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## The Bowron River Watershed: A Synoptic Assessment of Stream and Riparian Condition 20–30 Years after Salvage Logging

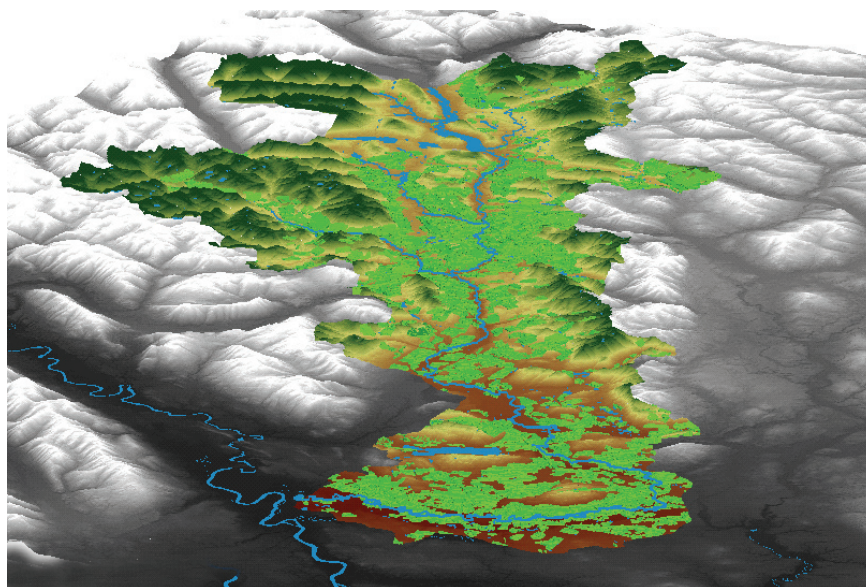
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### Introduction

Challenges associated with the current mountain pine beetle (*Dendroctonus ponderosae*) infestation have prompted investigation into the recovery of the Bowron River watershed, a basin that was extensively logged between the mid-1970s and the mid-1980s in response to a spruce-beetle outbreak. Although harvesting occurred before riparian reserve zones were implemented by the Forest Practices Code, comparisons can still be made because the

*Forest and Range Practices Act* allows for riparian harvesting under specific circumstances. Specifically, harvesting in riparian reserves is permitted under the Forest Planning and Practices Regulation s.51(f) for the purposes of sanitation or s.51(g) damage by insects as long as it will not have a material adverse impact on the riparian zone. Unfortunately, adverse effects may take months or years to manifest. Here we applied the Routine Riparian Effectiveness Evaluation to streams in the Bowron River watershed to identify those watersheds and attributes



affected by harvesting more than 20 years ago. This study follows the Interior Watershed Assessment Procedure (IWAP) completed for the Bowron in the mid-1990s, allowing for some qualitative comparison between techniques as well as identification of watershed recovery. This is a brief and partial summary taken from a study funded by the Canadian Forest Service (CFS), the B.C. Ministry of Forests and the B.C. Ministry of Environment. For full details and references, please see Nordin et al. (2008).

## Background

The Bowron River watershed is approximately 340 300 hectares in area and is located about 50 km east of Prince George in the central interior of British Columbia (Figure 1a). The Sub-Boreal Spruce (SBS) biogeoclimatic zone is dominant in the watershed with Engelmann Spruce–Subalpine Fir (ESSF) in higher elevations, and Interior Cedar–Hemlock (ICH) in lower elevations. Overall, the area has a cool and continental climate characterized by moderately short, warm summers and long cold winters. Soils in the lower, middle, and, to some extent, upper watershed are composed mainly of fine-textured surficial materials, including glacial-lacustrine and sandy glacial-fluvial deposits. The watershed is primarily drained by the Bowron River, which runs north from Bowron Lake Park to the Fraser River. The Bowron River and its tributaries support populations of sockeye (*Oncorhynchus nerka*) and chinook (*O. tshawytscha*) salmon. Rainbow trout (*O. mykiss*), Dolly Varden (*Salvelinus malma*), mountain whitefish (*Prosopium williamsoni*), white sturgeon (*Acipenser transmontanus*), and burbot (*Lota lota*) also exist.

In 1975, a blowdown event in Bowron Lake Provincial Park initiated a

spruce beetle outbreak. In response to the rapid spread of the beetle, harvesting was accelerated and continued intensively throughout the late 1970s and into the mid-1980s before tapering off in 1987. One notable post-harvest effect was a 50 000 ha clearcut, which covered approximately 30% of the upper portion of the watershed. Large portions of the middle and lower Bowron were also harvested and the primary road network still remains.

In the mid-1990s, Level 1 IWAPs were completed as part of the Bowron Watershed Cumulative Impact Assessment. These procedures used descriptive data to generate impact indicators to synthesize into four hazard indexes including peak flow, surface erosion, landslide, and riparian buffer. The riparian buffer index predicts possible changes to the stability of the streambanks and large woody debris supply caused by the removal of streambank vegetation. The final index rankings were low, moderate, and high impact. This study focused on all watersheds that ranked moderate or high in the riparian buffer category and several low-risk sites were used as references. For more information on the Bowron River Watershed IWAPs, please refer to Beaudry (1997).

## Methods

During the 1990s, the large drainage basin was sub-divided into 43 smaller basins and two residual areas for the purpose of conducting the IWAPs. We used the riparian buffer IWAP hazard scores to determine our sample sub-basins. Two stream reaches in each of moderate and high-risk sub-basins were chosen for field evaluation. The first was located at the lowest accessible reach before the stream entered the Bowron River mainstem. This lower reach was selected to represent cumulative effects of harvesting in the entire sub-drainage area; however, the riparian zone may or may not

have been harvested at the sample reach. The second reach was located within an upstream tributary where harvesting occurred within two riparian management areas (RMA) of the stream bank. The upper-reach site was selected to reflect harvesting effects at a smaller scale. At the end of the field season, three reaches from relatively small sub-basins in the northern portion of the watershed were excluded from the study because of accessibility limitations. Seventy sites were completed in total, including 11 reference sites that were low risk (not largely associated roads or harvesting) (Figure 1b).

## The Routine Riparian Effectiveness Evaluation

The Routine Riparian Effectiveness Evaluation (RREE) was created as a monitoring strategy to meet the sustainable management goals set forth in the British Columbia *Forest and Range Practices Act* (FRPA). Originally developed for coastal systems, the protocol is now being implemented in other geographic regions throughout British Columbia. The evaluation consists of a checklist with indicators and questions that guide the user toward a recommendation on the relative health and functionality of a stream and its riparian area. The following stream and riparian indicators correspond to the 15 main questions used in the 2007 version of the protocol to assess riparian, stream channel, and fish habitat health:

- channel bed disturbance
- channel bank disturbance
- in-stream large woody debris (LWD)
- channel morphology
- aquatic connectivity
- fish cover diversity
- moss abundance and condition
- fine sediments
- aquatic invertebrate diversity

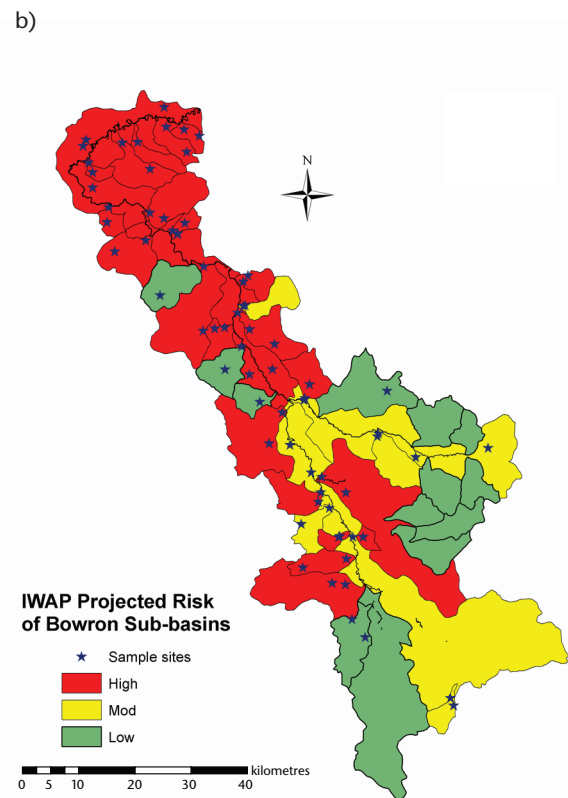
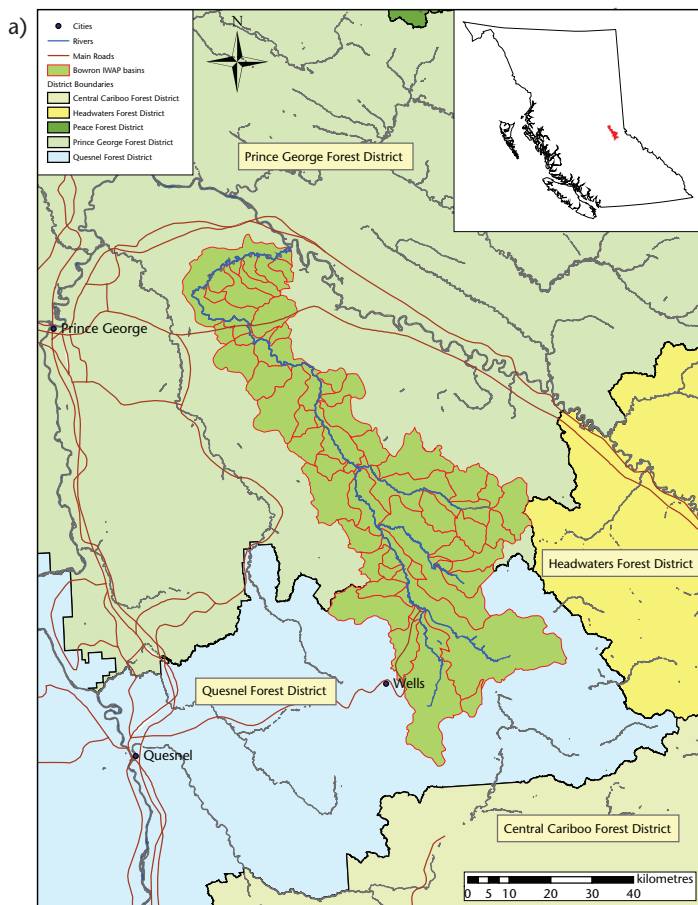


FIGURE 1 a) Location of Bowron River watershed and b) sub-basins coded by IWAP hazard ranking and 2007 RREE sample sites.

- windthrow frequency
- riparian soil disturbance
- LWD supply
- shade and bank microclimate
- disturbance-increaser and invasive plants
- riparian vegetation vigour, form, and structure.

Continuous and point measurements of specific attributes used to answer the indicator questions were taken along a homogeneous sample reach. Shade, multiple channels, and disturbed banks are a few examples of these attributes. Reach length was the greater of 100 m or 30 channel widths. Results were recorded as a percentage of the reach length or riparian area with the exception of invertebrates and LWD accumulations, which were

count values. The attribute measurements were compared to specific threshold values that led to a “yes” or “no” answer (pass/fail) for the indicator question. Conversely, the LWD supply and riparian vigour/structure questions did not have measurements specific to them, and indicator responses were based on field observations of the vegetation. The number of indicator “no” answers in the evaluation determined the condition of the site. The perfect stream would receive a “yes” answer for all 15 indicators, but this rarely occurs due to natural variability and thus there is some allowance for indicator failure in properly functioning systems. As a result, the final four outcomes and the number of “no” answers allowed for each category are:

- Properly functioning condition (0–2)
- Properly functioning but at risk (3–4)
- Properly functioning at high risk (5–6)
- Not properly functioning (> 6)

For more information on the RREE, please refer to Tripp et al. 2007.

## Results

As expected, the RREE evaluation scores corroborated the IWAP rankings (Figure 2). The upper-basin low-risk category scored significantly better than the other two groups. There was no difference between the medium- and low-risk categories and this could be because there were four



RREE outcomes and only three IWAP rankings, resulting in some overlap. High-risk sites showed some recovery by averaging higher than not properly functioning. This is probably due to the period of time since harvest and significant growth of deciduous species, which led to a passing score for attributes such as shade and bank root network. The lower-basin sites were not significantly different from one another, which could be a result of the high variance associated with low sample size in the low- and medium-risk categories. Lower sites appeared to fare slightly better than upper sites, which is probably because of the wider riparian buffer that was observed along larger streams (Figure 3).

The IWAP Riparian Buffer Index score is determined by removal of riparian vegetation, and the effect of this removal directly influenced many of the RREE indicators including LWD supply, streambank stability, complexity of riparian vegetation, and bank microclimate. Sites that had been logged to the streambank exhibited poor regrowth even though planting had been done within 2 years of harvest (Figure 4). Most of the woody vegetation within 10 m of the channels consisted of deciduous tree species and shrubs such as aspen (*Populus tremuloides*), red osier dogwood (*Cornus stolonifera*), alder (*Alnus* sp.), and willow (*Salix* sp.) (Figure 5). This observation agrees with Nierenberg and Hibbs (2000), who found that the limiting factor to conifer regrowth after harvesting in western Oregon's riparian zones was the competitive advantage of deciduous trees and woody shrubs. At many of the sites it was apparent that the deciduous trees were serving to control bank microclimate and provide a degree of bank stability; however, the LWD supply to the stream was found to be inadequate.

The medium- and high-risk sites were characterized by much more

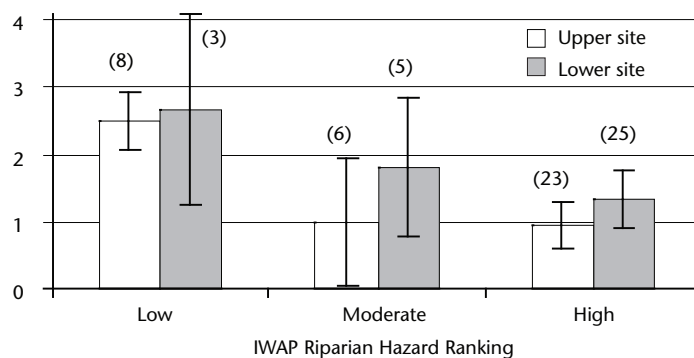


FIGURE 2 IWAP Riparian hazard ranking vs average 2007 evaluation score. NPF = not properly functioning, F/HR = functioning at high risk, F/R = functioning at risk, PF = properly functioning. Error bars = 95% CI.

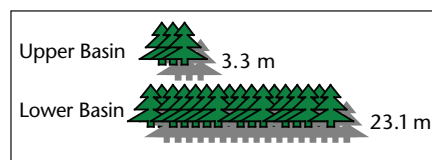


FIGURE 3 Average riparian buffer at upper- and lower-basin sites.



FIGURE 4 Poor riparian regrowth at "Hah Creek" upper-basin site, logged 1973.



FIGURE 5 Deciduous streambank vegetation at "Indian Point Creek" lower-basin site, logged 1985.

disturbed and bare ground compared to low-risk sites. Disturbed and bare ground is usually a reflection of compacted soil, which facilitates a greater amount of runoff to a stream channel. Bare ground also is a source of sediment which, when transferred to a stream, can affect invertebrates, fish, and channel morphology. Disturbed and bare ground at harvested sites was found both within the immediate vicinity of a stream (heavy equipment tracks) and farther away but hydrologically connected (old roads and landings). We noted an improvement in bare ground over time as evidenced by revegetated roads and skid trails at older sites. However, most of the ground cover in heavily compacted areas consisted only of grasses and forbs (Figure 6).

In addition to the poor growth at disturbed sites, many stream channels



FIGURE 6 Old landing site at "G Creek" upper-basin site, logged 1993. Compacted soil limits regrowth of vegetation.

in the harvested basins contained debris jams composed of logging-related materials. Sites logged 30 years before still contained surprisingly solid pieces of LWD with mechanically cut ends (Figure 7a). In addition, debris from stream-crossing deactivation was also occasionally left in the stream (Figure 7b). These jams can lead to accumulations of sediment and compromise fish passage. In some cases, equipment had repeatedly crossed the channel, compacting the banks and resulting in poor regrowth and reduced bank stability.

The 2007 spring water levels were higher than average, which altered streambanks across all sites and caused ambiguity among risk categories when compared to the bank disturbance indicator. Peak flow at the



FIGURE 7a Logging-related debris jam in stream channel at "Spruce Creek" lower-basin site, logged 1977.



FIGURE 7b Deactivated road crossing debris in stream channel at "Craze Creek" upper-basin site, logged 1977.

Bowron Box Canyon hydrometric station measured 420 m<sup>3</sup>/sec compared to a 30-year peak flow average of 319 m<sup>3</sup>/sec. Not knowing bank conditions before the flooding made it impossible to estimate the effects of harvesting for this indicator. Disturbed banks were recorded even in low-risk areas (Figure 8). Flooding may have also contributed to indicator failures for moss and aquatic connectivity (indicator that considers blockages restricting the flow of sediment, debris, and fish passage), thereby lowering the RREE score slightly for all groups.

Fine sediments were also seen among many of the sites, and soil maps indicate that there are large natural deposits of glacial-fluvial and glacial-lacustrine material throughout the watershed. The fine-sediment indicator in the RREE did not seem to correspond well with the Riparian IWAP ranking as this hazard index was based on riparian vegetation only. Therefore, large amounts of fines were seen in several of our low-risk sites, which contributed to several failures for the fine-sediment indicator, lowering the RREE scores for the low-risk groups. Fine substrate also contributed to fish cover indicator failures, as a sand and silt streambed rarely contains boulders, macrophytes, and void spaces for fish (Figure 9).



FIGURE 8 Disturbed banks at "Ames Creek" upper-basin low-risk site.



FIGURE 9 Fine sediments in streambank seen at "Lower Bowron" upper-basin low-risk site.

## Conclusions

The most significant resonant effect on streams exposed to salvage harvesting during the 1970s–1980s was the lack of mature vegetation in the riparian zone today. Sub-basins subjected to extensive riparian harvesting did not have large enough trees to maintain recruitment of adequate LWD to a stream. It is expected that LWD supply will be limited for decades, potentially affecting channel morphology, distribution of sediments, and coarse particulate organic matter, nutrient dynamics, stream temperatures, and, subsequently, fish habitat. Although there were numerous logging-related woody debris pieces left in the channels, over time they became aggregated into jams, which trap sediment and can impede fish passage. Flood effects and the natural occurrence of fine sediments resulted in some failures for the low-risk sites but these reaches still scored significantly better than the other two groups, reflecting the IWAP hazard scores.

Not all of the forest management activity that resulted in failures are still accepted practices today, but the most common reason for downgrading a stream from properly



functioning was associated with the removal of riparian vegetation, which is still an existing issue. Current regulations are more restrictive with respect to riparian harvesting compared to practices 30 years ago; however, s4–s6 classified streams do not require a riparian reserve zone and are often harvested to the stream edge. In addition, streams of all sizes may be subject to the removal of beetle-infected riparian timber under s.51(g) of the Forest Practices and Planning Regulation. Removing riparian timber may not only lead to stream degradation and possible conflict with other agencies, but would also increase management costs associated with returning the site to a free-growing status (e.g., brushing).

The Bowron retrospective study along with other regional projects supports the following guidance statements:

- Large woody debris (LWD) supply issues can be addressed by maintaining a streamside riparian buffer. Work completed for the Prince George Small Streams Study found that 77–98% of all active in-stream LWD originates from within 10 m of the streambank ([www.for.gov.bc.ca/hre/ffip/pgssp](http://www.for.gov.bc.ca/hre/ffip/pgssp)). Blowdown in the riparian zone is considered a natural process for LWD delivery to streams.

- IWAPS are recognized as a valuable forest management tool for identifying sensitive watersheds.
- Maintain natural drainage by installing fewer road crossings, specifically in areas of highly erodible soils.
- Soil compaction in the riparian area was found to enhance erosion as well as contribute to sediment delivery and streambank destabilization. Minimizing soil compaction in the riparian area will address this issue.
- Deactivate roads once they are no longer used.

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