Functioning Condition of Randomly Selected Reference Streams Associated with Recent Forest Harvesting in British Columbia (2005-2009)

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FREP

Extension Note #30

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1.0 Introduction

Reference streams (or stream reaches) are streams that are largely unaffected by human activities at the watershed scale. This does not mean the stream or watershed area upslope of the stream is necessarily in pristine condition or lacks significant impacts or disturbances, only that no significant disturbances attributable to humans exist. Reference condition, as opposed to pristine condition, allows for naturally occurring impacts. Reference streams encompass the entire range of natural disturbances caused by physical agents, such as floods, fires, landslides, or storms. These streams also encompass natural impacts caused by biological agents, such as diseases, insect infestations, or animal activities (e.g., beaver dams, excessive trampling or browsing by native ungulates, beetle kill). Reference streams are thus essential in helping establish natural background levels of disturbance in the absence of human activities.

From 2005 to 2009, district staff in the British Columbia Ministry of Forests and Range used a standard evaluation protocol (the FREP riparian checklist; Tripp et al. 2009) to assess the effects of forest harvesting on the "properly functioning condition" (PFC), or "health," of 1668 stream reaches in or beside randomly selected cutblocks in British Columbia (Tschaplinski 2011a, 2011b). This assessment asked 15 questions about a stream's channel and riparian conditions (e.g., "Is the channel bed undisturbed?", or "Is the riparian vegetation representative of unmanaged conditions?"). The more "No" answers to these questions, the poorer the condition of the stream reach. A reach with 0–2 "No" answers is considered in PFC, at risk (i.e., of not being in PFC) with 3–4 "No" answers, and at higher risk with 5–6 "No" answers. If the evaluator obtains more than six "No" answers on an assessment, then the stream reach is no longer considered to be in PFC.

During the assessments, it became apparent that some stream reaches were relatively unaffected by any human-related activities. These were considered potential reference sites that could be used to validate what properly functioning condition means in terms of the number of "Yes" and "No" answers on the FREP riparian checklist. The condition of these reaches could also serve to confirm, adjust, or otherwise "fine-tune" some of the evaluation protocol's thresholds, which are used to determine whether the degree of observed impacts are within the natural range of variability.

This extension note, which is intended for resource professionals and managers interested in riparian areas, describes the procedures and criteria used to designate

Key Message: The condition of reference streams (streams with little human activity adjacent or upstream of the sample reach) sampled between 2005 and 2009 supports the validity of the properly functioning condition (PFC) concept and the number of "no" answers used to define PFC in British Columbia. This was true regardless of biogeoclimatic zone, physiographic region or stream gradient. Of 51 streams considered in reference condition, 39 (76%) were in PFC, while 12 (24%) were in some intermediate condition of PFC. None were not in PFC.

reference streams. It also summarizes, by physiographic region (mountains, plateaus, plains), the basic attributes of these streams (e.g., channel width, riparian buffer width, slope, channel morphology, and elevation), their range of functioning condition, and the main impacts observed.

The reference streams identified here provide a valuable measure of natural condition for small streams in British Columbia. It is hoped this information will increase the awareness of the reference stream concept and reference conditions, and promote the identification of future reference streams. With more designated reference streams, FREP's ability to detect or track human versus natural changes in the functioning condition of streams should also improve.

2.0 REFERENCE STREAM SELECTION AND CRITERIA

All 1668 stream reaches sampled from 2005 to 2009 were reviewed to identify reaches with a minimum 10 m wide riparian buffer and no human-related impacts beside or upstream of the sample reach. Streams without human-related causal factors were considered candidates for reference streams.

Once reference stream candidates were identified, district staff were asked to confirm that the riparian widths reported on these streams were accurate and that none of the "No" answers on the riparian assessments were related to human activities. This confirmation process resulted in the identification of a final set of potential reference stream reaches. District staff were then asked to determine whether conditions in the watershed area upslope of each stream reach were similarly unaffected by human activities, or, if the level of human disturbance was sufficiently low, that the stream could still be considered in reference condition. Fifteen specific watershed-level criteria were used to determine whether the watershed upstream of the sample reach was in reference condition. Note that these 15 criteria are in no way related to the 15 questions used to assess PFC of individual stream reaches. To qualify as a reference stream, each stream had to meet all of the following watershed criteria.

1. No more than one road crossing above the reach, and none within 500 m unless a lake or large wetland is present between the road crossing and the stream reach.
2. No mass wasting (i.e., slides, sloughs, debris flows, etc.) related to human activities into any stream above the sample reach.
3. Road density above the lower-reach boundary is less than 0.3 km/km^2.
4. Road density within 100 m of a stream above the lower-reach boundary is less than 0.15 km/km^2.
5. Less than 15% of total stream length above the lower-reach boundary is logged to stream edge.
6. No dams, weirs, or power plants within 100 m of the upper-reach boundary.
7. No hydropower or irrigation intakes anywhere above the reach unless the water withdrawn is returned to the stream above the reach.
8. No hydro powerhouses anywhere above the reach unless the development is completely run-of-the-river (i.e., no dams capable of storing or drawing down more than 1 m of water in a lake or reservoir, above the natural high water mark or below the natural low water mark).
9. No mines above the lower-reach boundary (includes commercial scale gravel pits, not local rock pits).
10. No industrial or sewage effluents to any streams above the lower-reach boundary (includes seasonal concentrations of livestock or cottages; excludes solitary trapper's cabins).
11. Total human-related impermeable areas (roads, landings, well pads, roofs, parking lots) are less than 10% of watershed area above the lower-reach boundary.
12. Less than 10% of the watershed above the lower-reach boundary has intensive agriculture. (Most agriculture is intensive; an exception is summer grazing, which could occur on 20% of Crown land but not along any streams.)
13. Less than 10% of the watershed above the lower-reach boundary has trees less than 10 m tall, owing to human activities.
14. Less than 20% of the watershed above the lower-reach boundary has second-growth trees more than 10 m tall but less than 75 years old, owing to human activities.
15. The sum of the impacts for criteria 11–14 does not exceed 20% of the watershed area above the lower-reach boundary.

Stream reaches that had natural impacts, such as slides, fires, windthrow, insect or disease infestations, within or upstream of the reach were included as reference streams as long as they met the 15 criteria. This resulted in the inclusion of some streams that were clearly not in PFC, owing to recent natural events; however, since natural impacts are a normal part of watershed processes, these streams warranted inclusion. This extension note thus documents the range of natural conditions and impacts present on stream reaches in watersheds having potentially significant natural impacts but only slight use by human activities.

The criteria used in this extension note to assess the watershed condition of reference stream reaches are primarily based on measures already considered indicative

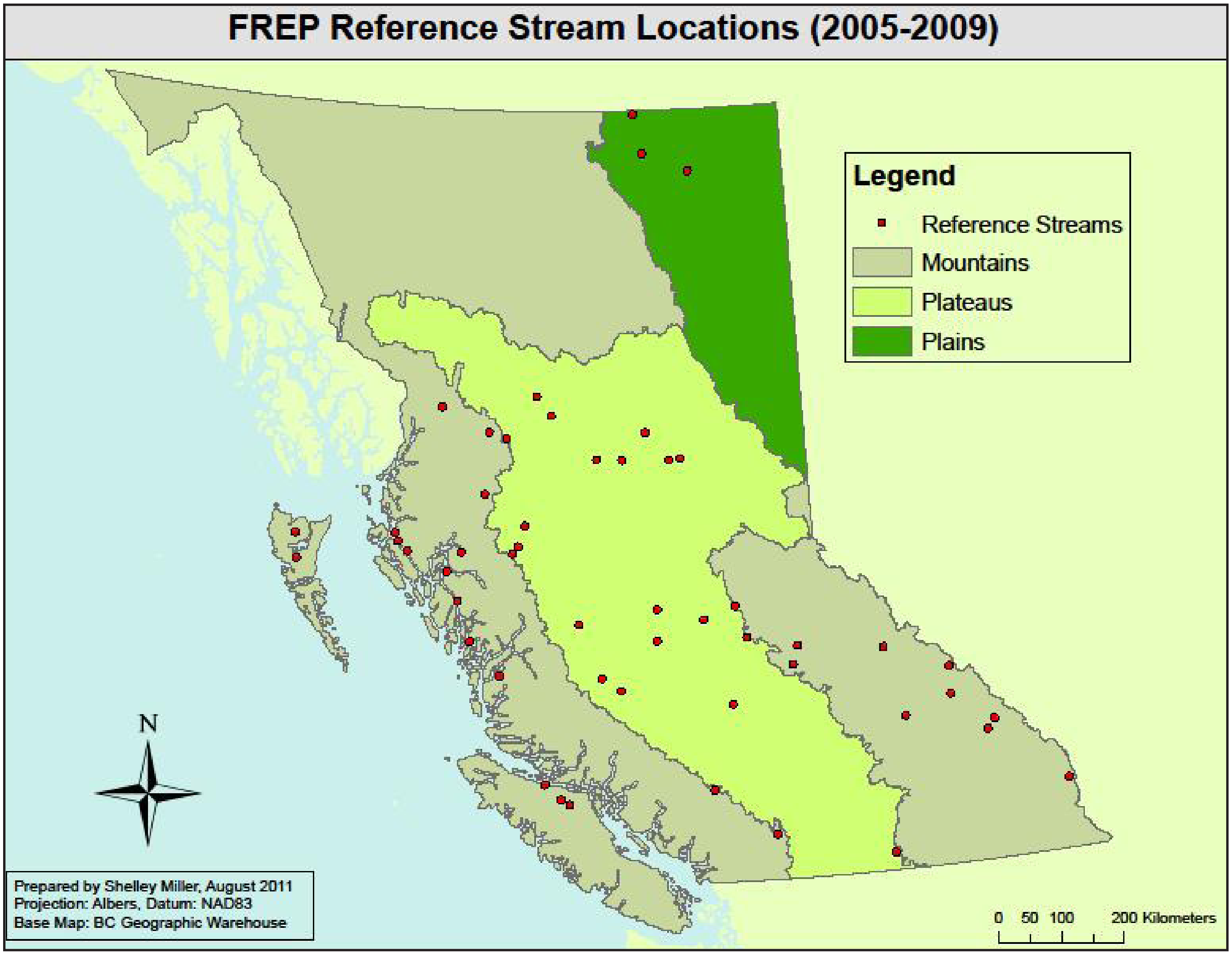

Figure 1. Location of FREP reference stream reaches relative to the three main physiographic regions of British Columbia.

of near-pristine watershed conditions in British Columbia. These included indicator values used to denote very low impacts (i.e., adjusted scores of 0.2 or lower used in the Watershed Assessment Procedure guidebook; see Table 1, B.C. Ministry of Forests 1995a, 1995b), plus those used to identify reference streams for monitoring benthic macroinvertebrates (Reynoldson et al. 1997; Rosenberg et al. 1999; Perrin et al. 2007). Other publications or theses consulted included Valdal (2006) and Valdal and Quinn (2011), for the effects of roads and logged stream length on resident cutthroat trout abundance; Jones and Post (2004) and Perry (2007), for the effects of second-growth forests on low streamflows; the Forest Practices Board (2007), for the effects of mountain pine beetle infestations on streamflows; and May (1998) and Zanbergen et al. (1999), for the effects of urbanization and impervious areas on streamflows and benthic invertebrates. Nevertheless, we acknowledge that the science behind the watershed criteria is not always directly specific to the indicators or as definitive as suggested, and that using the information to set thresholds typically involved professional judgement.

3.0 DISTRIBUTION AND CHARACTERISTICS OF REFERENCE STREAMS

Using the watershed-level criteria, 51 (3.1%) of the 1668 stream reaches assessed across British Columbia from 2005 to 2009 were sufficiently undisturbed by human activities to qualify as reference streams. Twenty-nine stream reaches were located in the province’s Mountain physiographic regions, 19 were located in Plateau regions, and 3 were located in the northeast Plains region (Figure 1, Table 1). The average number of reference streams per forest district (as they were in 2005) was 1.8, ranging from 0 in ten districts (Cascades, Headwaters, Kamloops, Kootenay Lakes, Okanagan Shuswap, Peace, Prince George, Sunshine Coast, South Island, Vanderhoof), to 5 in two districts (Columbia and North Coast).

Reference stream reaches were located in eight biogeoclimatic zones, three of which (the Coastal Western Hemlock [CWH], Sub-Boreal Spruce [SBS], and Engelmann Spruce–Subalpine Fir [ESSF]) were well represented with 8–15 reaches each. The Sub-Boreal Pine–Spruce (SBPS)

Table 1. *Physical characteristics, main biogeoclimatic zones, morphology, and overall mean functioning condition of FREP reference streams in the three main physiographic regions of British Columbia*

	PHYSIOGRAPHIC REGION			
	Mountains (*n* = 29)	**Plateaus (*n* = 19)**	**Plains (*n* = 3)**	**All (*n* = 51)**
Channel width (m)	3.0 (2.4, 0.5–9.3)[a]	2.1 (1.1, 0.4–4.6)	5.0 (2.9, 1.7–7.0)	2.8 (2.1, 0.4–9.3)
Gradient (%)	20 (14, 2–55)	4 (4, 1–17)	3 (2, 2–5)	13.3 (13.5, 1–55)
Minimum buffer width (m)	33 (18, 12–100)	36 (21, 20–100)	50 (10, 40–60)	35 (19, 12–100)
Elevation (m)	690 (520, 10–1800)	1080 (190, 730–1480)	390 (30, 360–420)	816 (41, 99–282)
Main biogeoclimatic zone	CWH (*n* = 15)	SBS (*n* = 10)	BWBS (*n* = 3)	CWH (*n* = 15)
Main morphology	Non-alluvial (*n* = 22)	Alluvial (*n* = 16)	Alluvial (*n* = 3)	Alluvial (*n* = 26)
Functioning condition (# "No" answers)	1.3 (1.6, 0–6)	1.5 (1.3, 0–5)	1.3 (1.5, 0–2)	1.4 (1.5, 0–6)

[a] Unless indicated otherwise (e.g., *n* = 29), numbers in brackets are the standard deviation and range of the sample.

zone was the least well represented with only one stream reach. The remaining zones (Boreal White and Black Spruce [BWBS], Interior Cedar–Hemlock [ICH], Interior Douglas-fir [IDF], Montane Spruce [MS]) each had 3–5 reference stream reaches. In the province's mountain regions, most reference streams were located in the CWH, followed by the ICH or ESSF. Reference streams in the plateau regions were mainly in the SBS, and all three streams in the plains region were in the BWBS.

Reference streams were further classified as alluvial or non-alluvial based mainly on the nature of their streambanks. Streams referred to as "alluvial streams" had streambanks that included a significant component of mineral material, which had been washed downstream by normal fluvial activities. Streams referred to as "non-alluvial" typically transport material out of the reach only when sufficient energy is present. These streams tend to be steep with bedrock or colluvium in the streambanks, although small, low-gradient, non-alluvial streams with banks composed of glaciofluvial or lacustrine deposits were also present. Non-alluvial streams accounted for 22 of the 29 reference streams located in the province's mountain regions; alluvial streams represented 19 of the 22 reference streams in the plateau and plains regions.

Reference stream reaches were generally small streams, averaging 2.8 m wide (range: 0.5–9.0 m). Located mainly in headwater areas, reference streams tended to be steep (average gradient 13.3%), especially in the mountain regions (average gradient 20%; range: 1–55%), and less so in the plateau and plains regions (average gradient 4% and 3%, respectively). All reference stream reaches were well protected with buffer widths of 33 m or more, mostly because these reaches were located in unlogged areas adjacent to cutblocks or in large wildlife tree patches within cutblocks.

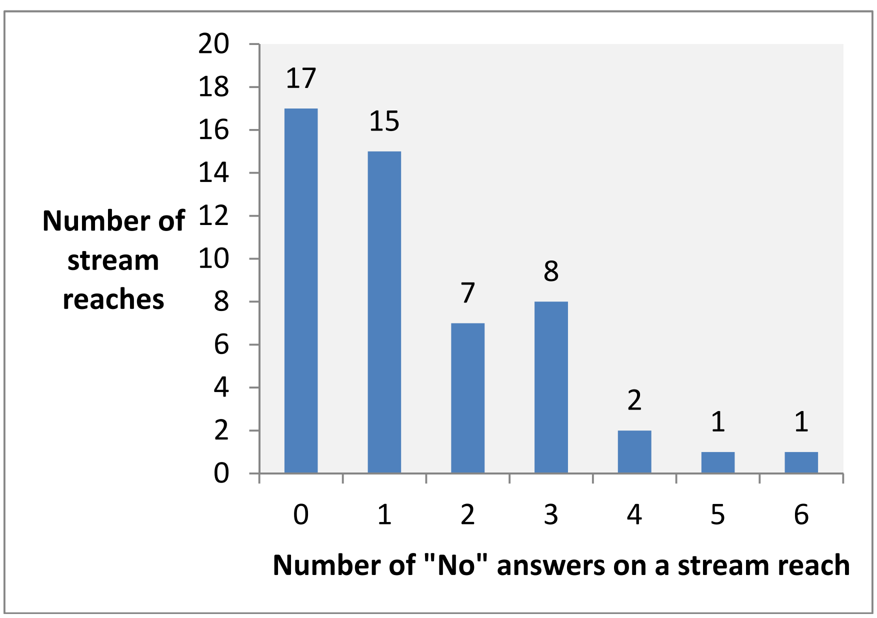

Figure 2. *Number of reference stream reaches by number of "No" answers on a FREP riparian assessment.*

3.1 PROPERLY FUNCTIONING CONDITION

The average number of "No" answers on an assessment of a reference stream reach varied from 1.3 to 1.5, depending on physiographic region (Table 1). The overall average number of "No" answers was 1.4 (range: 0–6). Overall, reference streams were therefore in PFC. Thirty-two (63%) of the 51 reference stream reaches had either zero or one "No" answer on the assessments (Figure 2). Only 12 (24%) streams had more than two "No" answers, and only two (4%) had more than four "No" answers. Because all streams had no more than six "No" answers, none were considered as "Not Properly Functioning."

3.2 CAUSAL FACTORS

Of the four streams with more than three "No" answers, one had six "No" answers related to a debris torrent that had swept through the reach, and one had five "No" answers owing to a severe storm and flooding. Both events had occurred within the previous 1–3 years. The remaining two reaches both had four "No" answers related to a combination of slides, torrents, and floods. All "No" answers were related to changes in the channel, mainly the streambed, banks, wood abundance and distribution, moss levels, and invertebrate diversity. Riparian characteristics were invariably intact on these streams and acceptably representative of unmanaged conditions. The most severely affected streams were also non-fish-bearing, non-alluvial streams. If these had been fish-bearing or alluvial, then the streams may have been considered "Not Properly Functioning"; however, questions on channel morphology and fish cover diversity were not applicable.

The most frequent "No" answers to riparian assessment questions (Table 2) were related to naturally high levels of fine- and sand-sized sediment (Question 8, n = 21), followed by low moss levels (Question 7, n = 13), and low

Table 2. Frequency of "No" answers to each question of the FREP riparian assessment by physiographic region for 51 reference stream reaches

FREQUENCY OF "NO" ANSWERS BY PHYSIOGRAPHIC REGION				
	Mountain (n = 29)	**Plateau (n = 19)**	**Plains (n = 3)**	**All (n = 51)**
FREP Riparian Assessment Question				
Question 1: Is the channel bed undisturbed?	4	0	0	4
Question 2: Are the channel banks undisturbed?	2	2	0	4
Question 3: Are channel large woody debris processes undisturbed?	3	1	0	4
Question 4: Is the channel morphology undisturbed?	0	2	0	2
Question 5: Are all aspects of the aquatic habitat sufficiently connected to allow for normal, unimpeded movements of fish, organic debris, and sediments?	6	1	0	7
Question 6: Does the stream support a good diversity of fish cover attributes?	1	2	0	3
Question 7: Does the amount of moss present on the substrates indicate a stable and productive system?	7	5	1	13
Question 8: Has the introduction of fine sediments been minimized?	9	10	2	21
Question 9: Does the stream support a healthy diversity of aquatic invertebrates?	2	6	0	8
Question 10: Has the vegetation retained in the Riparian Management Area been sufficiently protected from windthrow?	0	0	0	0
Question 11: Has the amount of bare ground or soil disturbance in the riparian area been minimized?	2	0	1	3
Question 12: Has sufficient vegetation been retained to maintain an adequate root network or large woody debris supply?	0	0	0	0
Question 13: Has sufficient vegetation been retained to provide shade and reduce bank microclimate change?	1	0	0	1
Question 14: Have the number of disturbance-increaser plants, noxious weeds, and (or) invasive plant species present been limited to a satisfactory level?	0	0	0	0
Question 15: Is the riparian vegetation within the first 10 m from the edge of the stream generally characteristic of what the healthy unmanaged riparian plant community would normally be along the reach?	1	0	0	1

invertebrate diversity (Question 9, *n* = 8). Debris torrents, slides, and floods were some of the principal reasons cited for low moss levels and low invertebrate diversity, but naturally high fine- and sand-sized sediment levels or unknown causes were also indicated. Temporary blockages accounted for all "No" answers to Question 5 (n = 7), mainly related to natural log jams or beaver dams. All other assessment questions accounted for, at most, four "No" answers. Of these, beaver ponds and dams reduced the range of fish cover options available (i.e., no boulders, cobbles, or gravel) for Question 6. "Debris torrents, floods, and sloughs or slides were the main causes cited for "No" answers to Question 1 (channel bed condition), Question 2 (channel bank condition), Question 3 (channel wood condition) and Question 11 (exposed soil). Wind was considered a contributing factor to the "No" answers for Question 3 (channel wood condition) and Question 11 (exposed soil) on one reach only, a 75-year-old stand in the CWH on Vancouver Island."

Questions on excessive windthrow (Question 10), the woody debris supply to streams (Question 12), or the presence of noxious weeds, invasive plants, or increaser plant species (Question 14) never received a "No" answer. The one "No" answer on overall vegetation vigour, form, and forest structure (Question 15) was related to a reach located in the 75-year-old forest that had complete canopy coverage with no openings and very little standing dead wood, coarse woody debris, or undergrowth. The one "No" answer on shade and bank microclimate (Question 13) was a torrented reach where the banks and adjacent riparian vegetation were scoured away.

The torrented stream with six "No" answers had the highest gradient (55%), but otherwise no obvious relationships were evident between the number of "No" answers and stream gradient. Average stream gradient ranged from 14% on reaches without "No" answers to 9, 15, 13, and 11% on streams with 1, 2, 3, and 4 "No" answers, respectively. With the exception of the two torrented and flood-damaged reaches in the ICH, the average number of "No" answers (0–2) was also consistent among different biogeoclimatic zones with more than one sample.

4.0 DISCUSSION

At 3% of the total sample population, reference streams that are substantially free of human disturbance are rarely encountered in FREP riparian assessments. No doubt this is a consequence of monitoring assessments that are usually focussed on the province's active harvest areas. Presumably, more reference streams would have been encountered if samples were selected in the province's undeveloped areas.

The average number of "No" answers on the present reference streams (1.4) was only slightly higher than the average number of "No" answers attributed to natural causes on the complete FREP data set (1.1, Tschaplinski 2011a, 2011b). Since both data sets show, on average, less than two "No" answers attributable to natural causes, this work supports the validity of the PFC concept and the number of "No" answers used to define PFC in British Columbia assessments. This was true regardless of physiographic region or biogeoclimatic zone. It was also true regardless of stream gradient, although gradient was obviously a factor in the small percentage of streams affected by a debris torrent.

Because many of the reference streams were in headwater areas, the slightly higher average number of "No" answers on reference streams compared to the full FREP data set may reflect the greater vulnerability of small headwater streams to the effects of slides and torrents. Larger streams may have been less susceptible to these impacts because of broader flood plains and less direct connection to steeper gradient headwaters.

The maximum number of "No" answers encountered on the present reference streams was six, and therefore more than six "No" answers seems to be a valid indication of "Not Properly Functioning" condition. Six "No" answers is equivalent to 40% of all possible "No" answers on FREP stream-riparian assessments. While other similar riparian assessment checklists (e.g., the "Montana" method; Hansen et al. 1995, 2000; Prichard 1998; Prichard et al. 1998) use a different scoring system to evaluate overall functioning condition, all use a similar cut-off to determine PFC (i.e., streams have to score at least 60% before experts, on average, consider them to be in PFC). Streams that had a "No" answer to more than 40% of 10 questions were invariably the same streams that experts, acting independently, also felt were no longer in PFC.

The reference streams identified here provide a valuable measure of natural condition for small streams in British Columbia. Other studies or programs (e.g., Canadian Aquatic Biomonitoring Network [CABIN]) use reference streams for assessing impacts, but these are mainly larger-order streams because of sampling requirements (e.g., a minimum of 300 invertebrates from timed kick samples in flowing water at summer low flow). FREP reference streams provide an independent measure of natural conditions on the province's lower-order streams where the CABIN procedures for sampling benthic invertebrates might be too difficult to implement. Unlike the reference streams of other studies where "pristine conditions" are emphasized, the FREP reference streams also include natural impacts. These streams are therefore a more potentially useful benchmark for detecting the effects of human activities on streams.

Reference streams represent a valuable data set that could be used to validate or "fine-tune" the thresholds used for various indicators in FREP's riparian management routine effectiveness evaluation protocol. Assuming the reference streams are good estimates of natural conditions (including impacts such as fires, floods, or slides), this may mean broadening the current thresholds to more accurately encompass the natural range of variability. For example, the 95% confidence limit for "shade" on the reference streams was 20–100%, indicating that the current threshold of 60% is too high. In other cases, the thresholds may underestimate impacts. In addition, conditions for reference streams where little human activity occurs suggest that current thresholds for coverage by increaser-disturbance plants (25%), or invasive plants and noxious weeds (5%), are much too high. Much lower thresholds (e.g., 2%) appear to be a more accurate measure of human-related disturbances.

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MORE INFORMATION

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