Aquatic Ecosystems Cumulative Effects Assessment Report

Elk Valley, Kootenay Boundary Region

Photo: District of Sparwood

Version 8

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EXECUTIVE SUMMARY

The Elk Valley in British Columbia's East Kootenay is rich in biodiversity, culture and economic wealth. Management of cumulative effects in the Elk Valley has been of increasing concern due to resource development and residential and recreational pressures as well as natural events.

The Ktunaxa Nation, BC Government, Industry, and other stakeholders have identified two valued components of the Elk Valley that pertain to aquatic ecosystems:

1. Riparian areas have high biodiversity and provide critical habitat for wildlife to live in and move through. They also play a key role in moderating flooding during high streamflow events. In addition, riparian areas provide ecological services to streams and other aquatic habitats by moderating water temperatures, filtering runoff, and acting as a source for large woody debris, among other services.
2. Westslope cutthroat trout (WCT; *Oncorhynchus clarki lewisi*) are of ecological, cultural, economic, and social importance to both residents and visitors to the Elk Valley. Most notably, the Elk River supports a world-class recreational fishery for this species. WCT are also good indicators of aquatic and watershed health, because they are highly intolerant of high water temperatures and require clean, well oxygenated gravel beds for spawning. As an easily angled sport fish, they are sensitive to increasing road access into natural areas. They are also susceptible to hybridization with introduced salmonids, especially rainbow trout. WCT is listed as a species of Special Concern by the Canadian government and is ranked as vulnerable in British Columbia.

Spatial and non-spatial data were used to assess historic, current, and potential future conditions, as well as to develop hazard maps. Three alternative future development scenarios, namely, business as usual, minimum, and maximum, and a higher natural disturbance scenario were defined to assess the response of indicators to variations in rates, spatial configurations, density or pattern of development and disturbance over the next 50 years. Seven indicators were selected for assessment of the status of riparian areas and WCT in the Elk Valley. These indicators were assessed at the level of Assessment Watersheds (AWs), as defined by the provincial government. The Elk Valley contains 78 AWs, varying in size from 19 km^2 to 104 km^2. Most AWs represent sub-watersheds, but 11 are face units, comprising slopes draining directly into the Elk River.

The chosen indicators are:

1. Riparian disturbance (percent disturbed riparian area);
2. Stream crossings (number per km^2, excluding bridges);
3. Road density within 100 m of any stream (km of road per km^2);
4. Road density on steep slopes (>60% grade) (km of road per km^2);
5. Equivalent Clearcut Area (ECA; percent);
6. Degree of WCT/rainbow trout hybridization (percent pure WCT);
7. Average warmest month stream temperature (ºC).

Aquatic ecosystem hazard was assessed for the first five indicators using benchmarks from the provincial aquatic ecosystems value assessment (AEVA) protocol. These five indicators were also rolled up into a combined hazard score using the AEVA protocol.

Retrospective Assessment

Retrospective assessment evaluated indicators to measure current hazard and compared them to historical values (where possible) to identify rates and patterns of change and their key causes.

1. Riparian disturbance: The vast majority of AWs in the Elk Valley (64 of 78) are currently at high hazard for riparian disturbance (i.e., >20% of riparian areas disturbed). Only 5 ranked as low hazard, with the remaining 9 ranked as moderate hazard. Highest hazards were found in the valley bottoms and in AWs affected by mining.
2. Stream crossings: Again, the vast majority of AWs (66 of 78) had high hazard, with 5 at moderate hazard and 7 at low hazard. Because so many AWs are at high hazard, prioritization will be necessary to address management and mitigation. Further assessment of stream crossings - particularly to assess type of crossing and other site-specific factors such as hybridization - will be important in the prioritization process.
3. Road density near streams: Of the 78 AWs, 71 are at high hazard, 2 at moderate hazard, and 5 at low hazard. Roads often parallel WCT streams, which can impair riparian function and lead to the degradation of habitats through stream bank armouring for road protection.
4. Road density on steep slopes: 30 of 78 AWs are at high hazard, 16 at moderate hazard, and 32 at low hazard. Roads on steep slopes can lead to mass wasting and sediment delivery to streams. There is considerable uncertainty in terms of where problems related to erosion may exist; therefore, further investigation into this hazard is required.
5. ECA: 11 of 78 AWs are at high hazard, 31 at moderate hazard, and 36 at low hazard. High hazard watersheds are particularly prone to increased peak flow and also to changes during low flow periods, both of which pose potential threats to WCT.
6. WCT hybridization: Most watersheds (59 of 78) showed no apparent hybridization between WCT and rainbow trout, with 16 watersheds showing moderate hybridization (96-99% pure WCT) and 3 showing high hybridization hazard (<95% pure WCT). Note, however, that DNA sampling was not conducted for all watersheds, and sampling error may lead to underestimation of the presence of rainbow trout in some watersheds.
7. Stream temperature: All watersheds appear to have warmest-month water temperatures that are well within the thermal tolerance for WCT (~20 ºC). In many tributaries, water temperatures may be below thermal optima (13 – 15 ºC).

The indicator roll-up (combining normalized scores for riparian disturbance, stream crossing density, road density near streams, road density on steep slopes, and ECA) finds 17 AWs (22%) at high hazard, 51 (65%) at moderate hazard, and 10 (13%) at low hazard. The analysis suggests that greatest hazard is found in the valley bottom and areas of high development. The five AWs at highest hazard are, in descending order of hazard: Lake Mountain and Clode Creek, Michel Creek - Lower, Elk Face Unit NE of Sparwood, Swift Creek, and Greenhills Creek.

Mining disturbance likely contributes the most intense hazard, represented by high levels of disturbance in individual AWs. However, the influence of roads is the most widespread source of hazard, especially in the southern and central portion of the watershed where road density is greatest. Low-hazard watersheds are almost exclusively found in protected northern portions of the watershed.

Prospective Assessment

The prospective assessment uses a well-validated landscape model to project how aquatic ecosystem indicators might respond to alternative future development scenarios, natural disturbance, and climate change. Future development scenarios suggest ECA at the scale of the Elk Valley is likely to decrease over time, with a reduction from 29% across all AWs to 27%. As a result, riparian disturbance is also likely to decrease under these scenarios. Conversely, higher natural disturbance is likely to lead to higher ECA, at 38% across all AWs at the end of the simulation period. Like ECA and riparian disturbance, the roll up hazard also decreases slightly under the future development scenarios and increases slightly under the higher natural disturbance scenario. Overall, landscape-scale change affecting aquatic indicators is likely to be greatest in the south eastern portion of the Elk Valley.

Perhaps the most substantial threat to WCT in the Elk Valley is change in stream temperature over time. Although it is likely that average summer stream temperature conditions remain suitable for WCT over the next 50-years, it is also likely that there will be higher variability. Some individual low-elevation AWs could experience upwards of 3 ºC of warming over the next half century, leading to substantial shifts in average conditions. Although extreme, these results suggest thermal regimes may become less suitable for WCT in the future, presenting a significant management challenge.

It is important to note that most of the key disturbances (e.g. mining and road development) have not been assessed at potential extreme levels. Cumulatively, more extreme future development scenarios coupled with higher rates of natural disturbance (i.e., climatic warming and associated increase in wildfire and pests) could ultimately lead to substantial changes in aquatic ecosystems.

Management implications

Results suggest that targeted management actions can reduce hazard to aquatic ecosystems in the Elk Valley. Mitigation should focus on management or deactivation of roads near streams to reduce hazard relative to aquatic ecosystems. Managing timber harvest levels can also mitigate hydrologic hazards caused by increased ECA, even with no change in annual allowable cut. Intensive mitigation efforts led to a substantial decline in overall hazard, especially in scenarios involving higher future rates of natural disturbance. However, mitigation to reduce road densities would require deactivation or reclamation of 75% and 90% of the roads near streams under the moderate and intensive mitigation scenarios, respectively. This is simply unrealistic. In general, mitigation effectiveness was highest in the southern and east-central portions of the Elk Valley, where road densities are highest. Efforts should target AWs that have higher environmental benefits per unit cost.

Other mitigation efforts include salvage harvest that offsets for factors like ECA and replanting after fire and pest disturbance, better maintenance of roads and stream crossing structures, and controls on movement of rainbow trout to reduce hybridization risk. In addition, tactical management responses such as improved monitoring and research to link indicators with WCT population status are critical, as are strategic shifts in regulation and policy to protect fish and fish habitat. Integrating these management responses through the Elk Valley CEMF is key to long-term sustainability of aquatic ecosystems.

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LIST OF ACRONYMS AND ABBREVIATIONS

AEVA- *Aquatic Ecosystem Value Assessment (Provincial Procedure)*
ALCES - *A Landscape Cumulative Effects Simulator*
AW- *Assessment Watershed*
BEC- *Biogeoclimatic Ecosystem Classification*
CAP- *Channel Assessment Procedure*
CEMF- *Cumulative Effects Management Framework*
COSEWIC- *Committee on the Status of Endangered Wildlife in Canada*
DFO- *Department of Fisheries and Oceans*
ECA- *Equivalent Clear-cut Area*
EKAMP- *East Kootenay Angling Management Plan*
EVWQP- *Elk Valley Water Quality Plan*
FLNRORD- *Forest, Lands, Natural Resource Operations and Rural Development*
FRPA- *Forest and Range Practices Act*
FSI- *Fish Sustainability Index*
FSW- *Fisheries Sensitive Watershed*
FWA- *BC Freshwater Atlas*
FWCP- *Fish and Wildlife Compensation Program*
IWAP- *Interior Watershed Assessment Protocol*
KNC- *Ktunaxa Nation Council*
LU- *Landscape Unit*
LWD- *Large Woody Debris*
PEM- *Predictive Ecosystem Mapping*
PIT- *Passive Integrator Transponder Units*
PSCIS- *Provincial Stream Crossing Inventory System*
QEP- *Qualified Environmental Professional*
QRP- *Qualified Registered Professional*
RAR- *Riparian Areas Regulation*
RBT- *Rainbow Trout*
RRZ- *Riparian Reserve Zone*
SARA- *Species at Risk Act*
THLB - *Timber Harvest Land Base*
TRIM- *Terrain Resource Information Management*
VC- *Valued Component*
VRI – *Vegetation Resource Inventory*
WCT- *Westslope Cutthroat Trout*
WHA- *Wildlife Habitat Area*

The purpose of this document is to outline the rationale, methods, and results of the Cumulative Effects Assessment (CEA) of riparian habitat and westslope cutthroat trout (collectively called aquatic ecosystems) in the Elk Valley as part of the Elk Valley Cumulative Effects Management Framework (CEMF). The following sections will provide details about the existing policy and management of riparian habitat and westslope cutthroat trout in the Elk Valley, indicators, associated thresholds, hazards, and mitigation/management strategies.

The assessment procedures were developed by a team comprised of BC government staff (Regional CEMF team as well as the provincial Cumulative Effects Framework (CEF) team), First Nations, consultants and industry partners, and the riparian habitat and westslope cutthroat trout Expert Teams refined the procedures. Further review was completed by the Elk Valley CEMF Working Group and a broader stakeholders' group (a.k.a. Workshop Group).

1.0 INTRODUCTION

1.1 ELK VALLEY CUMULATIVE EFFECTS MANAGEMENT FRAMEWORK

The Elk Valley study area (Figure 1) is in the East Kootenay Region of British Columbia, extending from Mount Fox in the north to Lake Koocanusa in the south. The Elk Valley is an area rich in biodiversity, culture, and economic wealth. Coal mining and forestry are the biggest industries in the region, with tourism playing a smaller but growing role. The Elk Valley is within ?amak'is (the Ktunaxa homeland), made up of Qu'kin (raven's land) and camna amakis (wood tick's land). The Ktunaxa people have a deep, long standing connection to the land and resources in the Elk Valley, including stewardship responsibilities, and to its spiritual value.

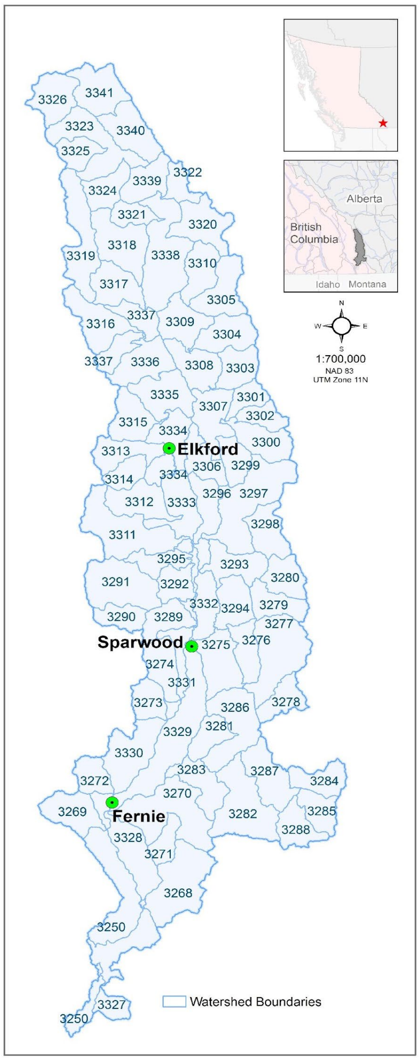

Figure 1. Study area boundary for the Elk Valley CEMF, showing the sub-watersheds used as assessment watersheds in this analysis.

The management of cumulative effects in the Elk Valley has been of increasing concern due to current and ongoing resource development. These developments include open pit coal operations, timber harvesting on public and private lands, increasing recreational pressures, and municipal development, all of which are contributing to stresses and cumulative effects on the watershed. There has been growing awareness of the need for a broadly accepted, credible, and workable approach to the management of cumulative effects both from a regional and provincial scale.

Developing a Cumulative Effects Management Framework (CEMF) is a condition in Teck Coal's Line Creek expansion Environmental Assessment certificate. In recognition of this, Teck Coal Ltd. (Teck) and the Ktunaxa Nation Council (KNC) worked together to hold a multi-stakeholder workshop in July 2012. The CEMF was launched during the initial workshop. Teck and KNC led this initiative until January 2015, when leadership was transitioned to the B.C. Ministry of Forests, Lands, Natural Resource Operations and Rural Development (FLNRORD). A Working Group comprising 11 organizations (Appendix A.5) oversees the CEMF business. Annual workshops have been held for a broader stakeholder group (a.k.a. Workshop Group).

The purpose of the CEMF is to develop an approach to assess historic, current, and potential future conditions of selected valued components (VCs) and to provide a practical and workable framework that supports decisions related to assessment and management of cumulative effects in the Elk Valley. In brief, the goal is to inform and support natural resource management decisions at all levels.

The Elk Valley CEMF is being implemented in four stages:

1. **Context**: includes establishing spatial and temporal boundaries and selecting VCs as the focus for the cumulative effects assessment.
2. **Retrospective Assessment**: includes assessing the historic and current conditions of each VC using indicators of quality and amount of required habitat. Additionally, benchmarks that reflect the hazard/risk to each indicator were set and VC conditions assessed in relation to these.
3. **Prospective Assessment**: includes forecasting potential future conditions. Four alternative scenarios were created to assess how different rates of development and natural disturbance may affect the VCs and their indicators into the future. In addition, two climate change scenarios and three mitigation options have been identified and integrated with the future development scenarios to shape future conditions.
4. **Management Action and Follow-up**: includes management recommendations and monitoring based on the results of the cumulative effects assessment.

1.2 Why Riparian Habitat and Westslope Cutthroat Trout?

Riparian Habitat

Riparian areas were selected as a VC in this assessment because they have high biodiversity and provide critical habitats, home ranges, and travel corridors for wildlife, acting as key linkages between low and high elevation terrain, and forested and non-forested areas throughout the landscape (Riparian Area Management Guidebook, 1995). Healthy riparian areas can be integral to floodplain resilience during high streamflow events, and thus are important to Elk Valley residents. Extensive flooding occurred most recently in 2013 and had a large impact on municipalities and riparian habitat in the area.

Riparian areas provide streams (and thus aquatic habitat) with a number of ecological services that vary in importance relative to stream size (channel width), gradient, streambed and streambank materials, channel morphology (e.g. riffle-pool, cascade-pool, and step-pool morphologies), dependence on large woody debris (LWD) for channel structure, and other factors including biogeoclimatic zone characteristics (Hogan *et al*., 1998a, b; Hogan and Bird, 1998a, b; Tripp *et al*., 2009).

These ecological roles and functions are incorporated in the concept of *Properly Functioning Condition* (PFC) used in the British Columbia Forest and Range Evaluation Program (FREP) for stream-riparian systems (Tripp *et al*., 2009, Tschaplinski and Pike, 2010). The concept has been developed and adapted for British Columbia from two approaches developed in the US Pacific Northwest by the Bureau of Land Management (BLM). These are the BLM PFC Method (Prichard *et al*., 1994, 1998) and the Montana Method (see Hansen *et al*., 1995).

Properly Functioning Condition in stream-riparian systems has been defined in the Forest Practices Code of B.C. (BC Ministry of Forests and BC Environment, 1995) as the ability of a stream, river, wetland, or lake and its riparian area to:

1. Withstand normal peak flood events without experiencing accelerated soil loss, channel movement, or bank movement;
2. Filter runoff;
3. Store and safely release water;
4. Maintain the connectivity of fish habitats in streams and riparian areas so that these habitats are not lost or isolated as a result of management activity;
5. Maintain an adequate riparian root network or LWD supply; and
6. Provide shade and reduce bank microclimate change.

When riparian areas are not functioning properly, this can hinder the ability of aquatic and terrestrial ecosystems to thrive. Therefore, this assessment evaluated the current and potential future status of riparian areas relative to their disturbance levels.

WESTSLOPE CUTTHROAT TROUT

Westslope cutthroat trout (WCT; *Oncorhynchus clarki lewisi*) was selected as a VC because of its ecological, cultural, economic, and social importance to residents of the Elk Valley, as well as to visitors to the Elk Valley. The Elk River and its tributaries support a world-class fishery, whose waters and banks are influenced by industry in the area as well as a large number of recreational anglers. Trout or qustit' (including WCT) from the Elk River and tributaries are also important to the Ktunaxa as they provide an important food source and hold cultural significance.

WCT are good indicators of aquatic and overall watershed health; their life history characteristics make them sensitive to development activities and angling pressure. As described by Haas (1998), they are dependent on riparian and instream cover and natural flow conditions. They require clean, well oxygenated, unembedded gravel substrate for repeat spawning and are highly intolerant of high water temperatures. Their habitats continue to be degraded throughout their range and as a sport species that is easily angled, they are susceptible to increasing road access into areas not previously accessible to anglers. The largest threats to the species in general are likely hybridization with introduced salmonids such as rainbow trout (*Oncorhynchus mykiss*; Carscadden and Rogers, 2011, Muhlfeld *et al*., 2009, Rubridge, 2003, Allendorf and Leary, 1988) and climate change, resulting in altered hydrologic and thermal regimes (MacDonald *et al*., 2014; Muhlfeld *et al*., 2017).

1.3 KNOWLEDGE SUMMARY

RIPARIAN HABITAT

DISTRIBUTION AND ECOLOGY

The Forest Practices Code definition of a riparian area is "the land adjacent to the normal high-water line in a stream, river, lake or pond and extending to the portion of land influenced by the presence of the adjacent ponded or channeled water" (BC Ministry of Forests and BC

Environment, 1995). In simple terms, riparian refers to the interface between aquatic and terrestrial ecosystems.

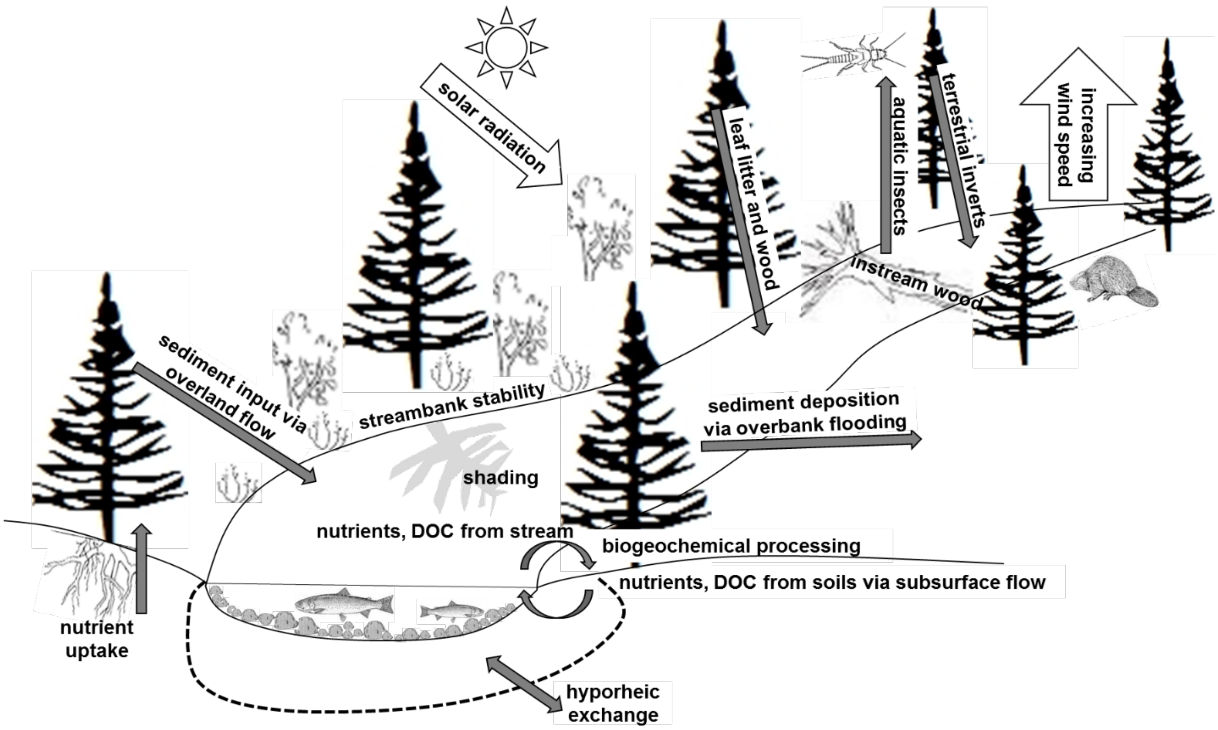

Figure 2. Conceptual depiction of riparian functions in mountain environments (adapted from Richardson and Moore, 2010).

Riparian areas have many functions (Figure 2). They support aquatic biological communities by filtering sediment and runoff, providing organic detritus and inorganic nutrients, and providing shade to moderate stream temperatures. Riparian areas are also a crucial part of the physical composition of the aquatic ecosystem as they provide the root networks that stabilize streambanks and provide structural elements such as large woody debris (LWD). LWD is particularly important in low gradient channels as it increases structural complexity and stability while reducing water velocity (Figure 2; Gregory, 1991, Naiman and Decamps, 1997, Naiman *et al*., 2000, Tschaplinski and Pike, 2010).

CONSERVATION THREATS

Anthropogenic disturbance has occurred extensively in riparian areas in the Elk Valley. Currently, the areas in the valley bottom surrounding the Elk River have the highest concentration of human development in the Elk Valley. However, activities like mining and forestry also occur in many of the tributaries to the Elk River. Natural disturbances like wildfire and pest outbreaks can alter riparian structure and have the potential to negatively affect riparian functions. Riparian zone restoration can be challenging and costly, and regaining full riparian function post-disturbance may take many years.

POLICY AND LEGAL CONTEXT

The primary legal act regarding riparian areas on crown land is the Forest and Range Practices Act (FRPA). This act requires the delineation of riparian reserve zones, riparian management zones, and riparian management areas for forest management purposes. This act also allows for the legal designation of areas such as Fisheries Sensitive Watersheds (FSWs) and Wildlife Habitat Areas (WHAs) which can set disturbance limits within the riparian area. FRPA also encompasses objectives for riparian vegetation retention.

The Private Forest Managed Land Act and Regulation is a piece of legislation used to manage private managed forest lands. Locally, the Elk Valley Official Community Plan (and OCPs for individual communities) contain policies related to minimizing impacts on sensitive features such as riparian areas and encourages best management practices be implemented.

WESTSLOPE CUTTHROAT TROUT

DISTRIBUTION AND ECOLOGY

WCT is the most northerly distributed of interior subspecies of cutthroat trout and is the only interior subspecies of cutthroat trout naturally occurring in Canada (McPhail, 2007). It is native to southeastern B.C., and the Elk River and its tributaries are world-renowned WCT fisheries (McPhail and Carveth, 1992).

WCT thrive in complex streams that provide a variety of habitat types (a combination of pools, riffles, and glides). Adult fish tend to occupy deep pools with abundant cover, while juvenile fish can occupy a wider range of habitat types, and fry (young fish) are constrained to lower velocity inter-gravel portions of streams. High-quality WCT habitat is largely controlled by riparian areas. Typically, healthy riparian and upland areas create high quality aquatic environments by providing large amounts of LWD that influence channel morphology. In addition to LWD, riparian and upland areas support terrestrial and aquatic invertebrate (insect) populations which in turn are primary food sources for fish.

Currently, WCT streams in the East Kootenay region of B.C. support some of the most economically important recreational fisheries in the province. These streams also support culturally and economically (e.g. subsistence) important fisheries for the Ktunaxa Nation. To manage angling quality, seven East Kootenay watersheds and their tributaries (Bull River, Elk River, Skookumchuck River, St. Mary River, Upper Kootenay River, White River, and Wigwam River) were listed as Class II waters in the spring of 2005. Of the seven classified waters, the Elk River supports the largest number of anglers (10,000+ angler days in the summer of 2002; Heidt, 2003) from Canada, USA and other parts of the world. Most of the fish (94%) caught by anglers within the Elk River and tributaries were WCT (Heidt, 2003).

Although there are many healthy WCT populations in the East Kootenay, the species was designated as ***Special Concern*** by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC, 2006) due to concerns regarding introduced species (hybridization and competition), habitat loss and degradation, and increasing exploitation. Also, it is listed as ***Special Concern*** in Canada on Schedule 1 of the Species at Risk Act (SARA). In British

Columbia, the WCT is ranked ***S3 (vulnerable)*** by the B.C. Conservation Data Centre and is on the provincial ***Blue List*** (2017). The B.C. Conservation Framework (2017) ranks WCT as a priority 2 under goals 1 and 2 (contribute to global efforts for species and ecosystem conservation and prevent species and ecosystems from becoming at risk). The Ktunaxa Nation has a unique conservation responsibility for WCT given that Ktunaxa ?amak'is encompasses the core of the WCT population range. A guiding Ktunaxa concept of Akxamis qapi qapsin relates everything that sustains life, from water and rocks to the sky. It is about a connection with all living things, including people and the land. It is through this lens that the vision of managing lands and resources within a self-sufficient and self-governing Nation is implemented.

CONSERVATION THREATS

Native species of interior cutthroat trout have experienced severe reductions in their distribution and abundance throughout their range due to over-harvest, habitat fragmentation, habitat degradation, and the introduction of non-native salmonids that compete, replace or hybridize with native cutthroat trout (Shepard *et al*., 2005, Hilderbrand and Kershner, 2000, Mayhood, 1999, Jakober *et al*., 1998, Thurow *et al*., 1997, Woodward *et al*., 2010). The future of WCT populations is likely to also be strongly influenced by climate change through altered streamflow and thermal regimes and spread of hybridization (MacDonald *et al*., 2014; Muhlfeld *et al*., 2017). Ongoing work seeks to understand trout hybridization in the Elk Valley. However, there is currently a major gap in knowledge specifically related to WCT population trends.

POLICY AND LEGAL CONTEXT

Within provincial legislation, there are few explicit objectives or policies related to WCT and their habitat. However, there are acts and regulations related to the broad protection and regulation of fish and aquatic habitats. The FRPA allows the regulation of lands that are important to fisheries values and can establish WHAs and FSW activities with one of the objectives being to prevent cumulative effects on fish.

The Riparian Areas Regulation (RAR) was enacted under Section 12 of the Fish Protection Act in July 2004 (The Fish Protection Act was re-titled the Riparian Areas Protection Act in February 2016). The RAR calls on local governments to protect riparian areas during residential, commercial, and industrial development by ensuring that a Qualified Environmental Professional (QEP) conducts a science-based assessment of proposed activities. The purpose of the Regulation is to protect the many and varied features, functions and conditions that are vital for maintaining stream health and productivity, including:

- Sources of large organic debris, such as fallen trees and tree roots;
- Areas for stream channel migration;
- Vegetative cover to help moderate water temperature;
- Provision of food, nutrients and organic matter to the stream;
- Stream bank stabilization; and
- Buffers for streams from excessive silt and surface run-off pollution.

Unfortunately, the RAR currently does not apply within the Elk Valley.

The Water Sustainability Act (WSA) regulates water diversion and use around streams to protect sensitive or protected fish populations. In 2014, the British Columbia Ministry of Environment approved the Elk Valley Water Quality Plan (Teck Resources Limited, 2014). The plan was developed to address the management of water quality contaminants released by mining activities throughout the Elk River watershed. These contaminants pose a threat to WCT populations.

The recreational fishery for WCT has seen increasingly strict regulations in response to population declines in recent decades. The East Kootenay Angling Management Plan (EKAMP) completed by the British Columbia Ministry of Environment summarizes regulatory measures implemented to address angling use issues on selected water bodies. Seven streams in the East Kootenay Region were designated as Classified Waters in 2005–2006. A River Guardian Program, which involves fisheries data collection, compliance monitoring, and angler education as part of the Province's Quality Waters Strategy, has also contributed valuable data for the management of this species (pers. comm. Kevin Heidt, FLNRORD; Heidt, 2014).

If a project is subject to an assessment under the Canadian Environmental Assessment Act (2012), measures must be taken to avoid or lessen any adverse effects of the project on the species. Additionally, Fisheries Protection and Pollution Prevention provisions of the Fisheries Act provide protection to this species and its habitat.

A Management Plan for WCT (British Columbia population) was developed in two parts with contributions from both Fisheries and Oceans Canada and the Provincial Government of B.C. (Fisheries and Oceans Canada, 2016). The overarching management objective within the Management Plan for WCT is the "long-term persistence of the species within its native range at abundance levels capable of providing sustainable benefits to society, within the context of broader ecosystem values" (BC Ministry of Environment, 2014). The management objectives outlined in the plan are to:

1. "Maintain the native distribution and genetic diversity of populations;
2. Maintain wild populations at abundance levels that prevent at-risk status assessment so that the populations can provide societal benefits;
3. Maintain, or rehabilitate, the capacity of natural habitat to meet abundance targets for populations; and,
4. Optimize sustainable recreational benefits."

2.0 Assessment Methods

2.1 Assessment Units and Reporting Units

The assessment and reporting of riparian habitat and WCT indicators was completed at the Assessment Watershed (AW) level. As part of a provincial initiative, the Elk Valley has previously been divided into AWs that define areas conducive to forest management. There are 78 AWs, which vary in size from 19 km^2 to 104 km2 (Figure 3**Error! Reference source not**

found.; Appendix A.4). The AWs are typically further subdivided into sub-watersheds and delineated into face units that do not have distinctive basin shapes with one common flow outlet. Face units typically consist of areas with small streams that drain directly into the Elk River and not into other tributaries. Face units constitute 11 of the 78 Elk Valley AWs and comprise the slopes adjacent to the Elk River. The AWs within the Elk Valley Landscape Units (LU) are presented in Figure 3.

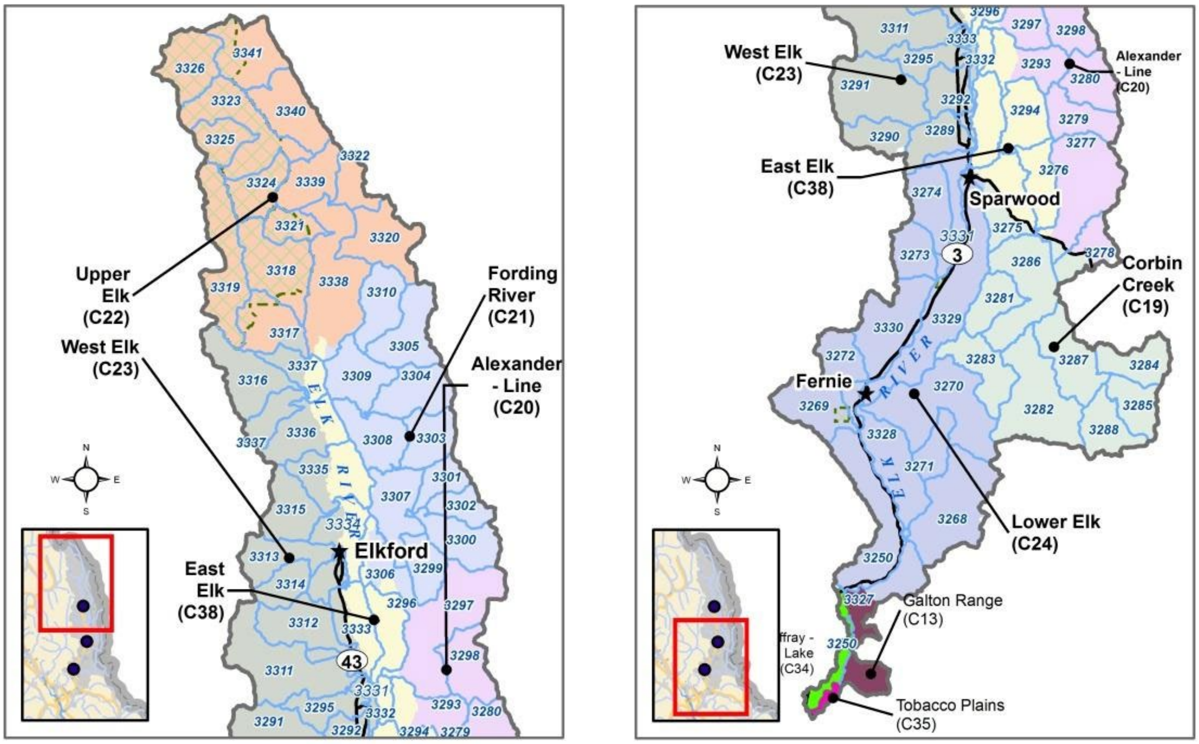

Figure 3. Assessment watersheds coloured by Landscape Unit in the north (left) and south (right).

2.2 Data Sources

Cumulative effects assessment requires that all landscape and land use data be compiled and integrated into a single dataset. The Elk Valley is a unique and challenging study area because 32% of the land is privately owned. This means that the Crown Forested Land Base that would be typically used as the forest base layer in the Vegetation Resources Inventory (VRI) would likely be unrepresentative in this study area. To overcome this, Predictive Ecosystem Mapping (PEM) was used to create an inventory of the whole land base, including private land. Though not as descriptive as VRI, this method better represents the complete study area and gives a more accurate assessment of the land base within the Elk Valley.

Water features were derived from the BC Freshwater Atlas (FWA). The FWA is a standardized dataset for mapping the province's hydrological features. The atlas defines watershed boundaries by height of land and provides a connected network of streams, lakes and wetlands. It provides a consistent base and coding system ensuring the province's various freshwater-related inventories are tied to a common base. A roads product was developed by Touchstone GIS Services Inc. based on a compiled road feature class (Figure 4), verified against 2005 orthophoto imagery. The year 2005 was chosen as it was the year that orthophotos were available for the whole of Elk Valley, and it is as close as possible to the change in management practices related to the Forest Practices Code of British Columbia Act and regulations, which came into effect on June 15, 1995.

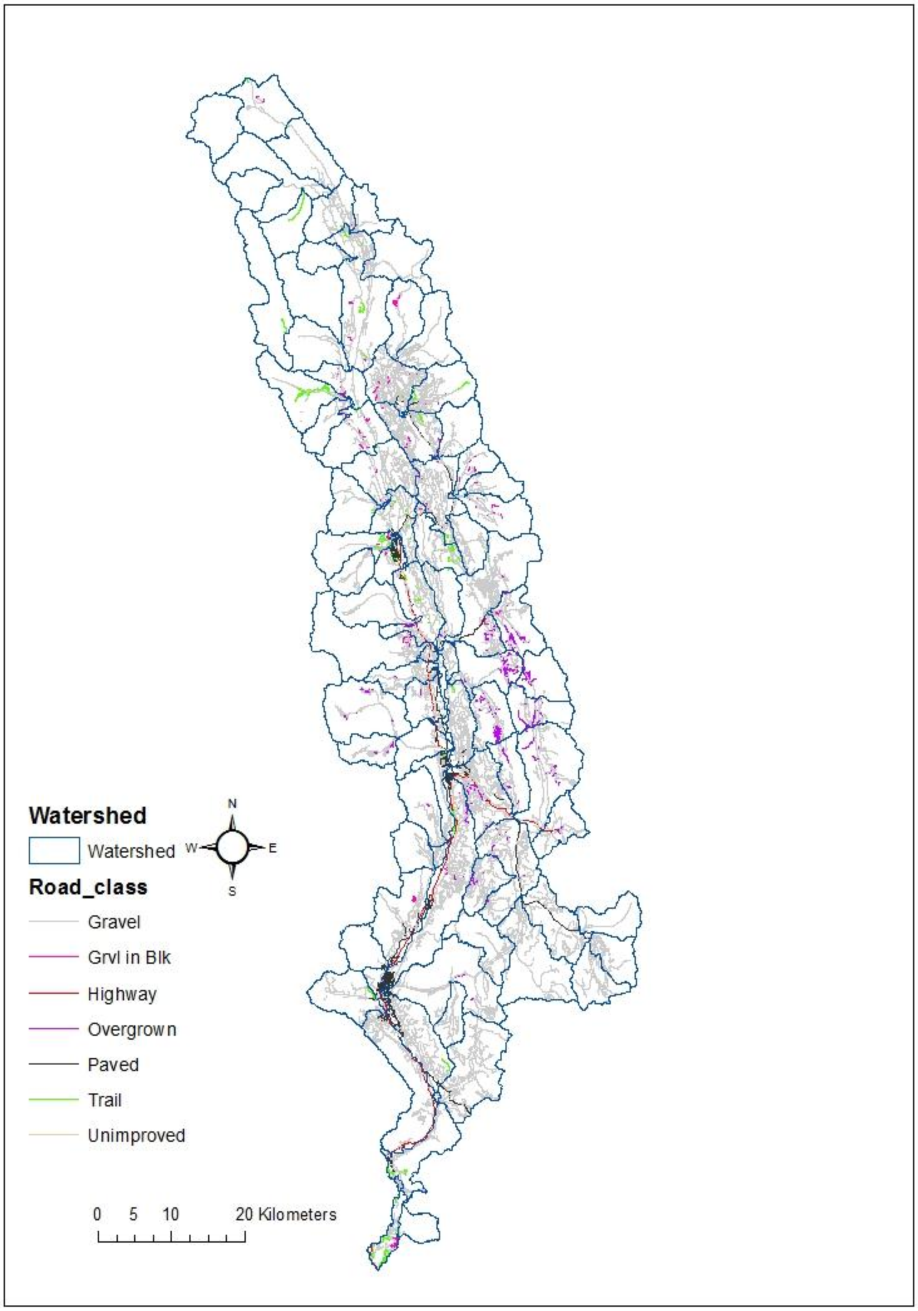

Figure 4. Roads in the Elk Valley categorized by class: Gravel (gray), gravel roads in harvest blocks (pink), highway (red), overgrown (purple), paved (black), trails (green), and unimproved (brown). Assessment watersheds are in blue.

The source roads feature classes are all from the BC Geographic Warehouse and include:

- As Built Roads
- Digital Road Atlas
- Forest Tenure
- TRIM

A disturbance layer was created using:

- Private land footprint from ICIS cadastre
- Age class 1 and 2 from the VRI or PEM (Nov 2015) structural stage 1-3 where no VRI (includes harvest, fire, pest)
- Permanent and Linear Structures including roads (described above), rail, transmission lines, sewer/effluent lines, trails and ski lifts and settlements- from BC TANTALIS, TRIM
- Mining footprint including pipelines, sand and gravel, drill/well sites and mineral production- from Teck, BC TRIM, BC TANTALIS

The PEM layer was used to identify natural and anthropogenic disturbances and categorize forest cover and forest age. PEM is a modeled approach to ecosystem mapping, whereby existing knowledge of ecosystem attributes and relationships are used to predict ecosystem representation in the landscape. This approach to mapping provides a framework that integrates the biotic and abiotic ecosystem components of the landscape. The PEM was updated and improved in a November 2015 version by Deb MacKillop, Audrey Ehman, and Andy Cagle (FLNRORD).

Descriptions of how indicators were derived from these data sources are provided below. A complete list of data sets is provided in Appendix A.1.

2.3 Indicators and Benchmarks

Values are not always measurable in their own right or data that measure a value directly may not always be readily available. Therefore, the cumulative effects assessment process uses measurable indicators to evaluate the status of, or threats to, the riparian and WCT VCs.

The following section describes the indicators used for the cumulative effects assessment of riparian habitat and WCT, as well as the associated benchmarks. These indicators were assessed and summarized for each AW in the Elk Valley. It is important to note that the Elk Valley CEMF did not assess water quality as it relates to WCT due to lack of access to data, with the exception of stream temperature. Water quality is being assessed through a separate process in the Elk Valley Water Quality Plan (Teck Resources Limited, 2014).

Indicators are the metrics used to measure and report on the condition and trend of a valued component.

Benchmarks are points along the continuum of a measured indicator that reflect the level of risk or hazard to a valued component.

Given that the cumulative effects assessment process can affect management decisions, it is important to consider the proper use of benchmarks. Many of the indicators such as stream crossings, riparian disturbance, peak flows, roads within 100 m of streams, and roads on steep slopes that were used in the riparian area and/or WCT VCs originate from the Interior Watershed Assessment Procedure (IWAP; B.C. Ministry of Forests, 2001). Since the development of the IWAP, a greater body of literature has developed and many more watersheds have been assessed. New benchmarks from the provincial Aquatic Ecosystems Value Assessment (AEVA) have replaced the IWAP benchmarks based on assessment from over 900 watersheds, many of which were assessed on a stream reach basis. As with the IWAP, these benchmarks are intended to be red flags that indicate when it is necessary to conduct further assessment prior to further development. Indicators and benchmarks from the IWAP have been updated based on current science and research and augmented with expert opinion to support assessment assumptions and minimize uncertainty. These benchmarks were not intended to be management maximums for development in specific watersheds. However, the benchmarks could be used to inform management decisions. Overall, these benchmarks can be described as hypotheses, which can be tested through additional analysis and field assessment.

Each of the seven indicators used in this assessment is described with the following structure:

- Scientific Context – description of the scientific basis for the selection of the indicator
- Management Context – what type of management decisions will be supported with this indicator
- Indicator Overview – description of the indicator, including units
- Data Sources – Data being analyzed, where they were retrieved, core assumptions
- Thresholds (Benchmarks) – thresholds identified to report the level of hazard
- Caveats or Data Limitations – gaps or limitations in the interpretation of the data

2.3.1 Equivalent Clearcut Area (ECA)

Scientific Context

Equivalent clearcut area (ECA) is the proportion of a watershed that responds hydrologically like a clearcut, and is an approach to assessing potential changes in snow processes and streamflow post-disturbance (Winkler and Boon, 2017). ECA is the percentage of the total watershed area that hydrologically responds like a clearcut (Winkler and Boon, 2017), and includes consideration of the effects of vegetation regrowth (i.e. number of years post-disturbance). ECA has been used as an index to assess the potential for changes in peak streamflow and water yield following forest disturbance, as these factors can affect aquatic ecosystems.

Management Context

The interpretation of ECA can be used to support decisions related to rate of harvest and cutblock size as well as location. ECA also supports decisions related to forest stewardship plan thresholds for conducting assessments in community and FSWs, forest certification targets, and an indicator of the likelihood of increased peak flows and water yield (Winkler and Boon, 2017).

Indicator Overview

Equivalent Clearcut Area (ECA; %)

ECA is calculated for individual cutblocks or disturbed areas (ha), then summed for the entire AW and divided by the total AW area. Areas within each AW affected by fire, harvest, and insect disturbances were assigned a proportion of hydrologic recovery (HR; Table 1) based on the forest stand age. ECA was calculated using:

$$ECA = Area * (1 - HR)$$

For example, an area of 100 ha that was disturbed 66 years ago would be assigned a 90% hydrologic recovery. This equates to 10 hectares of equivalent clearcut area.

Previous hydrologic recovery curves have applied the 1995 IWAP methods; however, Winkler and Boon (2015) suggest these methods no longer be applied given that newer research has been conducted. The Green (2015) curve cited in Winkler and Boon (2015) is used here, where tree height is related to snow recovery. Tree height was related to age (see Table 1) for the purposes of this study.

Table 1. Hydrologic recovery for fire, harvest, and insect disturbance. This relationship was based on tree height vs. recovery from Green (2015) cited in Winkler and Boon (2015) and used for recovery of riparian areas to disturbance. The relationship between age and height was assumed to be: age = 3.0093(height) + 6.215.

Forest Age (years)	ECA Hydrologic Recovery
24	0%
39	25%
48	50%
60	75%
66	90%

Data Sources

- Disturbance layer compiled by FLNRORD
- Forest age data
- BC TRIM DEM

Benchmarks

Benchmarks were taken from the Peak Flow Index in the AEVA protocol (CEF 2016) and used here for ECA:

- Low Hazard = <25%
- Moderate Hazard = 25-45%
- High Hazard = >45%

For hazard mapping, these benchmarks are further broken down in to smaller rating scales under each of the benchmarks, without changing the cut-offs for low, moderate and high hazard (CEF, 2016).

Caveats or Data Limitations

New recovery guidelines are being generated by FLNRORD that are refined for Biogeoclimatic (BGC) zones and forest types. These should be considered in subsequent CE assessments. ECA is most commonly used to assess the potential effects of forest disturbance on snow accumulation and ablation, peak streamflow, and water yield. While these factors can affect aquatic ecosystems, they are not explicit indicators of aquatic ecosystem function. However, ECA is still a useful indicator of land cover change, which can have substantial effects on riparian and aquatic habitat.

2.3.2 Riparian Disturbance

Scientific Context

The maintenance of riparian functions and services depends upon intact riparian areas (CEF, 2016). Logged and cleared riparian areas reduce food supply and cover for aquatic organisms, LWD supply, shade, precipitation interception, and filtering functions. Wood supply can take more than a century to recover in some clearcut stream systems. Urban, agricultural, and industrial (e.g., mines and well pads) development contribute to riparian disturbance as well as chemical and/or nutrient pollutants. Roads and agriculture contribute fine sediment. Roads in riparian areas can block side channels and small tributaries and can intercept and divert groundwater flow (a problem in floodplains). Stream crossings associated with roads contribute fine sediments and block fish passage (Provincial Aquatic Ecosystem Value Summary; CEF, 2016).

Based on a review of riparian recovery following fire by the Provincial AEVA team (unpublished), it was suggested that riparian areas are likely to have recovered in terms of their functions (Figure 2) 80-85 years following fire. The recruitment of LWD may be the longest process to reach recovery in a riparian area. Features and functions of the riparian area other than LWD processes appear to be generally recovered within 3-4 decades post disturbance. In the absence of a riparian recovery curve, the hydrologic recovery relationship for Equivalent Clearcut Area (ECA; Table 1) was used until scientifically defensible recovery curves for riparian functions are developed.

Management Context

Supports decisions related to permitting land alteration, riparian restoration, riparian retention guidelines, and stream protection.

Indicator Overview

Percent disturbed riparian area per AW (%; ha of disturbance/ha of riparian area)

Riparian areas can be difficult to delineate over large regions. Significant resources are necessary to conduct field studies and perform detailed analysis to delineate and investigate these areas, which may not be readily available. Typically, studies have used approximations to address these challenges, such as the use of fixed distances from waterbodies. These methods are often too simplistic and do not address the diversity and complexity of many riparian systems.

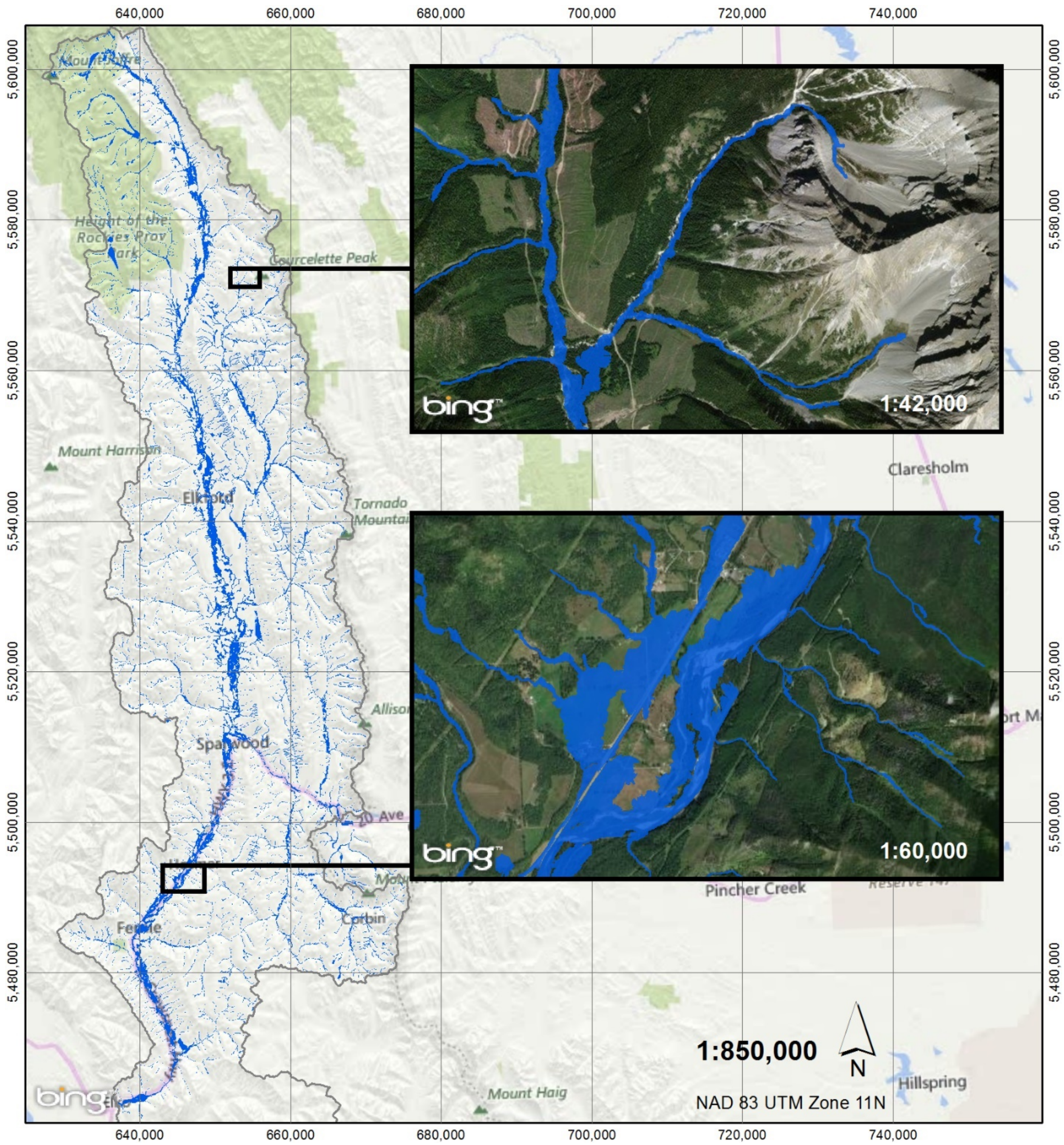

Figure 5. Estimated riparian area (blue polygons) throughout the Elk Valley.

Methods are available that use terrain analysis to predict the extent of riparian zones, which are made possible because of the correlation between topography and hydrologic processes. Terrain analysis may be automated if continuous topographic data are available. High-precision elevation datasets, like LiDAR, allow algorithms to compute hydrologic routing throughout the watershed to determine the locations of drainage channels, and the catchment area that drains through them. The catchment size and topographic slope surrounding these drainage regions may also be quantified. The degree of connectivity between these regions can be calculated using a cost analysis, whereby it is less expensive for water to move through flat-lying regions surrounding rivers, and more expensive to travel through steeper regions (Fernandez *et al*., 2012). Riparian areas for the Elk Valley were determined by this method using Digital Elevation Model (DEM) data from Teck, Canfor, and GeoBase (Figure 5). Disturbance types were classified by disturbance origin (natural and anthropogenic).

Natural and anthropogenic disturbances were summarized for each AW within the derived riparian area. A riparian reserve data layer was provided by Canfor. The reserves represent areas that are not disturbed by forestry activities; therefore, were subtracted from harvest areas and did not contribute to harvest disturbance.

Data Sources

- Road data as described in Section 2.2
- Water features were from the BC Freshwater Atlas
- Predictive Ecosystem Mapping (PEM)
- Riparian reserve zones (RRZ) provided by Canfor
- Disturbance layer

Benchmarks

Benchmarks were taken from AEVA protocol for riparian disturbance:

- Low hazard = <10%
- Moderate hazard = 10 - 20%
- High hazard = >20%

For hazard mapping, these benchmarks are further broken down in to smaller rating scales under each of the benchmarks, without changing the cut-offs for low, moderate and high hazard (CEF, 2016). This method is helpful to prioritize watersheds for mitigation measures.

Caveats or Data Limitations

The hydrologic recovery curve was used in lieu of a riparian recovery curve for disturbance caused by fire in riparian areas and that was specific to riparian functions. The hydrologic recovery curve is related to snow interception, while riparian forest recovery is highly influenced by fluvial processes, especially flood events, which can have a large influence on the recovery of riparian areas.

It is possible that LWD may not be recovered in areas disturbed by fire well before 1989. The extent of disturbance is not always apparent from the data (see Appendix A.3). There may be more tree retention within areas affected by fire and pests than hypothesized (currently assumed to be zero). Areas disturbed by agriculture may have had riparian planting completed to mitigate impacts. It is currently unknown what mitigation has taken place in mining areas.

2.3.3 Stream Crossings

Scientific Context

Road networks affect watershed functions and aquatic ecosystems through several mechanisms, including disrupting flow patterns, sediment delivery and transport, stream connectivity, and water quality (Jones *et al*., 2000). Of particular importance are stream crossings, which result in exposed soils that contribute fine sediment to streams, act as points of entry for road-related sediment transported along ditches and can be barriers to the movement of fish and other aquatic organisms (CEF, 2016). Stream crossings have potential long-term impacts on channel and bank stability due to vegetation removal and disruptions in fluvial processes.

The Provincial Stream Crossing Inventory System (PSCIS, 2011, cited by Thompson, unpublished) reported that 61% or 844 of the 1384 culverts assessed from the Kootenay Region are found to be problematic. Park *et al*. (2008) demonstrated that hanging culverts can result in substantial stream fragmentation, affecting fish populations. Results from these studies suggest that stream crossings have the potential to be problematic for aquatic ecosystems in the Elk Valley.

Management Context

The analysis of stream crossings supports decisions related to road network and infrastructure design (e.g. closed versus open culverts) and road construction, habitat connectivity, reclamation and access.

Indicator Overview

Number of stream crossings (e.g. roads, trails, culverts, and seismic lines) (#/km^2).

Stream crossings in this study were defined as any linear feature (e.g. road, trail, etc.) that crossed a mapped stream. Different types of stream crossings were not distinguished in this study. However, crossings were removed from the analysis if they were determined to be bridges based on data provided by Canfor. These were removed because they are not viewed as barriers to fish movement. However, it should be noted that bridge crossings can be sources of sediment production and can still affect geomorphological processes.

Data Sources

- Water features from B.C. FWA
- Linear features from road product developed by Touchstone GIS services as described in Section 2.2.
- Bridge locations provided by Canadian Forest Products Ltd. (Canfor)

Benchmarks

The benchmarks for stream crossing density were taken from the Provincial AEVA Protocol (CEF, 2016):

- Low hazard = <0.16 /km^2
- Moderate hazard = 0.16 - 0.32 /km^2

- High hazard = >0.32 /km^2

For hazard mapping, these benchmarks are further broken down in to smaller rating scales under each of the benchmarks, without changing the cut-offs for low, moderate and high hazard (CEF, 2016).

Caveats and Data Limitations

Though different types of crossings have different levels of impact (e.g. closed bottom culverts are the most disruptive), they are not completely distinguished in this phase of the study. Some crossings may be well designed and contribute little to no impact whereas others may have been poorly designed or have not been maintained. Field verification should be used to determine the extent of impact from stream crossing disturbance.

2.3.4 Road Density Near Streams

Scientific Context

Roads differ from natural environments given that they are nearly impervious, resulting in overland runoff generation and flow redistribution that contribute to chronic fine sediment production (Luce, 2002). Erosion from roads near streams is responsible for the majority of fine sediment delivery to streams (Hagans *et al*., 1986). Rates of erosion depend on soil texture, road gradient, road construction methods, maintenance standards, and precipitation (Rothwell, 1983). The number of roads near streams is good indicator of water quality and channel connectivity issues, and they provide easy access for anglers. Road density within 100 m of streams was selected as an indicator for this assessment based on the Interior Watershed Assessment Protocol (IWAP, 1995).

Management Context

The analysis of roads near streams supports decisions related to road construction and reclamation, as well as access management.

Indicator Overview

Total road length within 100 m of streams (km/km^2)

Road density near streams was determined using a 100 m buffer around all water courses and the road layer. Densities are reported for each of the AWs.

Data Sources

- Water features from B.C. FWA
- Road data as described in Section 2.2

Benchmarks

The benchmarks for road density near streams were taken from the Provincial Aquatic Ecosystem Value Assessment Protocol (AEVA, 2016):

- Low hazard = <0.08 km/km^2
- Moderate hazard = 0.08 - 0.16 km/km^2
- High hazard = >0.16 km/km^2

For hazard mapping, these benchmarks are further broken down into smaller rating scales under each of the benchmarks, without changing the cut-offs for low, moderate and high hazard as shown below (CEF, 2016).

Caveats or Data Limitations

Road type and slope direction have not been distinguished in this study although it is known that different types of roads and slope direction in relation to streams have varying effects on stream channels.

2.3.5 Road Density on steep slopes

Scientific Context

Road networks can affect flooding and debris flows (Jones *et al*., 2000). Roads on steep slopes are particularly problematic given that they can be unstable and may increase the chance of mass wasting by undermining or loading slopes, saturating soils and reducing the stability of soil root networks (Swanston, 1991). They can also alter surface drainage patterns and divert subsurface flow to the surface, increasing the chance of soil saturation and gully erosion.

Management Context

The analysis of roads on steep slopes supports decisions related to road network design, road construction and deactivation, as well as access management.

Indicator Overview

Total road length on slopes >60% (km/km^2)

Road density on steep slopes was calculated for each AW, where steep slopes were determined to be any slope greater than 60%.

Data Sources

- Slope derived from BC TRIM Digital Elevation Model (DEM)
- Road data as described in Section 2.2

Benchmarks

The benchmarks for road density on steep slopes were taken from the Provincial Aquatic Ecosystem Value Assessment Protocol (CEF, 2016):

- Low hazard = <0.06 km/km^2
- Moderate hazard = 0.06 - 0.12 km/km^2
- High hazard = >0.12 km/km^2

For hazard mapping, these benchmarks are further broken down in to smaller rating scales under each of the benchmarks, without changing the cut-offs for low, moderate and high (CEF, 2016).

Caveats or Data Limitations

Not all terrain with a slope greater than 60% is unstable; stability also depends on soil texture. Fans, gullies, and steep streams (usually on slopes greater than 60%) are particularly unstable and prone to failure but are not distinguished from other steep terrain in this study.

2.3.6 WCT/RB Hybridization

Scientific Context

Hybridization with non-native rainbow trout is often cited as the greatest threat to WCT persistence (Muhlfeld *et al*., 2009, Allendorf and Leary, 1988). Non-hybridized populations of WCT persist in only 10% of their historical range in the United States (Shepard *et al*., 2005) and less than 20% of their range in Canada (COSEWIC, 2006). The number of hybridized populations in the upper Kootenay drainage of the East Kootenay dramatically increased from 1986 to 1999 (Rubidge, 2003). Consequently, many remaining populations are restricted to small, fragmented, headwater habitats, where the long-term sustainability of these populations is uncertain (Cleator *et al*., 2009, Hilderbrand and Kershner, 2000a). A study by Muhlfeld *et al*. (2009) indicates that even low levels of hybridization between WCT and rainbow trout that are only detectable via genetic testing (i.e. no morphological differences apparent) can result in markedly reduced reproductive success; at 20% admixture, there was a 50% decrease in reproductive success.

Preliminary results utilizing discriminant analysis of principal components of the genotype data indicate that populations in the Elk River watershed are of native stock descent. The fact that populations of native WCT in the Elk watershed have colonized after the last ice age about 12,000 years ago emphasizes the high conservation importance of these populations. Furthermore, unlike in other areas of their range where only highly fragmented populations of pure WCT above barriers exist, many populations in the Elk River watershed are pure, robust and occupy large amounts of connected and diverse habitats (lake, stream and river).

Historic rainbow trout stocking programs in southeastern B.C. were the proximal cause of hybridization with native WCT. Specifically, a rainbow trout stocking program in the Koocanusa Reservoir was initiated in 1988 and continued until 1999, afterwards WCT or triploid (non-breeding) RBT were stocked instead (Bennett, 2007). Koocanusa Reservoir stocking only affects

WCT downstream of the Elko dam whereas other stocking programs such as Grave Lake and Summit Lake would influence WCT upstream.

Management Context

The analysis of hybridization supports decisions related to blocking source populations of invasive fish, hatchery stocking standards, and environmental restoration priorities.

Indicator Overview

Percent pure WCT per AW

Hybridization is reported as WCT allele frequency, calculated as the number of WCT alleles in a population (site)/total alleles in a population (site).

Populations have been sampled in the Elk River watershed for hybridization since 1999. Genetic techniques used on samples collected from 1999 to 2008 utilized 11 diagnostic microsatellite loci (Bennett, 2007). Samples collected from 2012 to 2016 were genotyped using a set of 95 single nucleotide polymorphic loci (SNPs). By using a larger set of diagnostic loci, SNPs allow higher precision for hybridization assessment.

Where no genetic sampling had been completed, expert opinion was used to determine hazard in an AW based on the historic presence of stocked rainbow trout in the watershed. If the watershed was in proximity to areas with known rainbow trout, a moderate hazard was assigned.

Data Sources

The data contained details of stream location and DNA sampling, and a risk rating for each watershed in the study area. Sampling occurred from 1999 to 2016, with ~80% of AWs collected in or after 2015. Sources include results from the genetic analysis prepared by Heather Lamson (pers. comm., 2018), presence/absence of rainbow trout in AWs, and reports by Rubidge (2003), Bennett (2007) and Lamson (2018).

Benchmarks

Benchmarks were created based on the Management Plan for the Westslope Cutthroat Trout (*Oncorhynchus clarkii lewisi*), British Columbia Population (Fisheries and Oceans Canada, 2016):

- Low hazard = 100% pure WCT
- Moderate hazard = 96-99.9% pure WCT
- High hazard = <95% pure WCT

Caveats or Data Limitations

DNA sampling did not occur in all watersheds and these were conservatively given a rank of moderate or high hazard based on the known presence of rainbow trout or historic stocking, or low if rainbow trout were not sampled in an AW.

2.3.7 STREAM TEMPERATURE

Scientific Context

Stream temperature is a dominant control on aquatic ecosystem function given that it has a direct influence on ecosystem productivity and the functioning of aquatic organisms (Webb et al., 2008). WCT require that summer stream temperature remains relatively cold (ideally below 18 ºC) for their survival (Isaak *et al*., 2011). Stream temperature can be altered by a range of anthropogenic and natural factors, such as drought, climate change, industrial development, wildfire, insect infestations, and stream channel alterations (Poole and Berman, 2001). Studies in this region suggest summer stream temperature is likely to increase under future climate conditions (Jones *et al*., 2013), and perhaps even more limiting, it is likely that winter stream temperatures will decrease in headwater streams (MacDonald *et al*., 2014). Changes in thermal conditions are ultimately likely to result in fragmented and constricted habitat and therefore, pose a substantial threat to WCT.

Management Context

Stream temperature information supports decisions related to angling closures, riparian protection, and long-term planning.

Indicator Overview

Average warmest month stream temperature (ºC).

Stream temperature was determined based on the model described below, where cell-based estimates were made for all streams and rivers in the Elk Valley excluding high elevation first and second order streams. These streams were omitted because they are not often suitable fish habitat and there were no stream temperature observations available for these types of streams.

Data sources

Daily average stream temperature data were available for 20 sites from North Coal, the Elk River Alliance, NWP Coal, FLNRORD, and the Water Stewardship Division of the Ministry of Environment and Climate Change Strategy. Data were available from 2012 to 2017. In addition to daily average stream temperature, daily average air temperature data were obtained from the Environment Canada site at Sparwood. Air temperature values were corrected for elevation with a lapse rate of -6.5 ºC/km across the watershed. Air temperature was positively correlated with stream temperature. Landscape variables included in the model are: forest age, slope, and valley confinement. All three variables were negatively correlated with stream temperature.

A stream temperature model was developed for the Elk Valley using methods similar to MacDonald and Jones (2016) and Jones *et al*. (2013), where a generalized linear regression model with cross-validation was applied (Figure 6). In this implementation, half of the data were used for model calibration and half were used for verification. The model fit was evaluated using the Akaike Information Criterion (AIC) as an objective function, where lower AIC values indicated a better statistical relationship. The model was also evaluated using Mean Absolute Error, R^2, normality of residuals, and the physical/heuristic meaning of parameter coefficients.

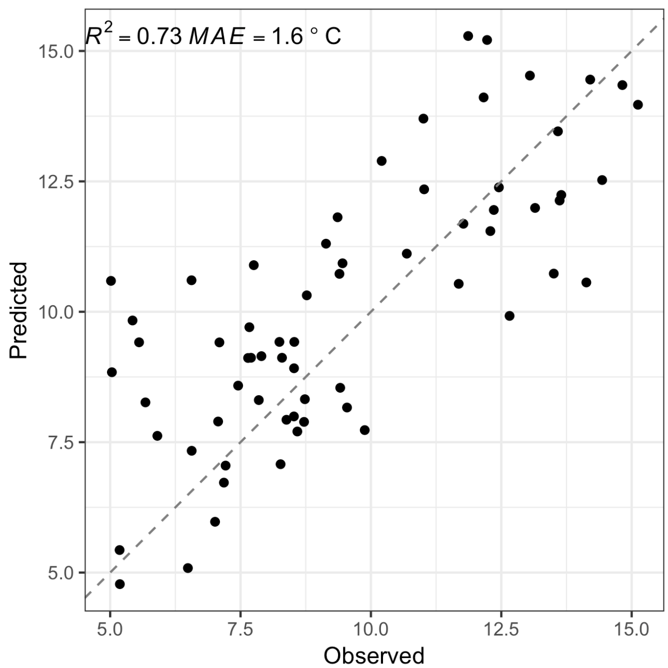

Figure 6 Observed and simulated monthly average stream temperature. The R^2 value suggests there is reasonable fit between observed and simulated values. The error in this analysis is approximately 1.6 ºC.

Benchmarks

There are no benchmarks for stream temperature. However, Bear *et al*. (2007) suggest the optimal thermal range for WCT is 13-15 ºC. The BC Water Quality Guidelines for WCT based on life history stage (B.C. Ministry of Environment 2001) are:

- Incubation = 9-12 ºC
- Rearing = 7-16 ºC
- Spawning = 9-12 ºC

Caveats or Data Limitations

Stream temperature observations were not available for a wide range of stream types, nor were they distributed across the study area. Therefore, the model is most applicable where measurements were available; improved monitoring will enable more robust models to be developed in the future.

2.3.8 INDICATOR ROLL-UP

A roll-up indicator provides a means of assessing all VC indicators in one consistent manner to evaluate cumulative effects. The indicator roll-up procedure was taken from AEVA protocol (CEF, 2016) and is similar to that of the Interior Watershed Assessment Procedure Guidebook (B.C. Ministry of Forests, 2001). Each raw calculated indicator value was translated into a normalized score between 0 and 1 (Table). All values within the lowest classification receive a normalized score of 0 while the remainder of the calculated values are divided into equal interval classifications (from 0.1-1.0), with an identified upper value serving as the highest classification, 1.0. The classification represents the normalized score for the assessment unit indicator (Table 2). Hybridization, and stream temperature were not included because they consisted of categorical data and in the case of stream temperature, benchmarks were not set. They will be discussed separately as complementary information.

Table 2. Indicator value score classification table. Values within a cell represent a range bounded by it and the number in the cell immediately to its right (adapted from Cumulative Effects Assessment Methods for Aquatic Ecosystems in British Columbia Standards for British Columbia's Values Foundation 2016).

						Score					
Indicators	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
Road Density near Streams	0	0.04	0.08	0.12	0.16	0.20	0.25	0.30	0.35	0.40	>0.45
Road Density on steep Slopes	0	0.03	0.06	0.09	0.12	0.15	0.20	0.25	0.30	0.35	>0.40
Stream Crossing Density	0	0.08	0.16	0.24	0.32	0.40	0.50	0.60	0.70	0.80	>0.90
Riparian Disturbance	0	0.03	0.06	0.09	0.12	0.15	0.18	0.21	0.24	0.27	>0.30
ECA	0	0.06	0.12	0.18	0.24	0.30	0.36	0.42	0.48	0.54	>0.60

2.4 PROSPECTIVE ASSESSMENT

A prospective assessment was completed to assess how aquatic indicators may respond to the cumulative effects of future projects, broader scale changes in environmental conditions, and potential mitigation actions. The intent of the prospective assessment was not prediction, which is unattainable due to uncertainty and contingency (Peterson *et al*., 2003). Instead, a scenario analysis was completed to compare the consequences of multiple scenarios that differed with respect to the rate, pattern, and type of development and natural disturbance. The future condition analysis provides a mechanism to contrast the benefits and liabilities of land-use options such as management practices and development rates, and to assess the influence of uncertainties such as natural disturbance trajectories in the face of future climate conditions (Duinker and Greig, 2007).

The following are the principles that were used in the development of the prospective assessment framework:

1. The assessment must support the goals of the BC Cumulative Effects Framework and the Elk Valley CEMF;
2. The assessment must inform decisions regarding the management of cumulative effects in the Elk Valley within the context of applicable policies, plans and programs (e.g. the Area Based Management Plan);
3. The assessment must be capable of distinguishing among alternative scenarios;
4. The assessment must be conducted at the watershed scale and apply to a time period applicable to both certain and reasonably foreseeable actions[1].

The following are the principles used in the development of the alternative future (50-year) scenarios:

- There must be a "reference scenario", which is business as usual, against which other scenarios can be compared
- Each scenario must include interactions (either positive or negative) between human activities and VCs
- The scenarios must be distinct enough that decision-makers can clearly discern differences among the scenarios in terms of effects on values and based on best available information about potential future development
- The number of scenarios must be manageable and feasible
- There must be sufficient information to support analysis of each scenario, and the information must be of acceptable quality
- The scenarios must not be in conflict with policies or legislation; however, results may trigger changes in policy or regulation
- The scenarios must be amenable to comparisons of before and after mitigation

The following are the three future development scenarios defined by the CEMF Working Group:

1. <u>Reference Scenario</u>: This scenario represents a "business as usual" progression in development. Current rates of change in indicators were used to model future conditions.
2. <u>Minimum Scenario</u>: This scenario is meant to present a case where the intensity of human activities in the Elk Valley declines. This scenario takes the reference case and either subtracts from it, or substitutes activities which are assumed to be associated with fewer environmental impacts.
3. <u>Maximum Scenario:</u> This scenario is meant to provide decision-makers with an understanding of cumulative effects from the combination of all currently proposed (from 2015) or projected human activities in the Elk Valley.

In addition to the future development scenarios, we assessed changes in future natural disturbance regime through increases in wildfire and insect outbreaks, where the average fire size doubles by the end of the simulation period (FLNRO, 2014) and all mature spruce and pine – leading stands were disturbed by pests. We also assessed two future climate scenarios available

[1] Reasonably foreseeable actions are those that are expected to proceed (e.g. a proponent has publicly disclosed its intention) and may also include hypothetical actions that are of potential concern for cumulative effects should they proceed. A major criterion is whether future actions are likely to affect the same VC

from Climate BC/WNA version 5 (Wang *et al*., 2012). The future climate scenarios used were driven by the CanESM2 General Circulation Model (GCM) and two greenhouse gas emissions scenarios. The emissions scenarios represent potential future greenhouse gas concentrations, referred to as Representative Concentration Pathways (RCP). This project used RCP 4.5 and RCP 8.5, where the 4.5 and 8.5 represent radiative forcing (W/m^2) by the year 2100 relative to pre-industrial values. The RCP 4.5 Scenario can be viewed as representing some greenhouse gas emissions control where emissions peak in around 2040, whereas the RCP 8.5 Scenario assumes emissions continue to rise until 2100.

Projecting the cumulative effects of multiple drivers over large spatial and temporal scales was aided by computer modelling. Modelling provides a formalized process for integrating the range of information that is required for prospective assessment of cumulative effects. Further, involvement of planning participants in the modelling process can foster a common understanding of cumulative effects, thereby informing objective decision making.

The scenario analysis was completed using ALCES Online, a computer model designed for comprehensive assessment of the cumulative effects of multiple land uses and natural disturbances to ecosystems (Carlson *et al*., 2014). The model's ability to simulate landscape dynamics at a range of spatial extents (e.g., local, regional, provincial) and across long time frames (e.g., decades) allows scenarios to be assessed at scales that are relevant to management and policy development. A key motivation behind the development of ALCES Online was to improve the accessibility of scenario analysis to stakeholders and planners, which is achieved through an intuitive web-delivered interface.

The flexible simulation engine and relative ease at which scenarios can be defined made it possible to explore the outcomes of numerous scenarios to develop an understanding of the range of land-use options and uncertainties that exist. Simulation outcomes in terms of changes in the abundance, location, and age of natural and anthropogenic land cover types were applied to create maps of future landscape composition and indicators of interest. Indicator relationships were implemented using a calculator that allows for simple to complex indicator relationships as represented by mathematical equations, logic statements, dose-response curves, and spatial rules (e.g. buffers or patch analyses).

3.0 RESULTS

3.1 RETROSPECTIVE ASSESSMENT – HISTORIC AND CURRENT CONDITIONS

The purpose of the retrospective assessment is to map the current conditions, reflective of historic disturbance affecting riparian areas. The primary questions addressed in the retrospective assessment are:

- What are the current conditions?
- What have been the rates or patterns of change from historic condition?
- What have been the key stressors or causes of change?

3.1.1 EQUIVALENT CLEARCUT AREA (ECA)

In terms of ECA, there are 36 watersheds in low hazard (46%), 31 watersheds in moderate hazard (40%) and 11 watersheds in high hazard (14%) (Figure 7). The high hazard watersheds are particularly prone to the risk of increased peak flow, which may result in surface erosion and transport of sediment and debris into stream channels, negatively impacting fish habitat. In addition, watersheds with high ECA values can have altered streamflow regimes. Changes in low flows as well as high flows pose potential threat to WCT given that they are particularly vulnerable to high stream temperature conditions.

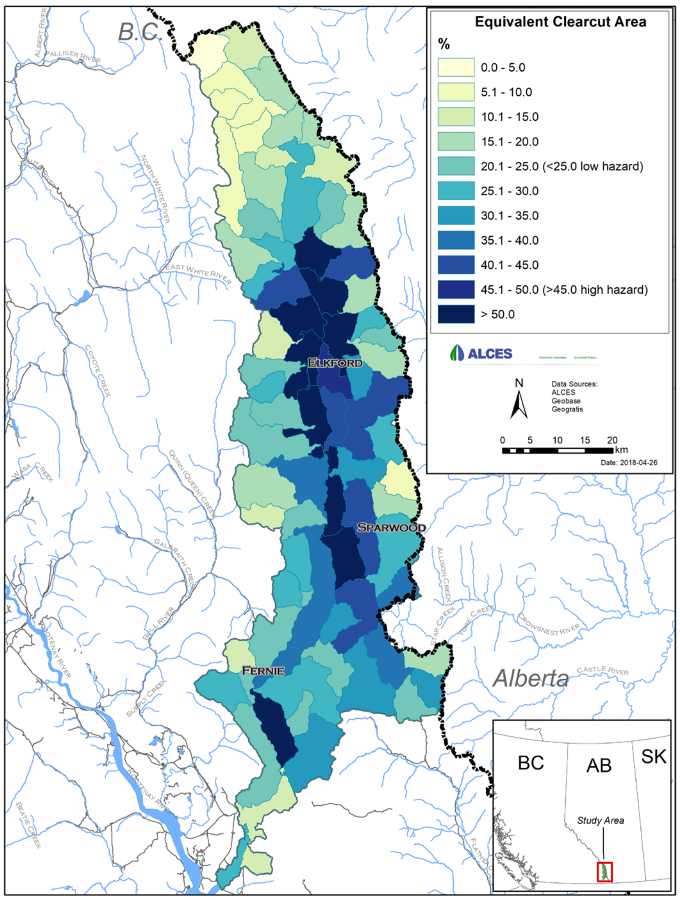

Figure 7 ECA proportions in 78 AWs in the Elk Valley. Darkest blue watersheds indicate highest calculated hazards; brightest watersheds indicate lowest calculated hazards.

3.1.2 RIPARIAN DISTURBANCE

Of the 78 AWs in the Elk Valley, 64 AWs (82%) currently have high hazard for riparian disturbance (>20%), and of those that had a high hazard, 38 AWs (59%) had riparian disturbance >30% (Figure 8). There were 9 watersheds ranked as moderate hazard (11.5%), and 5 ranked as low hazard (6.5%).

These results suggest that the valley bottoms in the Elk Valley and mining-affected AWs are currently areas with the highest riparian hazard. The valley bottoms are where most human activities have taken place, with urban development, transportation networks, and agricultural development. Mining activity can completely remove riparian areas; therefore, it is intuitive that these AWs currently have the highest overall riparian hazard. One limitation of this indicator is that the extent of disturbance identified in this analysis is not necessarily reflective of how riparian areas are functioning. Therefore, it is imperative to field-truth the results of this analysis and to attempt to calibrate levels of disturbance to riparian function.

Particular attention should be paid to the watersheds with the highest riparian disturbance hazard ratings (>30%). This level of disturbance is also important to consider for infrastructure and humans. For example, Coal Creek, Michel Creek, and the Elk River near communities present a substantial challenge for riparian area management given that infrastructure and human dwellings occupy the floodplain. AWs with high value fish habitat are also important to focus on, as riparian disturbance in these areas could have a more substantive effect.

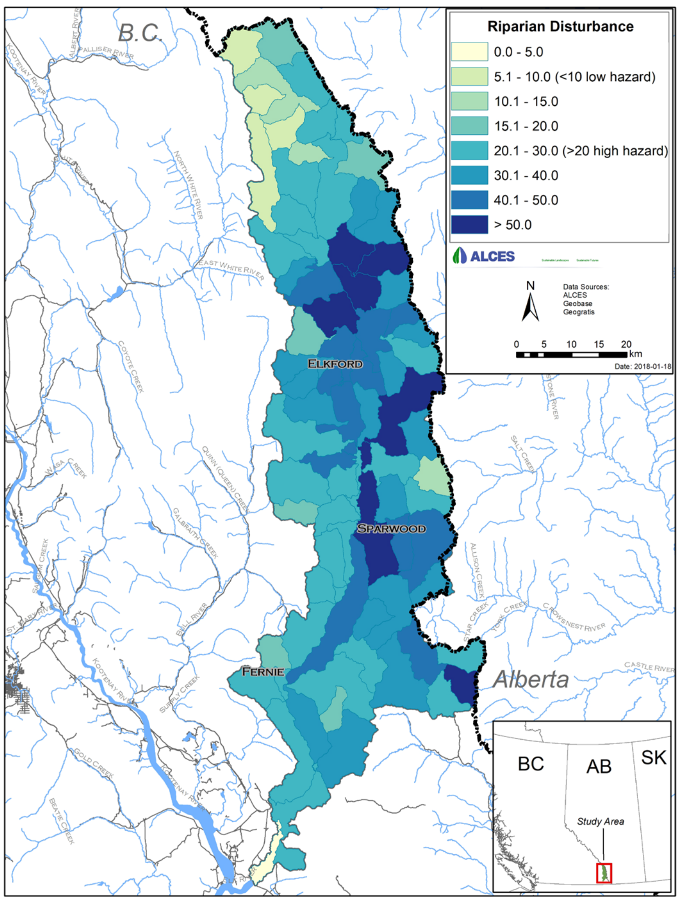

Figure 8 Riparian disturbance in 78 AWs in the Elk Valley. Darkest blue watersheds indicate highest calculated hazards; brightest watersheds indicate lowest calculated hazards.

Not all alterations to riparian ecosystem services and functions caused by human related and natural disturbances recover at the same rates. The large majority of riparian fire disturbance would have occurred in the Elk Valley 80-85 years ago (Figure 9). The recovery curve used in this analysis may be conservative in suggesting that a riparian disturbance is 90% recovered after 66 years. Riparian functions other than LWD processes appear to be generally recovered within 3-4 decades post disturbance, in the absence of permanent disturbance like urban development or mining. That said, it is unlikely that post-fire salvage logging occurred at the time of the 1930's fires; therefore, these burned areas likely did continue to provide LWD recruitment to the streams.

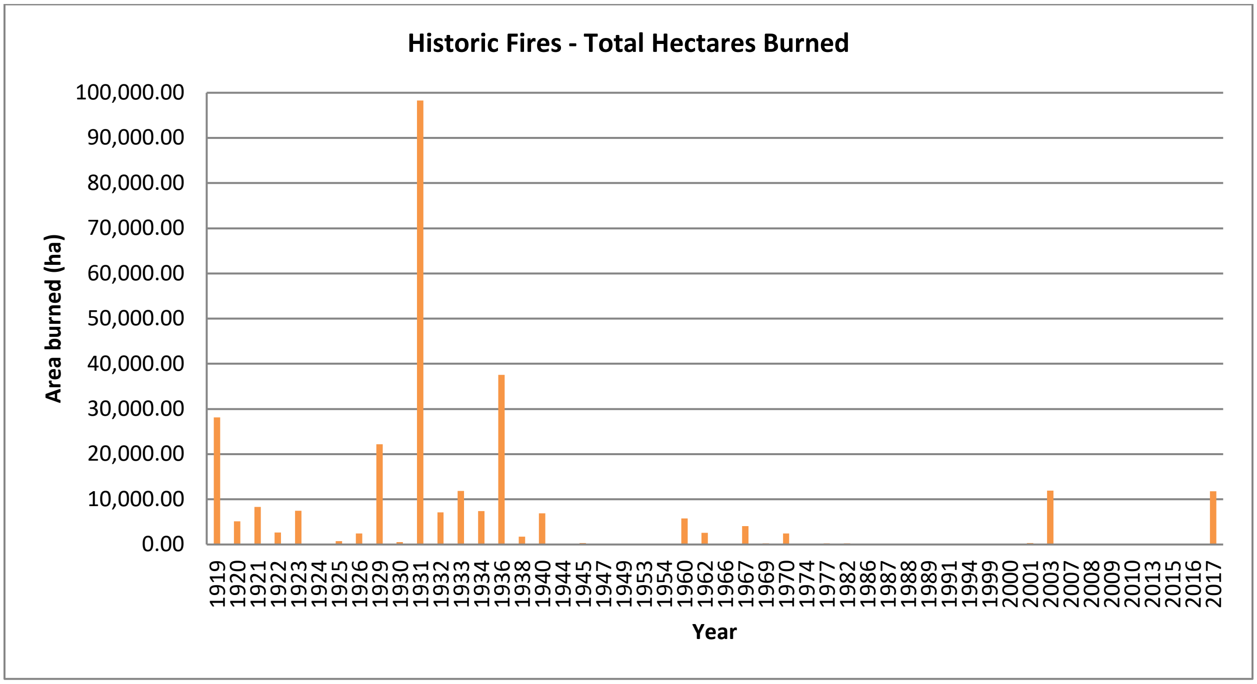

Figure 9 Annual total area burned in the Elk Valley between 1916 and 2017.

3.1.3 Stream Crossings

Of the 78 AWs, 66 (85%) had a high hazard ranking, 5 (6.5%) had a moderate hazard ranking, and 7 (8.5%) had a low hazard ranking for stream crossings (Figure 10). Due to the large number of high hazards AW's in the Elk Valley, prioritization will be necessary to address site specific management and mitigation. Swift Creek (3308), Dry Creek (3299) and Wheeler Creek (3281) had some of the highest densities of stream crossings in the Elk Valley at 5.04 km/km^2, 3.10 km/km^2, and 3.07 km/km^2, respectively.

Though different types of crossings have different levels of impact (e.g. closed bottom culverts are the most disruptive), they are not entirely distinguished in this phase of the study (e.g. Figure 11). Some crossings may be well designed and contribute little to no impact whereas others may have been poorly designed or have not been maintained.

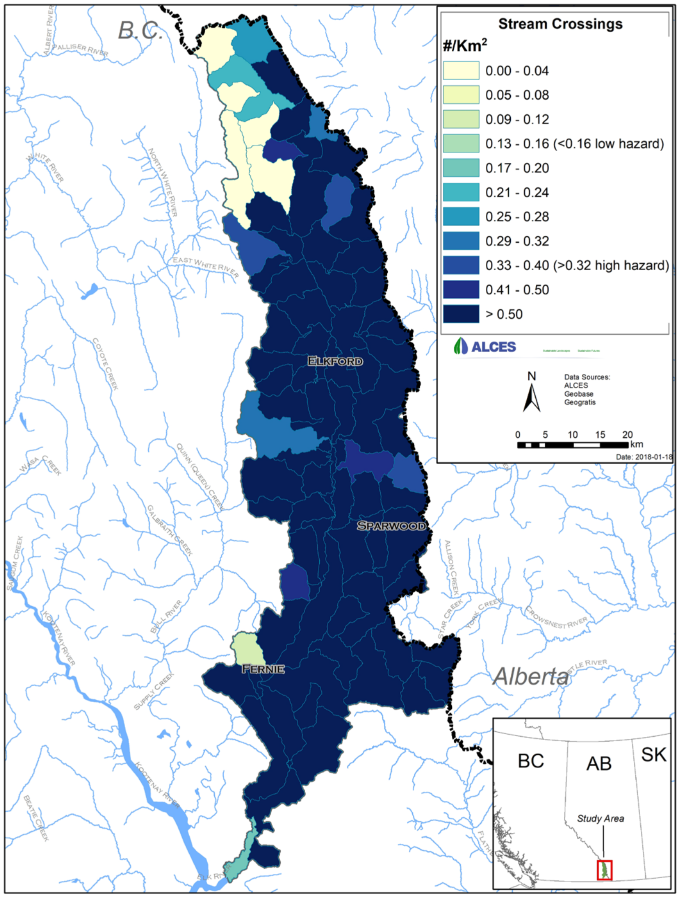

Figure 10 Stream crossing hazard in 78 AWs in the Elk Valley. Darkest blue watersheds indicate highest calculated hazards; brightest watersheds indicate lowest calculated hazards.

Historically, road expansion occurred from the early 1900s, and mining exploration and forestry drove many of the road patterns visible today. Early stream crossing structures do not always meet current standards, and many have not been replaced since construction. Field verification can determine the extent of impact from stream crossing disturbance and whether the crossings are barriers to fish migration. To prioritize field verification of stream crossings, those in which the crossing might be a barrier alienating large lengths of channel upstream and streams with high fish habitat value should be focused on first. In certain instances, stream crossing barriers may need to be maintained to prevent hybridization of introduced and native fish species. Further assessments on the type of crossing and incorporation of site specific data can help improve this indicator in the future and assist with prioritization.

Figure 11 Unmaintained culvert on Chauncey Creek in the Elk Valley, demonstrating a closed-bottomed culvert that prohibits fish movement upstream (photo: Taye Ayele).

3.1.4 ROAD DENSITY NEAR STREAMS

Road densities within 100 m of streams varied between 0.0 – 1.7 km/km^2. There are 2,058 km of total near-stream roads (all types), with 85% of those being gravel. There are 71 AWs (91%) that are high hazard and have >0.16 km/km^2 of roads near streams. Two AWs (2.5%) are at a moderate hazard (0.08-0.16 km/km^2) and 5 (6.5%) are at a low hazard (<0.08 km/km^2) (Figure 12).

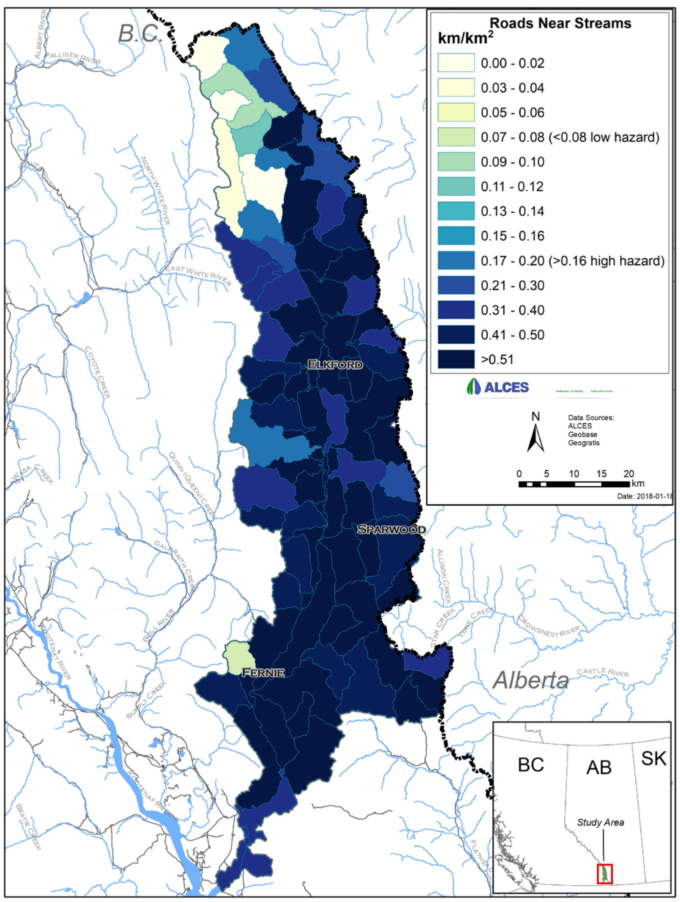

Figure 12 Road density within 100 m of streams in 78 AWs in the Elk Valley. Darkest blue watersheds indicate highest calculated hazards; brightest watersheds indicate lowest calculated hazards.

While increasing road density within a watershed can have effects on WCT by increasing access and altering drainage and sediment deliver, roads within 100 m of a stream have higher potential to have negative effects. Transportation infrastructure can often parallel WCT streams, impairing riparian function (e.g. shading and filtering capacity) and leading to the hardening of stream banks to protect the infrastructure.

3.1.5 Road Density on Steep Slopes

The total length of all roads in the Elk Valley on steep slopes is 552 km with an average density of 0.15 km/km^2. There are 32 AWs (41%) at a low hazard (<0.06 km/km^2), 16 (21%) fall into a moderate hazard category (0.06-1.2 km/km^2) and 30 (38%) are at a high hazard (>1.2 km/km^2) (Figure 13). These results suggest there are several AWs in the study area that require further investigation to assess the hazard to aquatic ecosystems as it relates to high levels of road development on steep slopes.

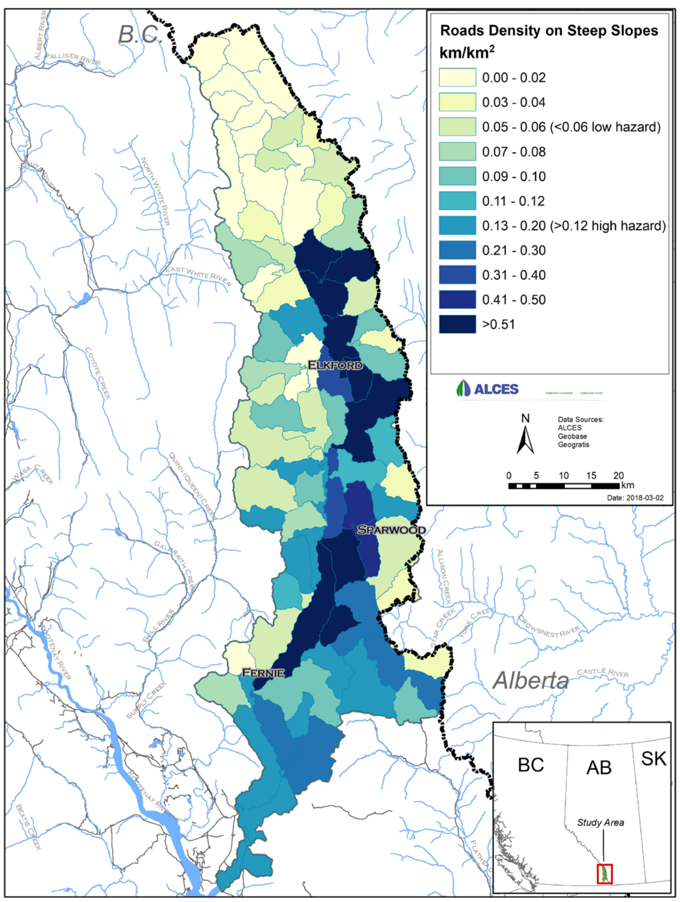

Figure 13 Road density on steep slopes in 78 AWs in the Elk Valley. Darkest blue watersheds indicate highest calculated hazards; brightest watersheds indicate lowest calculated hazards.

3.1.6 WESTSLOPE CUTTHROAT TROUT-RAINBOW TROUT HYBRIDIZATION

Levels of pure WCT over the 20-year period from 1996 to 2016 varied between 75% and 100% (100% having no hybridization; (Figure 14). Overall, most AWs (76%) fall into a low hazard category (no hybrids). Overall, 21% fall into a moderate category (96-99% pure WCT) and 4% are at a high hazard (<95% pure WCT).

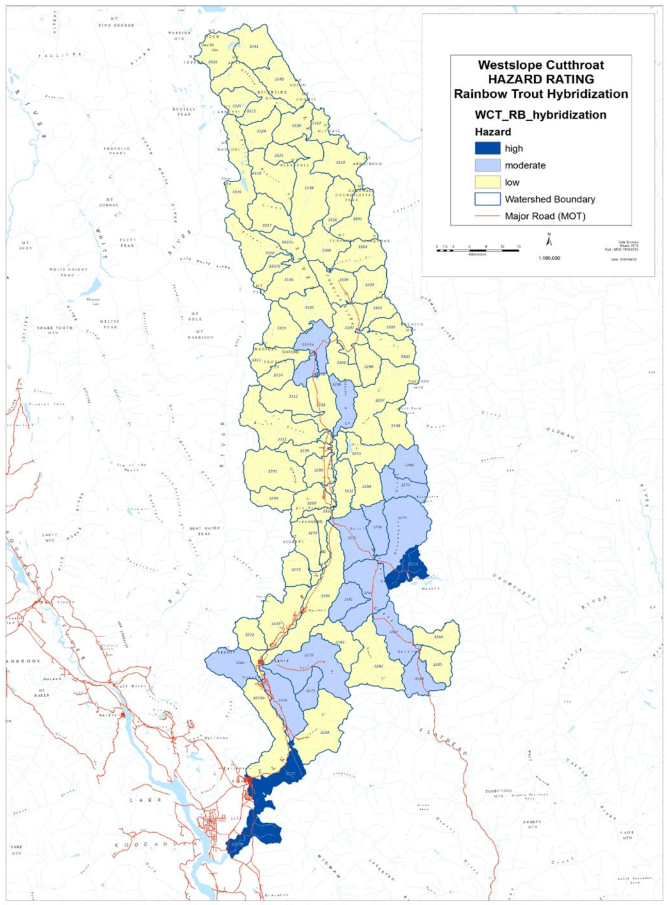

Figure 14 WCT hazard rating for Rainbow Trout Hybridization for 78 AWs in the Elk Valley. High risk ≤ 95% WCT (dark blue), moderate risk = 95% - 99.9% WCT (light blue), and low risk = 100% WCT (pale yellow).

DNA sampling was not conducted for all watersheds, but as sampling programs continue into the future the analysis and subsequent hazard rankings for each watershed will be updated to increase confidence in these results. DNA sampling was recently conducted (2016) South of Elko (high hazard), Morrissey Creek (low hazard), Lizard Creek (moderate hazard), Coal Creek (moderate hazard), Michel Creek (moderate hazard), Lower and Upper Alexander Creek (moderate hazard), Grave Creek (moderate hazard), Harmer Creek (low hazard), Upper and Lower Fording Watershed (low and moderate hazard, respectively), Forsyth Creek (low hazard), Weary Creek (low hazard) and the Elk Face unit North of Forsyth Creek (low hazard). There may in fact be hybridization in some of the watersheds found to be low hazard due to sampling error (i.e. RBT may exist despite RBT not being detected) or due to no sampling in an AW, but continued monitoring will help to increase confidence in results.

Indirectly, habitat degradation can increase susceptibility to displacement and hybridization with introduced salmonids, and isolated populations are unlikely to be recovered through immigration in the short term (COSEWIC, 2006). Thus, the hybridization indicator has linkages to riparian disturbance and road density. Increases to stream temperature can also stress populations of WCT and increased warming due to climate change can increase the risk of hybridization in the future (COSEWIC, 2006).

3.1.7 Stream Temperature

The average simulated warmest month stream temperature value across the Elk Valley (including all tributaries) was 6.2ºC, suggesting the thermal conditions are well suited to WCT, and potentially, that there are tributaries that are currently below the thermal optima. The simulated maximum warmest month stream temperature was 13.2ºC, again well within the thermal tolerance for WCT (Figure 15). The distribution of stream temperature values is largely skewed towards tributaries, which are simulated to be relatively cold.

Further field verification should be conducted to confirm the thermal conditions of tributaries; however, there is anecdotal evidence that some streams in the study area are relatively cold throughout the year (pers. comm. H. Tepper).

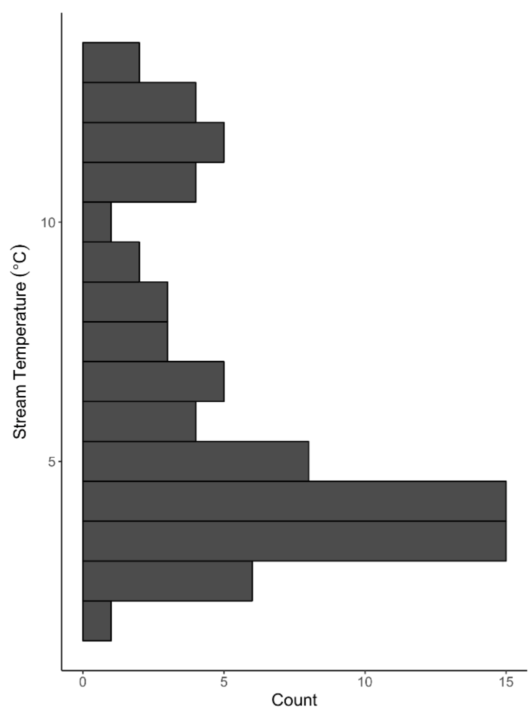

Figure 15 Distribution of simulated average warmest month stream temperature across AWs in the Elk Valley.

3.1.8 Indicator Roll-up

As described in Section 2.3.8, the indicator roll-up hazard map is created from the average of the normalized values for five indicators – ECA, riparian disturbance, road density near streams, road density on steep slopes, and stream crossing density (Figure 16). The results suggest that the majority of the watersheds (65%) fall under moderate hazard, followed by 13% for low hazard and the remaining 22% fall under high hazard (Figure 16). Overall, the analysis suggests the valley bottom and areas where development is high are the areas where aquatic ecosystems are at the greatest risk. The five highest hazard AWs are: Lake Mountain and Clode Creek, Michel Creek – Lower, Elk Face Unit NE of Sparwood, Swift Creek, and Greenhills Creek, from highest to lowest, respectively. This suggests that overall the most intense hazard is associated with mining disturbance; however, high road development also results in high hazard.

Mining activities have historically removed WCT habitat in the upper watershed (largely by infilling with waste rock), resulting in a reduction of available habitat. The effect of reduced habitat on WCT populations has not been evaluated as part of this assessment; however, tributary habitat plays a key role in the life history of WCT. An ongoing tributary evaluation program is a regulatory requirement and is being conducted by Teck Coal Ltd. The tributary evaluation program can provide valuable input to the cumulative effects assessment and management process in terms of quantifying available habitat and habitat loss in the Elk Valley.

Stream crossings and road density near streams play a large role in the hazard roll-up and have caused the greatest hazards across the Elk Valley to date, with the clear majority of the watershed exhibiting high hazard. The influence of roads (e.g., stream crossings and road density near streams) is demonstrated by elevated roll-up hazard in the southern and central portion of the watershed where road density is greatest. In contrast, low hazard AWs are almost exclusively located in the protected northern portion of the watershed.

The aquatic hazard roll-up suggests that hazards for WCT populations are associated with populated areas and areas with substantive road development. These factors can affect WCT populations by increasing angling access, habitat fragmentation, and sediment inputs. In addition, thermal conditions likely present hazards to WCT along the mainstem Elk River and in the larger tributaries like Michel Creek.

The indicator roll-up map identifies watersheds where cumulative effects of land use may influence aquatic ecosystems and where further assessment is needed to determine the actual conditions of the AWs. Field verification should consider a range of low to high hazard AWs, with an objective of quantifying current conditions. This will enable the Elk Valley CEMF to verify that hazard values are representative of the indices given. Follow up work relative to cumulative effects should also evaluate potential future changes in chemical water quality to constructively guide management decisions.

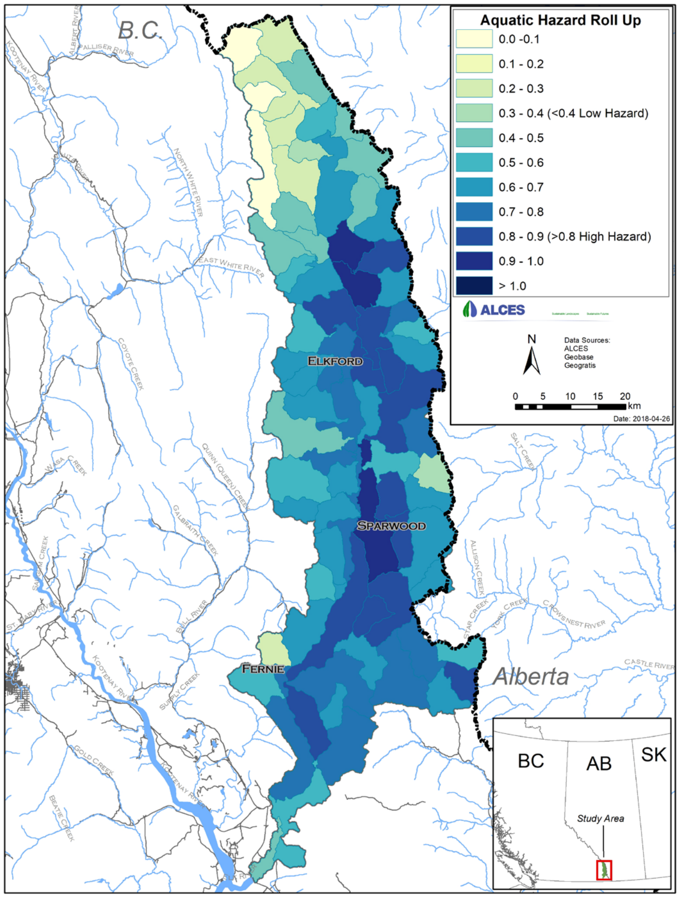

Figure 16 A roll-up of five pressure indicators for 78 AWs in the Elk Valley. The roll-up classified a low hazard where the normalized score falls below 0.4 and a high hazard where the normalized score exceeds 0.8.

3.2 Prospective Assessment - Future Condition Analyses

The following section presents the response of each of the indicators to potential future conditions explored through 50 years (2016 to 2065) for the prospective assessment.

3.2.1 ECA

ECA and associated hazard due to potential hydrologic change decreases by approximately 2% under most future scenarios (Figure 17). The decrease in ECA is a function of the forest aging over time, especially in areas outside of the Timber Harvest Land Base (THLB) and outside of private land given that harvest is expected to continue in these areas. However, under a more extreme natural disturbance regime with much higher rates wildfire and pest outbreak, average ECA increases over time from 29% to 38% (Figure 17). More severe wildfire is expected under future climate conditions (Boulanger *et al.*, 2014), underlining the importance of examining the effects of natural disturbance, and implementing applicable management strategies where and when possible. It should also be noted that the forest age data layer that was used identifies younger forest in some portions of the study area (like adjacent to avalanche chutes) where natural disturbance and harvest have not occurred in recent decades. If forest age has been underestimated in these areas, the simulated decline in ECA through time will be exaggerated.

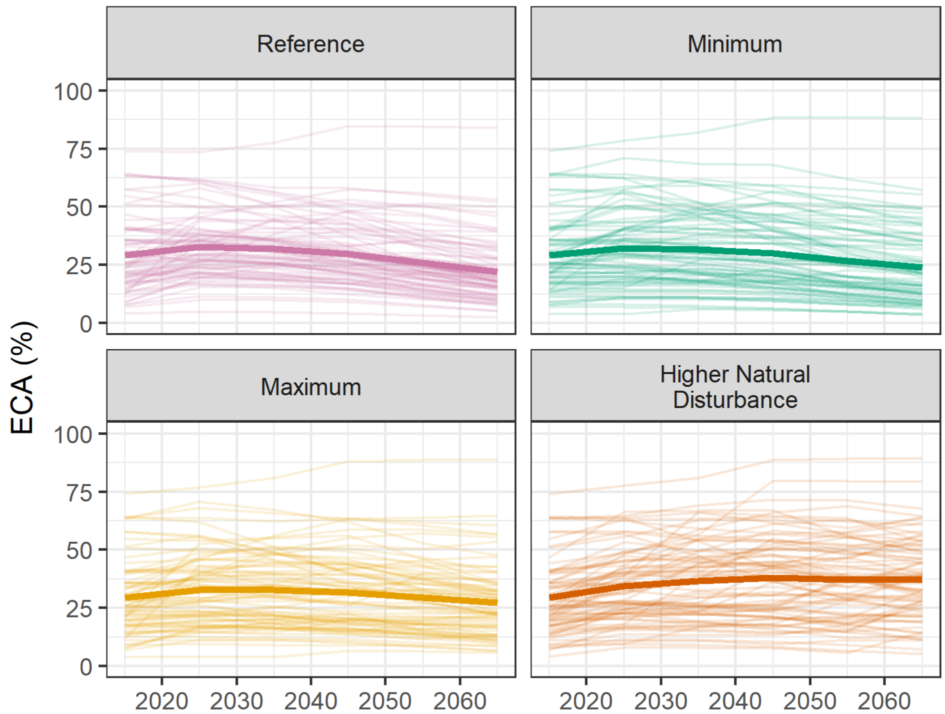

Figure 17 ECA (%) at the scale of the study area under Reference (purple), Minimum (green), Maximum (orange), and Higher Natural Disturbance (red). The dark lines represent the Elk Valley average, while the lighter lines represent individual AWs.

Figure 18 demonstrates that by the end of the 50-year simulation, increases in ECA are expected for AWs in the southern portion of the study area, the Dry Creek AW (increases to 100% ECA), and under the Higher Natural Disturbance Scenario. Like road density, ECA increases in those AWs where forest harvest is simulated to increase dramatically relative to the current condition. This includes AWs like Marten Creek, where ECA is simulated to increase by approximately 50% in the Reference and Maximum future development scenarios in the first decade of the simulation. However, in the case of Dry Creek, the increase in ECA is caused by mine expansion.

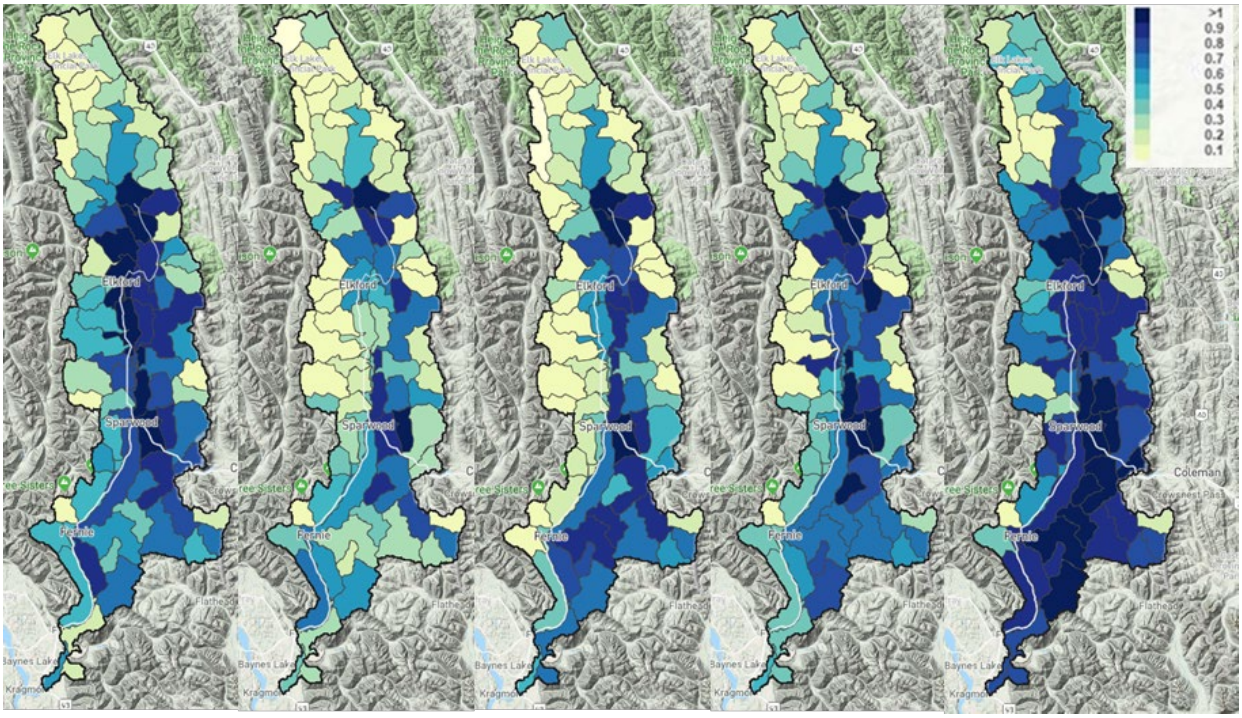

Figure 18 ECA hazard today (left) and after five decades under the Reference, Minimum, Maximum, and Higher Natural Disturbance scenarios (from left to right).

3.2.1 Riparian Disturbance

Future development scenarios implemented here suggest that under the Reference and Minimum scenarios, riparian disturbance is likely to decrease over time across the study area, while under the Maximum Scenario there could be a slight increase (Figure 19). This is due to a large proportion of forest aging from the 1930's fires and harvest is not occurring in riparian reserves under future scenarios, resulting in riparian forest recovery. Other future development like road construction and mining do not affect riparian disturbance at the scale of the study area in future scenarios; however, some AWs are likely to still experience increased disturbance, particularly those that are mined.

Under the Higher Natural Disturbance Scenario, however, it is likely that riparian disturbance will increase at the scale of the study area, demonstrating the large-scale effects of natural disturbance (Figure 19).

A general assessment at the scale of the study area provides important insight into the overall condition of the riparian area. However, individual AWs can have fundamentally different responses to potential future scenarios (Figure 19). Like the retrospective assessment, Lake Mountain and Clode creeks are expected to have the highest riparian disturbance under all future scenarios. The future trend towards continual increasing disturbance from mining is consistent across AWs where mining occurs. However, the effect of harvest and natural disturbance is much more variable. A simple analysis of the variability in riparian disturbance across AWs suggests that higher natural disturbance also results in a higher degree of variability among AWs.

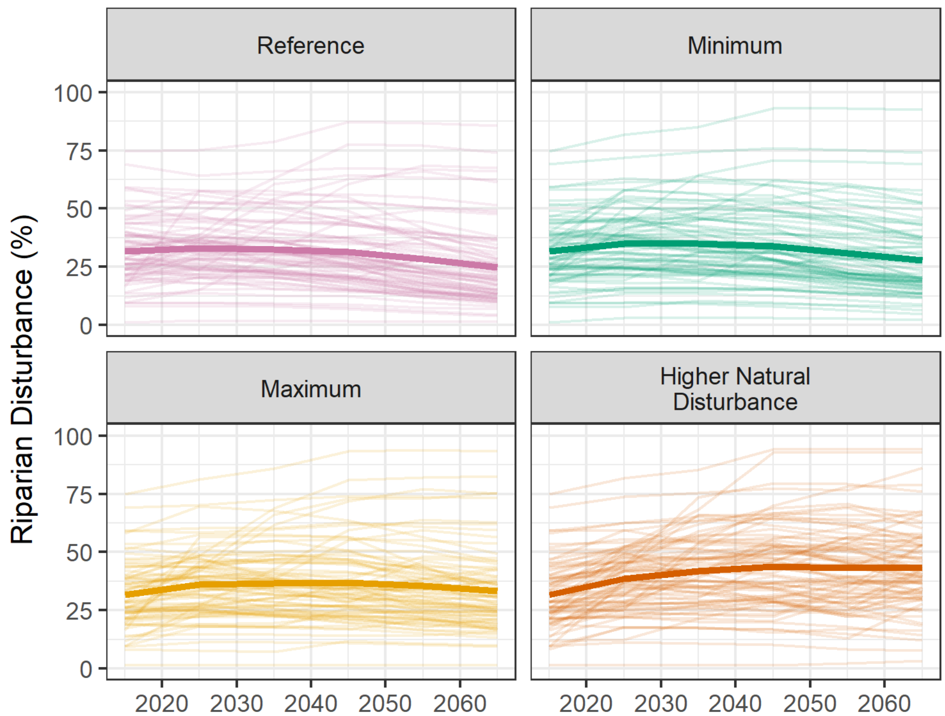

Figure 19 Riparian disturbance (%) at the scale of the study area under the Reference (purple), Minimum (green), Maximum (orange), and Higher Natural Disturbance (red) scenarios. The dark lines represent the Elk Valley average, while the lighter lines represent individual AWs.

3.2.2 Stream Crossings, Roads near streams, and roads on steep slopes

All road indicators are directly related to the density of roads within a watershed and given that there is substantial uncertainty in where roads will be built, the prospective assessment uses change in overall road density as a measure of these indicators. Road density in general is expected to increase by 2065 in all scenarios (Figure 20). However, road density was already high in the Elk Valley in 1950, and thus the increase in road density going forward is not substantial (Figure 21), nor does it differ substantially between scenarios at the scale of the study area. This is due to the fact that, on average, high levels of road development are not required to access new cutblocks.

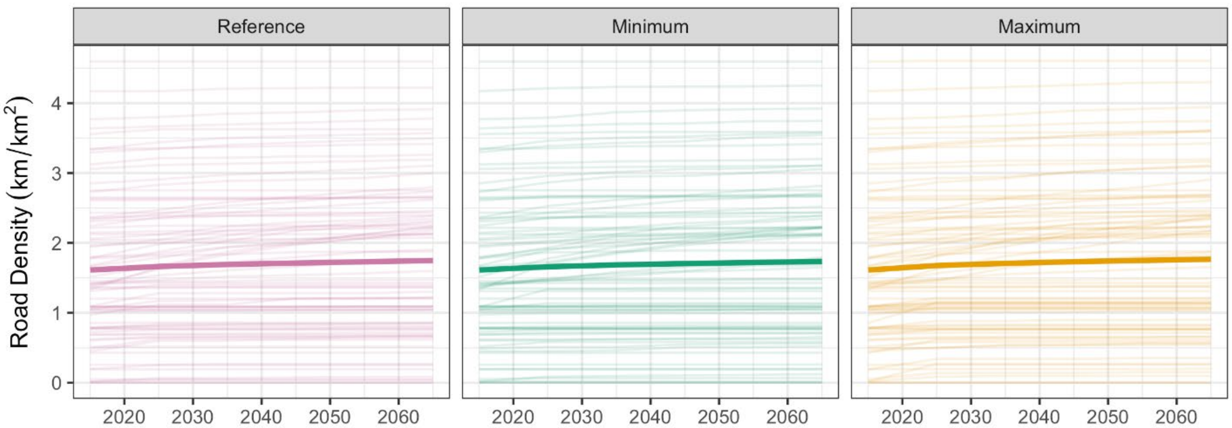

Figure 20 Total road density (km/km^2) at the scale of the study area under Reference (purple), Minimum (green), and Maximum (orange) scenarios. The dark lines represent the Elk Valley average, while the lighter lines represent individual AWs.

The greatest change in road density relative to 2015 is simulated to occur in the Coal Creek AW, with an increase in overall road density from 1.2 to 2.0 and 1.9 km/km^2 under the Reference and Minimum scenarios in 2065, respectively. This increase is associated with the relatively high growth in forestry on private managed forest land in this AW. Marten Creek experiences the highest simulated increase under the Maximum Scenario, reaching 2.2 km/km^2 by 2065, compared to a current road density of 1.3 km/km^2. These large changes in road density are in response to increases in forest harvest in all cases and occur primarily in southern portions of the study area. In fact, the greatest changes are consistently in AWs in this portion of the study area, with the lowest changes occurring in the northern portion of the study area associated with little to no industrial activity.

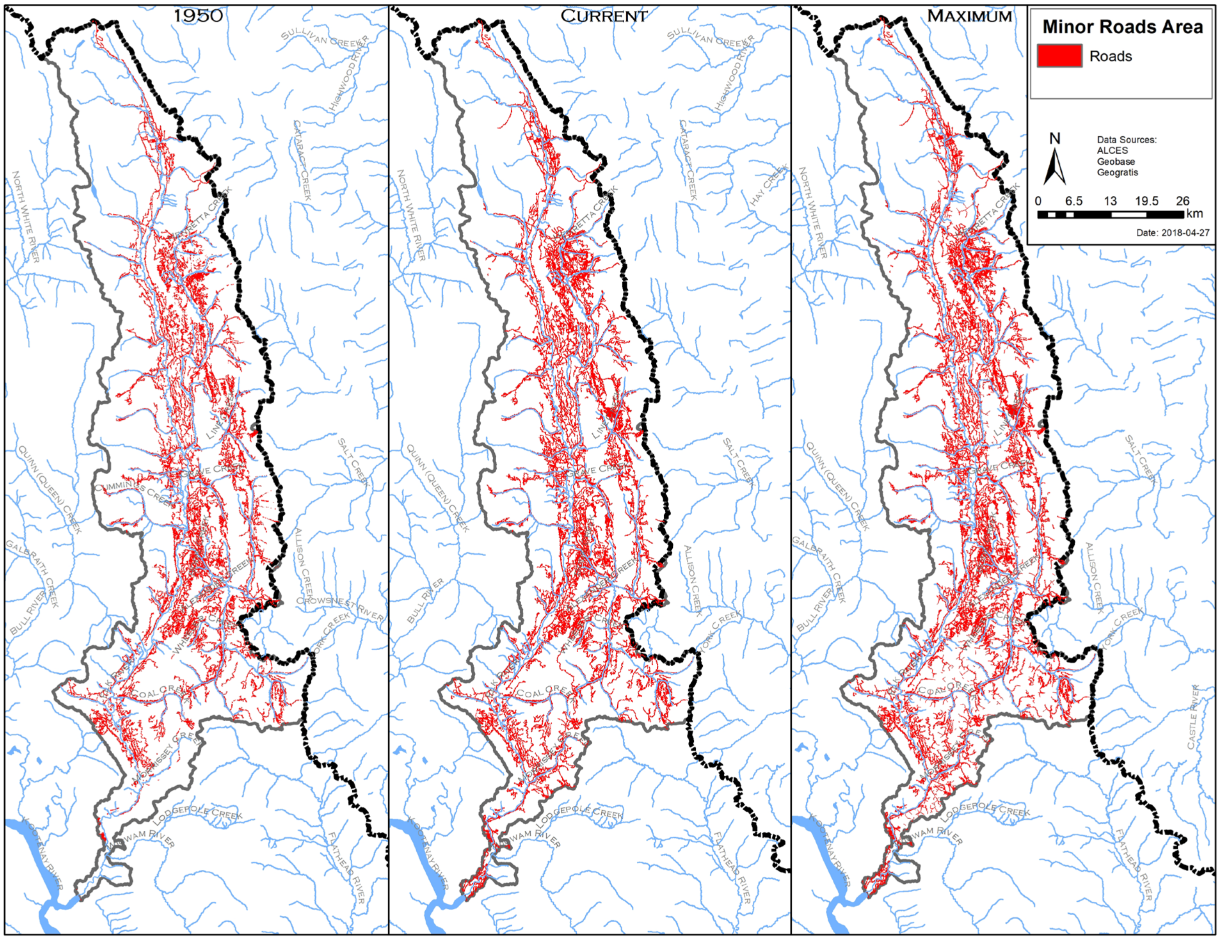

Figure 21 Road development in the Elk Valley in 1950 (left), 2015 (middle), and 2065 under the Maximum Scenario (left to right).

3.2.4 Stream temperature

Stream temperature simulations used the Maximum Scenario with two potential future climate scenarios (Figure 22). The Representative Concentration Pathway (RCP) 4.5 and 8.5 scenarios both result in warmer air temperatures into the future, with RCP 8.5 showing greater change. The effect of land use is apparent in the average warmest month stream temperature simulations for the RCP 4.5 scenario, where the effect of forest age is muting the effect of changes in future climate. This land use effect is outweighed under the RCP 8.5 scenario, where air temperature change is large enough to offset the effect of aging forest across the landscape.

Both future scenarios suggest the average warmest month stream temperature is likely to increase, with changes in the average stream temperature of approximately 1 ºC to 2 ºC in the next 50 years. Maximum warmest month stream temperature is estimated to increase by about 1 ºC and 3 ºC under the RCP 4.5 and RCP 8.5 scenarios, respectively. These results suggest that under future climate warming and Maximum future development conditions, it is likely that the thermal regimes of streams and rivers in the Elk Valley will change. This is consistent with findings from previous work demonstrating that thermally suitable habitat for native salmonids in the Elk Valley is likely to decrease in the future (Jones, 2016).

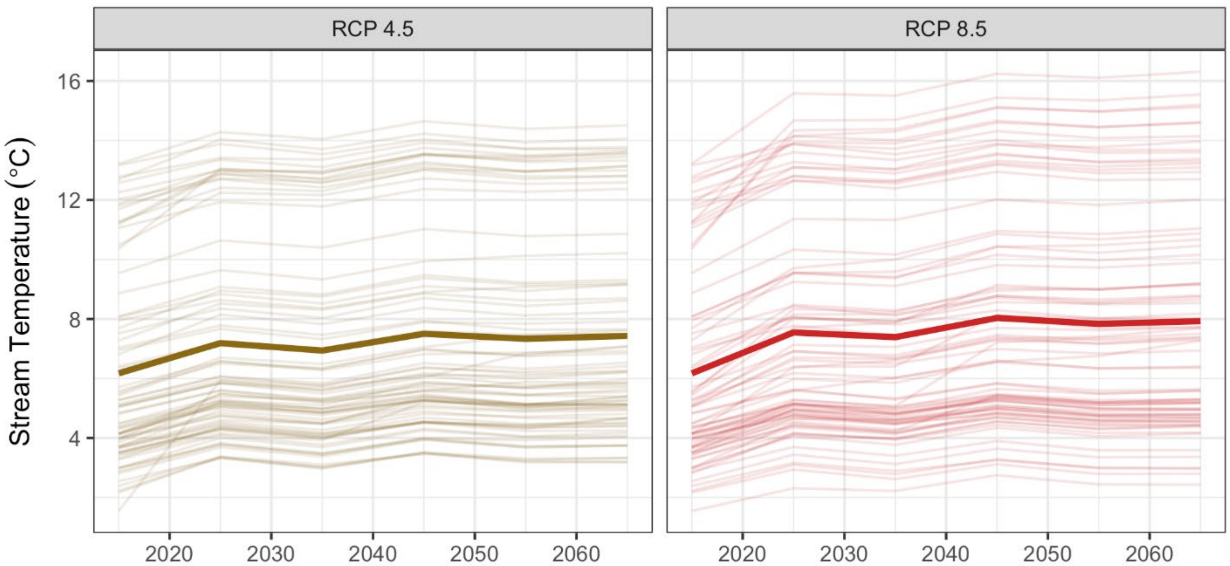

Figure 22 Average warmest month stream temperature at the scale of the study area from 2015 to 2065 under two climate change scenarios with the Maximum Scenario, where the dark lines represent the average across the Elk Valley and the lighter lines represent individual AWs.

3.2.5 Hazard roll up

Aquatic hazard as indicated by the roll-up index was relatively stable in the prospective analyses (Figure 23). Roads remained the dominant Elk Valley-scale stressor due to the high hazard created by current road and crossing densities. The road network expansion that did occur during the simulation was focused in the valley bottom and south and east of Fernie (Figure 23) in response to timber harvest on private managed forest land, and caused elevated hazard to aquatic ecosystems in those AWs (Figure 23). For example, Coal Creek, Marten Creek, and Matheson Creek were simulated to have 65%, 46%, and 36% more roads in the Reference Scenario, respectively. This is in contrast with the study area-wide average of a 10% increase. Overall, Figure 24 demonstrates that the roll-up indicator was relatively insensitive to development rate, due to the large extent of the existing road network relative to future road growth and the fact that areas with current high hazard levels are areas where much of the future development is expected to occur.

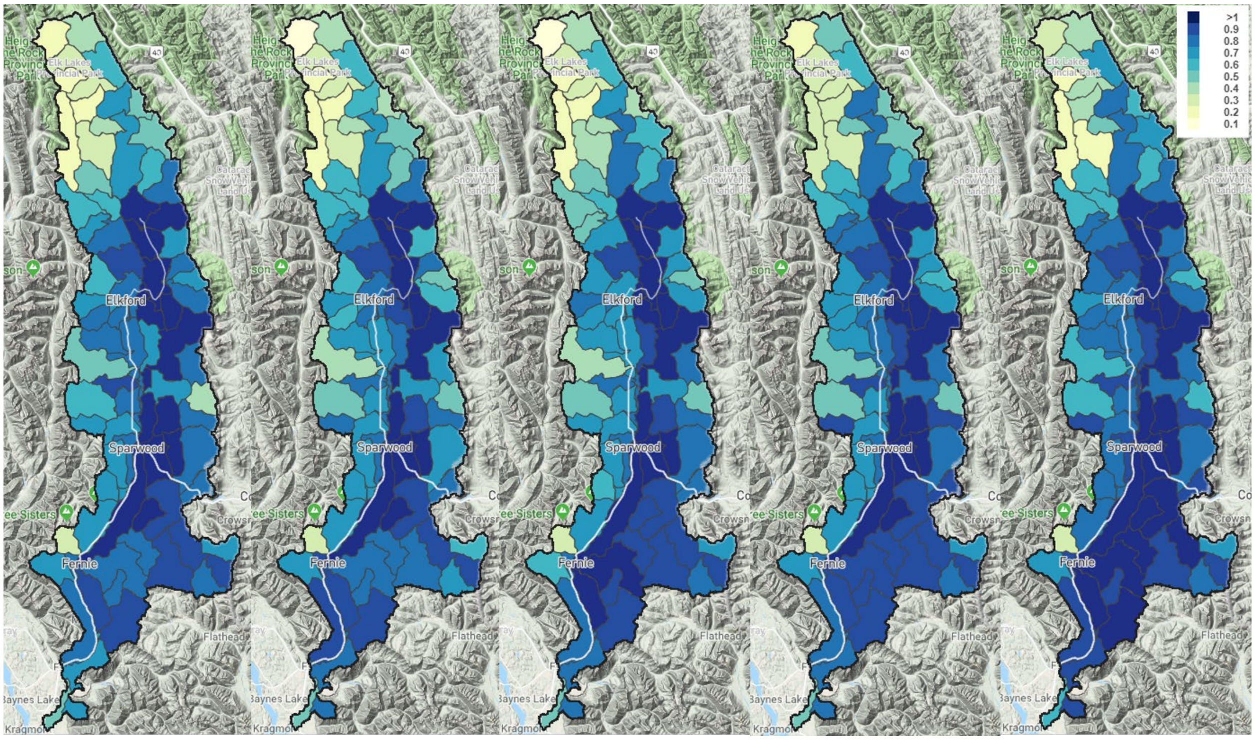

Figure 23 Roll-up hazard index today (left) and after five decades under the Reference, Minimum, Maximum, and Higher Natural Disturbance scenarios (from left to right). Hazard is calculated as a roll-up of 5 indicators for 78 AWs in the Elk Valley. The roll-up classified a low rating where the normalized score fell below 0.4 and a high rating where the normalized score goes above 0.8.

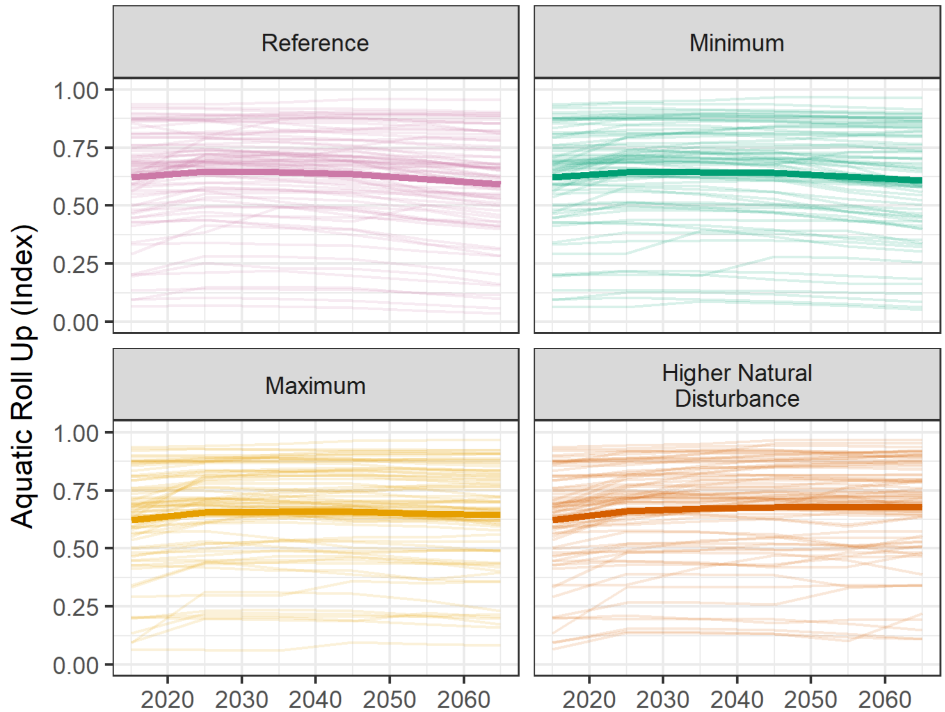

Figure 24 Hazard roll-up from 2015 to 2065 under Reference, Minimum, Maximum, and Higher Natural Disturbance scenarios. Hazard is calculated as a roll-up of 5 indicators for 78 AWs in the Elk Valley. The roll-up classified a low rating where the normalized score fell below 0.4 and a high rating where the normalized score goes above 0.8. The dark lines represent the Elk Valley average, while the lighter lines represent individual AWs

3.3 Conclusions

This analysis suggests hazard to aquatic ecosystems is relatively high in the valley bottoms and in smaller AWs where extensive human development has occurred or is expected to occur. These hazards are related to habitat disturbance (upslope and in-stream), potential for angling pressure, and potentially affected water quality (physical and chemical). This analysis also identified that climate and land use change are likely to pose threats to aquatic ecosystems in the future, with altered landscapes and shifting thermal regimes.

Indicators used in this assessment can be viewed as high level hypotheses, where higher levels of disturbance are likely influencing aquatic ecosystems. These results should be used to inform management responses and develop priorities in terms of mitigation actions. However, it is imperative to update the results of this analysis in the future through field verification and incorporation of new data when available.

4.0 Mitigation and Management recommendations

Managing and mitigating the effects of land use and climate change on aquatic ecosystems are fundamental to the cumulative effects process. This section describes current management practices and evaluates mitigation scenarios.

4.1 Extent of Current Management practices

There are currently many management activities taking place in the Elk Valley and provincially that are relevant to aquatic ecosystems. In terms of reducing riparian disturbance and ECA, forestry companies on Crown land have an obligation to reforest harvested land within two years. Fisheries Sensitive Watersheds (FSWs) have been designated through FRPA, the Government Actions Regulation, and an order sets management direction to conserve important watershed level attributes protecting fisheries values. Community watersheds are designated under FRPA and the Government Actions Regulation. These require special management to conserve the quality, quantity and timing of water flow and prevent cumulative hydrological effects having a material adverse effect on water. Like community watersheds and FSWs, other values like domestic water use are also managed to a higher standard. For example, companies with Forest Stewardship Council (FSC) certification, like Canfor, conduct hydrologic assessments in sensitive watersheds where ECA is at 25% or above. Canfor also installs bridges or open- bottom culverts on fish-bearing streams and implements sediment control measures on key fish streams.

Private lands are managed differently; however, programs are available to help land owners restore their properties. For example, funding is available through the Fish and Wildlife Compensation Program. A riparian planting program is available to help mitigate agricultural riparian disturbance, but it is unknown at this time to what extent the program is being implemented. Mining disturbance can result in habitat loss; therefore, there is ongoing work in the Elk Valley to offset this loss through habitat construction projects. Also, Teck is currently implementing the Elk Valley Water Quality Plan, which was developed to mitigate the effects of mining operations on chemical water quality.

Forests subjected to fire and pest disturbance are left to regenerate naturally unless funding is made available. Funding for forest regeneration is prioritized by risk and need. Replanting of pest-affected land appears not to be any more effective than allowing natural regeneration to occur (pers. comm. Art Stock, FLNRORD Entomologist, Nelson, BC).

A Management Plan for the Westslope Cutthroat Trout in British Columbia was prepared by the B.C. Ministry of Environment (2014). The plan identifies several management actions and prioritized these as essential (urgent and important, needs to start immediately), necessary (important but not urgent), or beneficial.

4.2 Mitigation Scenario Modelling

Three levels of mitigation measures were simulated (Table 3):

1. Current mitigation practices: Business as usual with regard to development and current mitigation practices;
2. Moderate mitigation: Improved mitigation on future developments, or restoration of past developments (e.g. no net loss); and
3. Intensive mitigation: forward management and mitigation of development, and retrospective reclamation.

Table 3. Mitigation scenarios developed for Riparian and WCT indicators and modelled in ALCES.

Moderate mitigation	**Intensive mitigation**
Reduce stream crossing densities to below 0.32/km	Reduce stream crossing densities to below 0.16/km).
Reduce road density to below 0.12 km/km^2 within 100 m of streams	Reduce road density to below 0.06 km/km^2 within 100 m of streams
No harvest >30% ECA in sensitive AWs and no harvest >40% in other AWs	No harvest above H60; no harvest >30% ECA in sensitive AWs and no harvest >40% in other AWs

The mitigation scenarios aimed to reduce stream crossings, road densities near streams, and ECA, and were compared to the Higher Natural Disturbance Scenario given that this had the largest effect on aquatic ecosystem indicators. Reductions in stream crossings were simulated to occur in conjunction with the removal of roads near streams during the mitigation scenarios, resulting in substantial reductions in road density across the study area.

Removal of roads near streams during the mitigation scenarios achieved substantial reductions in overall road density. Implementing the road reduction strategies across the entire basin is likely unrealistic, given that the majority of roads are located close to streams. Over 2,000 km of road are located within 100 m of streams; this would need to be reduced to approximately 500 km and 200 km under moderate and intensive mitigation strategies, respectively. It is important to note that the intensive mitigation scenario was unable to reduce road densities near streams below 0.6 km/km^2 without removing Forest Service Roads or highways. Therefore, targeting watersheds that have higher expected environmental benefits associated with the relative costs is integral to the implementation of mitigation actions as part of managing cumulative effects of land use on aquatic ecosystems.

While less impactful than roads, strategies to mitigate hazards caused by ECA were also assessed given that there was a simulated increase in hazard under a scenario of elevated natural disturbance (fire and pests). Overall, intensive mitigation resulted in higher ECA reductions. Intensive mitigation resulted in substantial decreases in ECA for AWs like Alexander Creek and Wheeler Creek, with reductions in ECA of 60% and 45% relative to the Higher Natural Disturbance Scenario, respectively. It is important to note that these mitigation strategies were implemented with no change in annual allowable cut, suggesting that the measures may be feasible and offer some promise in terms of managing ECA to reduce the hazards associated with hydrologic change.

Implementing these strategies did result in substantial decline in overall hazard to aquatic ecosystems (Figure 25). The largest differences relative to the Higher Natural Disturbance Scenario were simulated to occur in Weary Creek and Alexander, with hazard reductions of 50% and 53%, respectively. Again, this is primarily a function of reducing road densities near streams, which functionally would reduce hazard by reducing angler access, sediment delivery, and stream fragmentation. Within the context of current and future development, it is not likely that road densities will be reduced to these levels. In addition, there is currently no information on the influence of roads on WCT populations in the Elk Valley; therefore, it would be unreasonable to implement this strategy across the study area. However, studies have shown significant negative effects of road densities on WCT abundance, particularly roads near streams (Valdal and Quinn, 2011), so justification could be made to reduce road disturbance in these areas.

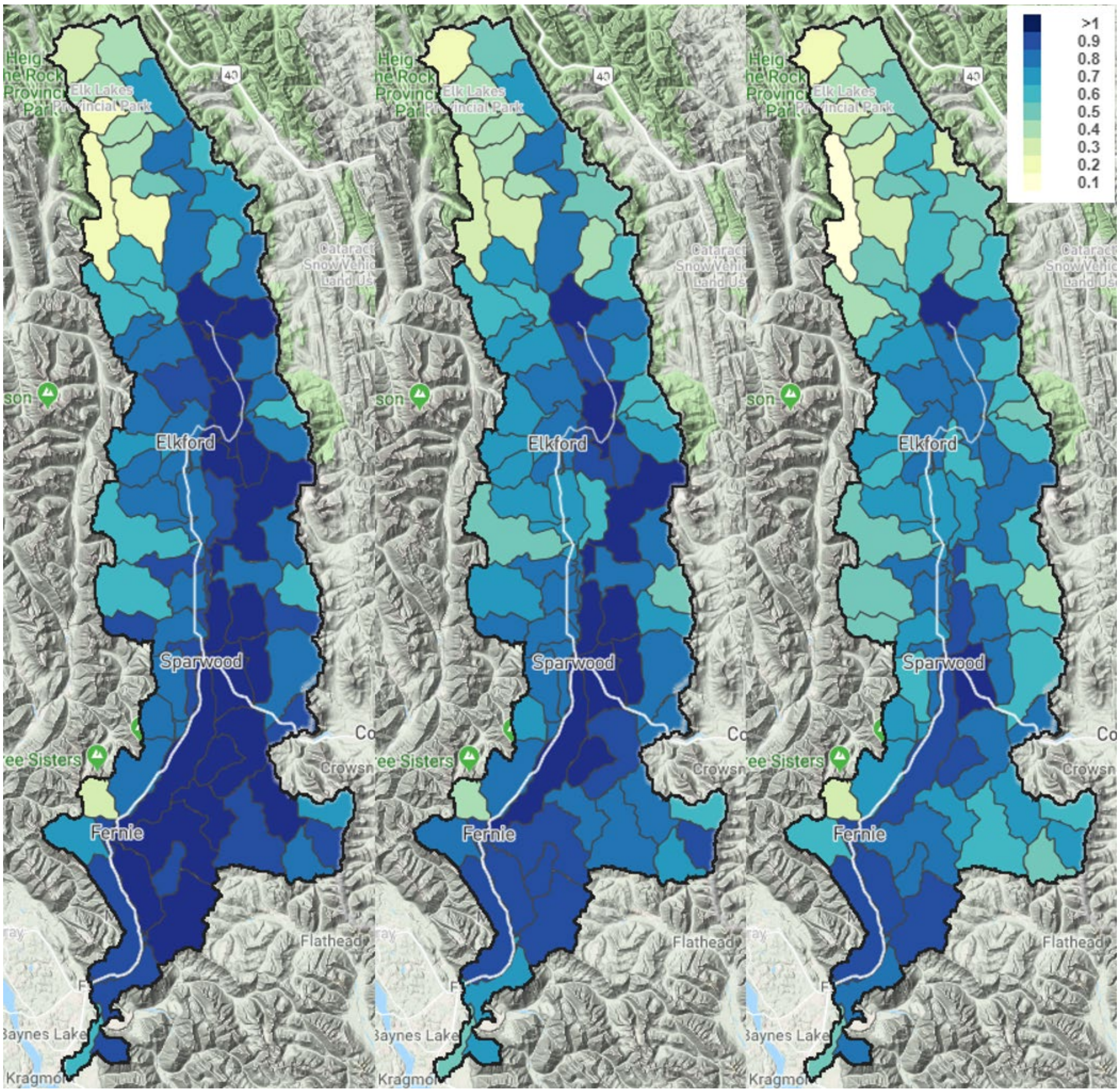

Figure 25 A comparison of the roll up hazard at the end of 50-year simulations of the Higher Natural Disturbance, Moderate Mitigation, and Intensive Mitigation scenarios (left to right). Hazard is calculated as a roll-up of 5 indicators for 78 AWs in the Elk Valley. The roll-up classified a low rating where the normalized score fell below 0.4 and a high rating where the normalized score goes above 0.8

Mitigation strategies were evaluated in terms of their effectiveness, where differences in roll-up hazard were evaluated through the implementation of intensive mitigation within each AW. The improvement in indicator performance (i.e. lower roll-up hazard) was then normalized by dividing each AW's improvement by the maximum improvement occurring across all AW's. The result was a mitigation effectiveness index ranging from 0 to 1, with a higher value indicating greater VC improvement.

Mitigation effectiveness was highest in the southern and east-central portions of the Elk Valley (Figure 26), where road density creates higher hazard for WCT. This highlights areas where mitigation may be most effective and where future work could be targeted. Interestingly, there is also a temporal aspect that must be considered. For example, mitigation implemented now may be more effective in specific AWs at later time periods. This temporal aspect should be considered when evaluating where and when to implement mitigation.

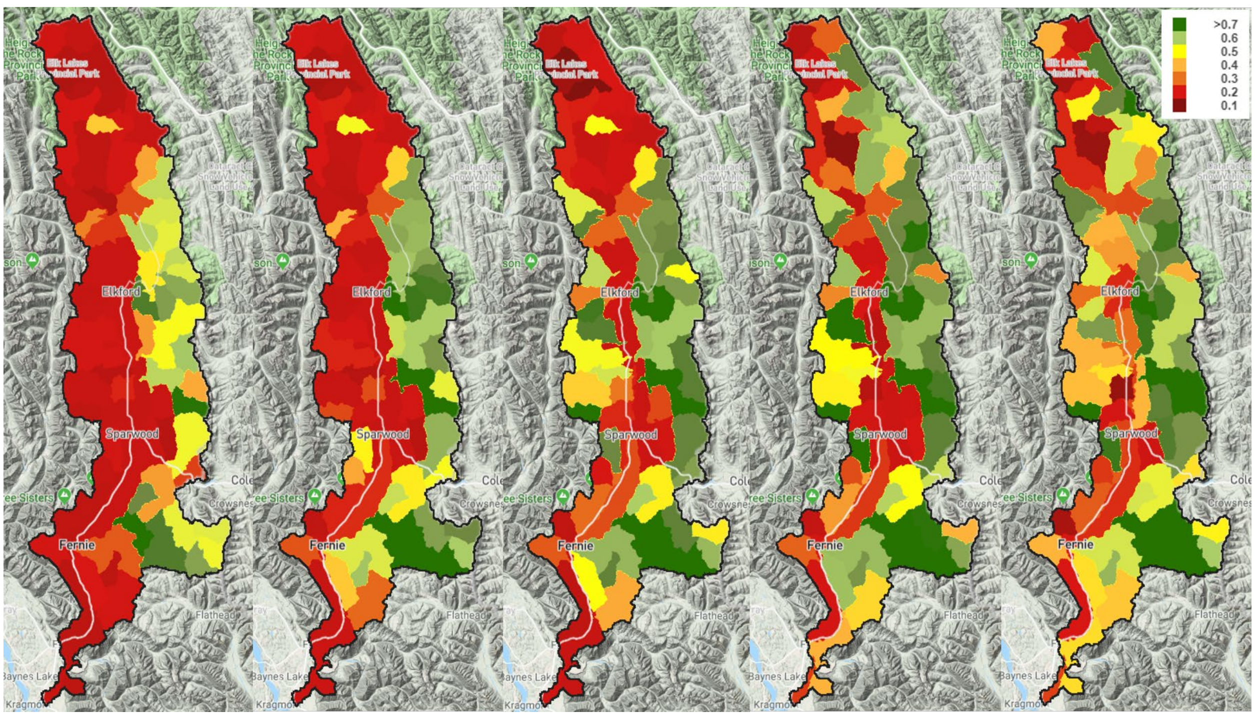

Figure 26 Mitigation effect for the roll-up score under the Higher Natural Disturbance Scenario and Intensive mitigation in each future decade (from left to right), where higher effect is indicated in green and lower effect is indicated in red. Mitigation effectiveness index ranges from 0 (red) to 1 (green), with a higher value indicating greater indicator improvement.

4.3 Operational Management Responses

Operational responses include consideration of site- or project-level guidance or implementation of measures to mitigate the effects of projects or activities, typically undertaken by proponents. These include the mitigation measures described in section 4.2 above.

Proposed mitigation is ideally left until field assessment confirms the likelihood of impact and the requirement for mitigation. Field assessments should also then prescribe which mitigation is appropriate and to what extent. Sensitivity to hydrologic impacts can differ depending on unique watershed characteristics. However, until field work is completed, management decisions must consider the potential impacts identified by the CEMF and restrict permitting for development if need be. Besides restricting development, some of these potential management decisions prior to field work could be:

Natural Disturbances:

- **Fire** – Fire can dramatically alter forest structure and watershed-scale processes. Fire is a natural and required part of long-term cycles that play a key role in shaping aquatic and terrestrial environments. However, there is often desire to salvage harvest post-fire. The combined effects of harvest and fire pose substantial threat to riparian forests and aquatic ecosystems. Potential mitigation measures include:
    - Planting post-fire
    - Post-fire salvage harvest, where the goal is to not further disturb riparian areas or significantly affect runoff regimes

- **Pests** – Like fire, pests can alter riparian forest structure. Potential mitigation measures for pests include:
    - Permitting for proposed development should acknowledge nearby pest outbreaks and the potential direction of infestation movement (particularly for spruce budworm). These areas could be targeted for harvest, if appropriate
    - Carefully designed salvage harvest to help mitigate the spread of pests

- **Stream temperature** – Changes in stream temperature pose a substantial threat to WCT populations by isolating and constricting habitat. It is likely that stream temperature regimes will shift under future climates. Potential mitigation measures for adapting to climate change effects include:
    - Maintain and restore healthy riparian areas to increase stream shading
    - Avoid altering the hydrologic regime though human disturbance, limit ECA with an aim to de-synchronize runoff so that groundwater can be recharged slowly
    - Maintain healthy stream channels and avoid over-widening through recreation and industrial activity (wider streams are susceptible to warming)
    - Impose angling closures when stream temperatures are high in the summer

Anthropogenic Disturbances:

- **Agriculture** – Agriculture has removed or degraded riparian areas in many cases through land conversion or grazing. This has resulted in a net loss of riparian forests. Potential mitigation measures include:

    - Riparian planting and fencing (connect with existing programs) - good examples are Cows and Fish in Alberta or the B.C. Cattlemen's Association where fencing riparian areas have been shown to be an effective mitigation strategy

- **Forestry** – Effects of forestry are related to riparian harvest and removal of upland vegetation. The effects of forestry roads are described below. Possible forestry-related mitigation measures include:

    - Early planting and stand enhancement (e.g. brushing). This may have negative consequences for other VCs like grizzly bear
    - Where there is high hazard for floods, limited increased ECA may be acceptable where the development will not significantly add to peak flows
        - For example: Selective tree harvest with <30% basal area removal will help keep the forest canopy intact; small openings (< 2 tree heights); harvest in the lower part of the AW (<H70); or where runoff is desynchronized from peak flows
    - Retain riparian forests on some small streams (e.g. S6 that are wider than 1 m or those with perennial flow)

- **Mining** – Historical mining practices have buried many streams and riparian areas with spoil from the mining process. This has resulted in the loss of aquatic and terrestrial habitats. Possible mitigation measures of mining-related disturbance include:

    - Prompt re-vegetation of riparian areas and stream restoration/habitat offsetting.
    - Altered waste rock dump design, where valley fill is not required

- **Roads** – Effects of high road density include: increased sediment input, altered hydrologic regimes (peak/low flows), increased angler access, and increased stream fragmentation. Possible mitigation measures include:
    - Remove existing hanging culverts, with thought given to possible negative effects (ex. increased hybridization risk) and funding - Tributary Evaluation Program.
    - Install effective stream crossing structures, such as bridges, where needed.
    - Improve engineering of roads/crossing structures in the future (i.e. for reduced sediment input, reduced fragmentation, etc.)
    - Maintain or rehabilitate roads to minimize sediment input
    - Deactivate roads near streams where possible - this could include varied levels of deactivation from cross ditching to minimize hydrologic effects to complete road roll back in highly sensitive areas

- **Hybridization** – Hybridization with rainbow trout is often cited as the greatest threat to WCT. Possible mitigation measures include:
    - Control source populations of invasive fish to avoid further gene mixing:
        - Stock only sterilized (triploid) rainbow trout in the Kootenay Region
        - Limit stocking of any rainbow trout (including triploid) in lakes with outlets to native WCT habitat

        - Determine feral sources of rainbow trout through genetic sampling
    - Retain existing structures like falls or culverts that are preventing further spread of invasive genes
    - Mitigate for stream temperature changes – healthy riparian buffers and low ECA/road densities can help regulate stream temperatures, which is important in pure WCT populations
    - Reconstruct or rehabilitate stream channels; this would include improving degraded stream channels so that they function better for all life stages of WCT
    - Employ compensation/offsetting for permanent disturbances

4.4 TACTICAL MANAGEMENT RESPONSES

Tactical management responses include processes to improve consistency and/or coordination in applying current policy direction, or to seek further information, that may be undertaken by government, proponents, stakeholders and/or First Nations. This can include assessment, monitoring, evaluation, research, coordination, collaboration, guidelines, management plans, etc.

The analysis conducted to date indicates past and future disturbance patterns and can be used to direct tactical mitigation efforts in the Elk Valley. These efforts should aim to reduce uncertainty in the understanding of how aquatic ecosystems are responding to disturbance.

Below are potential tactical-level management responses:

- Develop a Fish Sustainability Index (FSI), like the approach conducted by the Alberta Environment and Parks Fish and Wildlife Division (MacPherson *et al*., 2014). The FSI was developed to enable consistent fish stock assessment and provide a provincial-scale evaluation of the status and sustainability of fish species. The FSI is used in the following ways (Source: http://aep.alberta.ca/fish-wildlife/fisheries-management/fish-sustainability-index/default.aspx):
    - To allow for broad comparisons to changes in fish species sustainability and population trend over time;
    - To allow for comparisons between fish sustainability and management action;
    - To direct effective future recovery and management actions;
    - To educate decision-makers, conservation partners, private industry and the public on the status and risk of fish species compared to historical levels, how the condition of surrounding watershed is influencing fish population health, and threats that may jeopardize population persistence; and
    - To provide information to assist in the development of specific watershed restoration plans and integrated watershed strategies.
- Develop and conduct an inventory of stream crossings. A stream crossing assessment should first focus on high (pure WCT) fishery value areas (e.g. upper Fording River and Grave Creek). This assessment would feed into the development of a fragmentation index that is focused on maintaining habitat connectivity in order to promote the recovery and resilience of WCT populations

- Conduct hydrologic assessments in watersheds where hazard ratings are high to understand potential for mitigation
- Provide education to riparian land owners/stewards. Riparian planting within existing subsidy program
- Provide education for Municipalities/RDEK on maintaining aquatic ecosystem and riparian health
- Conduct comprehensive benthic invertebrate monitoring
- Conduct research on small stream riparian buffers and properly functioning condition
- Develop Regional ECA limits (from post-field assessments)
- Monitor selenium and other contaminants through the EVWQP
- Regulate angling pressure – This is the most accessible lever to pull and can have a great impact considering number of angler days on the Elk River and its tributaries. Classified waters angling management plan provides a direct mechanism for reducing angling pressure
- Implement a long-term population abundance monitoring project for juvenile and adult WCT in the Elk River using PIT (Passive Integrator Transponder Units) tag mark-recapture methods (recommended option from feasibility and cost analysis for the Elk River)
- Model water quantity (supply and demand) to fully assess potential future conditions. This modelling should tie into existing monitoring throughout the study area.
- Monitor stream temperature throughout the Elk Valley, with a study design that is adequate for informing stream temperature models

4.5 Strategic Management Responses

Strategic management responses include measures to define or establish strategic direction for the management of land and/or resource values, typically led or coordinated by government. This can include new objectives for valued components, new acts and/or regulations.

The overall strategic goal should be to maintain healthy and diverse aquatic ecosystems. Diverse ecosystems ultimately have the resiliency required to withstand current and potential future disturbance. Resilient aquatic ecosystems should support genetically diverse, abundant fish populations with appropriate age class distributions by providing adequate protection to fish themselves and to the habitat in which they live. Likewise, healthy riparian ecosystems should also support a range of terrestrial species with complex habitat. Obtaining this overall goal requires strategic direction and action.

- Establish “no go zones” for future mining development in critical tributary systems, such as the Chauncey and Ewin Creek sub-basins, which are the last tributaries in the Upper Fording watersheds that are still relatively undisturbed. Both watersheds have moderate total fish habitat; however, they represent important tributary streams
- FLNRORD should develop specific legal objectives for WCT populations and habitat
- Develop and implement policy and legislative changes for Private Managed Forest that are consistent with the FRPA to maintain riparian areas, stream habitat, and overall healthy watersheds

- Develop Riparian Reserve Zones (no harvest areas) or Riparian Management Zone (harvest with prescribed partial retention of trees) for small streams as determined by the District manager of FLNRORD
- Establish a Water Sustainability Act pilot project to explore regulatory and policy requirements at the watershed scale through Section 43 (Water Objectives) – (in process)
- Implement regulation changes. Options include: angling closures, removal of kill zones for WCT (catch and release only), classified waters and more stringent angling regulations for the entire Elk River, such as what has been done for Michel Creek. Michel Creek became a classified water in 2015, separate from the Elk River, after an Angling Management Review, which resulted in significant reductions in angling pressure through catch and release regulations and seasonal closures

4.6 Conclusions

Mitigating hazard to aquatic ecosystems presents a substantial challenge. Although uncertainty is inherent in this assessment, results suggest that targeted management actions can be taken to reduce hazard. Specifically, reducing the cumulative effects of angler access and potential for water quality, aquatic and riparian habitat degradation will ultimately result in more resilient aquatic ecosystems. Modelling results demonstrated that operational measures like deactivating roads and managing harvest levels yield substantial benefits in some cases. Tactical management responses such as improved monitoring and research directed at linking indicators with fish population status are critical. Likewise, strategic shifts in regulation and policy that protect fish and fish habitat are needed. Integrating these levels of management response through the Elk Valley CEMF is key to the long-term sustainability of aquatic ecosystems and the success of the CEMF.

5.0 Recommendations for future CE Assessments

Analysis conducted for the Elk Valley CE Assessment relied upon available datasets, expert opinion, and research. This was the first CE Assessment conducted for the Elk Valley and is reflective of numerous inputs from the Expert Teams and the Working Group. Given that this was the first attempt at CE Assessment for the Elk Valley, there are a number of recommendations to improve future iterations of this assessment. These include but are not limited to:

- Updates to data and indicators
    - Include more refined soils mapping and comprehensive Terrain Stability mapping to improve estimates of erosion potential
    - Include coupled slopes and streams (developed in FSW project)
    - Include watershed characteristics affecting peak streamflow (being developed in FSW)
    - Incorporate a recovery curve for riparian functions (i.e. in-stream wood recruitment, shading, bank stability, and water quality) following harvest, fire, and pest infestation

  - Include updated Watershed Assessment Standards being developed by Association of Professional Engineers and Geoscientists
  - Include an indicator of WCT habitat loss
  - Include an indicator of fishing pressure
  - Develop quantitative hypotheses for the effects of indicators on aquatic ecosystems (similar to the Fish Sustainability Index)
  - Include an assessment of water quantity (supply and demand)
  - Develop stream temperature benchmarks specific to WCT in the Elk Valley
  - Incorporate water quality indicators

- Updates to CE assessment methods
  - Include a wider range of potential future conditions in prospective assessment, considering a maximum potential development scenario
  - Include an analysis of the Range of Natural Variability (RoNV) for riparian disturbance to support the refinement of benchmarks

6.0 REFERENCES

Allendorf, F.W., and R.E. Leary. 1988. Conservation and distribution of genetic variation in a polytypic species, the cutthroat trout. Conservation Biology 2:170-184.

B.C. Conservation Data Centre. 2017. Species Summary: *Oncorhynchus clarkii lewisi*. B.C. Ministry of Environment. Available: http://a100.gov.bc.ca/pub/eswp/ (accessed May 25, 2017).

B.C. Conservation Framework. 2017. Conservation Framework Summary: *Oncorhynchus clarkii lewisi*. B.C. Ministry Of Environment. Available: http://a100.gov.bc.ca/pub/eswp/(accessed May 25, 2017).

B.C. Ministry of Environment. 2001. Water Quality Guidelines for Temperature: Overview Report., B.C. Ministry of Environment, Victoria, BC. 12 pp.

B.C. Ministry of Environment. 2014. Management plan for the Westslope Cutthroat Trout (*Oncorhynchus clarkii lewisi*) in British Columbia. Repr. of 1st ed., B.C. Ministry of Environment, Victoria, BC. 98 pp. (Orig. pub. 2013).

B.C. Ministry of Forests, Lands, and Natural Resource Operations (FLNRO). 2014. Wildfire Management Branch Discussion Paper – Proactive Wildfire Threat Reduction. Victoria, B.C. FNR-2014-00274. 379 pp.

B.C. Ministry of Forests. 2001. Interior Watershed Assessment Procedure (IWAP) Guidebook. 2nd ed., Version 2.1. Forest Practices Branch, B.C. Ministry of Forests, Victoria, B.C. Forest Practices Code of British Columbia Guidebook.

B.C. Ministry of Forests and BC Environment, 1995. *Biodiversity guidebook-forest practices code of British Columbia.,* Victoria, British Columbia: Ministry of Forests and Ministry of Environment.

Bear, E.A., T.E. McMahon, and A.V. Zale. 2007. Comparative thermal requirements of westslope cutthroat trout and rainbow trout: Implications for species interactions and development of thermal protection standards. Transactions of the American Fisheries Society. 136: 1113-1121.

Ben-David, M., T.A. Hanley, and D.M. Schell. 1998. Fertilization of terrestrial vegetation by spawning Pacific salmon: The role of flooding and predator activity. Oikos 83(1): 47-55.

Bennett, S.N. 2007. Assessing the Extent of Hybridization Between Westslope Cutthroat Trout and Introduced Rainbow Trout in the Upper Kootenay River, British Columbia. PhD thesis, Utah State University.

Burke, S. 2014. Michel Creek Retrospective Assessment: An Assessment of Selected Riparian and Fish Habitat Indicators. University of Waterloo. Commissioned for the Elk Valley Cumulative Effects Management Framework (CEMF).

Buttle, J. M. 2011. The effects of forest harvesting on forest hydrology and biogeochemistry. In Forest Hydrology and Biogeochemistry (pp. 659-677). Springer, Dordrecht.

Boulanger, Y., S. Gauthier, and P.J. Burton. 2014. A refinement of models projecting future Canadian fire regimes using homogeneous fire regime zones. Canadian Journal of Forest Research 44: 1-12.

Carlson, M., B. Stelfox, N. Purves-Smith, J. Straker, S. Berryman, T. Barker, and B. Wilson. 2014. ALCES Online: Web-delivered Scenario Analysis to Inform Sustainable Land-Use Decisions. In: D.P. Ames, N.W.T. Quinn and A.E. Rizzoli (Eds.). Proceedings of the 7th International Congress on Environmental Modelling and Software. June 2014, San Diego, California.

Carscadden, K. and S. Rogers. 2011. Genetic analysis of Westslope Cutthroat Trout from the upper Fording River drainage, British Columbia. Report prepared for Golder Associates Ltd., Calgary, AB.

Cleator, H., J. Earle, L. Fitch, S. Humphries, M. Koops, K. Martin, D. Mayhood, S. Petry, C. Pacas, J. Stelfox, and D. Wig. 2009. Information relevant to a recovery potential assessment of pure native Westslope Cutthroat Trout, Alberta population. Department of Fisheries and Oceans. Canadian Science Advisory Secretariat Research Document. 2009/036. iv + 26 pp.

COSEWIC. 2006. COSEWIC assessment and update status report on the westslope cutthroat trout *Oncorhynchus clarkii lewisi* (British Columbia population and Alberta population) in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. vii + 67 pp. (www.sararegistry.gc.ca/status/status_e.cfm).

Cumulative Effects Framework (CEF). 2016. Aquatic Ecosystems – Value Summary: Executive Summary to the Aquatic Ecosystems Assessment Protocol. 25 pp.

Cumulative Effects Assessment Methods for Aquatic Ecosystems in British Columbia Standards for British Columbia's Values Foundation (BCVF). Version 1.1 (Oct 2016). Prepared by the Aquatic Ecosystems Working Group – Ministries of Environment and Forest, Lands and Natural Resource Operations – for the Value Foundation Steering Committee. 31 pp.

Duinker, P. and Greig, L. 2005. The Impotence of Cumulative Effects Assessment in Canada: Ailments and Ideas for Redeployment. Environmental Management Vol. 37, No. 2, pp. 153–161

Eaglin, G.S., and W.A. Hubert. 1993. Management Briefs: Effects of logging roads on substrate and trout in streams of the Medicine Bow National Forest, Wyoming. North American Journal of Fisheries Management. 13(4): 844–846.

Fernandez, D., J. Barquin, M. Alvarez-Cabria, and F.J. Penas. 2012. Quantifying the performance of automated GIS-based geomorphological approaches for riparian zone delineation using digital elevation models. Hydrology and Earth System Science. 16: 3851-3862.

Fisheries and Oceans Canada. 2016. Management Plan for the Westslope Cutthroat Trout (Oncorhynchus clarkii lewisi), British Columbia Population, in Canada [Proposed]. Species at Risk Act Management Plan Series. Fisheries and Oceans Canada, Ottawa. iv + 115 pp.

Forest Practices Code Riparian Management Area Guidebook. 1995.

Forman, R.T.T and L.E Alexander. 1998. Roads and their major ecological effects. Annual Review of Ecology and Systematics 29(1): 207-231

Grant, G.E., S.L. Lewis, F.J. Swanson, J.H. Cissel, and J.J. McDonnell. 2008. Effects of forest practices on peak flows and consequent channel response: A state-of-science report for western Oregon and Washington. General Technical Report PNW-GTR-760. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 76 pp.

Green, K. C., and Y. Alila, 2012. A paradigm shift in understanding and quantifying the effects of forest harvesting on floods in snow environments, Water Resources Research. 48, W10503, doi:10.1029/2012WR012449.

Gregory, S.V. 1991. An ecosystem perspective of riparian zones. BioScience. 41(1): 540 – 551.

Haas, G. 1998. Indigenous fish species potentially at risk in BC, with recommendations and prioritizations for conservation, forestry/resources use, inventory and research. B.C. Ministry of Fisheries. Vancouver, B.C. Fisheries Management Report No. 105.

Hagans, D.K., W.E. Weaver, and M.A. Madej. 1986. Long term on-site and off-site effects of logging and erosion in the Redwood Creek Basin, Northern California. In *American Geophysical Union meeting on cumulative effects.* Technical bulletin 490(1): 38-65.

Hamilton, S.J. 2004. Review of selenium toxicity in the aquatic food chain. Science of the Total Environment, 326: 1-31.

Hansen, P.L/. R.D. Pfister., K. Boggs., B.J. Cook., J. Joy, and D.K. Hinckley. 1995. Classification and management of Montana's riparian and wetland sites. Miscellaneous

Publication No. 5. Montana Forest and Conservation Experiment Station. School of Forestry, University of Montana Missoula. 646 pp.

Health Canada. 2014. Guidelines for Canadian Drinking Water Quality: Guideline Technical Document — Selenium. Water and Air Quality Bureau, Healthy Environments and Consumer Safety Branch, Health Canada, Ottawa, Ontario. Catalogue No H144-13/4-2013E-PDF

Heidt, K.D. 2003. Elk River Creel Survey 2002 - Quality Waters Strategy (River Guardian Program). Prepared for B.C. Ministry of Water, Land and Air Protection, Kootenay Region, Cranbrook, B.C. 24 pp.

Heidt, K.D. 2014. Five Year Summary of the Kootenay Region River Guardian Program (2009-2013). B.C. Ministry of Forest, Lands and Natural Resource Operations.

Hilderbrand, R. and J. Kershner. 2000. Movement patterns of stream resident cutthroat trout in Beaver Creek, Idaho-Utah. Transactions of the American Fisheries Society. 129(1): 1160– 1170.

Hogan, D.L. and S.A. Bird. 1998a. Forest management and channel morphology in small coastal watersheds: Results from Carnation Creek and the Queen Charlotte Islands. In M.K. Brewin and M.M.A. Monita (Tech Coords). (Forest-Fish Conference: Land Management Practices Affecting Aquatic Ecosystems. Proc. Forest-Fish Conf.) May 1-4, 1996, Calgary Alberta. Natural Resources Canada. Canadian Forest Service. Northern Forestry Centre Edmonton, Alberta. Inf. Rep. NOR-X-356, pp. 209-226.

Hogan, D.L. and S.A. Bird. 1998b. Stream channel assessment procedures. In Carnation Creek and Queen Charlotte Islands Fish/Forestry Workshop: Applying 20 Years of Coastal Research to Management Solutions. D. Hogan, P. Tschaplinski, and S. Chatwin (editors). Ministry of Forests, Research Branch, Land Management Handbook No. 41, Victoria, British Columbia, pp. 189-200.

Hogan, D.L., S.A. Bird, and M.A. Hassan. 1998a. Spatial and temporal evolution of small coastal gravelbed streams: The influence of forest management on channel morphology and fish habitats. In Gravel-Bed Rivers in the Environment, Gravel-Bed Rivers iv. Edited by P.C. Klingeman, R.L. Beschta., P.D. Komar, and J.B. Bradley, Water Resources Publications, Chapter 17, pp. 365-392.

Hogan, D.L., A. Cheong, and J. Hilger. 1998b. Channel morphology of small central interior streams: Results from the Stuart Takla Fish/Forestry Interaction Program. In M.K. Brewin and M.M.A. Monita (Tech Coords). (Forest-Fish Conference: Land Management Practices Affecting Aquatic Ecosystems. Proc. Forest-Fish Conf.) May 1-4, 1996, Calgary Alberta. Natural Resources Canada. Canadian Forest Service. Northern Forestry Centre Edmonton, Alberta. Inf. Rep. NOR-X-356, pp. 209-226.

Isaak, D.J., S. Wollrab, D. Horan, and G. Chandler. 2011. Climate change effects on stream and river temperatures across the northwest U.S. from 1980-2009 and implications for salmonid fishes. Climatic Change. DOI 10.1007/s10584-011-0326-z.

Jakober, M., T. McMahon, R. F. Thurow, and C. Clancy. 1998. Role of stream ice on fall and winter movements and habitat use by bull trout and cutthroat trout in Montana headwater streams. Transactions of the American Fisheries Society. 127: 223-235.

Jones, J. A., F. J. Swanson, B. C. Wemple, and K. U. Snyder. 2000. Effects of roads on hydrology, geomorphology, and disturbance patches in stream networks. Conservation Biology. 14(1): 76-85.

Jones, L. A. 2016. Predicting climate-induced impacts on seasonal stream temperatures in the crown of the continent ecosystem. Dissertation presented in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Systems Ecology. The University of Montana, Missoula, MT. December 2016.

Jones, L. A., C. C. Muhlfeld, L. A. Marshall, B. L. McGlynn, and J. L. Kershner. 2013. Estimating thermal regimes of bull trout and assessing the potential effects of climate warming on critical habitats. River Research Applications. DOI: 10.1002/rra.

Lamson, H. 2018. Evaluation of current westslope cutthroat trout hybridization levels in the Upper Kootenay drainage. Project Year 3 (2017/18). UKE-F18-F-2461. Prepared for the Fish and Wildlife Compensation Program.

Luce, C. H. 2002. Hydrological processes and pathways affected by forest roads: What do we still need to learn? Hydrological Processes. 16: 2901-2904.

MacDonald, R. J., S. Boon, J. M. Byrne, M. D. Robinson, and J. B. Rasmussen. 2014. Potential future climate effects on mountain hydrology, stream temperature, and native salmonid life history. Canadian Journal of Fisheries and Aquatic Sciences. 71: 189-202.

MacDonald, R. J., and L.A. Jones. 2016. Stream temperature modelling for the eastern-slopes of the Rocky Mountains. Prepared for Alberta Environment and Parks.

MacPherson, L., M. Coombs, J. Reilly, M. G. Sullivan, and D. J. Park. 2014. A Generic Rule Set for Applying the Alberta Fish Sustainability Index, Second Edition. Environment and Sustainable Resource Development, Edmonton, Alberta, Canada. 51 pp.

Mayhood, D. W. 1999. Provisional evaluation of the status of Westslope Cutthroat Trout in Canada. In L. M. Darling (ed). Proceedings of the Biology and Management of Species and Habitats at Risk, Kamloops, BC, 15–19 February, 1999. B.C. Ministry of Environment, Lands and Parks, Victoria, B.C., and University College of the Cariboo, Kamloops, B.C. pp 579-585.

McPhail, J. D. 2007. The freshwater fishes of British Columbia. University of Alberta Press, Edmonton, AB. 696 pp.

McPhail, J. D. and R. Carveth. 1992. A Foundation for Conservation: The Nature and Origin of the Freshwater Fish Fauna of British Columbia. Report from the University of British Columbia Fish Museum, and Department of Zoology, Vancouver, B.C.

Muhlfeld, C. C., R. P. Kovach, R. Al-Chokhachy, S. J. Amish, J. J. Kershner, R. F. Leary, W. H. Lowe, G. Luikart, P. Matson, D. A. Schmetterling, B. B. Shepard, P. A. H. Westley, D. Whited, A. Whiteley, and F. W. Allendorf. 2017. Legacy introductions and climate variation explain spatiotemporal patterns on invasive hybridization in native trout. Global Change Biology. DOI: 10.1.111/gch.13681.

Muhlfeld, C. C., S. T. Kalinowski, T. E. McMahon, M. L. Taper, S. Painter, R. F. Leary, and F. W. Allendorf. 2009. Hybridization rapidly reduces fitness of a native trout in the wild. Biology Letters. 5:328–331.

Naiman, R. J. and H. Decamps. 1997. The ecology of interfaces—riparian zones. Annual Review of Ecology and Systematics. 28: 621 – 658.

Naiman, R. J., R. E. Bilby, and P. A. Bisson. 2000. Riparian ecology and management in the Pacific coastal rain forest. BioScience. 50: 996 – 1011.

Nelitz, M. A., E.A. MacIsaac, and R.M. Peterman. 2006. A science-based approach for identifying temperature-sensitive streams for rainbow trout. North American Journal of Fisheries Management. 27: 405-424.

Park, D., M. Sullivan, E. Bayne, and G. Scrimgeour. 2008. Landscape-level stream fragmentation caused by hanging culverts along roads in Alberta's boreal forest. Canadian Journal of Forest Research. 38: 566-575.

Peterson, G.D., G.S. Cumming, S.R. Carpenter. 2003. Scenario planning: a tool for conservation in an uncertain world. Conservation Biology 17(2): 358-366.

Poole, G. C. and C. H. Berman. 2001. An ecological perspective on in-stream temperature: Natural heat dynamics and mechanisms of human-caused thermal degradation. Environmental Management. 27: 787-802.

Prichard, D. 1998. A User Guide to Assessing Proper Functioning Condition and the Supporting Science for Lotic Areas. Riparian Area Management Technical Reference 1737-15. U.S. Department of the Interior. Bureau of Land Management. National Applied Resource Sciences Center. Denver, CO.

Prichard, D., C. Bridges, S. Leonard, R. Krapf, and W. Hagenbuck. 1994. Riparian area management: process for assessing proper functioning condition for lentic riparian-wetland areas. Technical Reference 1737-11. U.S. Department of the Interior. Bureau of Land Management. Service Center. Denver, CO. 46 pp.

PSCIS. 2011. Provincial Stream Crossing Inventory System. http://www.for.gov.bc.ca/ftp/hcp/external/!publish/web/fia/PSCIS-User-Guide.pdf Government of British Columbia. July 2011.

Richardson, J. S., and R. D. Moore. 2010. Stream and Riparian Ecology. In Compendium of Forest Hydrology and Geomorphology in British Columbia. R.G. Pike, T.E. Redding, R.D. Moore, R.D. Winker, and K.D. Bladon (eds). B.C. Ministry of Forests and Range, Forest Science Program, Victoria, B.C., and FORREX Forum for Research and Extension in Natural Resources, Kamloops, BC Land Management Handbook. 66(2): 441-460.

Riparian Area Management Guidebook. 1995. Forest Practices Code, Province of B.C. https://www.for.gov.bc.ca/tasb/legsregs/fpc/fpcguide/riparian/Rip-toc.htm B.C. Ministry of Forests Lands and Natural Resource Operations. Victoria, B.C.

Ripley, T., G. Scrimgeour, and M. S. Boyce. 2005. Bull trout (*Salvelinus confluentus*) occurrence and abundance influenced by cumulative industrial developments in a Canadian boreal forest watershed. The Canadian Journal of Fisheries and Aquatic Sciences. 62: 2431-2442.

Rothwell, R. L., 1983. Erosion and sediment control at road-stream crossings. The Forestry Chronicle. 52(2): 62-66.

Rubidge, E. 2003. Hybridization and introgression between introduced rainbow trout (*Oncorhynchus mykiss*) and native westslope cutthroat trout (*O. clarkii lewisi*) in the Upper Kootenay River drainage, B.C. M.Sc. Thesis. Dept. of Zoology. University of British Columbia, Vancouver, B.C.

Shepard, B. B., B. E. May, and W. Urie. 2005. Status and conservation of westslope cutthroat trout within the western United States. North American Journal of Fisheries Management. 25:1426-1440.

Shepard, B. B., L. Sanborn, L. Ulmer, and D. C. Lee. 1997. Status and risk of extinction for Westslope Cutthroat Trout in the upper Missouri River basin, Montana. North American Journal of Fisheries Management. 17:1158–1172.

Swanston, D. N. 1991. Natural processes. In W.R. Meehan (editor). Influences of Forest and Rangeland Management on Salmonid Fishes and their Habitats. American Fisheries Society. Special Publication. 19: 139-179.

Teck Resources Limited. 2014. Elk Valley water quality plan. Teck Resources Limited, Sparwood, British Columbia. xxxii + 256 pp.

Thompson, R. Unpublished. Assessing fish passage at culverts - The method, its metrics and the preliminary findings from over 4000 assessments. Ministry of Environment. https://www.for.gov.bc.ca/hfp/fish/fishpassage.html.

Thurow, R. F., D. C. Lee, and B. E. Rieman. 1997. Distribution and status of seven native salmonids in the interior Columbia River basin and portions of the Klamath River and Great Basins. North American Journal of Fisheries Management. 17:1094–1110.

Tripp, D. B., P. J. Tschaplinski, S. A. Bird and D. L. Hogan. 2009. Protocol for evaluating the condition of streams and riparian management areas (Riparian management routine effectiveness evaluation). Version 5.0. Forest and Range Evaluation Program, B.C. Ministry of Forests and Range, and the B.C. Ministry of Environment. Victoria, BC. 111 pp.

Tschaplinski, P. J. and R. G. Pike. 2010. Riparian management and effects on function. In Compendium of Forest Hydrology and Geomorphology in British Columbia. R.G. Pike, T.E. Redding, R.D. Moore, R.D. Winker, and K.D. Bladon (eds). B.C. Ministry of Forests and Range, Forest Science Program, Victoria, B.C., and FORREX Forum for Research and Extension in Natural Resources, Kamloops, BC Land Management Handbook. 66(2): pp.497 – 525.

Valdal, E. J. and M. S. Quinn. 2011. Spatial analysis of forestry related disturbance on westslope cutthroat trout (*Oncorhynchus clarkii lewisi*): Implications for policy and management. Applied Spatial Analysis. 4: 95-111.

Walker L., R. MacDonald, S. McPherson, C. Barnes, C. Cipriano, G. Preston, M. Clarke, M. Chernos, D. Marcotte, C. Hopkins, and J. Byrne. 2016. Elk River Flood Strategy. Report was prepared for the Regional District of East Kootenay, Columbia Basin Trust, Real Estate Foundation of B.C., and Teck Coal.

Wang, T., A. Hamann, D. Spittlehouse, and T. N. Murdock. 2012. ClimateWNA – High-resolution spatial climate data for western North America. Journal of Applied Meteorology and Climatology. 61: 16-29.

Webb, B.W., D.M. Hannah, R.D. Moore, L.E. Brown, and F. Nobilis. 2008. Recent advances in stream and river temperature research. Hydrological Processes. 22: 902-918.

Winkler, R. D., R. D. Moore, T. E. Redding, D. L. Spittlehouse, B. D. Smerdon, and D. E. Carlyle-Moses. 2010. The effects of forest disturbance on hydrologic processes and watershed response. In Compendium of Forest Hydrology and Geomorphology in British Columbia. R.G. Pike, T.E. Redding, R.D. Moore, R.D. Winker, and K.D. Bladon (eds). B.C. Ministry of Forests and Range, Forest Science Program, Victoria, B.C., and FORREX Forum for Research and Extension in Natural Resources, Kamloops, BC Land Management Handbook. 66(2): 179-212

Winkler, R. and S. Boon. 2015. Revised snow recovery estimates for pine dominated forests in interior British Columbia. B.C. Ministry of Forests, Lands, and Natural Resource Operations. Victoria, B.C. Extension Note 116. www.for.gov.bc.ca/hfd/pubs/Docs/En/En116.htm

Winkler, R. and S. Boon. 2017. Equivalent clearcut area as an indicator of hydrologic change in snow dominated watersheds of southern British Columbia. B.C. Ministry of Forests, Lands, and Natural Resource Operations, Victoria, B.C. Extension Note 118. www.for.gov.bc.ca/hfd/pubs/Docs/En/En118.htm

Woodward, G., D. M. Perkins, and L. E. Brown. 2010. Climate change and freshwater ecosystems: Impacts across multiple levels of organization. Philosophical Transactions of the Royal Society B. 365: 2093-2106.

APPENDIX

A.1 DATA SOURCES

The following datasets were used to develop the disturbance layer and for mapping.

- PEM (Nov 2015)
- BASELINE THEMATIC MAPPING (BTM)
- Mine Disturbance Footprints(TECK)
- BC Hydro Transmission
- BC TANTALIS
- BC Enhanced Thematic Base map (EBM)
- BC TRIM BASEMAPPING
- Canfor Harvest Openings and Reserves
- BC Wildfire Services Historic Fire Polygons
- BC Forest RESULTS (Reporting Silviculture Updates and Land Status Tracking System) - openings and forest cover
- BC TRIM DEM
- BC Freshwater Atlas
- BC VRI
- Digital Road Atlas
- FTA Roads
- ICIS cadastre
- BCTS Harvest openings
- JEMI Fiber Blocks and Reserves
- BC Forest Health Aerial Overview
- TRIM DEM

A.2 Riparian Disturbance Analysis

I) Disturbance types were sequentially updated with this ranking:

1. Road – Paved
2. Road – Loose
3. Rail
4. Transmission
5. Trail
6. Campground
7. Built up
8. Mines
9. Agriculture
10. Forest Disturbances (ranked in descending chronologic order)
    - Harvest
    - Fire
    - Beetle

II) Disturbances were classified by disturbance origin (natural and anthropogenic):

a. Natural Disturbances:
- Bark Beetle
- Fire

b. Anthropogenic Disturbances:
- Harvest
- Mining
- Roads
- Transmission corridors
- Built up areas
- Campgrounds
- Trail
- Rail
- Agriculture

A.3 QUALITY CONTROL GOOGLE EARTH REVIEW

A Google Earth interpretation of disturbance along the Elk River mainstem was conducted to assess the accuracy of the disturbance layer that was used in the assessment for riparian disturbance. That layer was created by combining a variety of spatial inputs by GIS analysts. It should be noted that a limitation of this review is that the categories of the riparian disturbance layer and the Google Earth interpretation are not the same; therefore, a direct comparison cannot be made. The figure below shows an example of the Google Interpretation with an overlay of the disturbance class on top of the 2016 imagery. Interpretation was conducted by Katie Fraser (FLNRORD).

In this example, the only significant discrepancy arises in the portion of the forest that has been impacted by fire. This is understandable given a forest that has regenerated for the past 80 years will not appear markedly different from a forest with no recent fire history.

Table A.3.1

For each disturbance category delineated by the GIS disturbance layer, the total area that was identified as agriculture, urban, natural, logging, mining, linear or forested in a Google Earth interpretation are identified in the matrix below. E.g. 358 ha of what was interpreted as "mining" in Google Earth was categorized as agriculture in the disturbance category.

GIS analysis disturbance category	**Google Earth interpretation category**						
Riparian Disturbance (bank length[m])	**Agriculture**	**Urban**	**Natural**	**Logging**	**Mining**	**Linear**	**Forested**
AGRICULTURE	2458	24	310	281	358	637	1507
BUILT UP	0	176	0	0	0	0	0
FHF_IB	15	0	56	405	0	0	1179
FIRE	405	0	3788	0	0	327	8905
FIRE_p1937	1340	5	29825	6833	76	5413	81333
HARVEST	0	0	5831	2988	0	0	1405
MINE	0	0	0	0	181	30	0
MINE - EVO	0	0	0	0	118	10	385
RAIL	0	0	0	0	0	43	0
ROAD - LOOSE	35	0	250	62	44	386	763
ROAD - PAVED	249	32	175	0	0	1545	770
TRANSMISSION	0	0	253	45	53	460	165

A.4 Assessment Watershed Name and ID

Watershed ID	Assessment Watershed Name	Area (km^2)
3250a	Elk Face Unit - SW of Fernie	84.15
3250b	Elk Face Unit - S of Elko	19.21
3268	Morrissey Creek	84.13
3269	Lizard Creek	45.16
3270	Coal Creek	96.29
3271	Matheson Creek	22.45
3272	Fairy Creek	27.78
3273	McCool Creek	28.90
3274	Lladnar Creek	39.20
3275	Michel Creek - Lower	53.90
3276	Erickson Creek	32.53
3277	Alexander Creek - Lower	84.37
3278	Summit Creek	30.96
3279	Alexander Creek - Mid	34.62
3280	Alexander Creek - Upper	34.96
3281	Wheeler Creek	29.03
3282	Leach Creek	84.15
3283	Marten Creek	41.92
3284	Andy Good Creek	33.95
3285	Corbin Creek	30.33
3286	Michel Creek - Mid 1	68.68
3287	Michel Creek - Mid 2	51.64
3288	Michel Creek - Upper	35.14
3289	Cummings Creek - Lower	32.46
3290	Telford Creek	26.77
3291	Cummings Creek - Upper	74.55
3292	Littlemoor Creek	28.20
3293	Grave Creek	41.95
3294	Harmer Creek	38.98
3295	Nordstrum Creek	26.56
3296	Fording River - Lower	33.72
3297	Line Creek	97.72
3298	Line Creek - South	40.20
3299	Dry Creek	28.39
3300	Ewin Creek	41.79
3301	Todhunter Creek	21.63
3302	Ewin Creek - North	23.26
3303	Chauncey Creek	35.06
3304	Kilmarnock Creek	43.86

3305	Henretta Creek	48.73
3306	Grace Creek	33.56
3307	Greenhills Creek	48.11
3308	Swift Creek	43.23
3309	Lake Mountain & Clode Creeks	42.79
3310	Fording River - Upper	38.72
3311	Brule Creek	86.63
3312	Weigert Creek	45.49
3313	Boivan Creek	38.03
3314	Boivan Creek - South	24.44
3315	Crossing Creek	41.92
3316	Bingay Creek	52.57
3317	Forsyth Creek - Lower	42.90
3318	Quarrie Creek	62.03
3319	Forsyth Creek - Upper	70.51
3320	Aldridge Creek	51.27
3321	Bleasdell Creek	21.76
3322	Weary Creek	21.92
3323	Cadorna Creek	68.14
3324	Cadorna Creek - South	32.39
3325	Abruzzi Creek	26.11
3326	Upper Elk Lakes	44.32
3327	Elk Face Unit - E of Elko	63.27
3328	Elk Face Unit - SE of Fernie	54.14
3329	Elk Face Unit - NE of Fernie	103.51
3330	Hartley Creek	68.43
3331	Elk Face Unit - SW of Sparwood	32.19
3332	Elk Face Unit - NE of Sparwood	42.55
3333	Elk Face Unit - S of Elkford	54.21
3334a	Elk Face Unit - NE of Elkford	
3334b	Elk Face Unit - SW of Elkford	
3335	Elk Face Unit - N of Elkford 1	51.76
3336	Elk Face Unit - N of Elkford 2	48.74
3337a	Hornickel Creek	24.88
3337b	Lowe Creek	23.70
3338	Elk Face Unit - N of Forsyth Cr	95.30
3339	Gardner Creek	37.82
3340	Elk Face Unit - N of Cadorna Cr	50.17
3341	Tobermory Creek	51.41

A.5 List of Current CEMF Working Group Members

#	Name	Organization
1	Taye Ayele	Chair, FLNRORD
2	Marcin Haladaj	FLNRORD
3	Lyle Saigeon	FLNRORD
4	Cassidy van Rensen	FLNRORD
5	Bill Green	KNC
6	Alison Burton	KNC
7	Warn Franklin	Teck Coal Ltd.
8	Steve Hilts	Teck Coal Ltd.
9	Kevin Podrasky	Teck Coal Ltd.
10	Lee-Anne Walker	Elk River Alliance
11	Kari Stuart-Smith	Canadian Forest Products Ltd.
12	Terry Melcer/ Scott Beeching	District of Sparwood/Elkford
13	Andrew McCuaig/ Brian Dureski	CanWel Fibre Corp.
14	Mark Hall	ENV
15	Darin Welch	MoTI
16	Mark Vendrig	North Coal Ltd.
17	John Pumphrey	North Coal Ltd.
18	Jeff Berdusco	North Coal Ltd.
19	Art Palm	NWP Crown Mountain Project
20	Michael Keefer	NWP Crown Mountain Project
VC TEAM LEADS		
1	Peter Holmes	Old & Mature Forest, FLNRORD
2	Herb Tepper	WCT, FLNRORD
3	Alan Davidson	Riparian Habitat. FLNRORD
4	Kim Poole	BHS, Aurora Wildlife Research
5	Garth Mowat	Grizzly bear, FLNRORD
TECHNICAL SUPPORT		
1	William Burt	FLNRORD
2	Rhian Davies	FLNRORD
3	Ryan MacDonald	ALCES Group
3	Kathleen McGuinness	Touchstone GIS Services Inc.