of future projects. Our objectives were to 1) identify historical restoration projects 2) identity a contact and/or lead for the selected historical projects 3) determine how these projects transpired, how they were funded, and the successes and failures of each project.

5.2 Methods

The riparian working group identified known riparian restoration projects. The team contacted the leads for these projects and asked questions by person, phone, or email. We recorded and documented the responses and acquired any associated documentation, and then developed recommendations for future projects.

For each project, we asked: 1) how was the project funded 2) how was the project initiated 3) did the project have any follow up monitoring 4) what were the success and failures of the project?

5.3 Results

The identified projects included Sutherland Creek, Kettle River and Private Wetland, the City of Grand Forks, West Kettle River, Lassie Creek, Trapping Creek, and Boundary Creek. The team visited three of the projects on-site (Sutherland Creek, Private Wetland, West Boundary), discussed two projects in-person but off site (Kettle River and Lassie Creek), discussed one previously visited site by email (City of Grand Forks Kettle River), and discussed two projects over email and by reviewing reports (Trapping Creek and Boundary Creek). The projects had a variety of contexts in terms of ownership, funding, rationale, and monitoring, with varying degrees of success (Table 11).

The main drivers for these projects included: stewardship opportunity (Sutherland Creek, Lassie Creek, and private property projects on wetland and Kettle River); available funding (Trapping, Boundary, Burrell Creeks); and risk of loss of land (City of Grand Forks Kettle River, and 2 private property projects on West Burrell and Sutherland Creek).

Two (Trapping and Boundary Creeks) of the five projects on public lands were initiated because of the availability of funding through a provincial program (Forest Renewal BC) and led by Pope & Talbot, a former logging company. This program also funded a project on Burrell Creek (not reviewed). A local person initiated the Lassie Creek project with support from Pope & Talbot, the Lonely Loon Fly Fishers and Gilly Funding.

The Christina Lake Stewardship Society (CLSS) led the Sutherland Creek project to enhance spawning kokanee habitat, and continues to support and implement restoration projects. The City of Grand Forks initiated the other project on public land to protect a recreational trail through funding from the Recreational Infrastructure Grant (RiNC).

Loss of land was the main driver for two of the other private land projects, with one project covered by the Agricultural Research and Development Corporation (ARDCorp) Environmental Farm Plan Fund, and the other funded by the landowner. The remaining two projects on private property were on the Kettle River and a private wetland, funded by the landowner.

The restoration projects we reviewed had a range of successes and challenges. Trapping and Boundary Creeks were successful in achieving channel definition and preventing scouring. There was also riparian planting associated with the project. However, livestock ranging in the area damaged riparian plantings and trampled the banks. The Kettle River project in the City of Grand Forks was successful in protecting recreational infrastructure, and addressed multiple values (boulders for instream fish habitat and wildlife tree placement) and included tree planting to mitigate lost vegetation (L. Tedesco, personal communication). However, there was no formal monitoring and planted trees have been vandalized and never replaced.

The Lassie Creek project had a culvert installed for fish passage and CWD was placed to enhance habitat, mimic the natural environment, and prevent livestock access to the creek. This project was relatively simple in nature, and achieved its objective of creating fish passage and cover. The work on Sutherland Creek was a success in achieving channel definition and mitigating sedimentation infilling. However, there was considerable damage done to the riparian plantings by beavers and nearby residents had a negative perception based on misconceptions of aquatic ecosystem function.

The West Kettle project seemed to have the most challenges – almost half of the erosion control structures failed. One of the biggest concerns was the long-term negative perception by the landowner. There was no support when the project failed and there was no follow up monitoring. The landowner incurred some major financial costs associated with the project that have been lost in the failure of the work. The landowner has now lost trust in the support and funding of outside agencies.

Most of the projects on private land aimed to prevent erosion and protect land while public land projects encompassed several objectives, likely due to the involvement of a variety of stakeholders. This sometimes had negative consequences. For example, one project used only riprap for bank stabilization with no beneficial native plantings, and another project removed mature cottonwood trees for bank stabilization.

Table 11. Historical Restoration Projects, Successes and Failures in the Kettle River Watershed.

Project	Owner-ship	Funding	Reason for project	Monitor-ing	Successes	Failures
Sutherland Creek	Public	Fisheries Renewal BC (FsRBC)	Sedimentation and infill of Kokanee spawning habitat	No	• Bank Stability • Less infill and sedimentation	• Negative public perceptions from some nearby residents • Beaver damage to vegetation planted • Riparian vegetation did not establish
Sutherland Creek	Private	Landowner	Erosion & loss of land	No	• Bank Stability achieved (with Riprap)	• High Cost to Landowner • No associated riparian re-vegetation
Kettle River/ Wetland	Private	Landowner	Stewardship	By land-owner	• Habitat creation benefit to wildlife • Long Term	• Works being done non-compliance with regulatory body
					• Recreational benefit	• Not all values considered • No riparian re-vegetation •
Lassie Creek	Public	Gilly Fund/In-kind Pope & Talbot	Stewardship	No	• Stream rehabilitated with culvert & CWD • Fish use	• Follow up • No documentation
City of Grand Forks	Public	RiNC grant	Erosion loss of recreational infrastructure	No	• Bank Stability achieved (with Riprap) • Multiple values recognized (fish habitat and bird nesting habitat)	• Failed riparian revegetation and not replanted • Loss of riparian vegetation (including vandalism)
West Kettle River	Private	ARDCorp Environmental Farm Plan	Erosion & loss of agricultural land	Not officially but by land-owner	• Good News Story and landowner recognition	• Structural failure of erosion control methods • Erosion and land loss continues • No riparian revegetation

Project	Owner-ship	Funding	Reason for project	Monitor-ing	Successes	Failures
						• Not all values considered – mature cottonwoods lost • No post project support to landowner • Unhappy landowner • Works being done non-compliance with regulatory body
Trapping Creek	Public	Watershed Restoration Program / Forest Renewal BC	Funding available	Yes short term	• Bank stability • Effective in maintaining channel definition	• Range cattle ate planted vegetation and trampled banks • High costs for little on ground work completed
Boundary Creek	Public	Watershed Restoration Program / Forest Renewal BC	Funding available	Yes short term	• Bank stability • Effective in maintaining channel definition	• Range cattle ate planted vegetation and trampled banks

5.4 Discussion – Restoration Learning

Reviewing past restoration projects reveals several key lessons. First, most projects did not include formal monitoring, which is a common concern with restoration projects (Bernhardt et al., 2007). While short term and informal monitoring can provide some insights, our understanding of the factors of success or failure was constrained by the limited anecdotal evidence around projects. An important step for future projects developed under the restoration program would be the recording of simple post-project information (photo-point monitoring locations as well as vegetation and slope profile transects, landowner and agency contacts) Simple documentation and archiving of this information will enable much easier monitoring and future site improvement.

Furthermore, understanding the context of challenges will be particularly important for improving restoration success, improving opportunities for adaptive management of the restoration program. For instance, when people vandalized or accidentally damaged restoration works, what could project managers have done to prevent these losses? How could we use a combination of signage, fencing, public education, or placement of vegetation works that considers human and livestock use?

A second consideration is the importance of incorporating multiple values in restoration projects. A simple habitat enhancement for one species of fish or bird may have both positive and negative consequences on other values including recreational use and enjoyment, landowner perception, erosion control, or other aspects. We recommend vetting project concepts and reviewing project outcomes with a multi-stakeholder working group composed of people involved in restoration in the Boundary (the Boundary Habitat Stewards) as a cost-effective means to involve key stakeholders and incorporate multiple values.

6 Synthesis and Recommendations

6.1 Land and Resource Management

The coarse scale assessment found that range and forestry were dominant land uses, with extensive natural and human-influenced disturbances including Mountain Pine Beetle and historical fires. Resource roads made up 3.4% of riparian areas. As linear features with over 10,000 stream crossings, resource roads amplify disturbance related to sedimentation and habitat fragmentation. Developed urban areas have a smaller footprint on riparian areas than other land uses, but disproportionately impact the riparian areas of the grassland ponderosa pine ecosystem, one of the rarest in the province.

The fine scale analysis showed how increasing human activity decreases riparian health. The Kettle subwatershed (along the valley floor near Midway and Grand Forks) had the most urban land use and the poorest riparian health scores. The team also found the lower elevation plots had the highest cover of invasive species. Plant diversity and forb species richness tended to increase in sites with less human disturbance, lower numbers of invasive species and higher riparian integrity. Sites with higher forest structure diversity had notably higher number of species of forbs and overall plant diversity.

Range and forestry are two of the most extensive land uses across the watershed. Under the BC *Forest and Range Practices Act* (FRPA) - Forest Planning and Practices Regulations (Province of British Columbia, 2004a), a number of restrictions on logging and other activities near water bodies are in place to protect riparian areas and aquatic systems. These restrictions depend on the size of water body, presence of fish and/or fish protection designations, biogeoclimatic zone, and location in a community watershed (Tschaplinski & Pike, 2008). Under FRPA, most fish-bearing streams and larger wetlands are required to have a riparian reserve zone where no harvest is permitted, and a broader riparian management zone with targets for tree retention (Province of British Columbia, 2004a; Tschaplinski & Pike, 2008).

However, no riparian reserves are required for the smallest streams, even though small (first and second order) streams make up about 80% of total stream length. This makes it particularly important to consider the cumulative effects in these higher elevation systems.

Numerous studies demonstrate the impacts of riparian forest harvesting on streams and downstream aquatic conditions (Nordin, Maloney, & Rex, 2009; J. S. Richardson & Béraud, 2014). All tributary streams, even wetlands and ephemeral streams, have been found, individually and cumulatively, to exert strong influences on downstream rivers, lakes and estuaries (Alexander et al., 2015). An evaluation of forest practices in the Kootenay-Boundary region recommends that retention is increased on small streams, particularly perennial streams that make contributions to downstream habitat, drinking water, and fisheries (Government of Britiish Columbia, 2015). Given the importance of smaller low order streams, this recommendation of increasing retention should be extended to all streams, not only perennial streams.

FRPA also requires range use plans or range stewardship plans to manage range practices. Guidelines and best management practices inform livestock producers about how to protect watercourses and riparian areas (Ministry of Forests, 2002). Under the Range Planning and Practices Regulation, range practices “must not adversely affect the function of riparian areas” (Province of British Columbia, 2004b). This regulation should be re-examined

The impacts are cumulative when multiple land uses co-exist in a watershed. For instance, logging and road building allows more access for livestock and off-road vehicles to riparian areas and watercourses, creating greater risks of riparian vegetation degradation, erosion, and sedimentation. Range managers and foresters have developed new practices to mitigate these impacts, for instance placing large woody debris across small streams to prevent damage from cattle. This practice is being implemented in Okanagan watersheds but is not yet common in the Boundary (Clayton Bradley, personal communication).

Mountain Pine Beetle disturbances can cause hydrological changes and increased sedimentation in watercourses, due both to loss of canopy cover by tree mortality and disturbance associated with salvage logging. The Province has determined the hydrologic sensitivity of watersheds to MPB infestations that includes 3rd order watersheds of the Kettle River Watershed (Ministry of Forests Lands and Natural Resource Operations, 2014). Minimizing harvesting within riparian areas will help to mitigate the effects of MPB infestations and salvage logging on water and watersheds (Ministry of Forests Lands and Natural Resource Operations, 2014).

Management for MPB started in the mid 1970’s in the Fiva Creek area north of Westbridge. During the 1990s much of the area from Lost Horse Creek south to Fiva Creek was also slated for MPB salvage (Gyug & Simpson, 1991).

Roads may have a small footprint in the watershed overall but their impacts are disproportionately (Forman & Deblinger, 2000; Jones, Swanson, Wemple, & Snyder, 2000; Reed, Johnson-Barnard, & Baker, 1996) and can have long lasting effects (Findlay, T. Scot & Bourdages, 2000). Roads pose a serious problem in watersheds and the solutions need to be multifaceted, including coordinated access planning, restoration, decommissioning, and better due diligence.

Understanding the relative location of different land uses gives us an understanding about the potential site specific and cumulative effects on the ground. We were able to identify direct and indirect impacts of various pressures throughout the different subwatersheds and land use types. The subwatersheds that had the highest amount of urban land cover (Kettle River and Christina Creek) and agriculture (Brown Creek and Boundary Creek) had the lowest riparian health scores. Several other studies have also demonstrated that as human activities or land uses intensifies, riparian function decreases. For instance, human activity is correlated with a decline in vegetation of riparian ecosystems (Obedzinski et al., 2001); agricultural lands tend to impact habitat and stream quality (Stewart, Wang, Lyons, Horwatich, & Bannerman, 2001); and developed areas have a vastly reduced vegetation structure (Wasser et al., 2015).

After human activity, elevation was a very important factor in explaining variation in riparian health. Elevation and development are correlated as development most often occurs in lower valley bottoms. Our findings suggest that developed and agriculture areas pose the greatest threat to riparian areas within the watershed, while riparian areas in the subwatersheds with a high cover of forestry development (higher elevation) are generally in better condition. However, forestry and range are certainly the dominant land use in the watershed compared to how much of the watershed is developed. The Ed James watershed has a high density of roads overlapped with range use. The lower scores of the riparian health assessments in this subwatershed suggests the riparian areas are negatively impacted, likely because of cumulative impacts associated with the roads and range use.

We can make some inferences about the fine scale data collected and how it might relate to the land uses of that subwatershed. For example, the high percent cover of non-native plants in riparian areas in urban development areas is logical, as human activity is the biggest vector of weeds. Forestry generally has stricter rules around riparian area management, which may reflect the higher riparian health assessment scores in those subwatersheds (Trapping and Wilkinson). In general, our study suggests that in areas of higher human use riparian areas are more threatened. Therefore, in these areas we must work harder to protect riparian values by improving and implementing guidelines, policies and regulations.

6.2 Pathways to riparian degradation and restoration

Development in floodplains can put people and their properties or businesses at risk. It also negatively influences the aquatic systems and associated habitats, highlighting the need to 'strike a balance' and use tools that will protect both development and aquatic ecosystems (Figure 32).

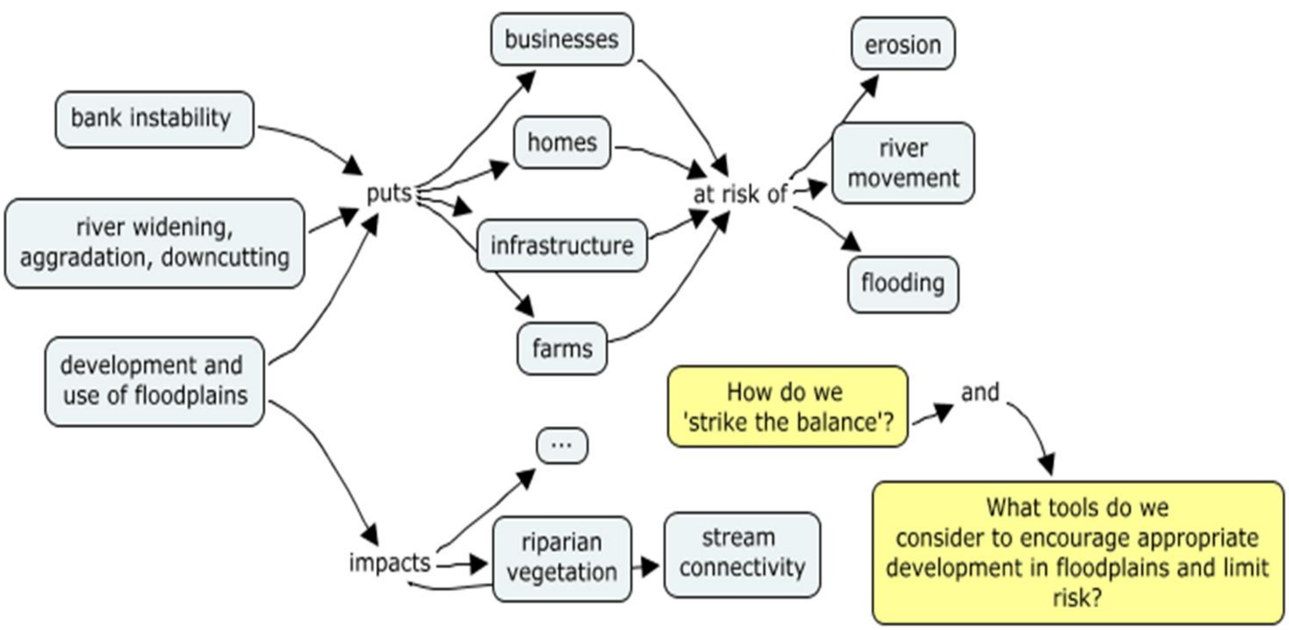

Figure 32. Risks to land and infrastructure and the impacts on aquatic systems when riparian areas and floodplains are degraded.

There are several reasons why development is correlated with riparian areas. Historical factors such as travel routes and ideal development around log driving are only some motives. Historical and present development both have led to degraded riparian areas and aquatic systems (Figure 33). Land managers and advisors need to highlight the benefits of retaining and restoring riparian functions, and encourage and incent their active involvement in protecting and restoring riparian function.

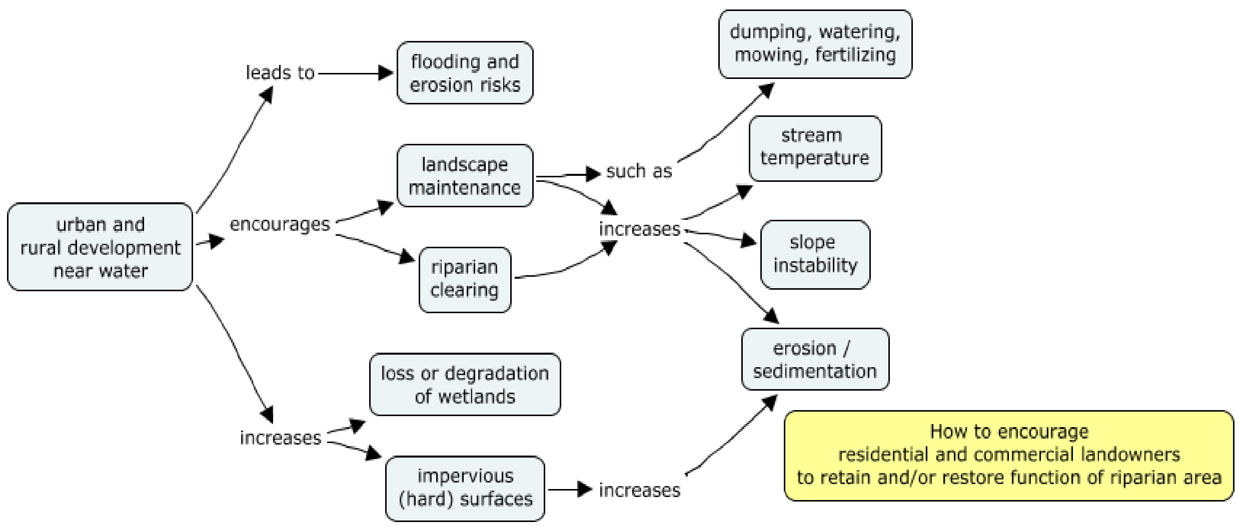

Figure 33. This concept map illustrates how development near water affects aquatic systems. Improving function of riparian areas near development requires residential and commercial landowners to adopt a different perspective of how to manage their properties near waterways and the contributions it will make to watershed health.

There are many unintended consequences to road infrastructure developed for resource extraction (Figure 34). Limiting impacts from the resource road network is a high priority in protecting streams and riparian habitat.

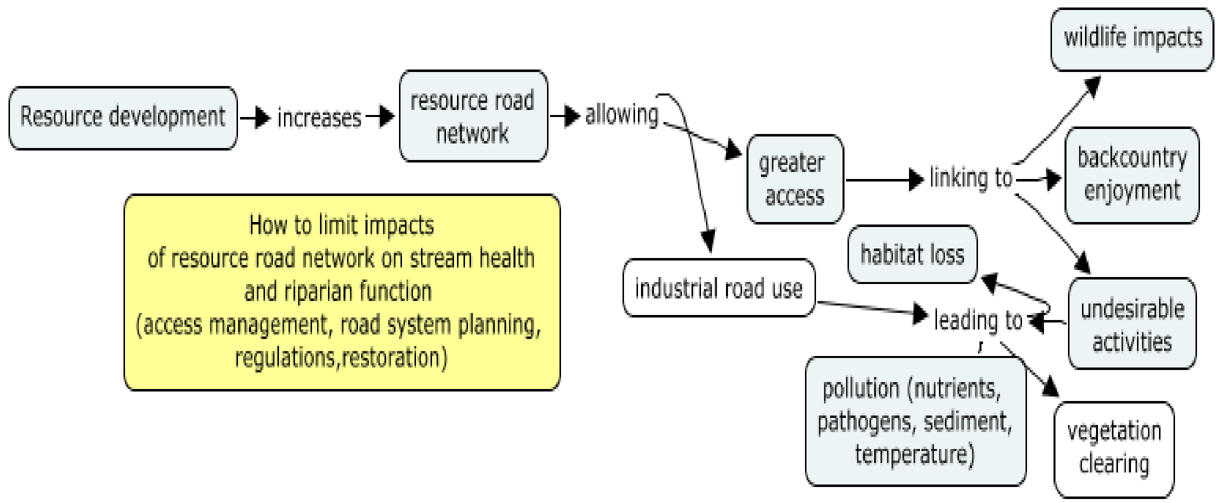

Figure 34. Risks of resource roads relating to human activities and impacts on riparian areas.

Numerous agricultural activities have the potential to impact riparian health and aquatic ecosystems when practiced inappropriately (Figure 35). There are several best management practices used by agricultural producers to mitigate their impacts on aquatic resources. Agricultural stakeholders need to identify what is currently working, what needs improvement, and agricultural producers can be supported in limiting their impacts.

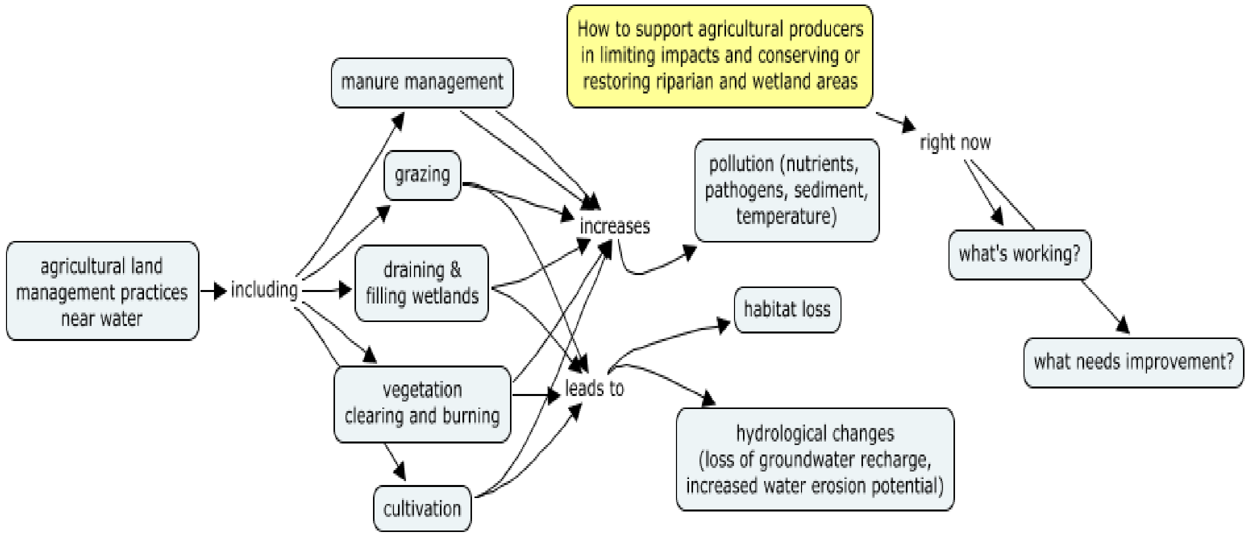

Figure 35. The figure outlines the risks of agricultural land practices to aquatic ecosystems and riparian areas. Encouraging agricultural stewardship is key to limiting impacts and conserving or restoring riparian and wetland areas.

6.3 The role of riparian buffers in mitigating impacts

Because of the well-known impacts of development, agriculture and resource management on water bodies and the risks to habitation from floods and erosion, various agencies in different jurisdictions have proposed guidelines and regulations for protecting or establishing riparian buffers and setbacks (Alberta Environment and Water, 2012; BC Oil and Gas Commission, 2013; Cox & Cullington, 2009; Province of British Columbia, 2004a; Washington State Department of Ecology, 2012). A *buffer* is a relatively natural and undisturbed area of shrubs and trees between the shoreline and active upslope land use. A *setback* is the distance separating structures or management from the edge of the water or the edge of the buffer, and can be used to ensure development is located a safe distance from steep slopes and areas subject to flooding, or to protect views of waterways (Washington State Department of Ecology, 2012).

Throughout urban areas, riparian ecosystems provide critical services in protecting shorelines and properties from erosion and mitigating the effects of flooding. The RDKB, City of Grand Forks, and Village of Midway have adopted floodplain management bylaws, and the City of Greenwood addresses flood risk through their zoning bylaw. These bylaws are in place to reduce the risk of injury, loss of life and damage to buildings and structures due to flooding, and specify restrictions on habitable areas within the designated (200-year) floodplain or specified setback distance and elevation from the natural boundary. The RDKB Floodplain Bylaw specifies flood levels as 3 m higher than the natural boundary of the Kettle and Granby Rivers and 1.5 m above all other water bodies. Floodplain setbacks are set at 30 m from the Kettle and Granby Rivers, 15 m from other watercourses, and 7.5 m from other water bodies and dykes (Regional District of Kootenay Boundary, 2004).

The RDKB has previously considered Development Permit Area guidelines for protecting water quality and habitat functions of riparian areas around Christina Lake and tributaries (Regional District of Kootenay Boundary, 2011). The objective of the draft guidelines was to seek the retention of a 15 m vegetated riparian buffer area on shoreline properties, with flexible application for shallow parcel depths and small lots. The RDKB suspended implementation of the draft guidelines pending further study of riparian conditions and potential guidelines across the watershed, which is now complete with this study.

Guidelines for buffers and setbacks vary depending on the type of activity (i.e. forestry, agriculture or land development), the type of water body, and the aquatic ecosystem functions or values under consideration. Typically, buffer and setback recommendations address several values: water quality: effect of slope on vegetation filtration; risks of groundwater contamination; flooding risk; shoreline migration; bank stability; and habitat value (Alberta Environment and Water, 2012).

The design of buffers and setbacks to protect these values depends on a number of factors that vary from site to site. For instance, wide, forested buffers are more effective at removing pollutants and sediment than grassy areas, and functions such as flood and erosion control have more to do with hydrology and landscape factors than the width of the buffer alone (Alberta Environment and Water, 2012).

Managers need to tailor setbacks and buffers to specific conditions: fish presence; vegetation cover type and composition; topography and slope; substrate; surficial aquifers, shallow groundwater and springs/seeps; floodplain and channel migration zones; and environmentally sensitive areas (Alberta Environment and Water, 2012). The authors recommend that the Implementation Team work with various sectors to establish setbacks and buffers across the watershed. These would be implemented through appropriate local government and resource management planning processes (i.e. zoning, forest stewardship plans), and supported by provincial legislation, guidebooks, incentives, and demonstration sites.

Table 12. Example riparian buffer widths for a variety of values and purpose. Steep slopes, areas susceptible to erosion, and areas with upslope development would require additional buffer width to protect riparian functions and slope stability, and setback and buffer guidelines would need to be adapted to local conditions.

Water body type	Ecosystem value / function	Buffer width / type	Source
Permanent water body	Water quality	20 m (clay and till) – 50 m (coarse-textured soil), not including steep slopes	(Alberta Environment and Water, 2012)
Streams	Fish protection & habitat	30 m – 100 m	(Jefferson County Department of Community Development, ESA Adolfson, Coastal Geological Services, & Shannon & Wilson, 2008)
All Water bodies	Microclimate	100 m	
Intermittent streams	Water quality	6-10 m native vegetation, perennial grasses	(O'Carroll, 2004)

Water body type	Ecosystem value / function	Buffer width / type	Source
Small wetlands	Water quality	10 m with shrubs and perennial grasslands	
All water bodies	Wildlife habitat corridors	100-400 m, depending on species	(Washington Department of Fish and Wildlife, 2010)
Wetlands and Streams	Water quality	30-m buffer for logging activity removed an average of 75 to 80% of suspended sediment in stormwater; reduced nutrients to acceptable levels; and maintained water temperatures within 10C of their former mean temperature.	(Lynch, Corbett, & Mussallem, 1985)
Streams	Vegetation	buffers at least 45m wide on each side of the stream are needed to maintain an unaltered microclimatic gradient near streams (but could extend up to 300m in other situations)	(Brosofske, Chen, Naiman, & Franklin, 1997)
Wetlands	Salamanders	>165m	(Semlitsch, 1998)
Wetlands	Ungulate winter range	A 20 metre no harvest buffer zone should be maintained around entire wetlands	(Gyug & Simpson, 1991)

6.4 Management Recommendations

All land users and managers that make decisions about land use practices have a role in implementing best management practices to protect riparian areas and aquatic systems. The following section identifies directions and tools to consider in conserving riparian areas and aquatic ecosystems. Several practices can mitigate or offset the impacts of land uses on riparian areas (Figure 36). The outcomes would clearly have benefits to communities, ecosystems, and society.

Findings from the assessment and related scientific literature point to this broad characterization of pathways to riparian impacts:

- Insufficient regulation, enforcement, incentives and awareness allow for riparian damage across all land use sectors.
- Road establishment, improper use and maintenance, and insufficient removal and remediation leave lasting impacts of sediment delivery to streams at stream crossings.
- Increasing human activity and infrastructure near and in riparian areas increases damage to riparian structure (vegetation, large woody debris, soils).
- Loss of structure reduces function (shade, in-stream habitat, erosion prevention, biodiversity).
- Loss of function combined with impacts from roads and development at stream crossings creates cascading downstream effects.

Creating solutions will involve coordinated and parallel action by different levels of government, resource management sectors, agriculture, private landowners, and other agencies. Therefore, the team recommends that policy and decision makers sectors:

- implement policy and regulatory support for protecting riparian and aquatic systems with *clear and consistent* development and management setbacks and buffers that include functional riparian vegetation for all waterbodies;
- implement riparian protection for small stream and non-classified drainages in forest management; and
- develop effective total planning, maintenance and access management for roads and trails within the context of cumulative effects management.

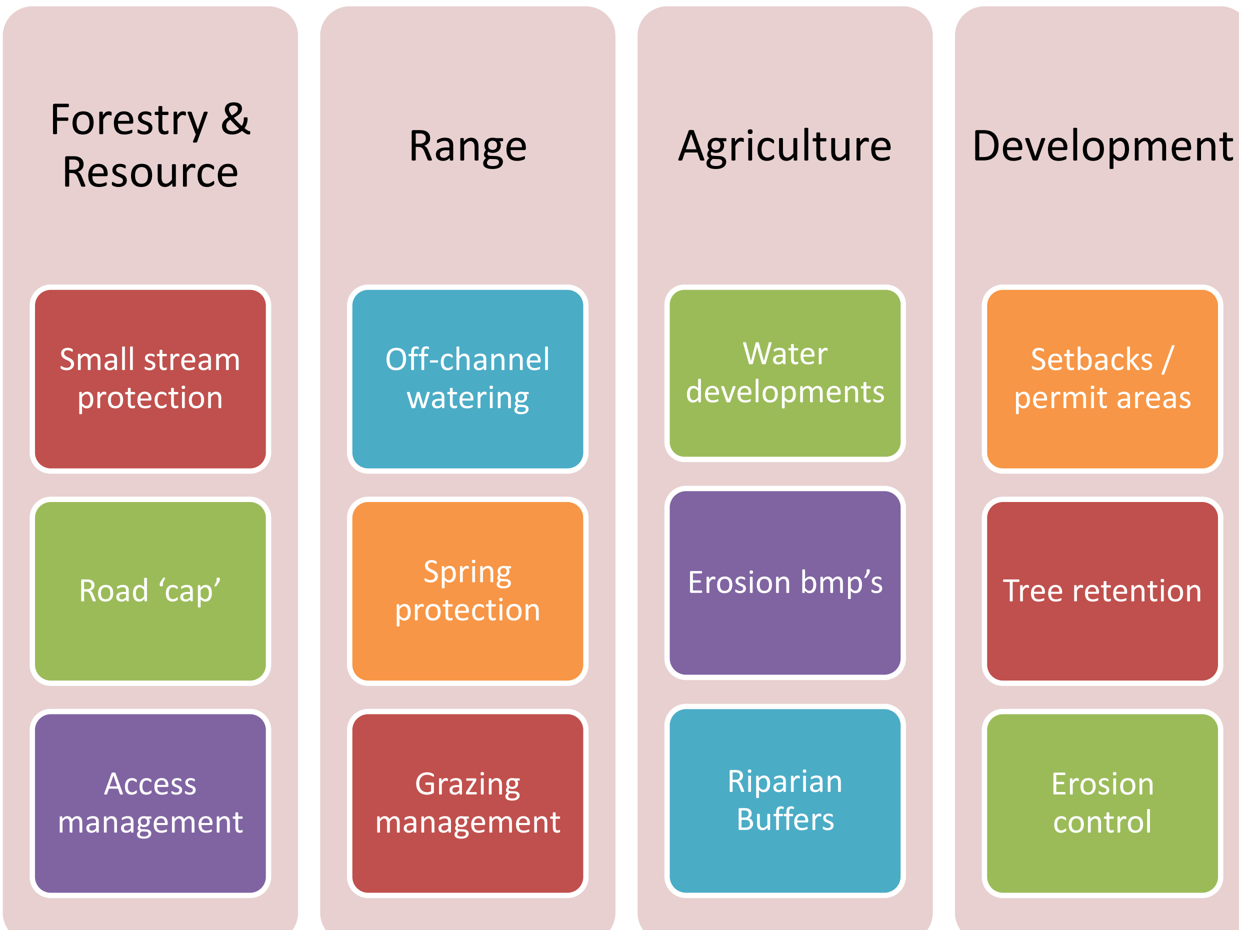

Figure 36. Tools available to address some of the riparian pressures and impacts for different land uses

Specific actions in support of riparian health need to be carried out by the responsible parties. The following is an opening discussion of actions for consideration by each jurisdiction and sector.

Provincial Government – Governing Public Resources & Commons

- Promote and regulate the conservation and restoration of healthy, functional riparian buffers and development setbacks to standard widths such as 6 m for small streams, 10 m for small

wetlands, and greater than 20 metres for permanent water bodies (30+ for fish bearing)(The KRWMP Stakeholder Advisory Group, 2014).
- Support efforts to regulate, restore, and protect riparian areas.
- Develop and implement resource management systems that adequately reflect cumulative effects of resource development and land uses.
- Encourage best management practices by all land users.

Regional Districts and Municipalities - Protecting Community Assets

- Promote and regulate the conservation and restoration of healthy, functional riparian buffers and development setbacks to standard widths such as 6 m for small streams, 10 m for small wetlands, and greater than 20 metres for permanent water bodies (30+ for fish bearing)(The KRWMP Stakeholder Advisory Group, 2014).
- Implement bylaws and other local government tools (i.e. the Green By-Laws Toolkit (University of Victoria Environmental Law Clinic & Curran, 2007)) to protect riparian and aquatic features.
- Use Best Management Practices e.g. Develop with Care Guidelines (Ministry of Environment, 2012) when considering land uses within, or near to, riparian areas.
- Establish Develop Permit Areas in the riparian areas of all waterbodies i.e. rivers, wetlands, lakes.
- Limit development and hard surfaces near water.
- Retain or restore permanent multi-layered native vegetation in riparian area (willow, cottonwood, red-osier dogwood).
- Strike the balance between protecting land and infrastructure and maintaining river function (flood & erosion planning & response).
- Improve function of riparian areas and wetlands near development & settled areas.

Resource Development Sector - Responsible Management Practices

- Mitigate the effects of the MPB infestation on water and watersheds by minimizing or eliminating harvest within riparian areas on smaller streams (Ministry of Forests Lands and Natural Resource Operations, 2014) .
- Introduce new techniques to reduce cumulative impacts of forestry, range management and off-road vehicles by placing woody range barriers on small streams and non-classified drainages (personal communication, Clayton Bradley, 2016).
- Where wetlands have continuous coniferous forest cover in the surrounding matrix, maintain a 20 metre no harvest buffer zone around entire wetlands with at least 50% of the perimeter of the wetland buffer zone be contiguous with coniferous forest of canopy closure great than 35% and height greater than 10 m. These areas are of high value and are very uncommon within areas that are at high risk of mountain pine beetle infestation (Gyug & Simpson, 1991).
- Increase coordination of access management planning.
- Increase consideration of hydrological and geomorphic impacts when developing land use plans.
- Retain or restore permanent multi-layered native vegetation in riparian area (willow, cottonwood, red-osier dogwood).

- Control erosion and sediment related to roads, agriculture, resource development, and commercial and industrial activity near water.
- Encouraging agricultural protection and conservation of wetlands and riparian areas.

Private – Stewardship and Compliance to Conserve Habitats and Protect Property

- Follow the Develop with Care Guidelines (Ministry of Environment, 2012) and comply with regulations when considering land practices within or near to riparian areas.
- Understand the benefits of riparian management on shorelines, properties, water quality.
- Pursue conservation measures on own lands as a way of protecting property.
- Retain or restore permanent multi-layered native vegetation in riparian areas (willow, cottonwood, red-osier dogwood).
- Collaborate with local stewardship groups to access resources and to benefit from local long term relationships.

Other organizations – Advocating for Environmental Values and Community Benefits

- Encourage user groups to become stewards of the environment and consider impacts on riparian areas in trail development and planning.
- Educate user groups on best management practices and tread lightly practices.

Restoration Practitioners – Ensuring Project Success and Benefits

- Implement restoration of riparian areas using previous works as guidance for prioritization:
    - Important watersheds for fish habitats (Glenfir Resources, 2002)
    - Prioritization of Riparian Cottonwood Ecosystems (Coleshill, 2013a)
    - South Okanagan Highlands Conservation Planning (Coleshill, 2013b)
    - Hydrologic sensitivity of watersheds to MPB infestation in the B.C. Interior (Ministry of Forests Lands and Natural Resource Operations, 2014)
- Consider riparian areas and fuel accumulation when developing ecosystem restoration prescriptions (Dwire et al., 2011).
- Establish local long term funding for restoration (funding that does not come and go).
- Establish long-term relationships with landowners vested in restoration work.
- Incorporate multiple values into projects.
- Incorporate monitoring into project planning.
- Reserve small portion of funds for subsequent years to address unforeseen circumstances.
- Identify threats to projects in planning phase in order to incorporate mitigation measures e.g. beavers, livestock, and public perception.
- Incorporate educational component of projects to ensure positive and informed public perceptions.
- Include community as much as possible in projects.
- Develop Memorandums of Understanding for restoration projects on private and jurisdictional lands to ensure future protection and maintenance of projects.

6.5 Next Steps

The key recommendation from this report is that each jurisdiction and resource sector develop and implement policy and regulatory support for protecting riparian and aquatic systems with *clear and consistent* development and management setbacks and buffers that include functional riparian vegetation for all waterbodies. The authors recommend that the Board of Directors for the Kettle River Watershed Authority endorse this report, and further that they formally request representatives of **each sector and jurisdiction** with land use and resource management authority to respond with a **commitment and timeline to propose how their sector will develop and implement these setbacks and buffers within their respective management planning frameworks**. Such commitment is required to spur appropriate management decisions and protection of the riparian resource.

Successful implementation of these recommendations will depend on a broad network of organizations and individuals working together, sharing information, finding resources, and supporting each other in watershed protection. The recommendations developed in this study were directly integrated in the Kettle River Watershed Management Plan. The Kettle River Watershed Management Plan is already investing in capacity-building and training for restoration practitioners and landowners in the region, strategic funding development and restoration projects.

Finally, there is a need to prioritize, fund and implement restoration work in riparian areas strategically throughout the watershed, based on the findings of this report and further expert input. The authors intend to develop and hold a follow-up workshop with local stakeholders and resource management experts to develop a risk management / restoration prioritization framework, strategy, and site selection approach for future projects.

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8 Appendix I Data Used for Coarse Scale Analysis

Table 13. Data and the sources used in a GIS for the Coarse Scale Analysis on Riparian Areas of the Kettle River Watershed.

GIS Layer	Source	Description	Date Acquired
1. **FWA_Streams**	Fresh Water Atlas	Aquatic Features	Nov 2013
2. **FWA_Wetlands**	Fresh Water Atlas	Aquatic Features	Nov 2013
3. **FWA_Ponds**	Fresh Water Atlas	Aquatic Features	Nov 2013
4. **FWA_Lakes**	Fresh Water Atlas	Aquatic Features	Nov 2013
5. **FWA_Rivers**	Fresh Water Atlas	Aquatic Features	Nov 2013
6. **Kettle River Watershed Boundaries**	Fresh Water Atlas	Boundary of the watershed	Nov 2013
7. **3rd Oder Watersheds**	DataBC	Boundaries of 3rd order watersheds in the Kettle River Watershed	Jan 2014
8. **RDKB: Area_C; Area_D; Area_E**	LRDW	Regional District Administrative Boundaries	Nov 2013
9. **Greenwood**	Created in GIS	Greenwood Municipal Boundary	Nov 2013
10. **Midway**	Created in GIS	Midway Municipal Boundary	Nov 2013
11. **GF_Mun_Boundary**	City of Grand Forks	City of Grand Forks Municipal Boundaries	Nov 2013
12. **BEC**	LRDW	Biogeoclimatic Zones	Oct 2013
13. **Riparian Suitability Model**	MFLNRO	Model created in a GIS	June 2014
14. **Protected Area**	DataBC	Municipal Zoned Parks and Provincial Parks	Nov 2013
15. **Culverts**	DataBC	Culvert locations	Nov 2013
16. **Developed**	Federal National Land Cover Classification	Layer of land developed based on LandSat Imagery	Jan 2014
17. **Fires**	MFLNRO	Historical Fires in the Boundary determined via on the ground, VRI	Feb 2012
18. **Forestry Tenures**	DataBC	Crown leases lands for timber rights	Nov 2013
19. **Forest Harvest Openings**	DataBC	Data submitted by forestry companies updating on harvest and silviculture duties	Nov 2013
20. **Mining**	Ministry of Energy and Mines Website	Past mining projects	Nov 2013
21. **Mining Tenures**	DataBC	Crown leases lands for mineral rights	Nov 2013
22. **Mountain Pine Beetle**	DataBC	Pest Infestation Layer	Nov 2013

GIS Layer	Source	Description	Date Acquired
23. **Private**	Integrated Cadastral Information/City of Grand Forks		Sept 2013
24. **Range Tenures**	DataBC	All Crown leased lands for grazing rights	Nov 2013
25. **Active Range Tenures**	DataBC	All Crown leased lands for grazing rights being actively grazed	Nov 2013
26. **Terrain Stability Mapping**	DataBC	Identified unstable areas by soil type and slope	Nov 2013
27. **Vegetative Resource Inventory**	DataBC	Vegetation	Nov 2013
28. **Mtn Bike Trails**	Local Mountain Bike Group	Mountain bike trails in local area; not tenured	Sept 2013
29. **ATV Trails**	Local ATV Group	ATV trails in local areas; used FSRs	Sept 2013
30. **Trans Canada Trail**	TCTrail Website	TransCanada Trail	Nov 2013
31. **FTEN_roads**	DataBC	Tenured locations of resource roads	Sept 2013
32. **Rd_density**	British Columbia Timber Sales	Resource roads database supplied by BCTS	Sept 2013
33. **DRA_MPAR**	DataBC	Digital Roads Atlas	Sept 2013

9 Appendix II Riparian Model

9.1 Background

The purpose of the threat analysis is to identify landscape and site level threats to the features, functions and conditions of riparian areas in the context of the larger watershed. In order to assess riparian threats you first need to know where your riparian areas are. At the time of the project there was no single layer available that spatially defined riparian potential for the range of water bodies of interest (i.e. streams, rivers, lakes, wetlands). Provincial floodplain mapping was available for the southerly portions of the Kettle and Granby Rivers but not tributaries or upper reaches. A standard buffer could have been completed (e.g. 15m on all water bodies), however we felt that there was enough digital information available to produce a more accurate representation of riparian habitats using new GIS modeling methods.

9.2 Methods

The Kettle Watershed Riparian Model project built on work done for the Ministry of Environment by Brian Calder, Senior GIS Analyst, Mapmonsters GIS Inc. and Hailey Eckstrand, GIS Analyst, Clover Point Cartographics Ltd. The Robson TSA Habitat and Species Capability Model (Calder and Eckstrand 2013) resulted in a rapid-deployment ecosystem model that produced ecosystem units with greater ecosystem resolution than BEC subzone but with less ecosystem resolution than site series. These GIS modelled ecosystem units, habitat subtypes, would then be combined with BEC subzone, and structural stage information, and linked to known species within the Robson TSA to produce species capability maps.

The team were only interested in riparian habitats for our model so used the riparian modelling methods employed by Calder and Eckstrand and built on them with a variable width riparian buffer following methods from Abood and MacLean (2011).

9.2.1 Model set-up

The following descriptions are excerpts from Robson TSA Habitat and Species Capability Model. Altered text specific to this project is italicized.

TRIM freshwater atlas was used to identify all water features: rivers, streams, lakes, pond and wetlands (Figure 37).

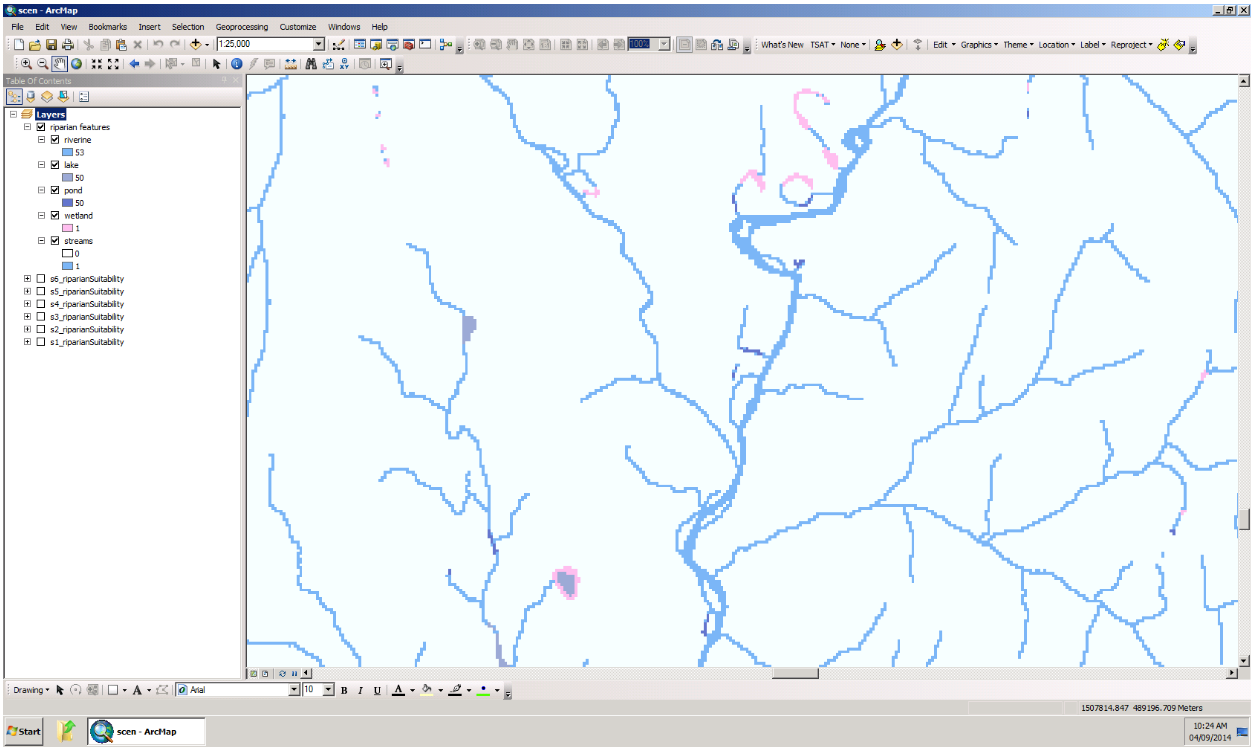

Figure 37. TRIM freshwater features at the confluence of the West Kettle and Kettle Rivers, Westbridge, BC.

Slope is a calculation of the maximum rate of change in a value from a given cell to its neighbours. It identifies the maximum change in elevation over the distance in a three by three-moving window. Slope was generated using the Spatial Analyst Extension in ArcGIS and *(for the Kettle project) was classified into different percent slope classes (*Figure 38 *and* Table 14*).*

Table 14. Variable classes and values in the first verions model.

Variable	Class 1	value	Class 2	value	Class 3	value
Slope	>10%	0	5-10%	1	0-5%	2
TPI	>0	0	<=0	1		
Wetness Index	<10	0	10-19	1	19-35	2

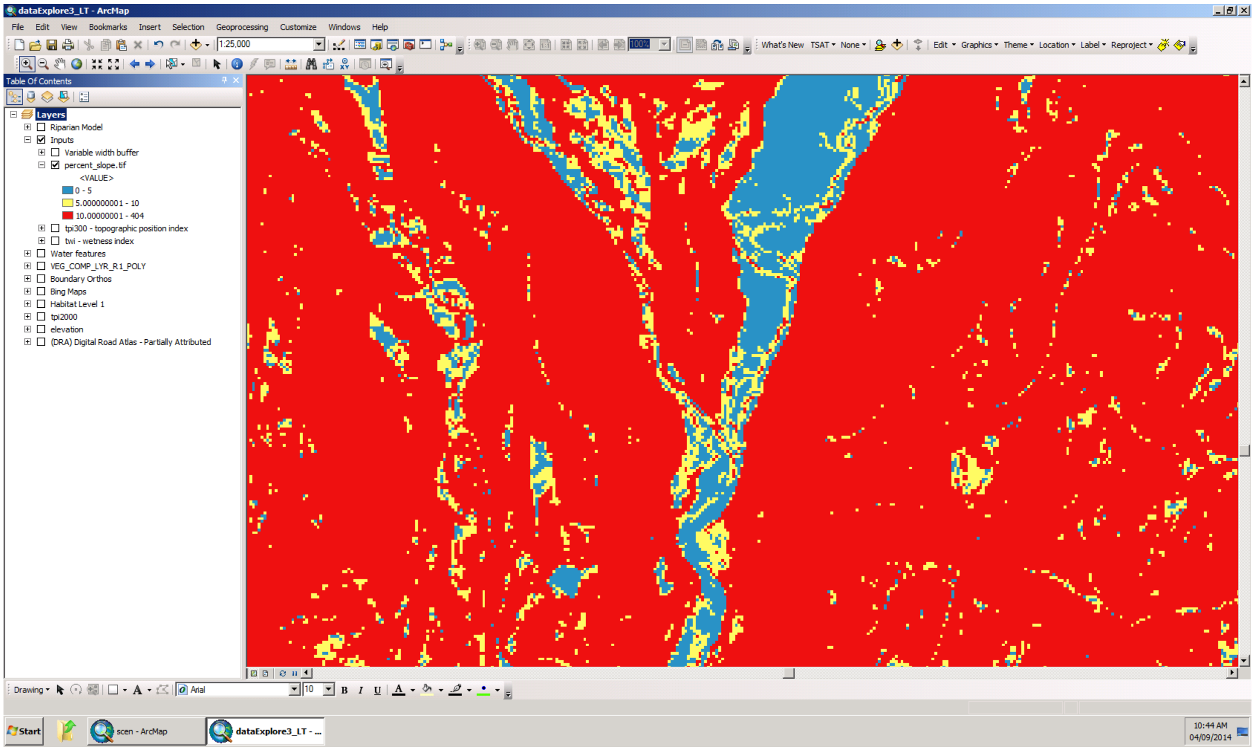

Figure 38. Slope percent classes at the confluence of the West Kettle and Kettle Rivers, Westbridge, BC.

The Topographic Position Index (TPI) tool was developed by Jeff Jenness and is available at http://www.jennessent.com/arcview/tpi.htm. The Land Facet Corridor Tool includes a TPI function (http://www.jennessent.com/downloads/Land_Facet_Tools.pdf) that produces a relative slope position surface from a DEM. *Very positive values are ridges, very negative values are sharp valley bottom, 0 is flat (*Figure 39 *and* Table 14*).*

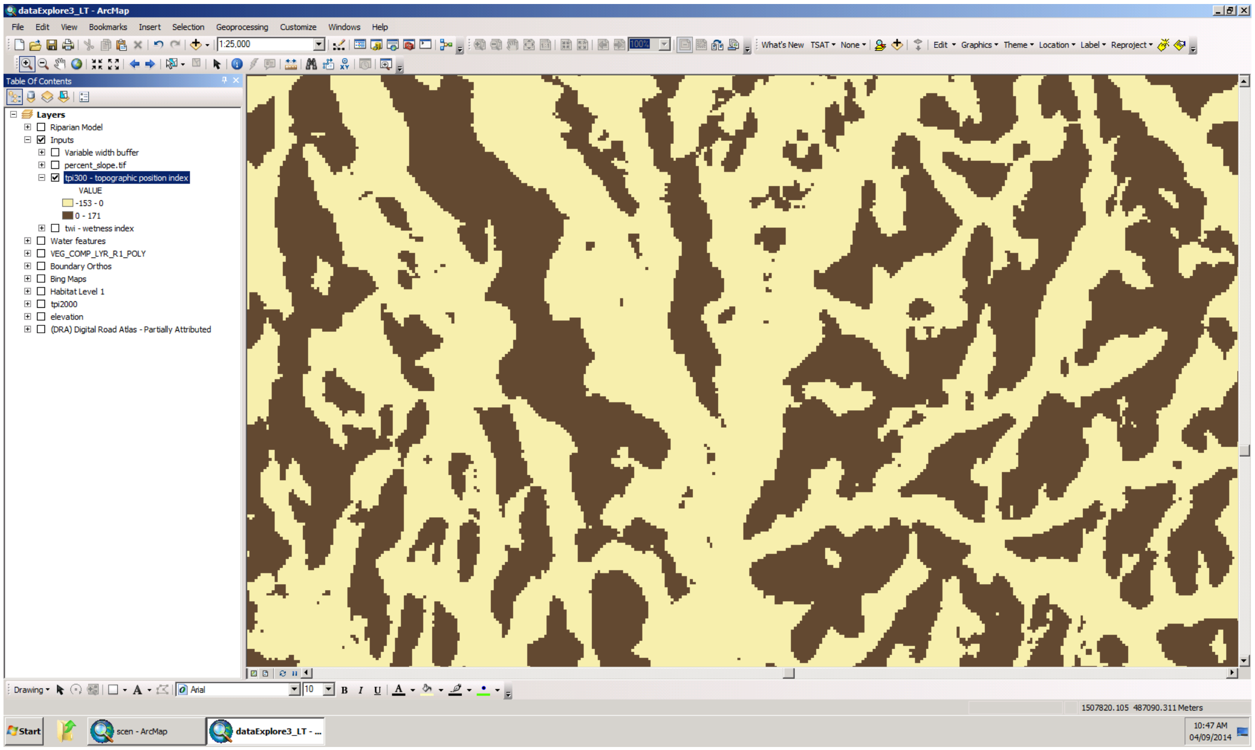

Figure 39. Topograpic position index (TPI) classes at the confluence of the West Kettle and Kettle Rivers, Westbridge, BC.

The TauDEM Wetness Index tool was developed by David Tarboton and can be accessed at http://hydrology.usu.edu/taudem/taudem5.0/index.html. The wetness index, also called the slope over area ratio, calculates the ratio of the slope to the specific catchment area. This function is related to the more common ln(a/tan beta) wetness index but area is in the denominator to avoid dividing by 0 where the slope is 0. The wetness index produces a continuous surface that was visually interpreted and classified *into three classes (*Figure 40 *and* Table 14*)*.

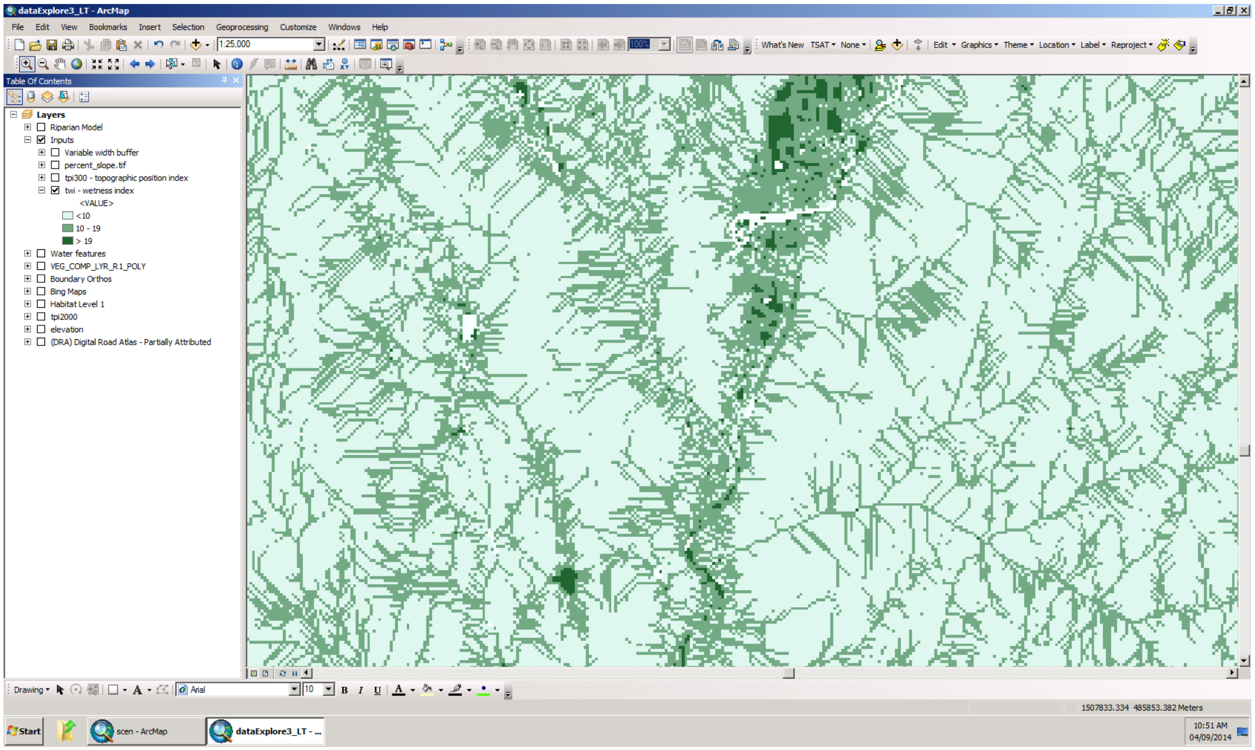

Figure 40. TauDem Wetness Index (TWI) classes at the confluence of the West Kettle and Kettle Rivers, Westbridge, BC.

9.2.2 Variable Width Buffer

The variable width buffer uses ArcGIS to buffer out on tangent from a stream or water body vertex until specified elevation difference is achieved, both sides of streams, outside of water body polygons. Initially a height of 1.5m was used (Figure 41).

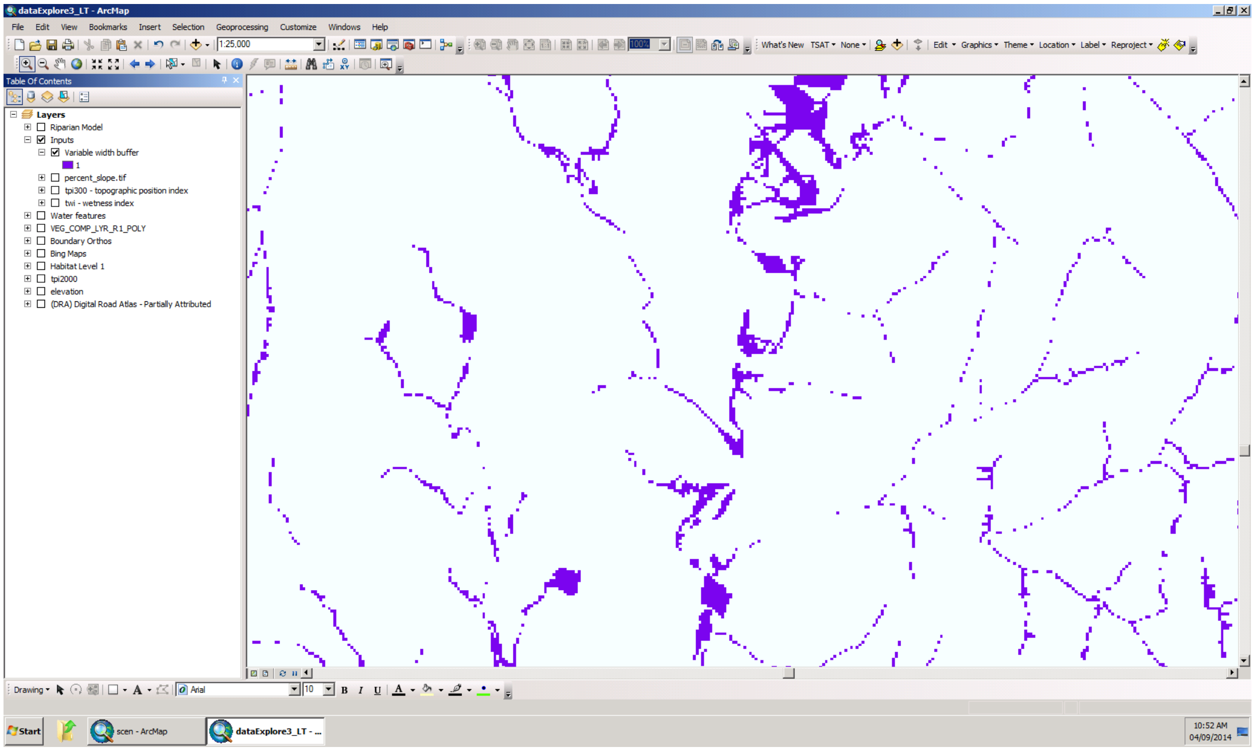

Figure 41. Variable width buffer using a tangent buffer of 1.5m at the confluence of the West Kettle and Kettle Rivers, Westbridge, BC.

9.2.3 Model Scenarios

The Riparian Working Group wished to evaluate alternative scenarios. The Abood and MacLean model considered the influence of water over topping banks only. We felt it was also important to consider subsurface influence of flood waters. As a result we want to have the elevation distance increased. We ran the model using 3m for the Kettle, West Kettle and Granby Rivers and 2m for all other water bodies (streams, lakes, wetlands). This did not provide us with improved results and in subsequent model runs we used 1.5m.

In the first version of the model, two raster equations were used: riparian suitability and riparian buffer.

- Riparian suitability (Figure 42) ranking was established using the equation: *Riparian suitability = slope class x TPI class x wetness index class.* For this ranking the higher the suitability scores, the better the suitability as riparian habitat.
- The riparian buffer (Figure 43) ranking was established using the equation: *Riparian buffer = riparian suitability x variable width buffer.*

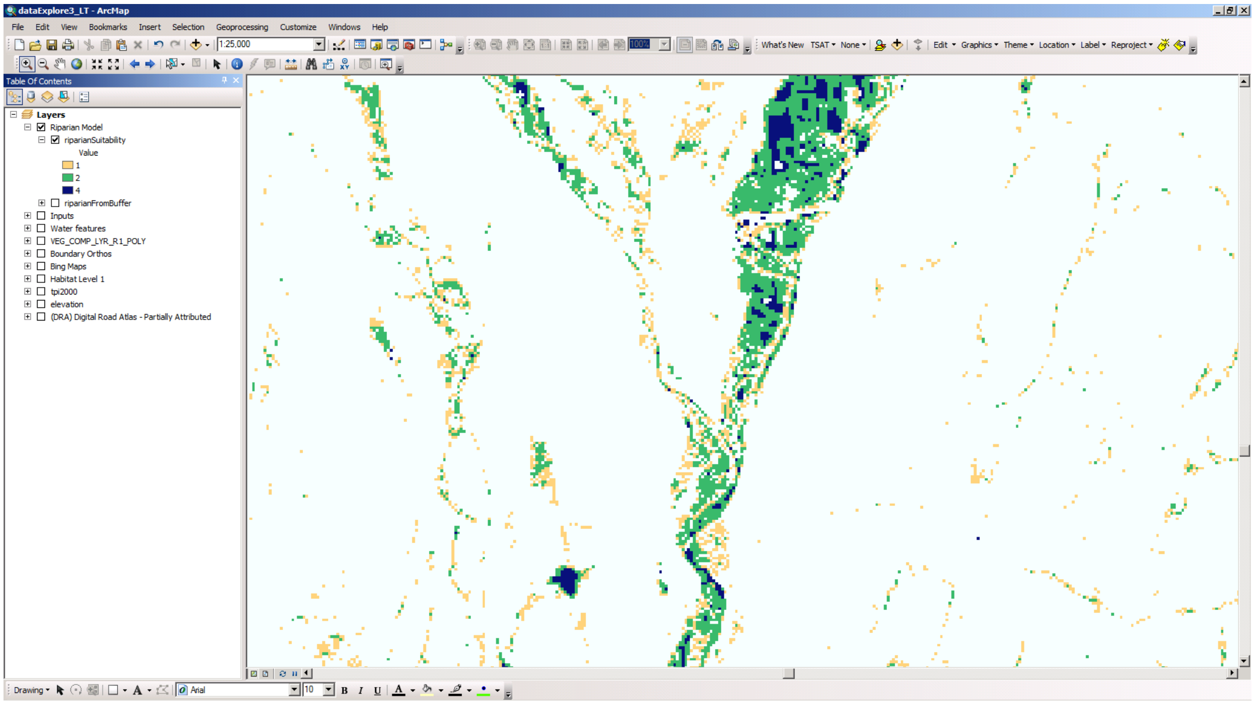

Figure 42. Calculated riparian suitability at the confluence of the West Kettle and Kettle Rivers, Westbridge, BC.

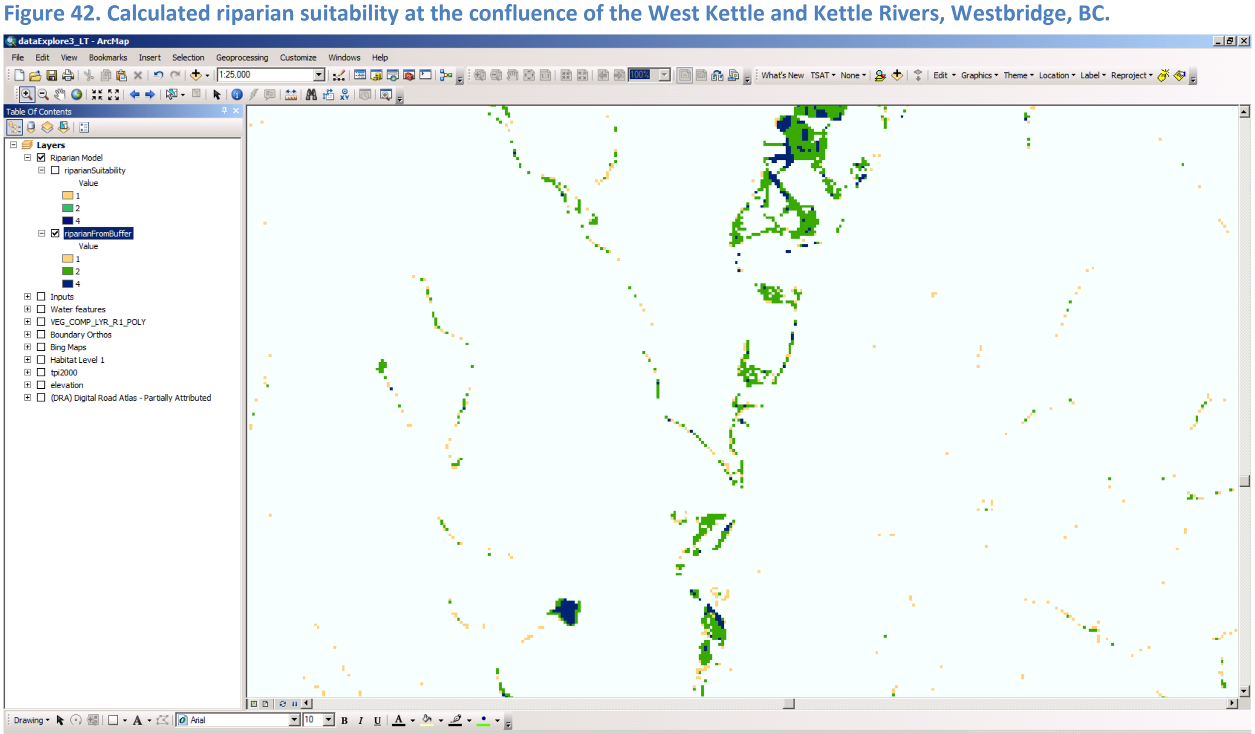

Figure 43. Calculated riparian buffer at the confluence of the West Kettle and Kettle Rivers, Westbridge, BC.

When these equations were used, we could see that frequently areas that were known to be riparian were being removed because one variable in the suitability equation didn't pick up on it (a '0' rank was cancelling out other relevant data in multiplication). In particular for riparian buffer, if something has been identified in the variable width buffer as riparian we don't want that cancelled out simply because riparian suitability was zero. Biologically we know that there is always riparian habitat along water bodies, suitability may be zero only because the data sets we are working with aren't at a scale to detect this.

In the next version (V2) of the model we tried four scenarios (Table 15) with having the class ranks for each variable additive as opposed to multiplicative.

Riparian buffer = slope class + TPI class + wetness index class + variable width buffer

Table 15. Comparison of model versions and variable class rankings.

Model version/ scenario	Variable width buffer	TPI	Wetness Index	Slope Class	Comment
V1/S1	0/1	0: >0 1: <= 0	0: <10 1: 10-19 2: 19-35	0: >10 1: 5-10 2: 0-5	First model run Maximum score 6 Figure 9.
V2/S1	0/2	0: >0 1: <= 0	0: <12, 1: 12-19 2: 19-35	0: >10, 1: 5-10 2: 0-5	Maximum score 7 change VWB and TWI Figure 10
V2/S2	0/2	0: >0 1: <= 0	0: <10 1: 10-19 2: 19-35	0: >50 1: 25-50 2: 5-25 3: 0-5	Maximum score 8 change VWB and slope class Figure 11
V2/S4	0/3	0: >0 1: <= 0	0: <12, 1: 12-19 2: 19-35	0: >10, 1: 5-10 2: 0-5	Maximum score 8 change VWB and TWI Figure 12
V2/S5	0/3	0: >0 1: <= 0	0: <10 1: 10-19 2: 19-35	0: >50 1: 25-50 2: 5-25 3: 0-5	Maximum score 9 change VWB and slope class Figure 13

9.2.4 Results

The following screen captures (Figures 44-48) provide a visual display of the differences between model scenario results at the confluence of the West Kettle and Kettle Rivers, Westbridge, BC. The move to an additive model improved results. The addition of slope classes did not prove beneficial. Model versions V2/S1 and V2/S4 provided the most accurate representation of ground conditions (Figure 44 and Figure 46). Model scenarios V2/S2 and V2/S5, with the additional slope class, resulted in over representation of riparian habitat (Figure 45 and Figure 48).

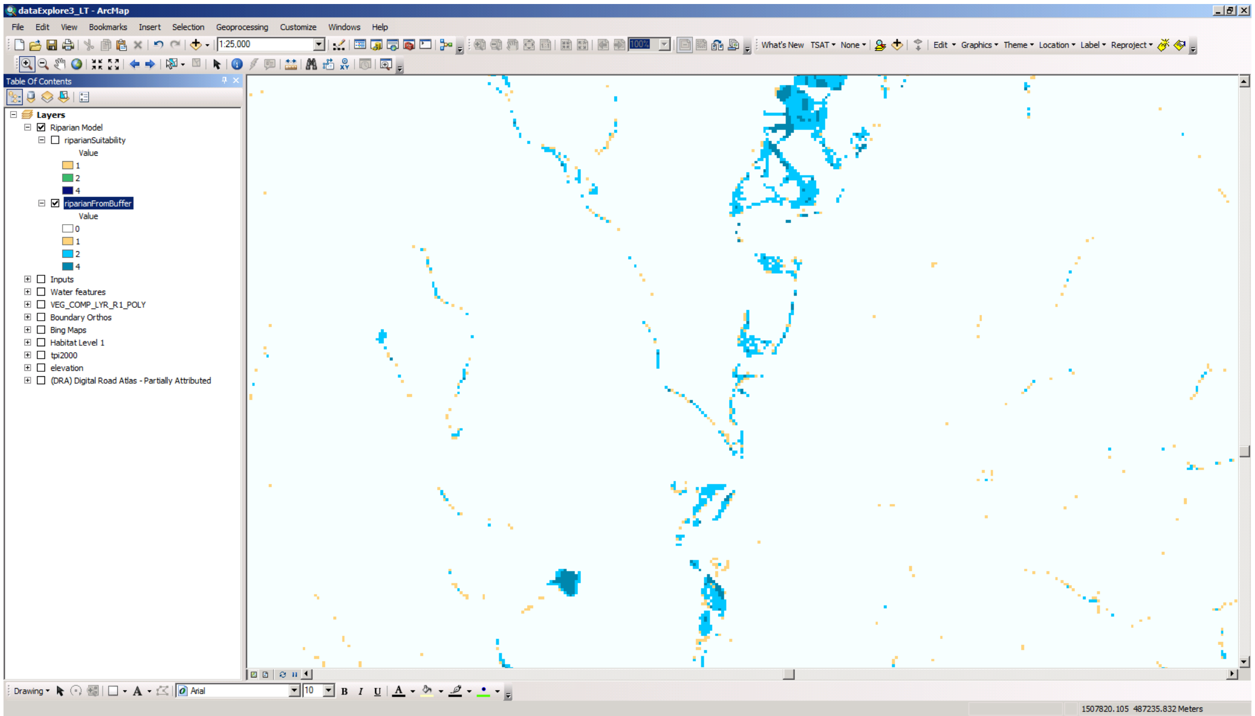

Figure 44. Model V2/S1

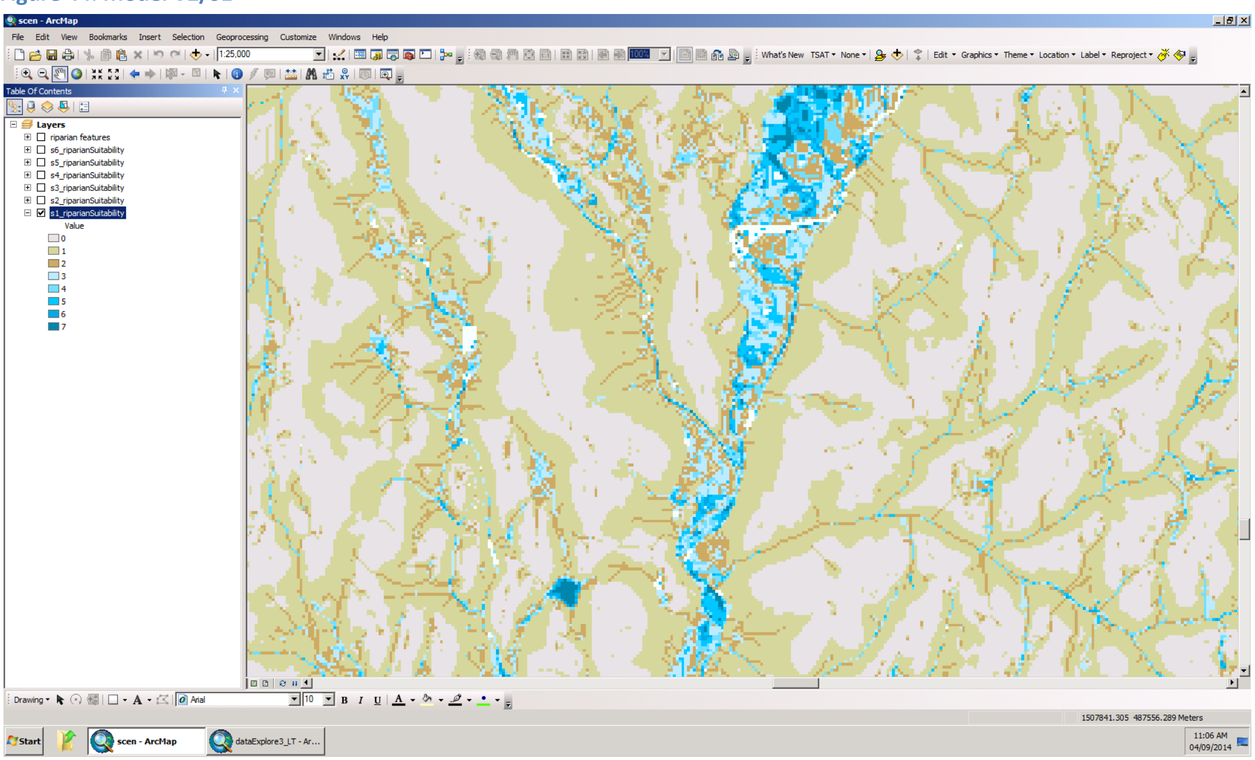

Figure 45. Model V2/S2

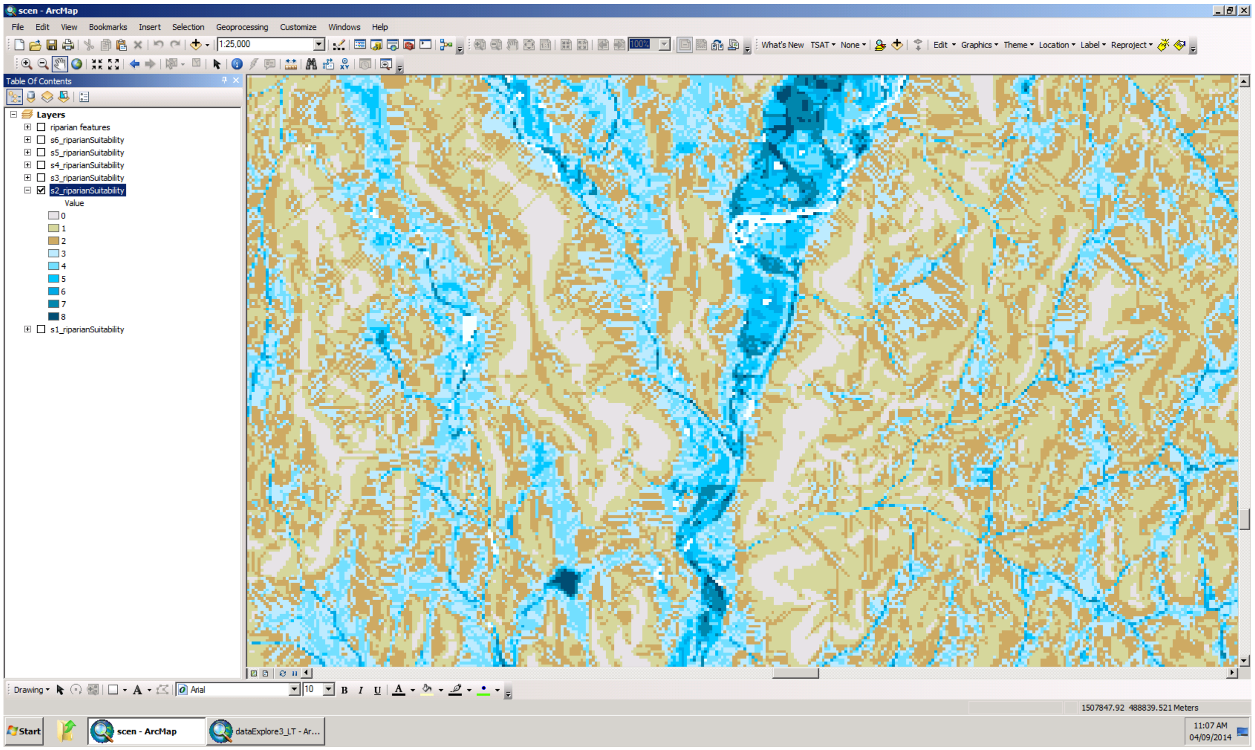

Figure 46. Model V2/S4

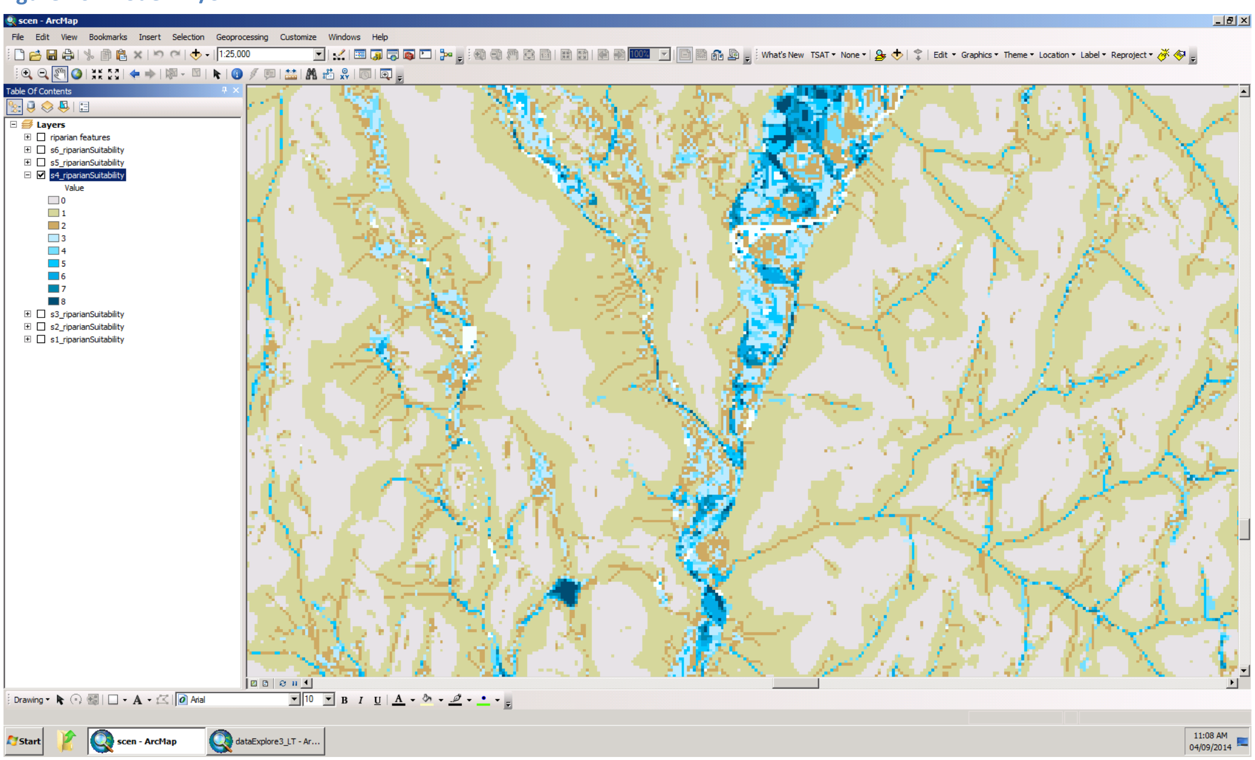

Figure 47. Model V2/S4

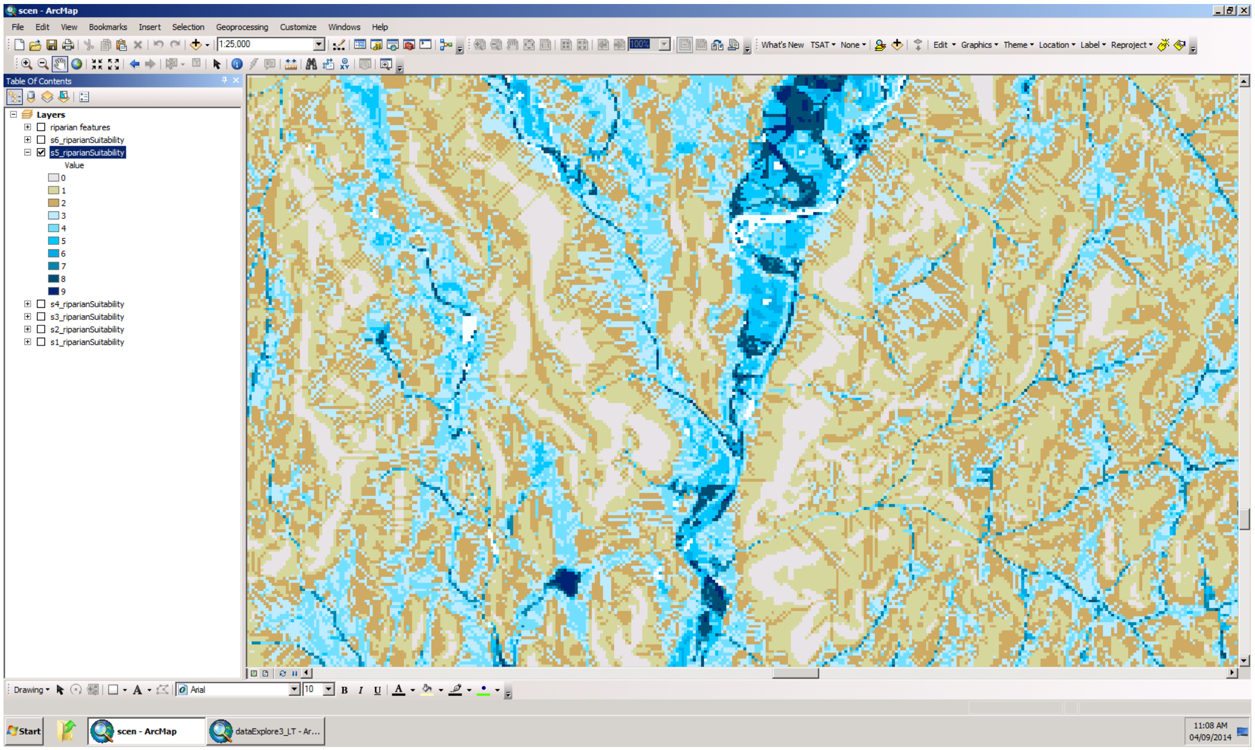

Figure 48. Model V2/S5

When model versions V2/S1 and V2/S4 are compared more closely (Figure 49) you can see that the total area identified as riparian does not vary just that in model V2/S4 some areas receive a stronger rating (darker colour areas) because of the 0/3 variable width buffer weighting.

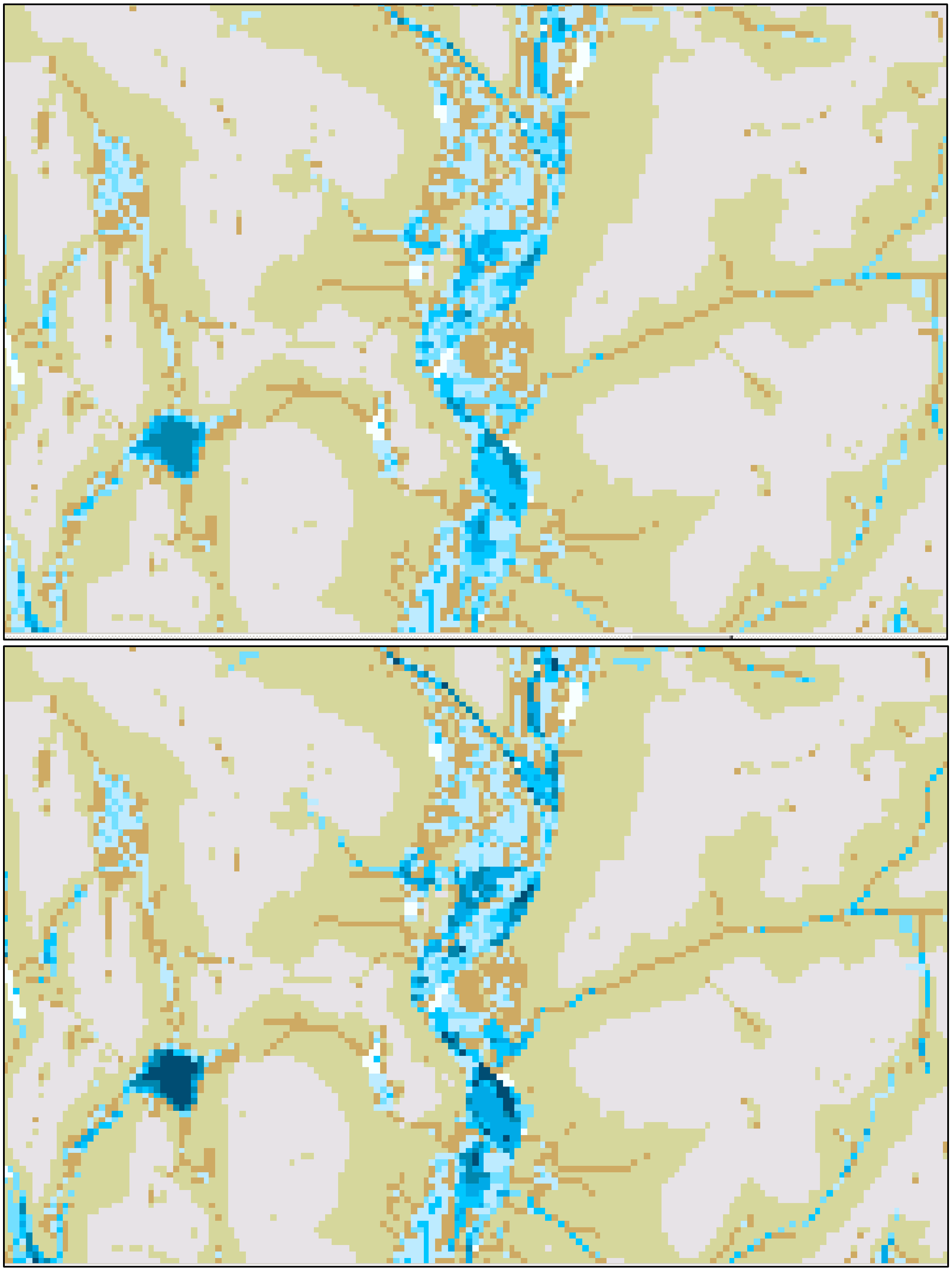

Figure 49. Close up comparison of model scenarios V2/S1 (top) and V2/S4 (bottom) just south of the confluence of the West Kettle and Kettle Rivers, Westbridge, BC.

9.2.5 Discussion

The current results were not utilized in the Riparian Threat Assessment because the results were not yet reliable enough. There were many areas that could be visually identified as riparian areas but could not be corrected consistently in the model because the necessary data was not available (e.g. high quality soils mapping).

The project team feels the work done to date is valuable and could still have application, with the following areas for improvement:

- Investigate the potential to use data collected during the threat assessment to further validate and test the model;
- Complete targeted field visits to further validate and test the data;
- If LiDAR imagery becomes available rerun the model with this additional information; and
- Continue to look at other methods and datasets for refining and improving the model. In particular the work done by David Theobold for the US Forest Service, Assessment of Threats to Riparian Ecosystems in the Western US.

9.2.6 Literature Cited

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Calder, B. and H. Eskstrand 2013. Robson TSA Habitat and species capability model. Prepared for Ministry of Environment, Victoria, BC.

Theobold, D.M., D.M. Merritt and J.B. Norman, III. 2010. Assessment of Threats to Riparian Ecosystems in the Western U.S. A report presented to The Western Environmental Threats Assessment Center, Priveville, OR by The U.S.D.A. Stream Systems Technology Center and Colorado State University, Fort Collins, CO.

9.3 Acknowledgments

The testing of project would not have been possible without the technical expertise of Lisa Tedesco, Habitat Biologist, and Will Burt, Regional Geomatics Specialist Ministry of Forests, Lands and Natural Resource Operations. Graham Watt, Kettle River Watershed management Plan coordinator and Jenny Coleshill, Granby Wilderness Society coordinator were also involved with every step of this project.

10 Appendix III: Supplemental results

Table 16. Land Cover Classes and areas (km²) of each class within 50 metres of Water Features in the Grand Forks Area.

Code	2014	1951
NLUELBP	0.073208686	0.007380583
NLUELES	0.018702792	0.035644763
NLUELLL	0.000379416	0
NLUELOT	0.01615079	0.00110162
NLUELRP	0.094229621	0.04474908
NLUELRR	0.001060631	0.005390672
NLUELRS	0.000575899	0.016383454
NLUELTS	0.019733264	0.027112041
NLWELES	0	0.011666639
NLWELRP	0	6.68363E-05
NLURORT	0.000214974	0
NLWELBE	0.000486794	0
NLWELRR	0.001271001	0
NLWELRS	0.011049424	0.045374978
NLWSLOP	0	0.002965584
NLWSLSP	0	0.000619968
NLWELTS	0.000815737	0
NWWWAST	0.000577102	0.000375513
VLUHGOP	0.008223008	0
VNWSTOP	0	0.003253881
VNUHEDE	0.001284014	0
VNUHEOP	0.021860577	0.000166665
VNUHESP	0	0.004133135
VNUHGDE	0.113379471	0.034814148
VNUHGOP	0.05658384	0.169720476
VNUHGSP	0.025564017	0.006392223
VNUSLDE	0	0.001978504
VNUSTDE	0.000323179	0
VNUSLOP	0	0.044964267
VNUSTOP	0.01647405	0
VNUSLSP	0	0.017900235
VNUSTOP	0	0.015240918
VNUTMOP	0	0.005055431
VNWELRS	0	0.000368032
VNWELES	0	0.000792484
VNWHEOP	0	0.001009116
VNWHESP	0.005094513	0
VNWHGSP	0	0.003644065

VNWHGDE	0.010892902	0
VNWHGOP	0.000703164	0
VNWSLDE	0.011230975	0.001981506
VNWSLOP	0.001365195	0.007451201
VNWSLSP	0.005082423	0
VNWSTDE	0	0.003973925
VNWSTOP	0	0.003898074
VTUTBDE	0.019321424	0.032171408
VTUTBOP	0.025506449	0.092951576
VTUTBSP	0.007681492	0.004564894
VTUTCOP	0.006326096	0.002330765
VTUTCSP	0.000513489	0
VTUTMDE	0	0.006398065
VTUTMOP	0.013146747	0.010199995
VTUTMSP	0.013029011	0.066738734
VTWSTOP	0	0.006239923
VTWTBDE	0.146241163	0.151554837
VTWTBOP	0.043586559	0.025890693
VTWTBSP	0.016482617	0.007908799
VTWTMDE	0	0.061499176
VTWTMOP	0.020948383	0.029556319

Table 17. Land Cover Classes and areas (km2) of each class within 50 metres of Water Features in the Rock Creek Area.

LANDCOVER CLASS	CURRENT	1938
NLUELRR	0	0.031863898
NLUELBP	0.004773561	0
NLUELES	0.059964931	0.005244485
NLUELRP	0.056001942	0.019417454
NLWELES	0.009387689	0
NLWELRS	0.017677299	0
VNUHEDE	0	0.05405813
VNUHEOP	0.09644707	0
VNUHGDE	0.040551687	0
VNUHGOP	0.023975795	0.019907664
VNUHGOP	0.037624748	0.074433793
VNUHGSP	0.026022803	0.004104191
VNUSLOP	0	0.007149044
VNUSLSP	0	0.004180042
VNWHEOP	0	0.006464689
VNWHGOP	0	0.001268919

VNWHGSP	0	0.004100182
VNWSLDE	0	0.001069735
VNWSLOP	0	0.088105112
VNWSLSP	0	0.018448815
VTUTMOP	0.00053948	0
VTUTMSP	0.000387013	0
VTUHGSP	0.000673092	0
VTUTBDE	0.090260972	0.021195658
VTUTBOP	0.10492623	0.032302662
VTUTBSP	0.01336688	0.010840096
VTUTCDE	0.205003254	0.003245858
VTUTCOP	0.025867142	0.009124917
VTUTCSP	0	0.0557854
VTUTMDE	0.069376751	0.205840795
VTUTMOP	0.054373746	0.034674318
VTUTMSP	0.011696449	0.021034764
VTWTBDE	0.019173694	0.089354839
VTWTBOP	0.036141754	0.039870286
VTWTBSP	0.028659989	0.024133415
VTWTMDE	0	0.000160468
VTWTMOP	0.000198751	0.036901167
VTWTMSP	0	0.002507358
Total	1.033072722	0.926788153