Watershed Assessments for Upper Highwood-Loomis Creek Proposed Logging 2023-2025

David W. Mayhood
Joshua Killeen

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Freshwater Research Limited

Technical Report No. 2024/03-1 **March 2024**

Cover: The Highwood River at its confluence with Loomis Creek, Kananaskis Country, Alberta provides outstanding angling for sizeable rainbow-cutthroat hybrid trout and a strong population of large native bull trout. With both waters holding threatened bull trout listed under Canada's *Species at Risk Act*, and Loomis Creek also holding an increasingly rare conservation population of near-pure westslope cutthroat trout, the Highwood River and Loomis Creek are both of unusually high value for conservation. They and their habitats will be affected by planned clearcut logging in their watersheds in 2023-2025.

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This technical report is open to public review at all times. Bring errors or substantive comments to the attention of the corresponding author, above. Substantive corrections will be posted in supplemental information.

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Abstract

West Fraser Cochrane (WFC), formerly Spray Lakes Sawmills (SLS), manages most of the Rocky Mountain East Slopes forest under Alberta jurisdiction in the Bow and Oldman River headwaters through a Forest Management Agreement (FMA) with the Government of Alberta. The company plans to log the lower watershed of Loomis Creek and much of the local forest draining to the Highwood River in 2023 through 2025.

High-value trout populations, including bull trout (*Salvelinus confluentus*) protected under Canada's *Species at Risk Act* (SARA), occupy waters in the area likely to be affected by logging. The limited forest management plan for the whole FMA broadly assesses the total managed area, but doesn't provide sufficiently detailed information to allow for a reasonable assessment of the effect of its planned logging on species at risk, other high-value trout species, or watershed integrity. Accordingly, we assessed the risk of changes to watercourses, riparian zones, and hillslopes in the Loomis Creek watershed and a selection of 36 small sub-watersheds using the BC Forest Service's Interior Watershed Assessment Procedure Level 1 supplemented with field observations and consideration of relevant technical documents and scientific literature.

Overall, 75% of the main watercourses in the 36 sub-watersheds (13 in the Loomis drainage, 14 in the Highwood mainstem drainage) were assessed at high to highest risk of significant alteration from the interaction of increased peak flows and increased surface erosion expected to result from WFC executing its logging plan. A remaining 8 (Loomis 6, Highwood 2) sub-watersheds scored as at moderate risk. Only one, draining to the Highwood River mainstem, scored as at low risk due to the small fraction of it being proposed for logging. The Loomis Creek watershed as a whole ranked as at moderate risk due to much of its headwater area being in a protected zone unavailable for logging. As the lower part of the Loomis basin is proposed for intensive logging, that part was assessed to be at highest risk, as is shown by the assessments of most of the tributary sub-watersheds there.

Although nearly all the sub-watercourses studied are not fish-bearing, they drain directly into habitat used by SARA-listed bull trout and a population of near-pure threatened westslope cutthroat trout of high value for that species' recovery. The assessed risk of increased sediment delivery is due to road erosion and increases in the magnitude and frequency of peak flows resulting from removing the forest from parts of these sub-watersheds. An increase in local stream temperatures is also likely. Planned mitigations under Alberta's Best Management Practices and Operating Ground Rules are uncertain to be as effective as required, and do not meet SARA legal requirements to protect threatened bull trout. This is a level one analysis, identifying problem areas needing further study in the field by a hydrologist and a fish biologist team to evaluate the potential effects of the proposed logging on critical habitat for protected at-risk bull trout, near-pure westslope cutthroat trout, and highly valued hybrid rainbow-cutthroat trout populations. Our results suggest that the proposed logging as planned poses a substantial threat to critical habitat for all life-history stages and individuals of all trout species in the study area.

Contents

Introduction

West Fraser Cochrane (WFC), formerly Spray Lakes Sawmills (SLS), intends to log approximately 11.8 km^2 of subalpine forest along the Highwood River and in the Loomis Creek watershed over the period 2023-2025[1] (SLS 2023). Streams in the areas affected, including the mainstem Highwood River and Loomis Creek, hold populations of threatened bull trout (*Salvelinus confluentus*), listed and legally protected under Canada's *Species at Risk Act* (SARA). The upper Highwood watershed serves as the principal spawning area for the species in the Highwood River watershed as a whole (Eisler and Popowich 2010). The Highwood River itself additionally holds a strong hybrid population of *Oncorhynchus mykiss* X *O. clarkii lewisi* (rainbow trout x westslope cutthroat trout) supporting a popular, highly valued angling fishery.

In addition to its bull trout, Loomis Creek also holds a population of increasingly rare, near-pure westslope cutthroat trout (M. Coombs, personal communication to D. Mayhood 2024-02-23). Such populations are of particular value in assisting recovery of SARA-listed threatened stocks of that species (Alberta Westslope Cutthroat Trout Recovery Team 2013; DFO 2019, 2020a).

Largescale forest removal such as that planned by WFC can have many effects on aquatic habitats and their fishes (Meehan 1991, Brewin and Monita 1998, Northcote and Hartman 2004, Scrimgeour *et al*. 2004, Luce and Danehy 2022). The additional roads required to log these areas increase surface erosion, runoff, and drainage density (every road also becomes a watercourse), increasing water and sediment delivery to streams (Furniss et al. 1991, Gucinski et al 2001). Insolation on the newly-exposed land surface (suggested by Hartman *et al*. 1982:596, Hewlett and Fortson 1982, Moore *et al*. 2005:818), and directly on the watercourses where they become exposed by logging, can increase water temperatures (Moore 2005). All such changes are highly variable depending on the watershed and the logging operation, but all can negatively impact trout populations in the receiving waters and are best assessed on a project-by-project basis.

Common hydrological impacts in snow-dominated watersheds such as those considered here include increases in the frequency and magnitude of peak flows, including floods (Green and Alila 2012, Kuraś *et al* 2012, Schnorbus and Alila 2013, Winkler *et al*. 2017, Johnson and Alila 2023), and changes in their time of occurrence (Winkler *et al*. 2017). The Highwood River poses significant flood risks to communities such as High River, most notably during the "unprecedented damage" caused during the flooding events of 2013 (Pomeroy *et al*. 2015). The Government of Alberta's South Saskatchewan Regional Plan (Government of Alberta 2018:58) makes it clear that protection of headwaters is the priority for the plan and that "forests will be managed with this as the highest priority (including water storage, recharge and release functions)."

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[1] WFC has postponed logging in the study area for winter 2023-2024, setting the plan back one year.

In Alberta, most (>66%) of the public forest is managed under Forest Management Agreements (FMAs) or other dispositions (Heelan Powell 2022). WFC manages the lands in the subject area under an FMA (Government of Alberta 2015). Like other FMAs, the terms of their agreement require WFC to have an approved forest management plan (SLS 2021a) and to operate by agreed-upon operating ground rules (Government of Alberta 2022, 2023a), but there is no requirement for operators or Alberta Forestry and Parks, the regulator, to conduct an environmental impact assessment either for the entire licenced area or for each year's operating plan.[2] As a consequence, there is negligible information available for the public to independently assess the environmental impacts of what amounts to largescale permanent reduction in forest cover.[3]

Here we adopt a watershed assessment procedure developed for inland forests of western Canada to begin to assess the physical environmental impacts of the WFC proposed logging in the upper Highwood River on the affected watersheds and their streams. These assessments will be used to evaluate effects on trout and their use of the study area (Mayhood, in prep. a) and what the assessed likely impacts mean for permitting and enforcement under SARA (Mayhood, in prep. b). We also expect to use this approach to assess the potential impact of substantial additional WFC logging affecting SARA-listed trout planned in the 20-y spatial harvest sequence for the upper Highwood (SLS 2021b:Figure 2-3).

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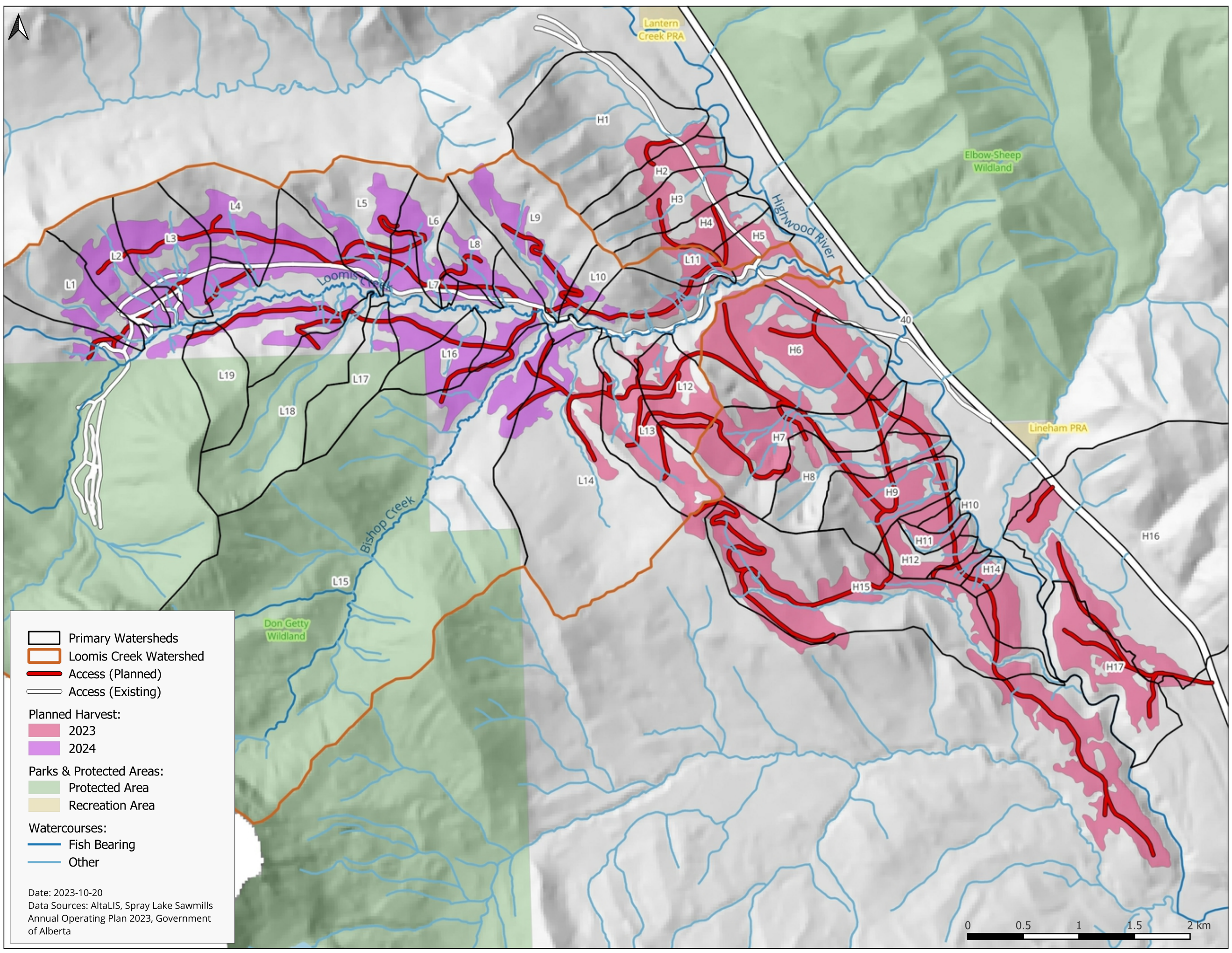
[2] Not one environmental assessment for forestry operations is listed on the Government of Alberta's Environmental Impact Assessments webpage for current or historical projects https://www.alberta.ca/environmental-impact-assessments, even though nearly 1,000 km^2 of Alberta forest was removed by logging in 2020 alone (https://cfs.nrcan.gc.ca/statsprofile/overview/AB).

[3]A quick reference to the Timelapse function of Google Earth Engine (https://earthengine.google.com/timelapse/) for Alberta's Rocky Mountain East Slopes will show that as old clearcuts regenerate trees, new clearcuts nearby remove them. The overall effect is to permanently reduce forested area (i.e., increase clearcut and equivalent area). For example, examine logged areas of the East Slopes forest for the period 1984-2022 between Crowsnest Pass and Highwood Crossing using the timelapse tool. That is the scenario that faces the upper Highwood River watershed.

Study Area

The study area is part of the upper Highwood watershed, Bow River drainage, including the tributary Loomis Creek watershed, and numerous small sub-watersheds slated for logging between 50.41540°- 50.49170°N and 114.73522° - 114.89042°W (Figure 1). The forest is subalpine, dominated by lodgepole pine (*Pinus contorta*), Engelmann-white spruce hybrid complex (*Picea engelmannii* x *P. glauca*) or Engelmann spruce alone at higher elevations; subalpine fir (*Abies lascarpa*) and subalpine larch (*Larix lyallii*) at higher elevations (Rowe 1972). Endangered whitebark pine (*Pinus albicaulis*), listed under SARA, has been reported from the area (Smith *et al* 2008:Figure 1). Trembling aspen (*Populus tremuloides*) is common in valley bottoms, and balsam poplar (*P. balsamifera*) is found in the riparian zone in small stands or as individual trees along the Highwood River and Loomis Creek.

Figure 1. The study area. The sub-watersheds studied are identified by a letter-number code.



The Loomis Creek valley was logged in the past (1960s, ABMI 2021), as attested by the old roadbeds (Figure 1), remains of logging camps or mills (Daffern 1985:172) and a fine network of trails in the upper valley visible in satellite imagery (Google Earth Pro, imagery dated

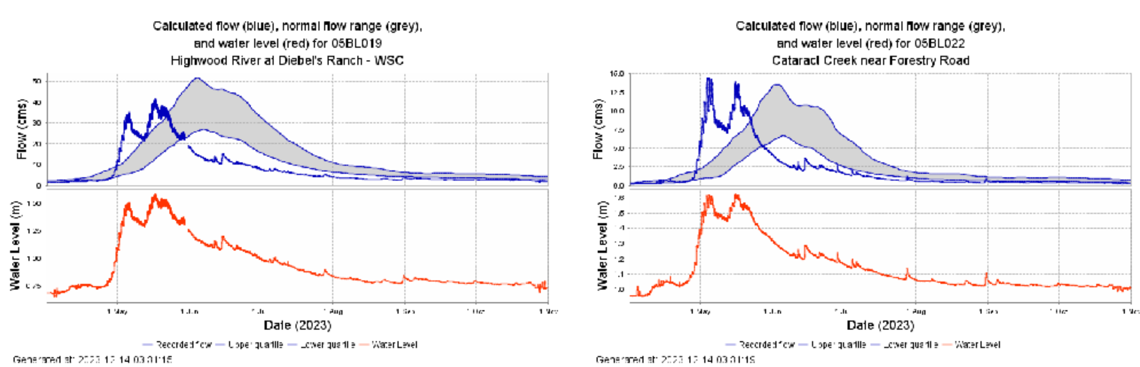
2013-08-31). The entire upper Highwood valley was burned by wildfire in 1936 (Patterson 1961:188 *ff*., Tymstra *et al*. 2005:Figure 4.6). Little to no recovery was noted by 1947, when “dangerous” erosion was reported, the river becoming “dirty within a few minutes after the beginning of a rain storm” (Miller and Macdonald 1949:33). The present regrown forest, however, is intact throughout the study area, save for Highway 40 — which does not pass through the planned clearcuts — and the old disused logging or exploration roads.

Low-relief (generally < 2 m) coarse alluvium dominates the valley bottom of the Highwood River throughout the study area, with an alluvial apron at the Loomis Creek confluence (Bayrock and Reimchen 1980). The Highwood valley bottom itself has been extensively reworked by floods. An esker forms a short length of the south hillslope of Loomis Creek near the mouth. A 3.5-km midsection of Loomis Creek flows through a deposit identified by Bayrock and Reimchen (1980:sheet 5+table) as talus, but by their definition (see also Reimchen and Bayrock 1977:35) is better classified as colluvium, being heavily forested over much of the area. The upper valley bottoms of Loomis and Bishop creeks are cirque till. The hillslopes and lower uplands paralleling the Highwood River and the south side of the lower half of Loomis Creek watershed are Late Wisconsinan ground moraine and lateral moraine; the adjacent uplands are bedrock-derived colluvium. The lower ~900 m of Loomis Creek is deeply incised into the local deposits.

Slopes of the valley walls along the major watercourses are steep. Active gullying and mass wasting of the steep hillslopes are common throughout, but actively eroding slopes are especially prominent on the north side of the Loomis Creek valley in its lower-middle reaches, and along the Highwood River downstream from Lineham Creek.

The climate is northern continental with cold winters and short, cool summers. January monthly longterm minimum and maximum temperatures are -13.8°C and -2.3°C, respectively; July monthly longterm minimum and maximum are 5.3°C and 19.0°C, respectively (Alberta Climate Information Service 2023)[4]. River hydrology is dominated by snowmelt, typically rising from late April, peaking in early June, declining from there through August, remaining near base flow from late August to April (Figure 2).

Figure 2. Hydrographs for the Highwood River (left) and Cataract Creek (right), both near the study area (Government of Alberta 2023b).



[4] Highwood Auto meteorological station (50.4100°N 114.7300°W, Highwood valley bottom upstream from Cat Creek)

Methods

We used the Level 1 Interior Watershed Assessment Procedure (IWAP, BC Forest Service 1995), slightly modified for the available data as described below, to evaluate risk from the proposed logging to the physical habitat of streams. This was supplemented with field observations documented with photographs and interpretation of satellite imagery (Google Earth Pro v. 7.3.6.9345 64-bit, Google LLC) along the Highwood River and Loomis Creek. Data sources used are shown in Table 1.

The IWAP level 1 analysis, developed from studies on 40 interior watersheds, attempts to provide objective measures of risk from artifacts of land-use known to cause impacts to streams and their watersheds. Watersheds flagged at high risk based on these measures can then be examined in greater detail to further clarify the extent of risk, and what measures may be taken to deal with it. Much of the science informing the procedure is considered in the volume edited by Toews and Chatwin (2001).

Table 1. Data sources used in the IWAP analysis.

Data	Source	Notes
Watercourses	WFC 2023/24 Annual Operating Plan (AOP) (SLS 2023)	Digitized based on AOP. Missing watercourses in sub-watershed id H16 were added based on AltaLIS data
Access Roads	WFC 2023/24 Annual Operating Plan (SLS 2023)	Digitized based on AOP
Harvest Areas	WFC 2023/24 Annual Operating Plan (SLS 2023)	Digitized based on AOP
Planned Crossings	WFC 2023/24 Annual Operating Plan (SLS 2023)	Digitized based on AOP
Loomis Creek Watershed	Alberta Forestry & Parks	Forest Management Plan, Watershed #72
Primary Watersheds	Dave Mayhood / Josh Killeen	Developed based on topography, watercourse locations
Digital Elevation Model	Alberta Provincial 25m Digital Elevation Model (Government of Alberta 2023c).	Slope class was calculated classified into 1 = 0-14%, 2 = 15-29%, 3 = 30-44%, 4 = 45+%
Fish-Bearing Watercourses	Alberta Fisheries and Wildlife Management Information System.	Watercourses identified and marked based on FWMIS records (Government of Alberta 2023d)
Surficial Geology	Alberta Geological Survey	Unit classes used with slope class to identify erodible soils based on Reimchen & Bayrock (1977) and Bayrock and Reimchen (1980). The following classifications were identified as erodible: unit_no in ('18','4b','4ba','8','9','10','11','12','13','14') and slope_class = 4 OR unit_no in ('4','21','23','28','25') and slope_class in (3,4) OR unit_no in ('5','7','7a','7b','3','3a','19','24','27') and slope_class in (2,3,4) OR unit_no in ('15','15a','16','22','29') and slope_class in (2,3,4) OR unit_no in ('6','17') and slope_class in (1,2,3,4).

We analyzed a selection of 36 sub-watersheds, including non-fish bearing face units (hillslope sub-watersheds without an obvious channel draining directly to a mainstem), plus first- and second-order[5] basins, because impacts on them are expressed downstream and will affect trout habitat in the fish-bearing reaches of the principal streams. Protection of small tributaries is frequently ignored or treated inadequately, yet these small watercourses are crucial to the health of the waters into which they drain (Alexander *et al*. 2007, USEPA 2015, Wohl 2017, Ferreira et al. 2023), are particularly sensitive to disturbance (Buttle *et al*. 2012), and are the source of serious erosion and sediment problems in logging operations (Shaw and Thompson 1986:30 *ff*., Chamberlin *et al*. 1991:183).

We did not include slope stability measures in the IWAP analysis. We conducted a survey of satellite imagery using Google Earth Pro, which allowed us to detect potential and existing mass wasting locations for field study. This was supplemented with field observations supported by photographs of selected locations observed during fish surveys. Groundwater features were recorded as we encountered them, as they are known to be important overwintering, spawning, egg incubation, rearing, and refuge habitat for trout.

Equivalent clearcut area (ECA) was taken to be zero as the current condition, and as 100% of the planned clearcut area for all watersheds and sub-watersheds analyzed. Buffer widths required under the operating ground rules between roads and watercourses, and between clearcuts and watercourses, were taken to be as shown on the annual operating plan imagery (Table 1).

As a point of clarification, WFC (SLS 2021a) calculates the equivalent clearcut area (ECA) as the percentage of forest cover removed in a watershed, adjusted for regrowth (hydrological recovery), in accordance with the method outlined by Silins (2003). The ECA in the IWAP we report here is assessed as the logged percentage of the entire watershed, whether forested or not, adjusted for regrowth, in accordance with the published method (BC Forest Service 1995). As a result for the same clearcut, the WFC calculation will always give a higher ECA than the IWAP method except when the watershed is fully forested, when the two figures will be the same.

A spreadsheet was developed for calculating the various IWAP measures, and is available online (see Supplemental Information), along with the raw data.

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[5] Strahler (1957) method

Results

Detailed results are provided in the Supplemental Information. Only a summary is provided here.

Present Condition

Although some parts of the study area were logged circa 1960, and the entire study area was burned in 1936, presently the area is showing approximately 100 percent hydrological recovery due to complete forest regrowth, so is effectively unlogged. Legacy roads within the area to be clearcut amount to 3.2 km within planned clearcuts in the direct-to Highwood drainages, and a total of 13.6 km in the entire Loomis Creek watershed, mostly dating from historical logging operations (Figure 1). These tracks are generally narrow and currently serve as hiking, backpacking, mountain biking, and climbing access trails.

Individual Physical Features

Numerous active surface erosion and mass-wasting features near watercourses currently exist in the study area (Figure 3 a-d, Appendix). We documented a total of 38 eroding hillslopes, 10 gullies, 9 slumps or landslides, 10 wetland areas, 17 wetland ponds, 7 groundwater seeps or boils, and 6 avalanche slopes among the physical features presently or potentially affecting watercourses. This is by no means a complete list, and many need ground truthing.

Figure 3. Selected physical features (black points) occurring in and near existing and planned clearcuts and roads. a, overview; b, lower Loomis; c, middle Highwood; d, lower Highwood. Not all those listed in the text could be labelled in these maps because Figures 3b-d do not cover the entire study area.

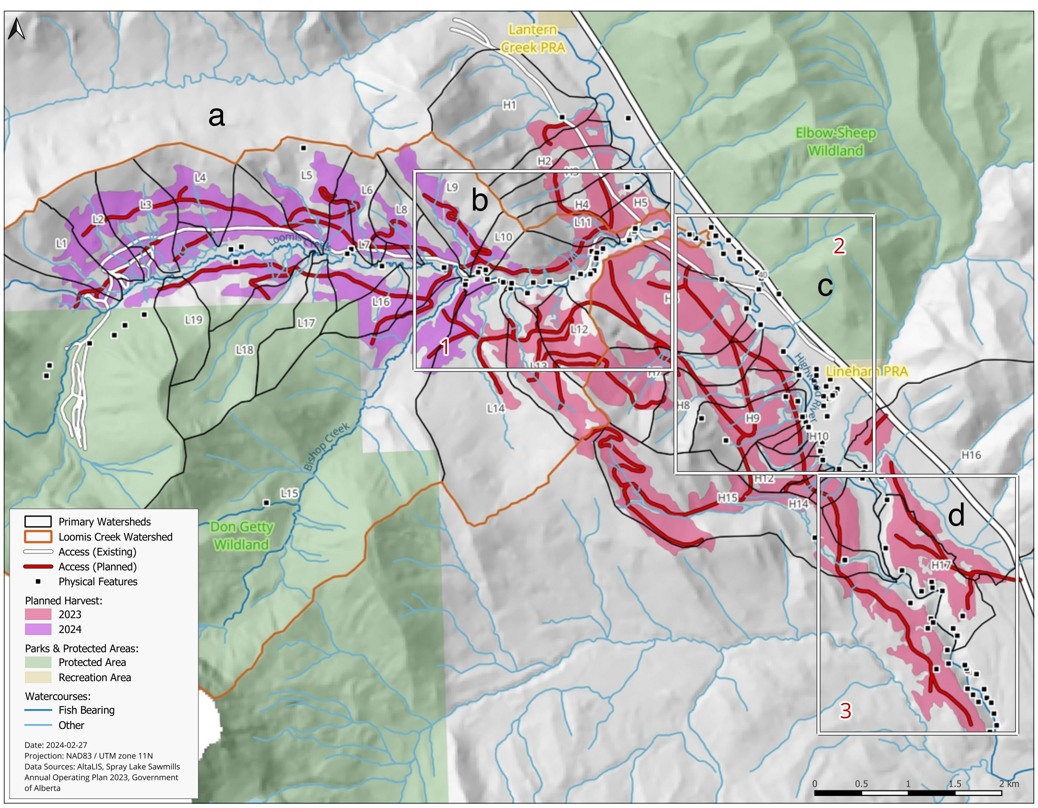
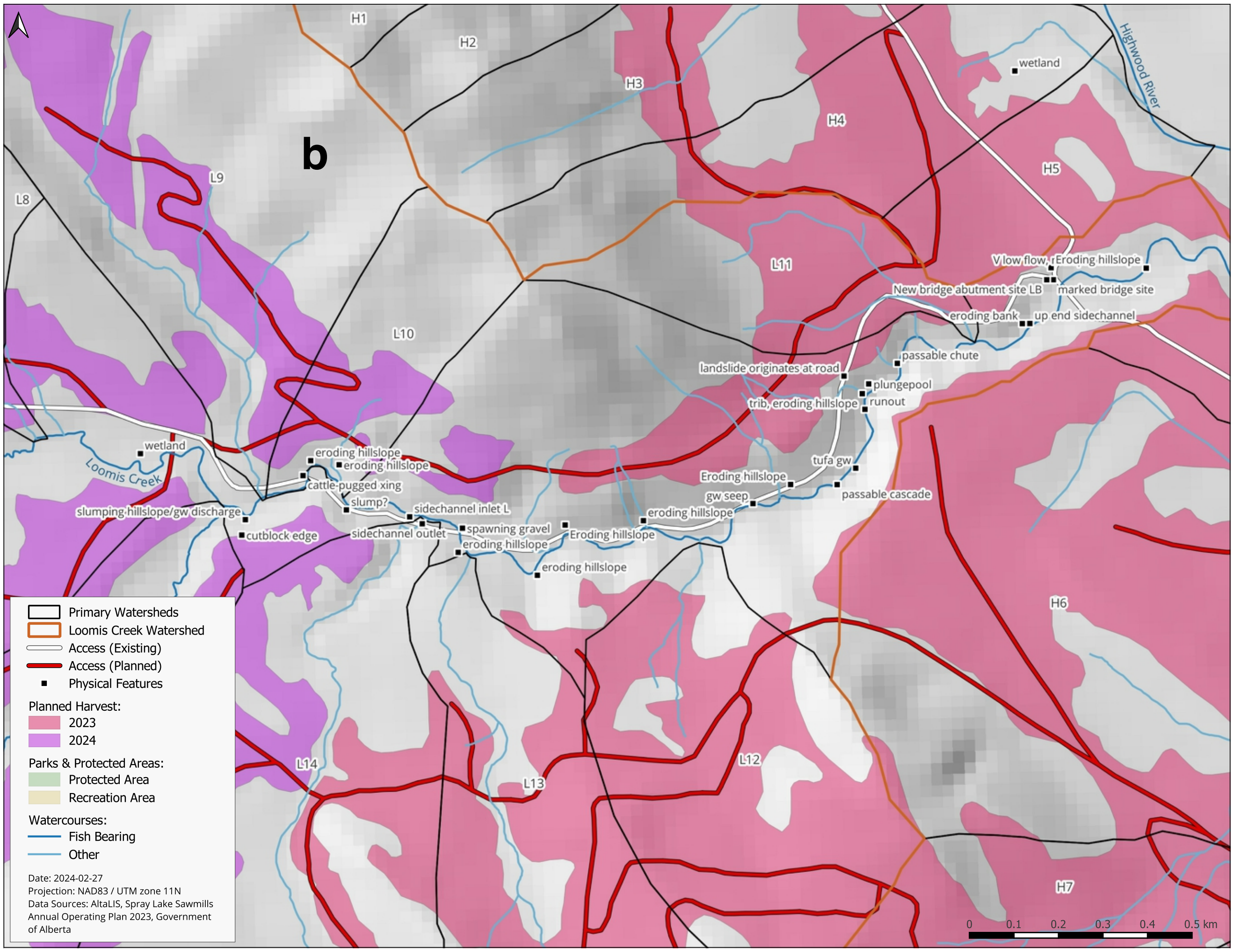


Figure 3b. continued. Lower Loomis Creek.



Some of the erosional and mass-wasting features in the Loomis Creek watershed are associated with the existing roadbed paralleling the creek (Figure 3b). For example, at the planned bridge crossing at approximately 50.4687°N 114.796344°W, it appears that gravel from a borrow pit at the site was once used as roadfill to cross Loomis Creek with one or more concrete culverts that have since blown out. This has created a gravel, cobble and boulder fan below the site which divides the streamflow into several small channels that could be a fish movement barrier at low flows. At 50.466878°N 114.802844°W, a landslide originates at the roadbed, apparently caused by drainage from the road being concentrated at the site and directed downhill there. Other active features in the Loomis Creek valley include a hillslope slump less than 100 m downstream from the mouth of Bishop Creek at which groundwater emerges and saturates the soil, and a particularly active large eroding hillslope at 50.465489°N 114.819781°W contributing gravel and other small sediment to Loomis Creek.

Figure 3c. continued. Highwood River mainstem, north section.

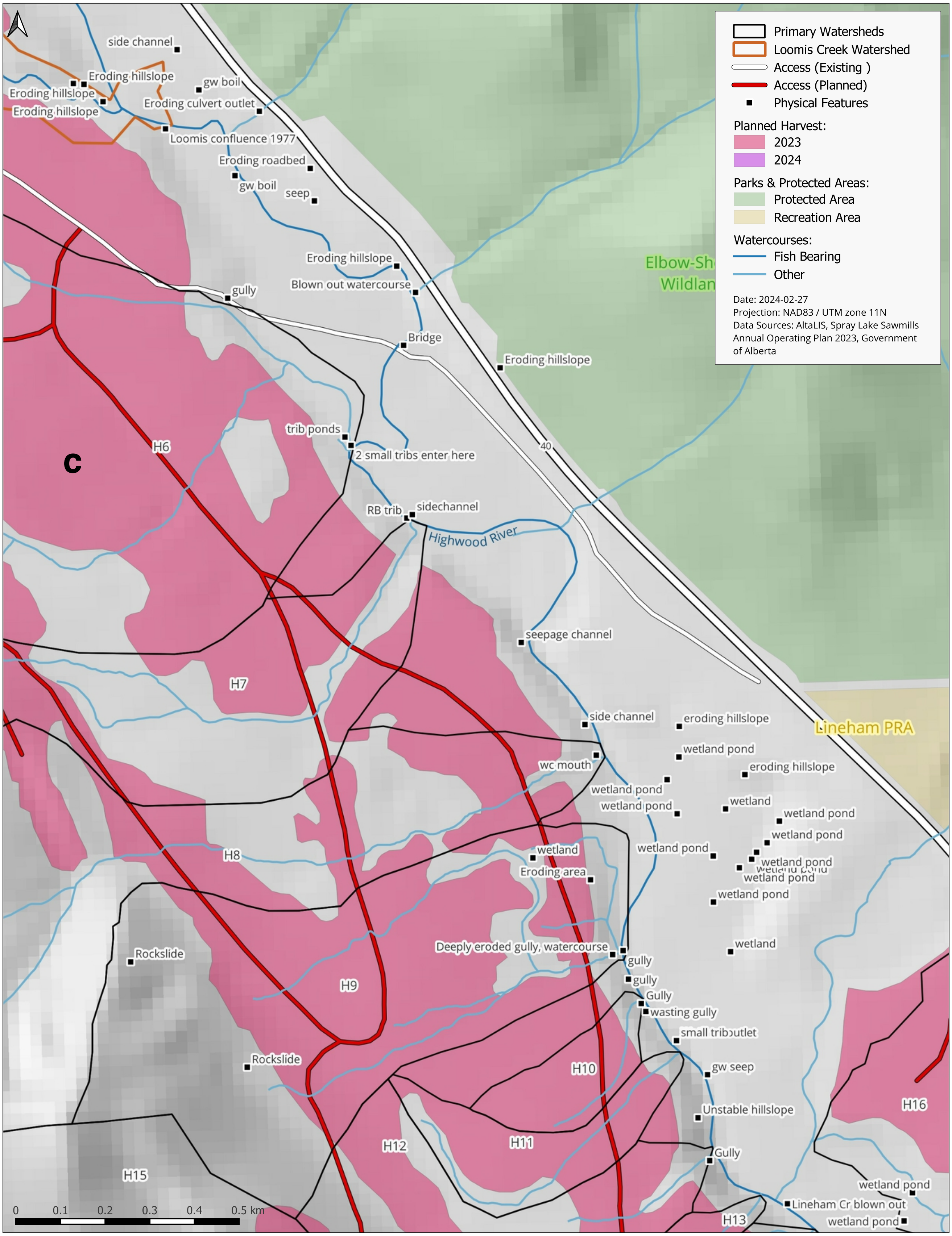
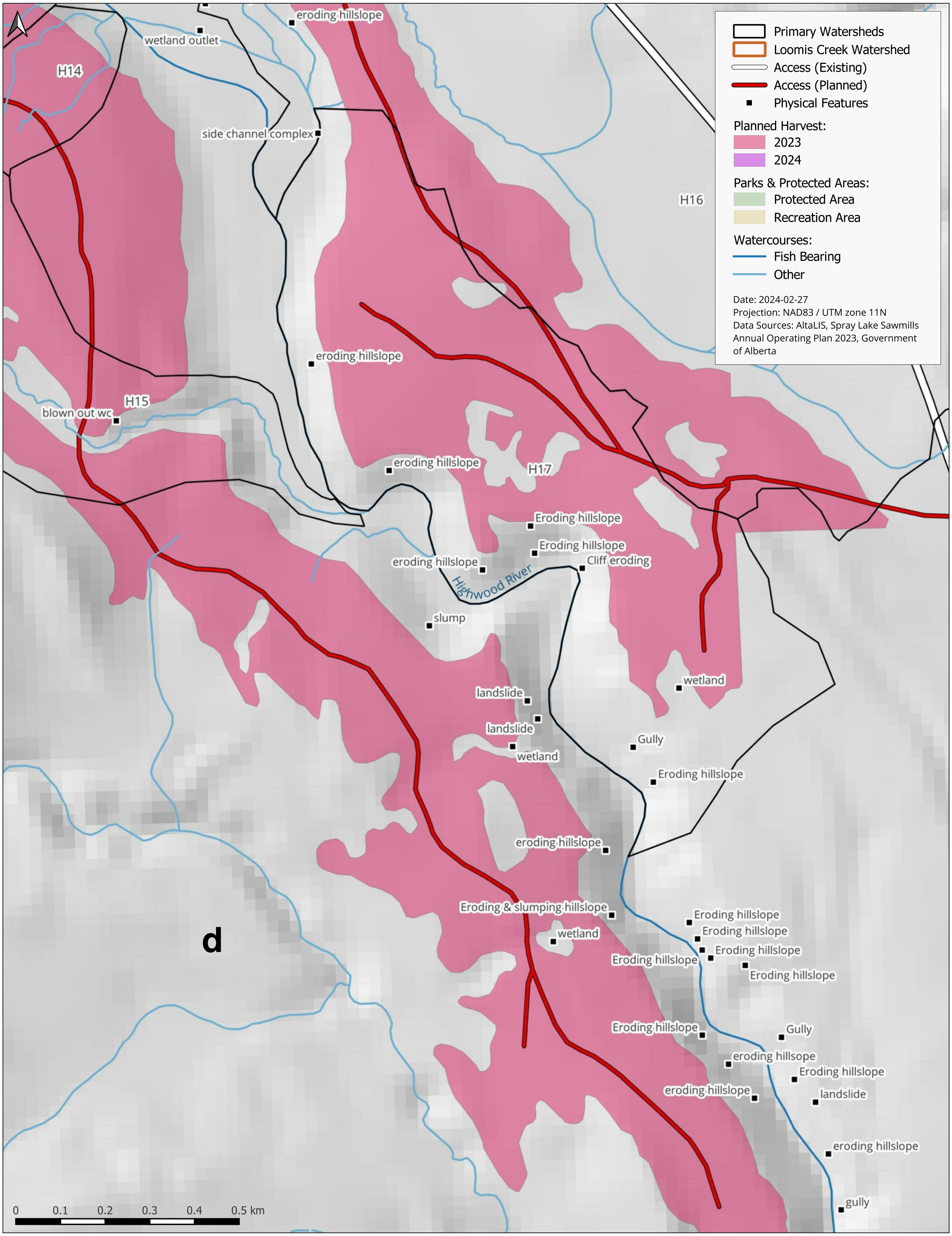


Figure 3d. concluded. Highwood River mainstem, south section.



These and other features are illustrated and discussed more thoroughly in the Appendix.

The newly-reopened main access road north of the Highwood Bridge closely parallels a tributary in the mid-Highwood mainstem area (Figure 3c). An old road runoff-initiated 1-2 m deep gully perhaps 50 m long was found there in August, but was filled in during recent road work. Ponds occur just above the mouth of this tributary that are potentially important to trout habitat in the mainstem Highwood. Just below the mouth of that tributary a left bank[6] watercourse marked as "LB tributary" is the outlet of a left bank side channel. This location is also the entry point for a tributary draining what appears to be a wetland largely surrounded by a planned upland clearcut.

Additional potentially important trout habitat is found downstream, in the form of groundwater seepage channels and watercourse mouths, both of which are often associated with trout spawning, overwintering, and feeding locations. Near the downstream end of the north Highwood mainstem section, above the Lineham Creek confluence (Figure 3c), are a number of gullies, mass-wasting and erosional features that, if disturbed, could affect trout habitat in the Highwood River mainstem. An extensive wetland with several ponds is linked to the mainstem on the left bank in this area, while several first- and second-order watercourses drain from a proposed upland logging area on the right bank.

A wetland-pond area, and a complex side channel system occur on the left bank of the Highwood River mainstem immediately downstream from the Lineham Creek confluence (Figures 3c-d), and are likely to be affected by planned clearcuts on the left bank of the Highwood River mainstem. These provide groundwater seepage to the mainstem that is often associated with trout habitat used for overwintering, juvenile rearing, spawning, and egg incubation. Several mass-wasting features, gullies, and eroding hillslopes are common downstream to immediately above the confluence with McPhail Creek, the end of our survey (Figure 3d). These could be affected by planned logging on both sides of the mainstem Highwood.

IWAP Assessments

As the available data do not allow us to fully calculate the IWAP riparian and mass-wasting hazards, we rely here on considering just the peak flow and the surface erosion hazards, and the interaction of the peak flow by surface erosion hazards.

For the Loomis Creek watershed (FMP72) overall, the present combined effects of the peak flow by surface erosion hazards indicate that watercourses are already at moderate risk. The hazard due to increased peak flows alone is low (0.1), what there is being entirely owing to existing road development (there are no hydrologically significant clearcuts), which increases the drainage density and the extent of watercourses intersected by roads. The surface erosion hazard alone is high (0.9) also owing to the extent of historical road development in the basin, and is probably underestimated: we could not accurately trace the entire network in the upper part of the basin.

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[6] By convention, left and right banks are determined while facing downstream.

Of the 19 mostly small sub-watersheds studied in the Loomis basin, 11 (L01-L11) are rated as having their watercourses currently at moderate risk, based on their peak flow by surface erosion interaction scores. The remainder are scored as at low risk under present conditions. Again, these scores are determined entirely by the present extent of road development, which creates mostly high surface erosion hazard assessments (0.8-1.0, except one, 0.6) in the moderate-risk sub-watersheds, but surface erosion low assessments (0.0-0.1) in the low-risk sub-watersheds. Peak flow hazard scores were low in the sub-watersheds (all but one fell in the range 0.0-0.2, the highest being 0.4), so contributed little or not at all to the present peak flow by surface erosion interaction assessments in the Loomis sub-watersheds.

For the Highwood sub-watersheds (H01-H17) taken together, the present combined effects of the peak flow by surface erosion hazards indicate that the watercourses are presently at low risk. Only watercourses H01-H05 were assessed as at moderate risk, the remainder being at low risk. Again, existing road development, in the form of the road crossing Loomis Creek to the Odlum Creek watershed, was responsible for the moderate-risk ratings.

Effects of Planned Logging

IWAP Peak Flow by Surface Erosion Interaction

Based on the combined peak flow by surface erosion interaction, while the planned logging does not change the present moderate risk assessment for the Loomis Creek watershed overall (Figure 4), most sub-watersheds showed increased risk levels. Of the Loomis Creek sub-watersheds, 3 increased from low risk to highest, 10 increased from moderate risk to highest, 5 increased from low risk to moderate, and only one (L01) showed no increased risk from the present condition (Figure 5).

The 17 Highwood sub-watersheds studied, taken together, will increase from their present low risk state to highest risk in response to planned logging (Figure 4). Of the Highwood sub-watersheds, 10 increased from low risk to highest, 1 increased from low risk to moderate, 1 increased from moderate risk to high, 3 increased from moderate risk to highest and 2 (H01, H16) showed no increased risk from the present condition (Figure 5).

These changes in peak flow by surface erosion interaction scores are attributable to increases in both elements of the interaction. Peak flow hazard increased overall from added road development, plus the clearcut area added by logging. Surface erosion hazard increased overall from the added road extent, especially the amount added within 100 m of watercourses, which additionally placed some lengths of road on erodible soils, and added many new crossings of streams by roads.

Figure 4. Risk of impact to watercourse channels measured by peak flow versus surface erosion hazard interaction scores, Loomis Creek as a whole and study sub-watersheds combined. 1-low; 2-moderate; 3-high; 4-highest. See supplemental data for detailed calculation.

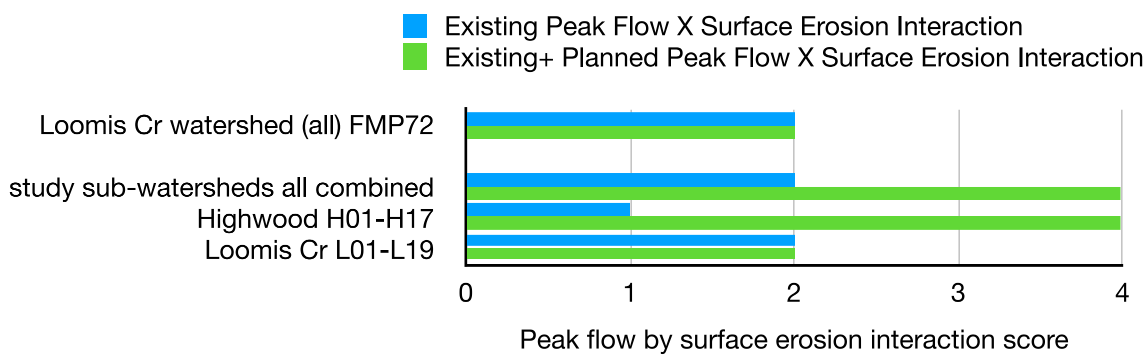
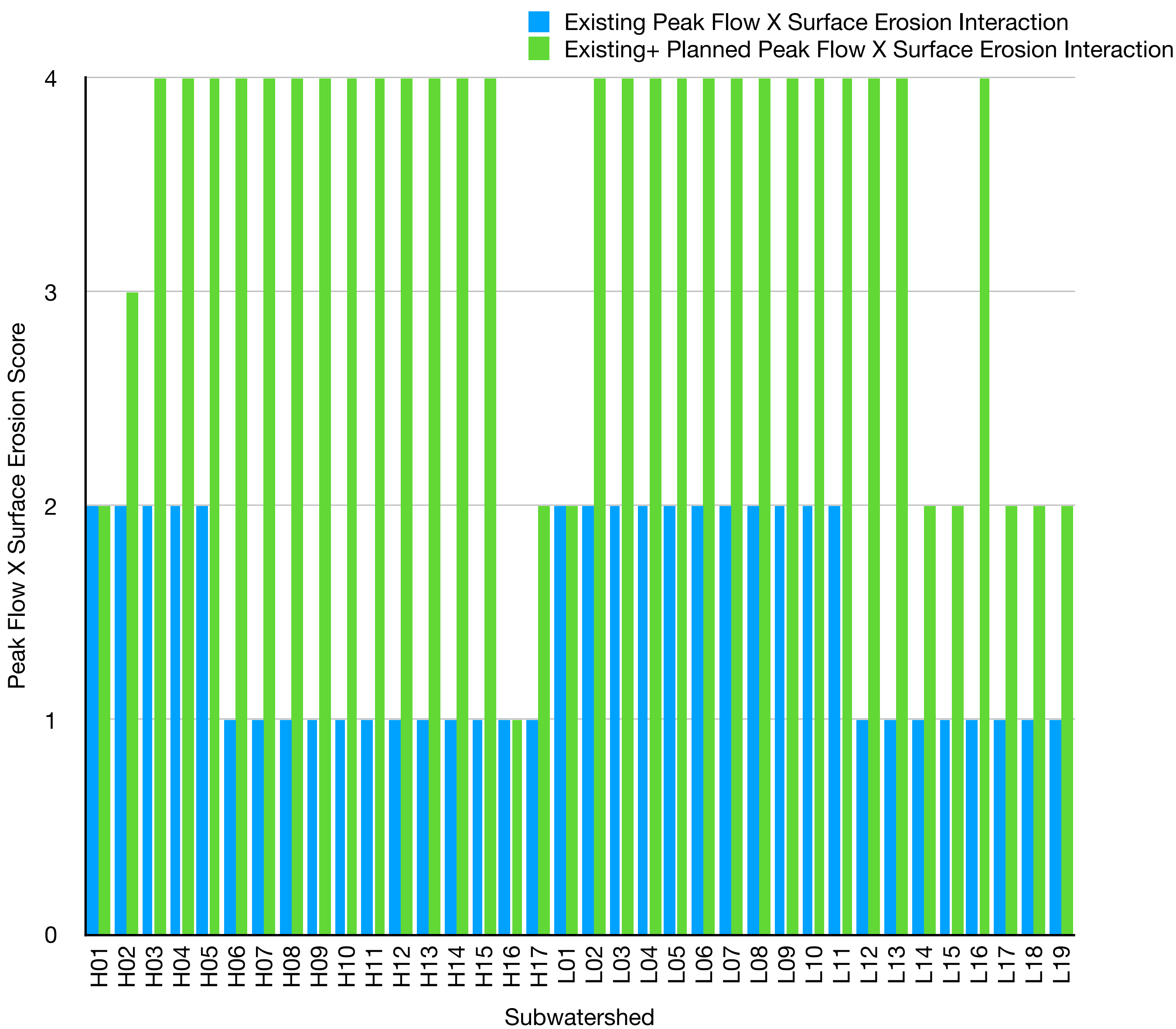


Figure 5. Risk of impact to watercourse channels measured by peak flow by surface erosion hazard interaction scores, individual sub-watersheds. 1-low; 2-moderate; 3-high; 4-highest.



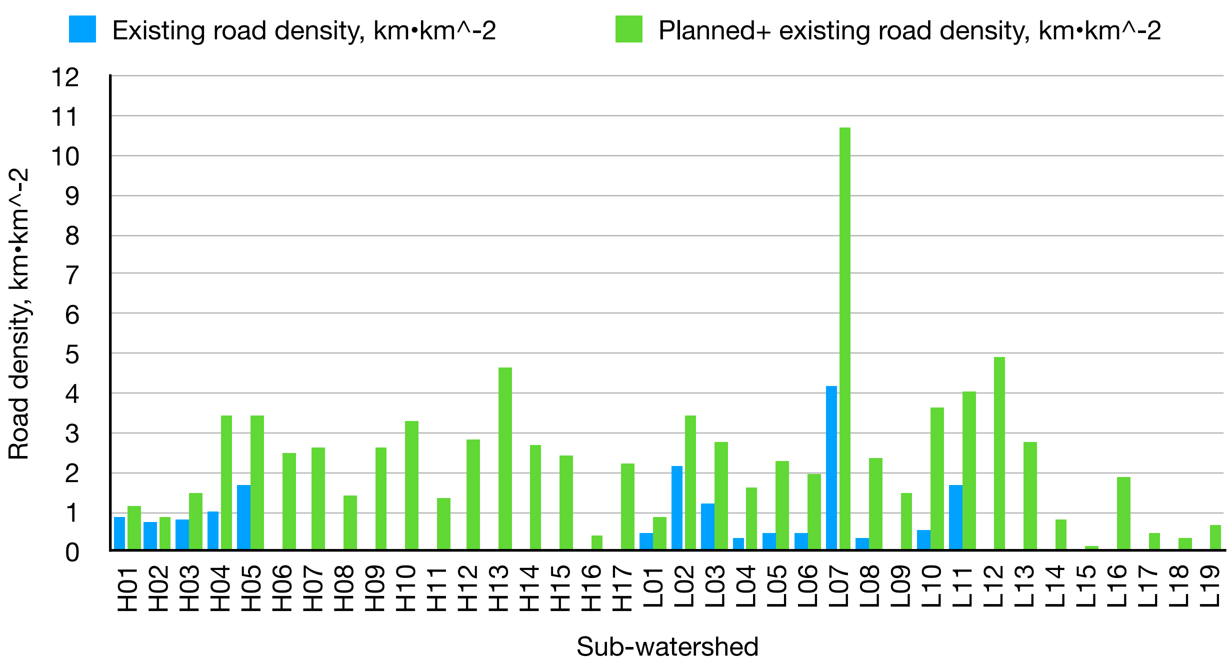
Road Development

A total of 23.9 km of new roads are planned in the overall Loomis Creek watershed, increasing total road length by a factor of 1.76 to a total of 37.5 km in the basin, creating a road density of 1.2 km•km^{-2}. Of the planned total road length, 27.5 km (73%) will be within 100 m of a watercourse, 16.5% (6.2 km) will be on erodible soils, and 8% (3.0 km) will be on erodible soils within 100 m of a watercourse.

Considering only the Loomis sub-watersheds combined, road length is planned to increase by a factor of 5.5 to a total of 20.2 km, creating a road density of 1.05 km•km^{-2} overall in this group. Individual basins L01-L19 are planned to have road densities ranging from 0.1 km•km^{-2} to 10.7 km•km^{-2} (Figure 6). Nine of those will have a road density greater than 2 km•km^{-2}; 3 are planned to equal or exceed 4 km•km^{-2}. Of the planned total road length in L01- L019, 15.7 km (78%) will be within 100 m of a watercourse, 21% (4.2 km) will be on erodible soils, and 9% (1.9 km) will be on erodible soils within 100 m of a watercourse.

The 20 km of planned new roads in the Highwood sub-watersheds combined will increase total road length in those sub-basins collectively by a factor of 7.7, to a total of 22.6 km, creating an overall road density of 1.7 km•km^{-2}. Individual sub-watersheds H01-H17 are planned to have road densities ranging from 0.4 km•km^{-2} to 4.6 km•km^{-2} (Figure 6).

Figure 6. Planned changes in road density, Loomis Creek sub-watersheds.



The IWAP treats the road network as a major sediment source, but also as an extension to the watercourse network, potentially contributing to the risk of increased peak flows. In short, roads are also watercourses. While not all of the additional road will be linked to the natural watercourse network, much of it will be connected to the natural drainage network at the planned stream crossings.

In the total Loomis Creek watershed, existing plus planned new roads will constitute 52% of the natural watercourse length, creating 1.16 crossings per km of the entire drainage network. Those roads in the individual Loomis sub-watersheds will comprise from 0.05 to more than 3.5 times the length of the natural watercourse network length (Figure 7). Planned road length in 7 of the sub-watersheds will equal or exceed total natural watercourse length. The total planned road length creates a total of 0-8.4 crossings per kilometre of natural watercourse length depending on the sub-basin (Figure 8). Of these, 12 (63%) exceed 1 crossing every 500 m, on average; 5 exceed 1 every 333 m.

Figure 7. Existing+planned road length as a proportion of natural watercourse length.

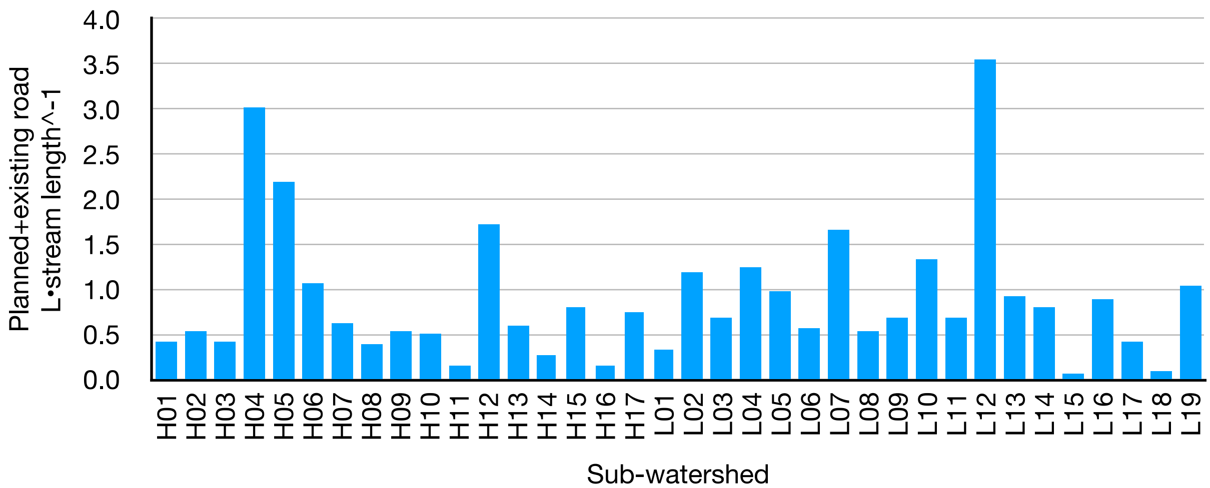
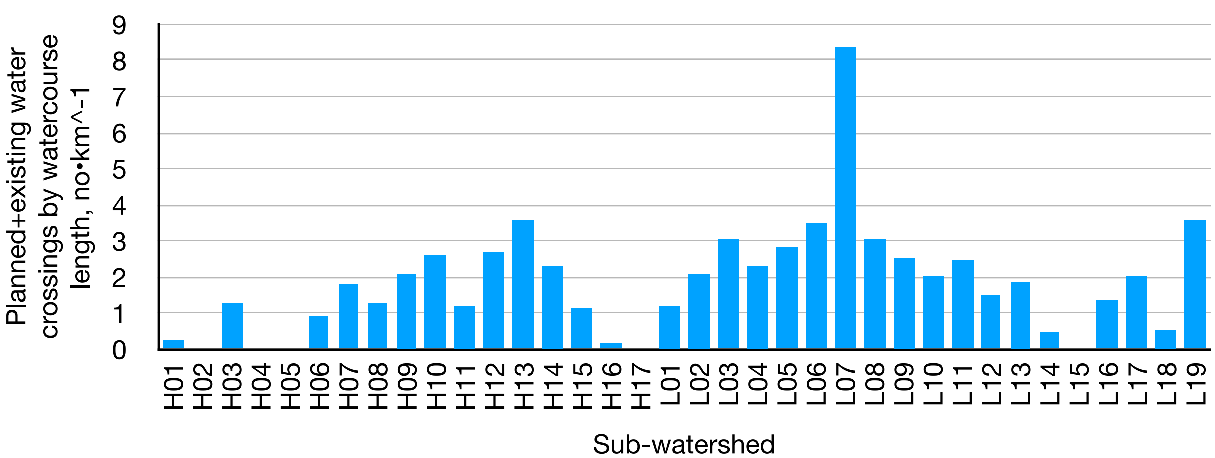


Figure 8. Existing+planned road crossings by natural watercourse length, no.•km^{-1}.



In the Highwood mainstem sub-watersheds, existing plus planned new roads in H01-H17 taken together will make up 0.15 to 3.0 times the length of the natural watercourse network (Figure 7). Much of the additional road in the Highwood sub-watersheds will connect to the natural watercourse network at 38 water crossings, 9.5 times the number at present. making a total of 0-3.6 crossings per km of watercourse length in the H01-H17 sub-basins (Figure 8). Of those sub-watersheds with water crossings, on average 5 will have a crossing every 500 m or less; 1 (H13) will average a crossing every 279 m.

The planned plus existing roads will increase drainage density in the Loomis Creek sub-watersheds taken together by a factor of 1.44 (range 1.05 to 4.54) over the natural drainage density, from 2.39 km•km^{-2} to 3.44 km•km^{-2}. Planned total watercourse density will range from 1.31 km•km^{-2} to 17.1 km•km^{-2}, averaging 5.25 km•km^{-2} (Figures 9, 10). The Loomis Creek watershed as a whole will have increased drainage density over natural by a factor of 1.52 owing to planned plus existing roads, from 2.32 km•km^{-2} to 3.51 km•km^{-2}.

In the Highwood mainstem sub-watersheds taken together, drainage density due to planned plus existing roads will increase over natural by a factor of 1.55 (range 1.15 to 4.03), from 0.89 km•km^{-2} to 1.38 km•km^{-2}, ranging in individual sub-watersheds from 2.47 to 12.6 km•km^{-2} (Figures 9, 10).

Figure 9. Change in drainage density over natural owing to roads as watercourses.

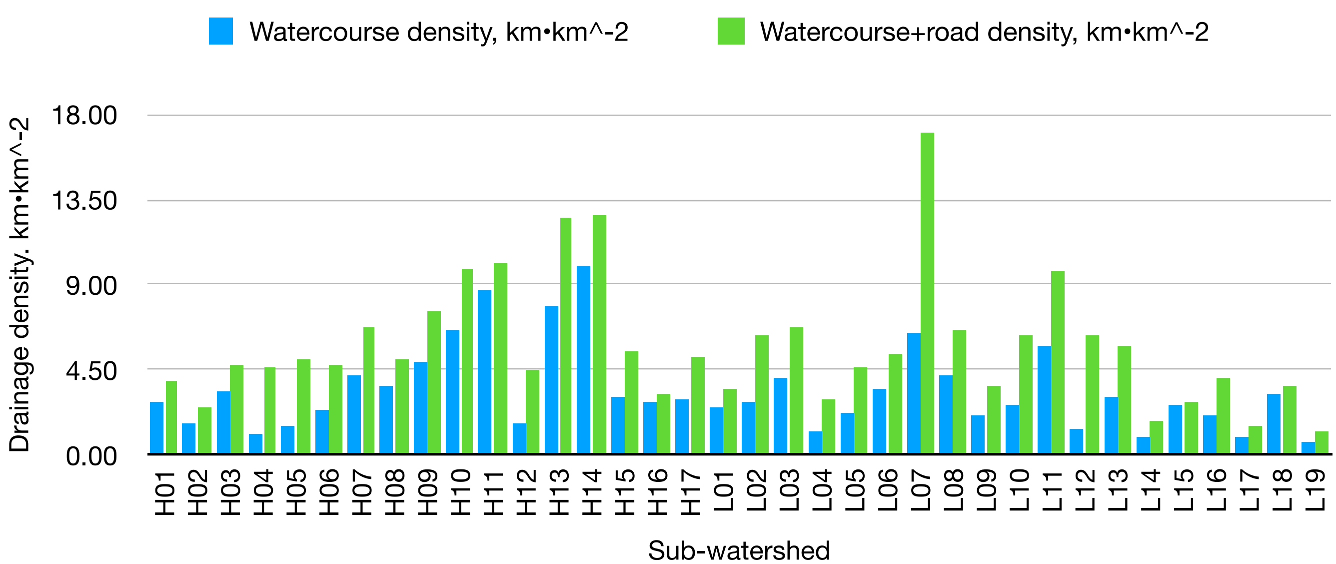
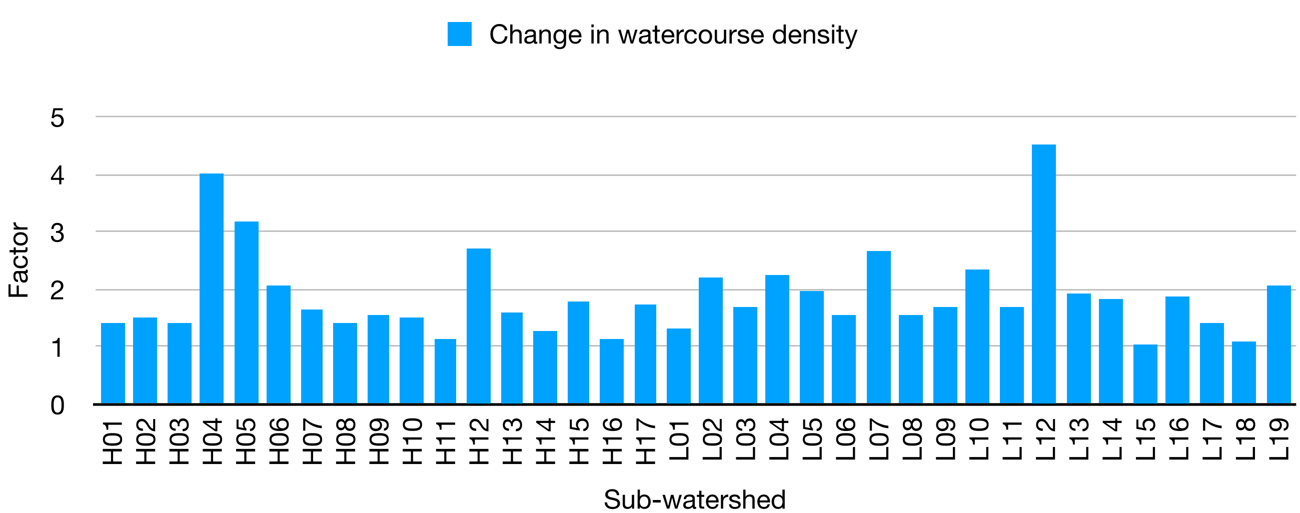


Figure 10. Factor increase in watercourse density owing to planned plus existing roads.



Clearcut Area [7]

Most of the sub-watersheds we studied are small. Only 4 sub-watersheds exceeded 150 ha in area, while the two largest (H16, L15-Bishop Creek) were 388 ha and 811 ha, respectively (Figure 9). The largest single watershed included in this analysis was that of Loomis Creek (FMP72), at 3134 ha (31.34 km^2).

The planned clearcut area overall in Loomis Creek basin is 5.5 km^2, 17.5% of its total area. Planned clearcut area in the individual Loomis sub-watersheds equals or exceeds 25% in 14, 50% in 7, and 75% in 2 sub-basins. Only 4 Loomis sub-watersheds are planned to have clearcut areas of less than 10% of their total area (Figure 11). The clearcuts extend to the banks of 13.3 km of natural watercourse, about 18% of the total watercourse length in the Loomis Creek basin. In the sub-watersheds L01-L19, clearcuts to the banks are planned to equal or exceed 25% of watercourse length in 12 sub-basins, 50% in 8, and 75% in 3 (Figure 12).

A total of 6.34 km^2 of land draining directly to the Highwood River mainstem, not including Loomis Creek, is planned to be logged in 2023-2025, approximately 2.1% of the upper Highwood River watershed above the mouth of McPhail Creek. Planned clearcuts in the sub-watersheds H01-H17 cover 36% of their combined area. Of those, clearcut area will equal or exceed 25% of the total area of 15 sub-watersheds, 50% of 11, and 75% of 5 (Figure 11). Only 2 Highwood sub-watersheds are planned to have clearcut areas of less than 10% of their total area.

The clearcuts planned in the Highwood sub-watersheds taken together extend to the banks of 9.9 km of natural watercourses, about 24% of the total natural watercourse length in this group. In the sub-watersheds H0-H19, clearcuts to the banks are planned to equal or exceed 25% of watercourse length in 10 sub-basins, 50% in 4, and 75% in 1 (Figure 12)

[7] Because all logged areas in this study will be new with an equivalent clearcut area of 100%, we use the term clearcut area here for brevity.

Figure 11. Area of sub-watersheds (**a**), and proportion of area planned to be harvested (**b**).

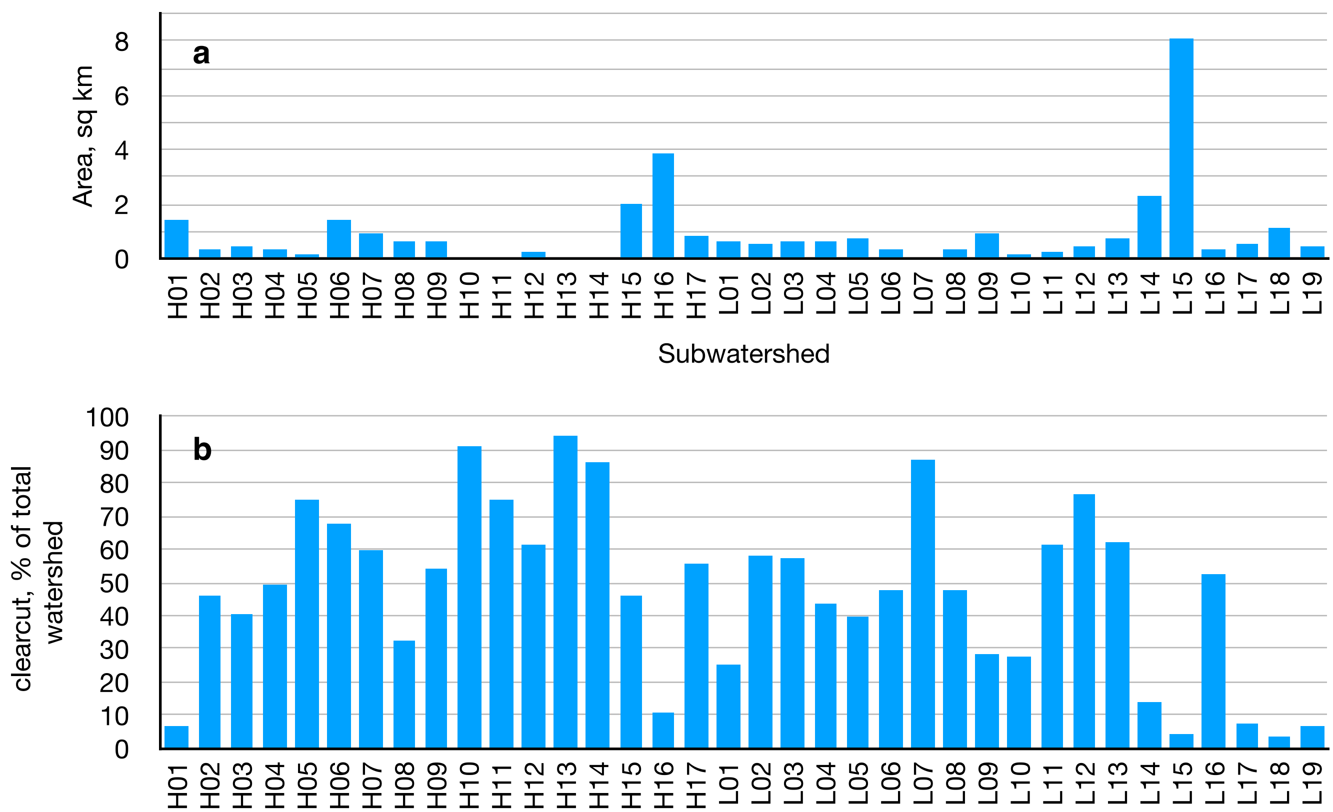
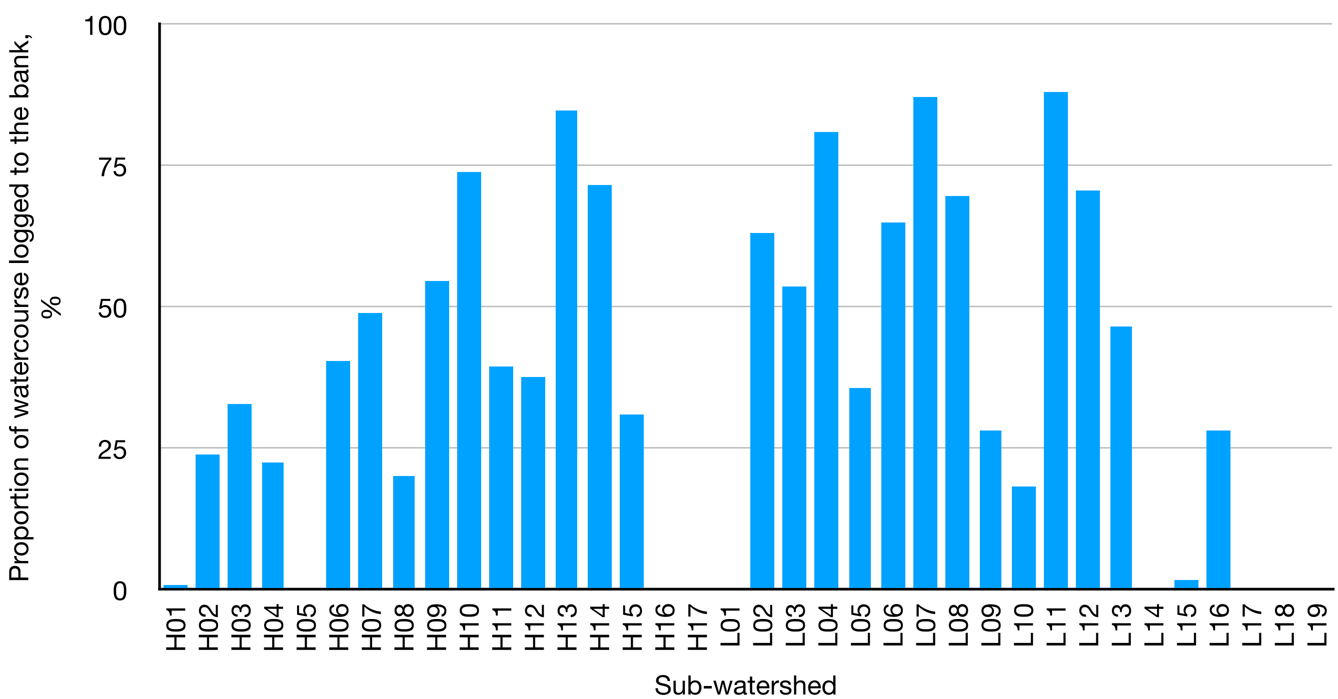


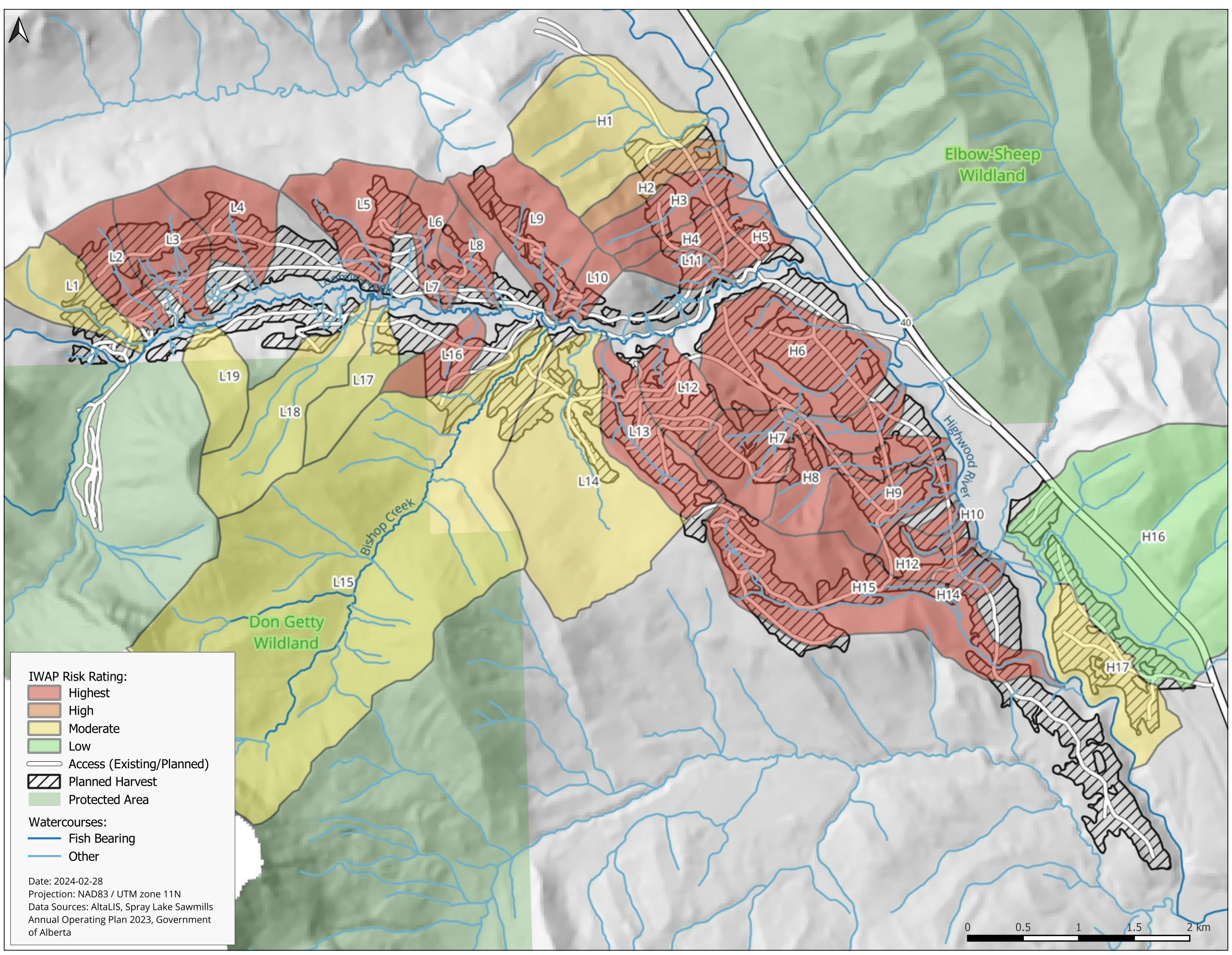
Figure 12. Proportion of watercourse length logged to the bank.



Discussion

Small watercourses throughout the study area are at increased risk from the proposed logging plans. Those at the highest rated risk are in the Loomis Creek watershed and Highwood right bank sub-watersheds (Figure 13). Of the 36 sub-watersheds studied, 24 (67%) received the highest risk rating. In the Loomis Creek basin alone, 13 of the 19 (62%) sub-watersheds received the highest risk rating, most of them draining the left bank, south-facing slopes. Trout have not been found in these small watercourses in the limited sampling reported to date[8], but they use the entire mainstem Highwood River and Loomis Creek throughout the area (Government of Alberta 2023d, Coombs 2023). Trout may use some of the small watercourses if accessible, especially in their lowest reaches, during periods when flows are sufficient to support them. Whatever the case, trout habitat in the mainstem Highwood River and Loomis Creek near the mouths of the sub-watersheds is vulnerable to changes to those tributaries.

Figure 13. Distribution of risk among 36 sub-watersheds in the upper Highwood logging area, based on IWAP analysis of planned plus existing road and logging development. Green, low risk; yellow, moderate risk; orange, high risk; red, highest risk.



8 Except that cutthroat trout occur in Bishop Creek (Government of Alberta 2023d), a third order watercourse and by far the largest of the sub-watersheds.

We emphasize the risk concerns of small watercourses[9] here because they are especially sensitive to disturbance (Buttle *et al*. 2012), and are subject to serious erosion and sediment problems in logging operations (Shaw and Thompson 1986:30 *ff*., Chamberlin *et al*. 1991:183). Small streams are particularly closely coupled with adjacent riparian and terrestrial environments. Impacts on small watercourses are expressed downstream and may affect protected at-risk trout and their critical habitats in the fish-bearing reaches of the principal streams. Such small headwaters make up 70%-80% of total channel length of river networks, so their health is essential to the health of the waters they flow into (Wohl 2017, Ferreira *et al*. 2023).

Significant concerns for watercourse health generally in logging operations are (Chamberlin *et al*. 1991, Swanston 1991, Waters 1995:24-36, Hartman 2004, Moore 2005, Luce and Danehy 2022):

- logging roads are sediment sources: they erode and deliver sediments to watercourses;
- logging roads intercept surface flow and shallow groundwater, concentrate runoff, and deliver it to watercourses at novel locations;
- clearcuts increase the frequency and magnitude of peak flows;
- clearcuts expose watercourses, the ground surface, and near-surface groundwater to the sun, increasing water temperature in receiving streams.

We now discuss the relevance of these issues to the logging planned for the upper Highwood.

Logging Roads

There is substantial evidence that trout populations are negatively affected by road networks in their watersheds.

In the Kakwa River watershed in northwestern Alberta, the probability of occurrence of bull trout in sub-basins declined precipitously with any increase in road density (Ripley *et al*. 2005). For example, a road density increase from 0 $km \bullet km^{-2}$ to 0.6 $km \bullet km^{-2}$ was associated with a 70% decrease in the probability of bull trout occurrence, from ~0.6 to ~ 0.18 (Ripley *et al*. 2005:Figure 2). For comparison, initial planned road density in Loomis Creek will be 1.2 $km \bullet km^{-2}$, extending for up to 3 years or more.

In watersheds draining the western slopes of the Continental Divide southeastern BC, westslope cutthroat trout abundance was negatively related to several IWAP measures of roads, including road density, roads on erodible soils, and roads within 100 m of streams (Valdal and Quinn 2010).

In 46 Swan River tributaries, Montana, road construction and maintenance contributed most anthropogenic fine sediment loading to stream substrates (Shepard *et al*. 1984). The same

[9] First- or second- order watercourses such as these are also termed headwaters (Wohl 2017). We do not use that term in that restrictive way here. We use headwaters in its more general sense to refer to all drainages flowing into mainstem streams and rivers.

study showed in a field experiment a strong negative correlation between fine sediments in the substrate and bull trout egg to emergence success, Bull trout juvenile population density was also negatively correlated to fines in the substrate (as measured by substrate score) in 26 Swan River tributaries. In a separate study, bull trout redd counts in 9 principal spawning streams in this same basin were negatively correlated with the density of logging roads (Baxter *et al*. 1999).

Huntington (1998) reported in a study of 1769 km of streams in the Clearwater basin, Idaho, that "streams in unroaded areas had higher quality trout habitat with significantly lower levels of fine sediment than those in roaded landscapes despite a relatively recent (<100 year) history of catastrophic wild fires in many unroaded watersheds." Habitat in unroaded areas tended to support more diverse and abundant populations of native trout. Extremely steep (>10.0% gradient), strongly confined streams with low sinuosity, and moderately steep (1.5-4.0% gradient), moderately confined, and moderately sinuous streams had median abundances of pool habitat significantly greater in unroaded areas compared to roaded areas. Low levels of cobble embeddedness in fine sediments were less common, and high levels far more common in managed (roaded) than in unroaded streams. Native trout (rainbow, steelhead, westslope cutthroat, and bull trout) occupied smaller percentages of the sampling stations within roaded as opposed to unroaded landscapes.

Dunnigan (1998) found that abundance of westslope cutthroat trout was positively correlated (p=0.01) with pool frequency in the Coeur d'Alene River drainage, Idaho, while pool frequency tended to be negatively associated with watershed road density (p=0.058).

Forest roads deliver increased loads of sediment and water to streams, or in some cases intercept and divert water and sediment from streams (Jones *et al*. 2000), in both cases changing and potentially damaging instream habitat for fish and other aquatic organisms. Roads can increase drainage density and the extent of the watercourse network substantially, intercepting and routing surface and subsurface runoff, potentially contributing to increased peak flows (Wemple *et al*. 1996, Wemple and Jones 2003). The IWAP therefore places considerable emphasis on road-related measures as indicators of risk to watersheds and stream habitat. Our IWAP results show that the planned additional length of roads, acting as watercourses, often more than doubles the length of watercourse in the sub-basins, with much of the added water and sediment entering the presently existing natural watercourse network at 122 crossings, contributing to the greatly increased risk to many of the watercourses in the sub-watersheds to be logged.

The consequences of such roads, especially when not adequately reclaimed, are already evident in the study area (several examples are shown in the Appendix under Logging Roads), even though the current IWAP risk is rated as only moderate overall in the Loomis basin, and low overall in the much larger Highwood basin. Even a moderate IWAP risk rating in this study therefore means there is significant risk of disturbance from clearcut logging.

The logging company is certainly aware of the issues with roads, and has ways of mitigating them, but there are serious limitations to the effectiveness of mitigation even when done properly. As part of their Forest Management Agreement (SLS 2021a:Annex I), WFC forestry road development, maintenance and management is governed by Best Management Practices (BMPs) and Operating Ground Rules (OGRs) applicable to logging operations in the entire province (Government of Alberta 2023a:45-49), with a special addendum to apply to WFC's operations covering the study area (Government of Alberta 2022:41,43). The province-wide OGRs for road classification, planning and design consist of a short list of some simple BMPs for design, which only need to be "considered;" five sentences of description; plus the ground rules proper, listing and tabulating some specific requirements.

For example under best management practices for roads, "Where topography (slope, elevation) limits the ability to locate roads away from riparian areas, temporary roads should be located as far away from the bed and shore of the watercourse as possible."[10] Under Ground Rules, rights-of-way shall be 20 m wide maximum, including 10 m width of road surface, and have a tenure of up to 3 years during winter or dry conditions (Government of Alberta 2023a:Table 3), although extensions will be entertained for approval.

Apart from the specific dimensions stipulated for road width, many protective treatments are discretionary, with much being left to the operator's judgment. For example, the ground rules for erosion control on roads are listed as progressive reclamation; cross drains and ditch blocks dictated by slope and soil conditions; and drainage water to be diverted off the ROW (right-of-way) in as short a distance as possible. Water crossings must adhere to the Alberta Government's Code of Practice for Watercourse Crossings (Government of Alberta 2019), which itself provides for plenty of discretion by operators.[11]

WFC proposes to decommission its roads within 3 to 5 years (SLS 2021a:Chapter 2:38). Terms extend from the timber year following the timber year in which the harvest area is approved, and may be extended with Government of Alberta approval (Government of Alberta 2023a:43). Depending on the class of road, the operable period for roads may extend seemingly indefinitely with Government of Alberta approval (e.g., Government of Alberta 2022:4.2.11.2). Considering disturbances from road building, even a few minutes is long enough for the effect of roads to be felt in stream trout habitat. Still, the specific addendum to FWC's Forest Management Agreement seemingly gives very wide latitude for amendments to road plans (e.g., Government of Alberta 2022:4.1.3.7). The effectiveness of decommissioning itself is questionable, given experience elsewhere in this FMA (Silvester Creek example in Appendix).

Given the many discretionary elements in the BMPs and OGRs, and given our experience with their operation elsewhere in the FMA, we believe it is highly unlikely that road building and use on the scale required for the planned logging operations can be effectively mitigated

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[10] In contrast, SARA specifically requires a fixed 30-m riparian strip of protected critical habitat on either side of watercourses that are themselves protected as critical habitat (DFO 2019, 2020b).

[11] See Schedule 2, Part 1 a, b, d, e, for example, which use the wording "where technically feasible," "if possible," "if not possible," "minimize disturbance," in connection with protective measures, showing that crossings take priority over other values, and that watercourse protection is often discretionary.

in the study area. This matter is of utmost importance where SARA-listed trout are concerned, and is discussed in more detail later.

Clearcuts

In snow-dominated hydrologies such as that in the study area, clearcuts may contribute to increased peak flows by holding more snow than the forest does, primarily as a result of reduced interception, reduced evapotranspiration, and increased exposure to the sun. The effect may be enhanced or partly mitigated by orientation, slope (Pomeroy *et al*. 2012), and very likely exposure to winds such as the chinook in southern Alberta. The risk of peak flow increases as assessed in the IWAP are mostly attributable to the amount of forest clearcut, or equivalent. Our results show that a large proportion of the small sub-watersheds are at high risk from peak flow increases owing to the large proportion of their area slated for clearcutting. Commonly more than 40% of the total area of these sub-watersheds face forest removal; half of all sub-basins studied are planned to have 50% or more of their area clearcut; a few, much more (Figure 11).[12]

In contrast to several studies relating roads to trout abundance and habitat quality, fewer relate clearcuts directly to those parameters. Two studies seem particularly appropriate to WFC's annual operating plan for the upper Highwood River.

Ripley *et al*. (2005) concluded that by using their observed negative relation between bull trout occurrence and percentage of sub-basins harvested derived from their most parsimonious logistic regression model, they forecast that forest harvesting over the next 20 years (from their study date) would result in the local extirpation of bull trout from 24% to 43% of stream reaches that currently support the species in the Kakwa River Basin at the northern end of the Rockies in Alberta. Their Figure 2 shows a strong negative relationship between the percentage of the sub-basin harvested and the probability of occurrence of bull trout, such that, for example, an increase from 0% to 20% of the sub-basin harvested is associated with a predicted decline of 53% in the probability of bull trout occurrence. In discussing their results, Ripley *et al*. (2005) noted that extirpations of bull trout from sites that currently support moderate and high densities of bull trout were projected in their analysis to increase disproportionately with forest harvesting.

In an analysis of several watersheds in the Kootenay River system draining the southern West Slopes of the Continental Divide in BC, Valdal and Quinn (2010) found no relationship between cutthroat trout abundance and equivalent clear-cut area, but recent logging adjacent to streams was a key parameter in a model predicting cutthroat trout abundance. They stated, "evidence from this study indicates that logging of non-fish bearing perennial and ephemeral

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[12] Recall from the Methods that the IWAP calculates ECA as a proportion of the total watershed area, while SLS (2021a) calculates it as a proportion of the forested area only. So, for example, SLS (2021a:Chapter 5:152) reports that initially (year 10), the ECA for Loomis Creek (watershed ID 72), which has large areas of unforested rock and shrubs, is 46% (of the currently forested area), whereas the IWAP calculation is 17.5% (of the total watershed area, including rock and shrubs) for the year logging is completed. The clearcut area we calculate here is thus actually a minimum estimate of the amount of total forest area removed in each sub-watershed.

streams is likely a key factor that has negative downstream effects on cutthroat trout abundance."

Runoff and streamflow

The principal concern with clearcuts in snow-dominated hydrologies such as the study area is the likelihood of an increase in the frequency and magnitude of peak flows, potentially coupled with an extended period of low flows. The frequency and magnitude of peak flows occurs primarily as a result of greater snow retention in the clearcuts resulting from lower interception by trees and lower evapotranspiration in the cutblocks. This, perhaps plus greater exposure to springtime sun leads to increased rate of snowmelt, advanced runoff timing, increased peak flows and an extended period of low flows. The higher peak flows can be expected to cause channel destabilization, lost or damaged aquatic habitat, and sometimes increased overall water yield. Specifically, higher peak flows lead to greater erosive forces in alluvial watercourses, thereby affecting trout habitat by widening and shallowing the channel, filling in pools and substrate interstices with sediment, and mobilizing more fine sediment in the water, so reducing water quality (Carver 2001:Figure 2).

There is a great deal of variation in the changes to streamflows from forest removal, including clearcut logging, in interior snow-dominated hydrologies. A detailed analysis of the impact of clearcut harvesting on streamflows therefore is beyond the scope of this report, however the following observations are informative for judging the possible impact of the 2023-2025 planned logging in the upper Highwood watershed.

In west central Alberta near Hinton, Swanson and Hillman (1977) calculated that the effect of clear-cutting would be "(1) an increase in streamflow during the snowmelt freshet, (2) an annual yield increase of 20-30%, (3) an increase in storm flow peak magnitude of four to five times, and (4) a longevity of more than 30 years before these effects begin to diminish." Actual measurements to validate their estimates on 9 logged and 9 unlogged catchments found 59% more flow during freshet, 27% greater yield over the gauging season, and an increase in storm peaks of 1.5-2 times.

In the 26 km^2 Redfish Creek basin, southeastern BC, equivalent clearcut area as a percentage of the total watershed ranging from ~8%-20% resulted in increases to peak streamflows between 11% to well over 20% (Whitaker *et al*. 2001, 2002:Figure 12a).

In the Marmot Creek Research Basin, Kananaskis drainage, Alberta, peak basin streamflow increased almost 15% in response to ~37% forest cover removal by clear-cutting on south-facing slopes (Pomeroy *et al*. 2012:Figure 10). On clearcut north-facing slopes, peak basin streamflow increased somewhat less: ~12%. At ~13% forest removal by clearcutting, basin peak flows increased 11% on south-facing slopes and ~8% on north-facing slopes, respectively.

Following the methodological critique of historical paired watershed streamflow studies by Alila *et al*. (2009) and Green and Alila (2012)[13], in which they emphasized analyses of changes in peak flow frequency as well as magnitude due to logging, these and other analyses by this research group have brought new clarity to the impact of clearcut logging on peak streamflows.

Alila *et al*. (2009:19, first paragraph) asserted that "*Perhaps it is not by coincidence that a correlation between forests, forest harvesting, deforestation, and floods was found in the few extraordinary studies that had not applied a chronologically paired event analysis [Anderson and Hobba, 1959; Swank and Vose, 1994; Schnorbus and Alila, 2004; La Marche and Lettenmaier, 2001; Bradshaw et al., 2007, 2009; Lin and Wei, 2008]*." [italics added] In other words, there was substantial evidence of forest removal causing higher peak flows, even floods, at that time.[14]

In a meta-analysis of postharvest data at four catchments (3–37 km^2) in interior BC and Colorado with moderate level of harvesting (33%–40%), Green and Alila (2012) demonstrated that harvesting increased the magnitude and frequency of all floods on record, and that the effects can increase unchecked with increasing return period.

In an analysis of a well-studied Okanagan watershed, Kuraś *et al*. (2012:17) stated:

"*Planned harvesting (50% harvest area with roads) is found to have both a statistically and physically significant effect (9%–25% over Control) on peak flows with recurrence intervals ranging 10–100 years for all three streamflow metrics. This indicates that the effects of this particular scenario may have substantial ecological, hydrological and geomorphological consequences. This is especially the case since increases in peak flow frequency following harvesting increase with [time], with the largest events (T = 100 years) becoming 5–6.7 times more frequent (compared to Control). This can lead to changes in channel form, for example, that could result in channel destabilization and stream bank erosion with a direct impact on downstream water quality*." [italics added]

A study of another BC interior (Okanagan) snow-dominated small watershed (Schnorbus and Alila 2013:532) showed:

"*Both large and small annual peak flow events are increased following harvesting. From a frequency perspective, events of a given magnitude are therefore expected to become more frequent following harvesting and, inconsistent with the prevalent hydrological wisdom, the larger the event the greater its increase in frequency. Depending upon the statistical test used (i.e., comparing distributions or comparing individual quantiles), peak flow impacts do not become statistically significant until harvest area exceeds 20% or 30% of the original forested area.*" [italics added]. Another study of the same watershed after 50% of the area was logged showed that, while annual water yield was little affected, there was a marked change in the timing and magnitude of April through June streamflow, with post-logging April and May water yield increasing by 29% and 19%,

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[13] For comments and responses to these papers, see Lewis *et al.* (2010), Alila *et al.* (2010), Bathurst (2014), Birkenshaw (2014), and Alila and Green (2014a, 2014b),

[14] We did not obtain a copy of Anderson and Hobba (1959), so were unable to confirm this statement for that source.

respectively, while June and July water yield decreased by 23% and 17%, respectively (Winkler *et al*. 2017). Annual water yield was little changed by substantial (50%) logging, but the peak was simply shifted to earlier in the year, leaving yields lower later in the season. That type of shift would leave streams drier for a longer period, especially in the fall and winter, when streamflows are most critical to fall-spawning species, and to all resident species for overwintering.

In two large and moderate-sized central BC interior watersheds, "*Harvesting only 21% of the watershed caused a 38% and 84% increase in the mean but no increase in variability around the mean of the frequency distribution in the Deadman River and Joe Ross Creek, respectively. Consequently, the 7-year, 20-year, 50-year, and 100-year flood events became approximately two, four, six, and ten times more frequent in both watersheds.… it is the inherent nature of snowmelt-driven flood regimes which cause even modest increases in magnitude, especially in the upper tail of the distribution, to translate into surprisingly large changes in frequency. Contrary to conventional wisdom, harvesting influenced small, medium, and very large flood events, and the sensitivity to harvest increased with increasing flood event size and watershed area.*" (Johnson and Alila 2023:abstract).

Recall that planned clearcut area of WFC's annual operating plan equals or exceeds 25% of the total watershed in 29, 50% in 18, and 75% in 6 of 36 sub-basins (Figure 9). These and other studies (Table 2) show that increases in peak flows are common and widespread for a variety of global locations, watershed sizes and proportion of catchments logged.

On the basis of the papers discussed above in this section, tabulated results from the literature (Table 2), the WFC (SLS 2021a, 2023) forest management plan, the present annual operating plan for the upper Highwood drainage, and from our level 1 watershed assessment based on WFC's data, we conclude that peak flows are likely to increase in study area sub-watersheds as a result of WFC logging, and that a shift in the annual peak flow to earlier in the year is reasonably likely to lead to earlier onset of low flows, which would cause low flows to persist over a more prolonged period. These changes have a significant likelihood of harming critical habitat of SARA-listed bull trout, a conservation population of near-pure westslope cutthroat trout, and a highly-valued sportfishing population of rainbow-cutthroat hybrid trout in the upper Highwood drainage.

Table 2. Studies of effects of logging on peak streamflows for a wide range of locations and basin sizes.

Watershed	Total area, sq. km	Proportion of area logged, %	Road length, km	Increased watercourse density from roads, %	change in peak flows	Source
Fool Creek, CO	2.89	40	14.2, 5.3		increase in magnitude and frequency, persistent ≥50y	Alila et al. 2009
WS1, Lookout Creek, OR	1.00	100	0		increase in magnitude and frequency	Alila et al. 2009
WS3, Lookout Creek, OR	"similar to WS1"	25	roaded	21-50	increase in magnitude and frequency	Alila et al. 2009
WS2, Lookout Creek, OR	0.60	0	0		control	Alila et al. 2009
Redfish Creek, BC	25	33			increased magnitude & frequency of floods	Green & Alila 2012
240 Creek, BC	5	40			increased magnitude & frequency of floods	Green & Alila 2012
Camp Creek, BC	37	37			increased magnitude & frequency of floods	Green & Alila 2012
Camp Creek, BC	37	24			mean peak flow increased by 31%; 2-4-fold increases in 10, 20, 50-y peak flows	Yu and Alila 2019
241 Creek, BC	4.74		4.7	37	+9-25% increase in magnitude 1:10-1:100 events, with 1:100 5-6.7x more frequent	Kuras et al 2012
241 Creek, BC	4.74	47			7 years post-logging, average April & May water yield increased by 29% and 19%, respectively. June & July water yield decreased by 23% & 17%, respectively.	Winkler et al. 2017
9 watersheds, Sweden, WY, BC, ID, AB	0.4-34.20	21-100			6y no change, 17 increased streamflow 5-79%	Winkler et al 2017:Table 1
3 Marmot Creek sub-basins, AB	2.35-2.94	4-36			peak flow increases 8-15%	Pomeroy et al 2012:Figure 10
9 watersheds, Hinton, AB	7.0-22.1	35-84			increased freshet, stormflow magnitude 4-5x, for 30+y	Swanson & Hillman 1977
Willow R watershed, BC	2860	≤ 30			increased mean & peak flows annual & spring, low flows no change, or inconclusive	Lin & Wei 2008
56 countries, Africa, Asia, South America					flood frequency negatively correlated with the amount of natural forest, positively correlated with natural forest area loss after controlling for rainfall, slope and degraded landscape area	Bradshaw et al. 2007
9 sub-catchments Deschutes drainage, WA	149 overall, sub-catchments 2.1-21	50 overall catchment,	547 overall catchment		sub-catchments mean annual flood due to forest roads alone increased in magnitude 2.2-9.5%; 2.9-12.2% for 10 year event. Mean ann. flood increased 7.7-21.8%, roads+harvest over pristine forest.	La Marche & Lettenmaier 2001

Stream Temperature

The IWAP does not explicitly consider stream temperature changes and their likely impacts, so we do so here. Our concern is for the effect of increased temperatures from clearcut logging on trout populations and their critical habitats. Particularly worrying is the proportion of total watercourse length planned to be logged to the banks. Twenty-two of the 36 sub-watersheds are planned to have more than 25% of their watercourse length left without a riparian buffer (Figure 12).

Clearcut logging commonly results in increases to summer stream temperatures, even when riparian buffers are employed (Moore 2005:136-138, Moore *et al*. 2005:136-138, Richardson *et al*. 2022:106-110). There is a great deal of variability in the data, but increases of 2-7°C post-logging appear to be common, while when riparian buffers of various sizes and types are employed, stream temperatures tend to show lesser increases in the order of 0-5°C (Moore 2005:136-137, Moore *et al*. 2005:Table 1). Elevated water temperatures can persist anywhere from 2-16 years.

Stream warming after clear-cutting is greatest in spring and summer, especially as measured by maximum temperature (Richardson *et al*. 2022). It is also greater during low discharge periods. Stream temperature typically increases downstream for some distance from the upper edge of cutblocks; however, there is wide variation in response magnitude. Wide, shallow reaches, as might result from increased sediment loading to alluvial channels like those common in this study, are especially sensitive to water temperature increases. Streambed temperatures can also increase after clear-cutting, with likely effects on trout incubation times to hatching.

Leaving a riparian buffer can reduce, but not always eliminate, streamwater and streambed warming (Richardson *et al*. 2022:108-109). Narrow buffers of standing forest trees are at risk of blowdown, which can reduce their effectiveness. Riparian buffers do not always appear sufficient in clear-cuts in WFC's management areas (examples in Appendix: Best Management Practices & Operating Ground Rules). Stream temperature recovery may extend over several years, from as low as ~ 2 years in narrow watercourses (≤ 1 m bankfull width) to ~12-16 years in wider (6-12 m) streams in productive forest areas. We should expect longer recovery periods in our lower-productivity East Slopes forests.

Shallow groundwater is warmed in summer when the forest is removed (Radler et al. 2010). It has been suggested that such warming can lead to warming of the stream (Hartman *et al*. 1982:596 Hewlett and Fortson 1982, Moore *et al*. 2005:818). Many highest-risk sub-watersheds in our study area lie along the south-facing slopes of Loomis Creek (Figure 13), where there are numerous small spring-fed watercourses. In addition to more and possibly earlier peak runoff from these sub-watersheds (Pomeroy *et al*. 2012:1900), we should expect warmer groundwater to enter Loomis Creek from these slopes.

Bull trout is a cold stenothermic species that is highly sensitive to increasing water temperatures. Small maximum daily stream temperature increases in the order of just 1-2°C at ambient water temperatures of 12-13°C can reduce bull trout numerical dominance and physical condition, rendering them less able to withstand invasion from rainbow trout (Haas 2001). Such small temperature increases are well within those to be expected from clearcut logging in the study area.

Westslope cutthroat trout are also cold stenotherms, but to a lesser degree. In a physiology study, metabolic performance of a southeastern BC population was optimal at ~15 °C and decreased substantially beyond this temperature, until lethal temperatures were reached at ~25 °C (Macnaughton *et al*. 2021). Preferred temperature was quite high, however, at 19.9°C. A previous study of westslope cutthroats from western Montana (Bear *et al*. 2007), had found an optimum growth temperature of 13.6°C, and an incipient lethal temperature of just 19.6°C. Differences possibly reflect inherent stock differences and local adaptation, which appear to be common in this species (e.g., Drinan et al. 2012; Strait *et al*. 2024).

Tolerance by westslope cutthroat trout of lower water temperatures than those favoured by rainbow trout has been invoked as one way in which hybridization between the species is checked, so that genetically-pure cutthroats are restricted to the upper reaches of streams in southern Alberta (DFO 2019). Rasmussen *et al*. (2010), for example, found that pure westslope cutthroats occupied upper Dutch Creek at mean summer water temperatures of <7.3°C, while rainbow trout and hybrids, unseparated from upstream reaches by physical barriers to upstream movement, were found in this stream only in the lower and middle reaches where temperatures were warmer. Rasmussen *et al*. (2010) also suggested, based on their study, that warming caused by clear-cut logging leading to increased stream temperatures could result in an upstream shift of rainbow trout alleles (i.e., an increase in hybridization in the cutthroat trout population).

BMPs, OGRs & the Species at Risk Act

Best Management Practices (BMPs) and Operating Ground Rules (OGRs) were discussed briefly under Logging Roads, where WFC uses them to deal with the environmental impacts of roads. We pointed out their discretionary nature. Here we discuss them in the context of their adequacy in meeting the strict protective requirements under the federal *Species at Risk Act* (SARA).

In Alberta, BMPs are general principles that, if followed, are expected to limit environmental damage (Government of Alberta 2019, 2022, 2023a). They are effectively unenforceable. OGRs are more specific directions to be followed to achieve the BMPs, and are relied upon in the current Forest Management Plan to protect, among other things, trout and their habitat in the study area. However,

"*While adherence to the listed Ground Rules is an expectation, there are any number of circumstances where a deviation from a rule may be deemed necessary by a timber disposition holder while planning or conducting operations. As such, requests to deviate from any of the listed Ground Rules may be possible but these requests are subject to a review and an approval decision by Alberta to ensure that the likely outcomes do not compromise our sustainability objectives.*" (Government of Alberta 2023a:8).

Again, there are rules, but there is wide discretion to alter the rules. In effect, the Government of Alberta is saying that if you don't like these rules, we'll make others you may prefer.

Discretionary protections such as Alberta's best management practices, operating ground rules, and water crossing guidelines leave considerable room for highly consequential failure (see the Silvester Creek example in the Appendix: Best Management Practices & Operating Ground Rules Failures). This is especially true given that in this case they are expected to protect the habitats of threatened and legally protected bull trout; a near-pure population of native cutthroat trout of high value (termed a conservation population[15]) for recovering threatened and legally protected westslope cutthroat trout (DFO 2019:pdf p. 128, DFO 2020a:1); and a hybrid rainbow-cutthroat hybrid trout population highly valued by anglers, yet only somewhat protected by discretionary measures under the federal *Fisheries Act*. In contrast, the SARA fish and habitat protection provisions to protect listed at-risk species are stringent non-discretionary legal requirements for which discretionary BMPs and OGRs are clearly inadequate.

SARA section 58(1) states:

> ***Destruction of critical habitat***
>
> *"58 (1) Subject to this section, no person shall destroy any part of the critical habitat of any listed endangered species or of any listed threatened species — or of any listed extirpated species if a recovery strategy has recommended the reintroduction of the species into the wild in Canada — if …*
>
> > *(b) the listed species is an aquatic species;"*

We are not lawyers or legal experts, however in the matter of discretionary protection of fishes and their habitat under SARA, we would draw attention to the carefully considered analysis of the Federal Court of Appeal (2012) which ruled that discretionary measures are insufficient to comply with the requirements of SARA habitat protection.

The Court ruled that section 58 requires the Minister of Fisheries, Oceans and the Coast Guard to ensure the critical habitat of SARA-listed fish is protected with stringent non-discretionary legal requirements (at para 125). The Court also noted that the legal duty to protect habitat under section 58 is different from habitat management, and that the Minister cannot rely on discretionary management measures to fulfil habitat protection obligations (at paragraph 114). The Court also stated that the Minister cannot use an agreement with another government to avoid non-discretionary habitat protection (at paragraph 119).

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[15] Study and assessment of which is priorized as Urgent for review of land-use applications (DFO 2019:56). On pdf p.128 paragraph A38 of that document, DFO plans to "Utilize agency-specific mechanisms (e.g., notations, Operating Ground Rules, Range Management Plans) to flag watercourses with Core and Conservation populations to ensure a high level of protection and review of land-use applications to ensure all levels of governments and responsible departments within governments are acting in a manner consistent with this recovery plan."

It seems apparent to us that discretionary BMPs and OGRs are clearly inadequate measures to comply with the habitat protection requirement of section 58, and further that the federal Minister of Fisheries, Oceans and the Coast Guard does not have the legal authority to rely on Alberta provincial BMPs and OGRs to provide adequate protection to threatened, SARA-listed bull trout occupying streams and the Highwood River within the study area. Yet that would be the effective result if the 2023-2025 logging plan goes ahead.

WFC's current forest management plan (SLS 2021a) relies on BMPs as adequate protection for streams and their trout populations, often citing a major review of BMPs in the USA (Cristan *et al*. 2016) in support (e.g., SLS 2021a:Chapter 7:58,66,77). Cristan et al (2016) did not include a review of BMPs or OGRs in Alberta, nor did it consider the effect of SARA. BMPs can be effective in actual forestry operations only to the extent to which they are complied with, as assessed by direct on-site data. Our data in this study raise questions as to how effective Alberta's BMPs and OGRs have been in providing actual protection for trout and their habitat (Appendix: Best Management Practices & Operating Ground Rules Failures).

Despite wide application of BMPs worldwide, water yield increases and total sediment yields from forestry operations are still high (Picchio *et al*. 2021). While site-specific, highly tailored applications of BMPs may improve matters, "BMPs are not perfect, and it is not possible to harvest, yard, and transport a large portion of the tree cover from a forested watershed and not alter the hydrology and water quality of the system. …," (Jackson *et al*. 2022:269). We concur. The consequence in the case of logging in the study area is that legally protected bull trout and their habitat are highly likely to be damaged, in breach of SARA.

This Study in the Context of the Southern East Slopes

This watershed assessment is only the latest of many conducted on Alberta's southern East Slopes since the mid-1990s, in which 136 small watersheds in the Bow and Oldman river drainages have now been assessed using BC Forestry's level 1 IWAP. This risk indicator procedure has identified almost all studied watersheds and their mainstem watercourses as at least at moderate or higher risk of damage from the cumulative effects of increased peak flows and increased surface erosion, especially as a result of clearcut logging (Sawyer *et al*. 1997, Sawyer and Mayhood 1998, Mayhood 2010, Erdle and Mayhood 2014, this study).

Taking a risk rating of at least "moderate" as indicating significant risk, most (87 of a sample of 90) had been at significant risk for 20 years to as much as 100 years at the time of assessment (mean 47.4 years, Mayhood *et al*. 2004). Cumulative effects assessments of our East Slopes watersheds by others using different approaches have given complementary results, and have raised additional concerns. All have issued warnings that we must improve management of our watersheds in southern Alberta so that we continue to have an adequate water supply, fish and wildlife populations remain viable, and the region remains livable for humanity (Schindler and Donahue 2006; ALCES 2010, 2011, 2012, 2020; Antoniuk and Yarmaloy 2011; Yarmaloy and Stelfox 2011; Fiera 2014; Farr *et al*. 2017, 2018a, 2018b; Smith and Cheng 2016a, 2016b; Smith *et al*. 2016; Boyer and Mayhood 2018; among others).

The Government of Alberta's South Saskatchewan Regional Plan (Government of Alberta, 2018) describes the importance of watershed management and headwaters protection, highlighting the importance of water storage, recharge, and release functions. This is relevant to both peak flows (flood) and summer low flows (drought). Projects such as the Upper Highwood logging should be considered within this wider integrated context.

The Highwood River poses significant flood risks to downstream communities such as High River during extreme flood conditions. In an intact forested state, the headwaters of the Highwood River provide water absorption and retention characteristics that reduce the rate at which water is released into streams and rivers. Removing effective forest cover in this area is likely to increase flood risk by increasing the frequency and magnitude of peak flows. It may also reduce late-season water availability by advancing the onset of low flows to earlier in the season. In snow-dominated watersheds such as those studied here, even relatively low levels of clearcut harvest in large basins have the potential to increase spring peak flows (Lin and Wei 2008), and the frequency and magnitude of flood events (Johnson and Alila 2023). On the other hand, more rapid release of water from East Slopes forests could result in reduced late-season water yield and earlier onset of low flows, prolonging the period of low flows at times when water is most needed: late summer through early spring (Winkler *et al*. 2017).

Conclusion

The upper Highwood drainage where WFC plans to log is documented critical habitat for SARA-listed bull trout, essential to maintaining the species in the entire Highwood River drainage. A SARA-listed population of bull trout occurs in Loomis Creek, as does a high value conservation population of near-pure westslope cutthroat trout. The Highwood River in the reach affected by planned logging also holds a population of hybrid rainbow-cutthroat trout supporting a popular sport fishery.

Twenty-four of the 36 (67%) small Highwood and Loomis Creek sub-watersheds were flagged by the IWAP as in the highest risk category from the combined effects of increased surface erosion and increased peak flows arising from clearcutting and road development. Planned logging in these sub-basins constitutes a threat to bull trout, near-pure westslope cutthroat trout, and the hybrid rainbow-cutthroat trout populations where the watercourses draining these sub-watersheds enter the mainstem Highwood River and Loomis Creek. These potential effects are being evaluated in more detail in a separate study, but the best available current evidence from this study and the literature suggest the following specific impacts from the planned logging.

- Peak flows in sub-watersheds and perhaps Loomis Creek will likely increase in magnitude and frequency.
- Higher peak flows in watercourses draining sub-watersheds are likely to erode those watercourses, delivering more sediment to Loomis Creek and the Highwood River mainstem.
- Higher peak flows may be followed by earlier onset of low streamflows, extending the period of low flows.
- Fine sediment loading is likely to increase in watercourses in sub-watersheds, Loomis Creek and the Highwood River, from planned roads and from hillslopes already eroding naturally below clearcuts.
- Stream temperatures are likely to increase during the open-water season as a result of the planned clearcut logging, particularly in watercourses draining the sub-watersheds draining to Loomis Creek from south-facing slopes.
- Critical habitat for SARA-protected bull trout, and for the conservation population of near-pure westslope cutthroat trout in Loomis Creek, are likely to be damaged given these data.
- Similarly, habitat for the rainbow-cutthroat trout hybrid population in the Highwood River may be damaged.

The literature and our own observations in the FMA documented in this report indicate that BMPs and OGRs are unlikely to be sufficiently effective to protect these trout populations. We showed these measures to have been inadequate elsewhere in the FMA. More seriously, their highly discretionary nature and their inadequate and inconsistent use means that for DFO to rely on them to protect the bull trout populations in the Highwood River and Loomis Creek is likely to be unlawful.

This study is assesses the risk to the study streams as trout habitat. The assessment points only to likely outcomes; it does not purport to predict actual outcomes. We urge Alberta Forestry and Parks and WFC to move toward process-based modelling methods (e.g., Chernos *et al*. 2023) to assess every annual operating plan, in contrast to the indicator methods, BMPs, OGRs and guideline documents used in the SLS (2021) forest management plan and this present study, to generate more reliable and more detailed conclusions, enabling less risky forest management.

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Supplementary Information

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Appendix

Existing Logging Roads Problems

Figure A1 a-d shows a common consequence of placing logging roads with inadequate protection too close to small watercourses. The road here may have been captured by the immediately adjacent watercourse on the right during flood flows. This right-of-way is planned as the main haul road, which has already been built through this location without any noticeable changes to protect it from the watercourse (Figure A1d). If uncorrected, we should expect a repeat of the legacy gully.

Figure A1. **(a)** Gully > 1 m deep on a legacy forest road at 50.46380°N 114.78333°W looking slightly downhill, as it was on 2023.08.29. The sediment removed from the gully has been partly deposited in the background, and in the immediately adjacent first-order watercourse on the right, which ultimately drains via a wetland pond **(b)** into the Highwood River mainstem at 50.46075°N 114.78030°W **(c)**. **(d)** Planned main haul road recently constructed through the same location as **(a)** seen on 2023.09.13. Photos a, c, d, D. Mayhood; b, M. Coombs.

A borrow pit, concrete storm drainpipe remains, and downstream braiding below a legacy logging road ford through Loomis Creek at 50.46896°N 114.79609°W suggests the following possible scenario (Figure A2). The original crossing was a gravel, cobble and boulder berm passing the main flow of the creek via (a) concrete culvert(s). The berm and culvert(s) was (were) blown out during flood flows at some point, depositing the concrete culvert and coarse fill below the crossing, creating a braided fan of small channels with little flow in each for a distance of tens of metres. That fan is now a potential barrier to fish movement at the lowest flows. Alternatively, Loomis Creek at the ford may simply be redistributing downstream borrow-pit deposits excavated for logging road use, having the same effect.

Figure A2. Ford, borrow pit, concrete drain remains, and braided low-flow channel, Loomis Creek at, and downstream from, approximately 50.46868°N 114.79663°W. **(a)** looking NW along legacy logging road right-of-way across Loomis Creek; **(b)**, concrete drain abandoned downstream from ford; **(c)**, looking upstream on Loomis Creek from the ford; **(d)**, much lower flow in southernmost channel of Loomis Creek approximately 200 m downstream from the ford at 50.46888°N 114.79319°W. Flow comparable to that immediately upstream of the ford resumes <100 m below this point.

In the Highwood mainstem drainage, a legacy logging road is presently being eroded, affecting a water crossing in sub-watershed H01 at 50.479842°N 114.806714°W (Figure A3). Fine sediment enters the watercourse as precipitation and snowmelt drains south down the road from the north, eroding the surface. The road thus becomes a watercourse, an extension to the natural channel. The natural watercourse parallels the road in what appears to be a series of wet areas to the west (left) of the road, crossing it as the now distinct channel turns east toward the Highwood. The road drops about 10 m over a distance of 100 m north of the water crossing. Already causing a problem, reconstruction and traffic on this road to access cutblocks in sub-watersheds H01-H05 as planned should be expected to create similar damage in locations all along it in similar terrain on this Late Wisconsinan ground moraine.

Figure A3. **(a),** Existing erosion on a legacy logging road in sub-watershed H01 at 50.479842°N 114.806714°W. What appears to be a wet area on the left drains across the road via a channel draining to the right, 400 m to the mainstem Highwood River. This road is planned to be used to access new cutblocks in sub-watersheds H01-H05. Under planned additional traffic, this road, all on similar Late Wisconsinan ground moraine, is prone to developing new instances of road surface erosion. Google Earth imagery 2013.08.31 **(b),** south end of the same road above Loomis Creek ford, at 50.46886°N 114.79614°W. The roadcut shows the Late Wisconsinan ground moraine the road is built on, overlaid with a high percentage of fines. (Bayrock and Reimchen 1980). D. Mayhood photo

On the existing Loomis Creek logging road at 50.46764°N 114.80245°W, the road intercepts seepage and surface flow, directing it down the right-of-way to a watercourse (Figure A4). That watercourse appears to have been enlarged as a landslide, with its runout deposited upstream in Loomis Creek. Because the landslide was initiated at the road, we suggest that intercepted water, likely enhanced by snowmelt and precipitation events over time, saturated the ground to the point where it failed, sending debris into Loomis Creek.

Figure A4. Groundwater and surface flow are intercepted by the legacy roadbed, turning it into an active watercourse **(a, b)**. The water has been directed to a low spot, which became saturated and failed, causing a landslide that sent debris into Loomis Creek channel, and upstream in the creek **(c, d)**. Photos **(a, b)** M. Coombs, **(c)** D. Mayhood, **(d)** Google Earth imagery 2013.08.31

The planned new logging road up Loomis Creek watershed will be little more than 100 m upslope from this point (Figure 1), will intercept the same water sources, and will be subject to the same potential problem as can presently be observed at this site.

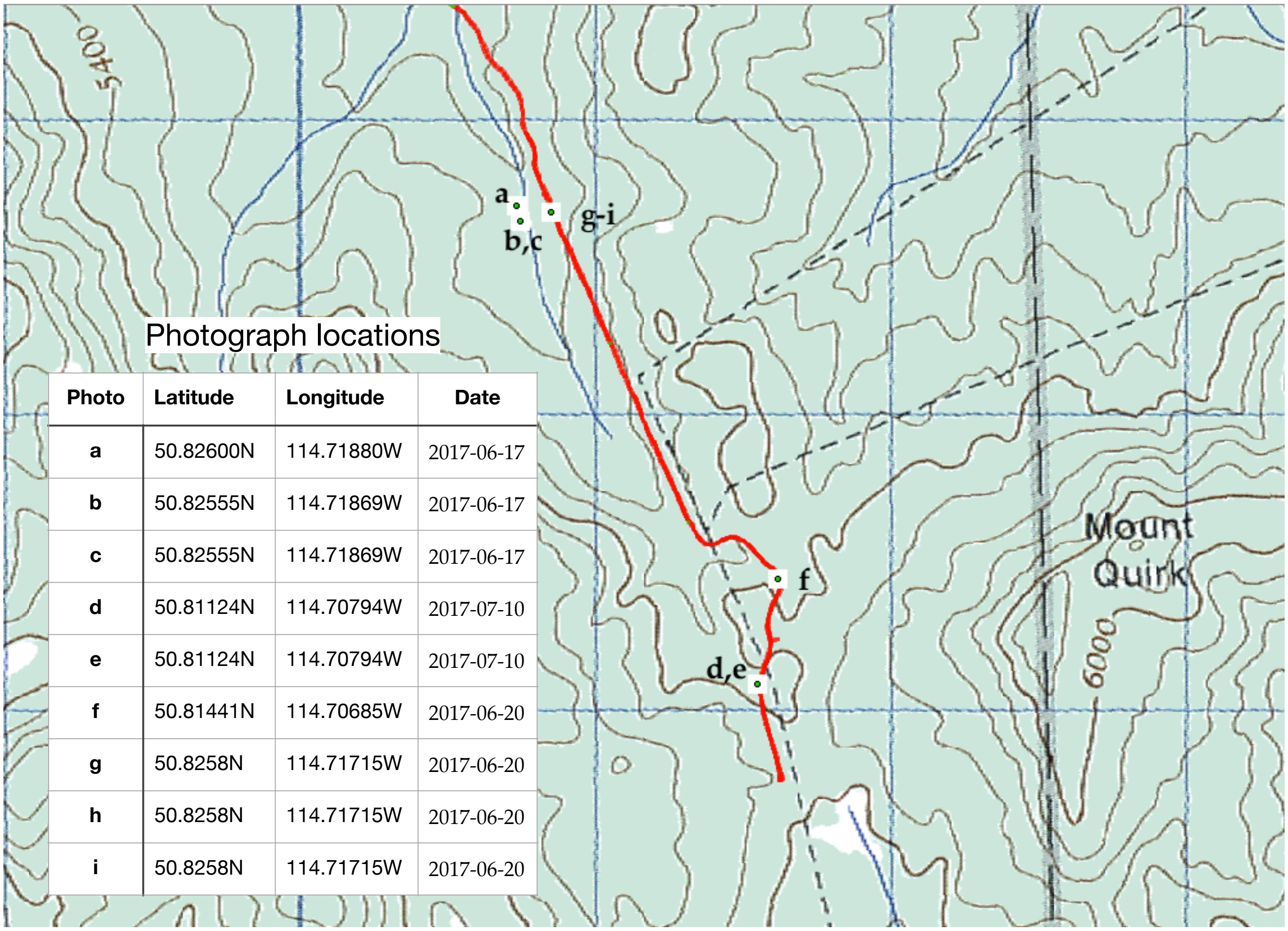
Best Management Practices & Operating Ground Rules Failures

Alberta Forestry, West Fraser Cochrane (WFC), and other logging companies rely heavily on best management practices and operating ground rules to mitigate clearcut logging effects on watercourses. Properly implemented, monitored, and enforced, these can significantly reduce sediment delivery from roads, but they are inadequate protection for trout habitat, especially for species and populations already at risk. Some examples from roads in the FMA follow.

A spawning site in Silvester Creek, critical habitat for a SARA-listed population of westslope cutthroat trout, is impacted by siltation from a mainline logging road (Figures A5:a-i, A6).

Figure A5. A spawning site in Silvester Creek, critical habitat and residence for a SARA-listed population of westslope cutthroat trout (DFO 2019), is impacted by siltation from a mainline logging road under Alberta BMPs and OGRs. **a**, spawning pair in heavily-silted substrate; **b** & **c**, silt deposits immediately upstream of the spawning site; **d** & **e**, silt-laden runoff from the mainline logging road (**d**) paralleling the creek upstream of the spawning site enters Silvester Creek at its origin (**e**); **f-i**, non-functional silt fences on mainline logging road bridges crossing intermittent tributaries to Silvester Creek. Locations: see Figure A6.

Figure A6. Locations and dates of the photographs in Figure A5. Mainline logging road in red. Streamflow to the north.



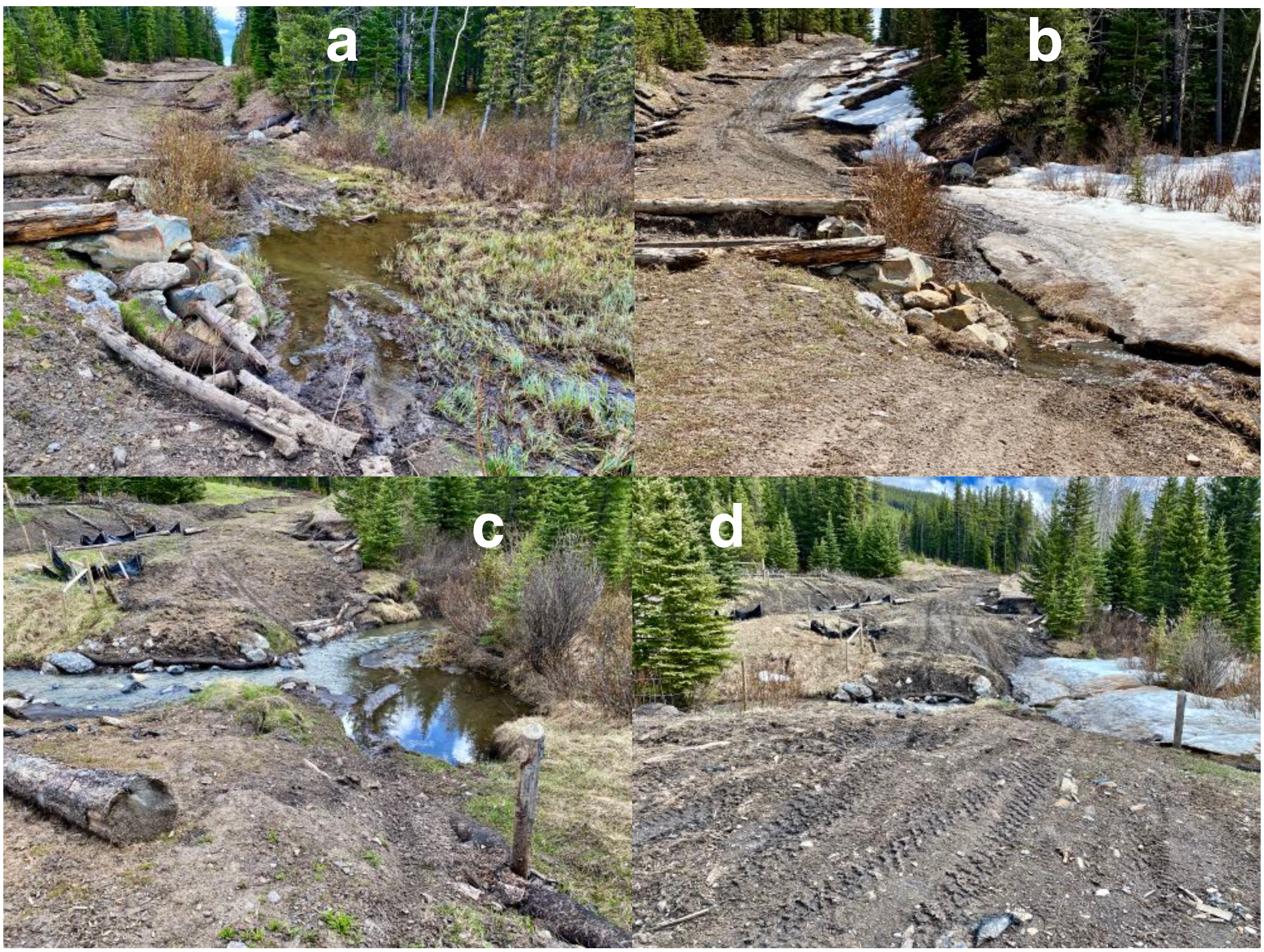
Photograph locations

Photo	Latitude	Longitude	Date
a	50.82600N	114.71880W	2017-06-17
b	50.82555N	114.71869W	2017-06-17
c	50.82555N	114.71869W	2017-06-17
d	50.81124N	114.70794W	2017-07-10
e	50.81124N	114.70794W	2017-07-10
f	50.81441N	114.70685W	2017-06-20
g	50.8258N	114.71715W	2017-06-20
h	50.8258N	114.71715W	2017-06-20
i	50.8258N	114.71715W	2017-06-20

A pair of westslope cutthroat trout were observed preparing to spawn in the upper reaches of Silvester Creek 2017-06-17 as evidenced by redd preparation (Figure A5:a, video available). The reach, including the spawning site, was heavily silted (Figure A5:a-c). A field survey showed the source of the silt to be the mainline logging road, the only significant upstream source of fine sediment. Sediment loading was initiated at the extreme upstream end of the valley approximately 300 m below the watershed divide between Silvester and Muskeg creeks (Figure A5:d,e; divide visible at the horizon line in d), thereby contaminating at its source the entire length of Silvester Creek with road-derived suspended sediment. Additional locations where road sediment entered the drainage network, and ultimately Silvester Creek upstream of the spawning site, are shown in Figure A5:f-i. These sites were bridged crossings clothed in heavy silt-filtration material intended to filter out sediment from runoff before it could enter the watercourse network; however many tears and imperfect seals were apparent in the material (Figure A5:f-h). In some cases, silt-laden road runoff could simply circumvent the filter material and enter the watercourse directly (e.g., Figure A5:i).

This mainline logging road has been partly decommissioned; however, it will continue to be a source of fine sediment to Silvester Creek for the foreseeable future (Figure A7:a-d). The road surface remains bare, road drainage and sediment-laden runoff are not under control, and closure to recreational off-road traffic is only partly effective, resulting in continued erosion of the road surface and its right-of-way. Continued impacts on the declining population of westslope cutthroat trout and its habitat (Mayhood 2013a,b; 2015, 2019:Figure A; Erdle and Mayhood 2014) in the affected Silvester Creek are to be expected until these problems are resolved.

Figure A7. A few of many decommissioning problems on the currently unused mainline logging road adjacent to Silvester Creek. **a**, runoff from a steep hill drains directly into a perennial tributary to Silvester Creek at 50.83839°N 114.72555°W, on 2020-05-26. Barriers to off-highway vehicle traffic are ineffective. **b**, same location one year later, 2021-05-13: the same problems persist. **c**, Similarly, upper Silvester Creek at a crossing at 50.83231°N 114.72184°W receives direct silt-laden runoff from the same logging road, and offers no significant barrier to motorized vehicles on 2020-05-26. d, the same location with the same issues one year later, 2021-05-13.



Despite the requirements for logging operators to use best management practices and to follow operating ground rules (Government of Alberta 2019, 2022, 2023a), many deviations from these can be found in the field, as shown above.

For an example elsewhere in WFC's FMA, logging access to Hidden Creek, critical habitat for SARA-listed bull trout and westslope cutthroat trout, from the Oldman River access road was completely unprotected at a ford of the Oldman River on 2015-08-14 (Figure A8). A thunderstorm caused heavy runoff of silt-laden water from the logging road surface within 10 minutes of storm onset, contaminating the Oldman River. No protective measures to prevent such occurrences were apparent at this location.

Figure A8. Logging road-derived suspended sediment enters at a ford of the upper Oldman River, providing access for extensive logging to Hidden Creek, at the onset of a thunderstorm on 2015-08-14. Heavier silt-loading followed within minutes. Hidden Creek holds threatened, SARA-designated populations of westslope cutthroat trout and bull trout (DFO 2014, 2019, 2020b). The Oldman River at this location holds critical habitat for SARA-listed bull trout (DFO 2020b) at this time or year, and holds a population of hybridized westslope cutthroat trout, highly-valued by anglers, as well. No protection from road-derived sediment was evident.

Following are some other examples of why BMPs and OGRs are often insufficient protection for trout habitat. Figure A9a shows a treed leave strip adequately shading an intermittent first-order tributary draining to protected westslope cutthroat critical habitat. Its narrowness leaves it vulnerable to windthrow, however. The silt fence clothing the rails and wings of the crib crossing looks entirely functional, but closer inspection reveals a leak (Figure A9b). Such failures are common issues with silt fencing (Cooke *et al*. 2015). Figure A9c: a too-sparse, incomplete buffer strip has been left to shade another first-order tributary in the same clearcut

Figure A9 BMP issues with access roads in Jumpingpound Creek tributary basins holding the last two remnant populations of SARA-listed westslope cutthroat trout in that system. **a**, bridged (crib) crossing of an intermittent stream draining to cutthroat critical habitat ~100 m away, showing an adequately treed buffer, as long as wind-throw does not damage it. **b**, an opening in the silt filter at that site. **c**, an intermittent stream with an inadequate riparian buffer in that same basin. **d**, road-derived sediment diverted into the buffer strip stops short of a tributary holding protected cutthroats. **e**, a bridge unprotected by silt material over that same creek. **f**, a detail of the bridge deck, showing a potential leakage point. Details in the text.

as that shown in Figure A9a. Because of the large, unshaded gap, this watercourse is vulnerable to warming by direct sunlight, and the very narrow strip of trees that are left are vulnerable to windthrow. The buffer strip shown in Figure A9d is intended to filter out road-derived sediment before it reaches the stream in the background. At this point it does, but additional rainfall-induced road runoff will enable new silt easily to overrun the existing deposit to reach the creek. Lesson: filters clog; natural filters can be difficult to maintain. Figure A9e shows an access road bridge unprotected by silt fabric wrap. In this view the stream below it appears to be protected by the solid panel on both sides of the deck. Closer inspection reveals a significant gap (Figure A9f) that allows silt-laden water on the deck to flow into the creek. All of these examples are quite minor in themselves, but the cumulative impact of many of these common failures in a watershed can cause harm to trout and trout habitat.

Other Potential Problem Areas for Logging in the Study Area

There are numerous features in the upper Highwood study area that are in a position to be disturbed by logging and road development.

There is a high, groundwater-soaked slumping hillslope just downstream from the Bishop Creek confluence with Loomis Creek (Figure A10). Flagging at the top of the hillslope marks a cutblock boundary there. A road oriented downslope is planned to be built to within 60 m of the cutblock edge. This slump is vulnerable to collapsing further downslope, potentially delivering large quantities of debris into Loomis Creek, a likely scenario if additional water is directed to it by the cutblock and new road. Bull trout were detected in eDNA samples from Loomis Creek immediately downstream from this area in late November 2023 (Coombs 2023).

Actively eroding sites are prominent along the north (south-facing} hillslopes along Loomis Creek (Figure 3b, main report; Figure A11a), and along the Highwood River on the west and southern east hillslopes (Figure 3c and d, main report; Figure A11b, A11c). Actively eroding gullies are common along the Highwood in the same areas. Increased runoff from clearcutting can be expected to increase erosion at many of these sites.

At Figure A11a, it appears on the logging plan that a clearcut boundary is less than 50 m from Loomis Creek, at the top of the slide area. It lies within sub-watershed L10, which is at highest risk, with a planned road density of >3.5 km•km^2 and a planned clearcut area a little less than 40%.

The gully in Figure A11b on the Highwood River is apparently the sub-watershed H11 watercourse outlet. H11 is rated at highest risk due to its 75% clearcut area and, though the road is short with only a single crossing, it has a high road density because of its small size. The high clearcut area can be expected to cause larger peak flows. As the photo shows, it is already heavily eroding and that can be expected to increase from the planned logging.

Figure A10. a, A high water-saturated bank slumps on the south hillslope of Loomis Creek at 50.46434°N 114.82190°W 2023-09-13. The slope is flagged at the planned clearcut limit at the timber margin. **b,** the saturated hillslope at the site. The figures mark the planned clearcut edge. **c,** the saturated hillslope drains directly into Loomis Creek, seen at the photo left margin. All photos D. Mayhood; hat tip to M. Coombs for detecting the the issue, and to K. Morrison and M. Coombs for locating the surveyed clearcut margin.

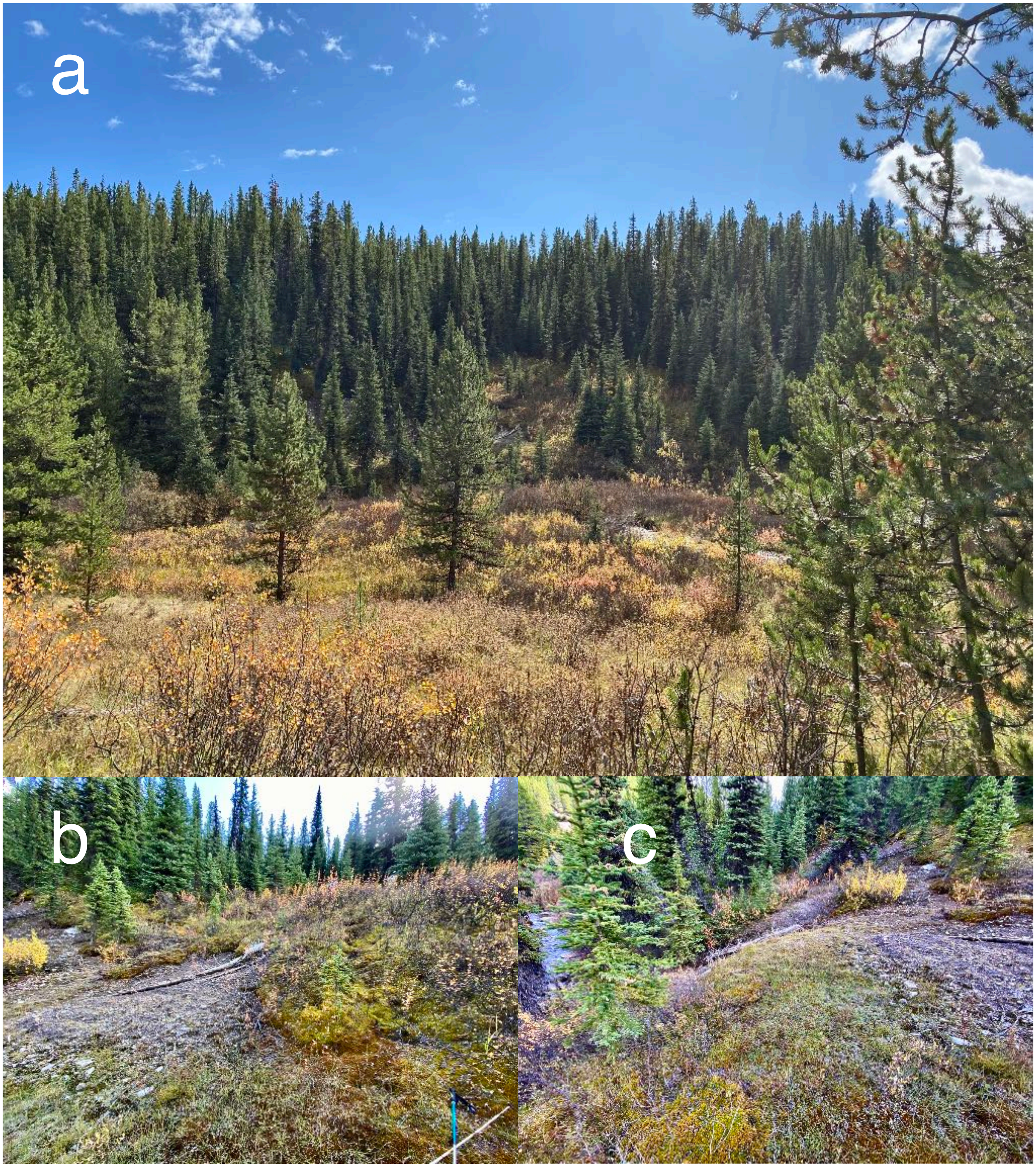
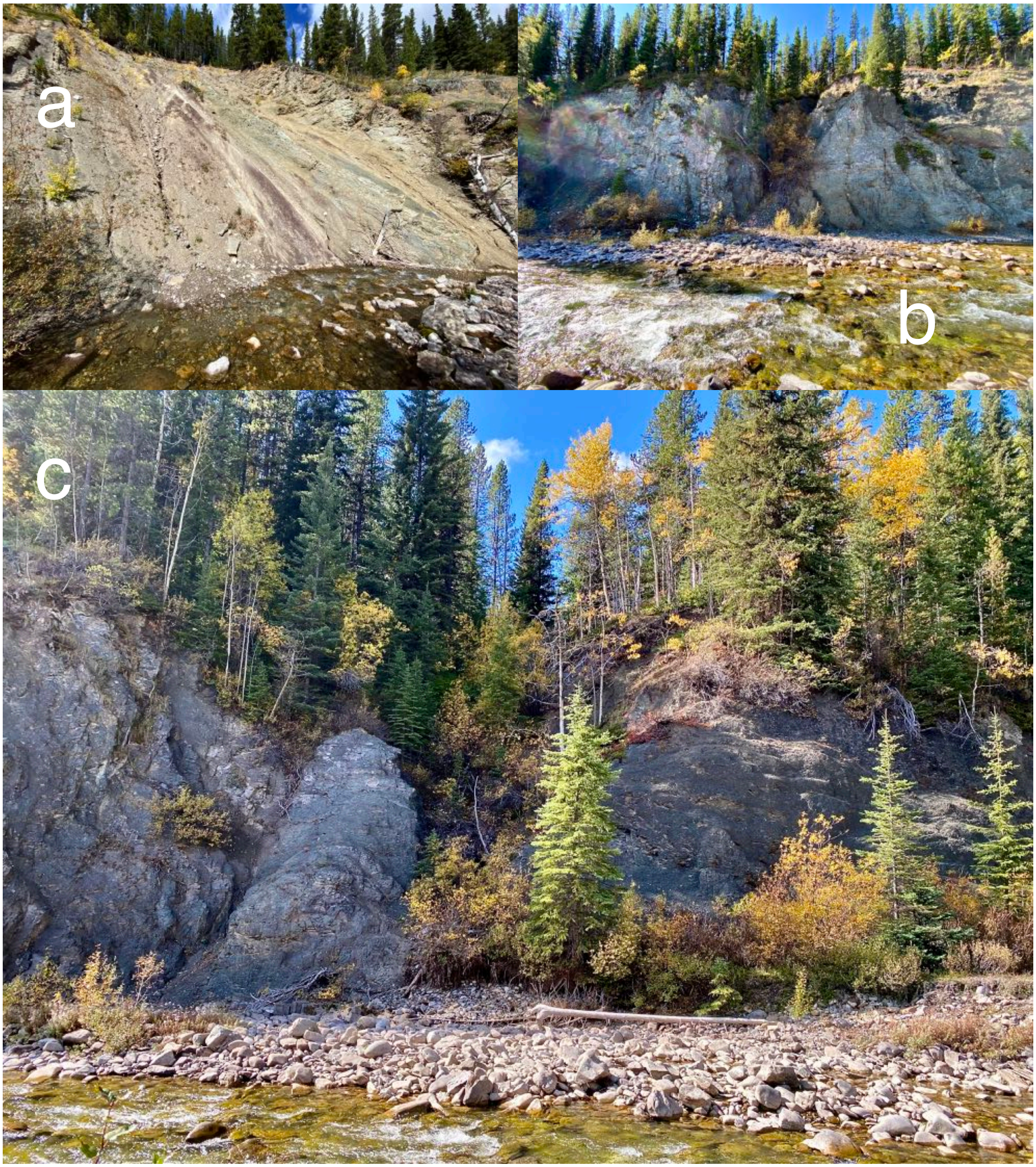


Figure A11. Examples of actively eroding hillslopes , Loomis Creek and the Highwood River within the planned logging area. **a**, eroding hillslope and landslide on south side of Loomis Creek at 50.50.46534°N 114.81985°W, 2023-09-13. **b**, gully and crumbling surficial deposit on bedrock (upper right), right bank of Highwood River at 50.44885°N 114.77031°W. **c**, gully on right bank of Highwood River at 50.45052°N 114.77149°W.



The gully in Figure A11c is the outlet of sub-watershed H09, which is larger than H11 and has extensive planned clearcuts (> 50% of total area) and a larger planned road network (> 2 km•km^2). A clearcut and a road are planned to skirt the top of the escarpment less than 100 m from the river. Expect enhanced erosion and added sediment delivery to the Highwood River here.