State of Stream Channels, Fish Habitats, and Adjacent Riparian Areas: Resource Stewardship Monitoring to Evaluate the Effectiveness of Riparian Management, 2005–2008

FREP

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Management of forest and range resources is a complex process that involves the balancing of ecological, social, and economic considerations. The key purpose of this extension note is to inform resource management professionals of the biophysical outcomes of management practices on riparian and stream function. This information will help enhance the knowledge on which professional advice and accountability are based, and help inform sound decision making.

From 2005 to 2008, B.C. Ministry of Forests and Range field staff assessed stream and riparian conditions of 1441 stream reaches in, or adjacent to, randomly selected cutblocks (harvest areas) that had been logged between 1996 and 2006 (Figure 1). The objective of these assessments was to determine whether forest and range practices had been effective in maintaining the "health" or "properly functioning condition" (PFC) of streams and the adjacent riparian areas (Figure 2). Properly functioning condition is defined as streams and the associated riparian areas that:

1. withstand normal peak flood events without experiencing accelerated soil loss, channel movement, or bank movement;
2. filter runoff;
3. store and safely release water;
4. maintain the connectivity of fish habitats in streams and riparian areas so that these habitats are not lost or isolated as a result of management activity;
5. maintain an adequate riparian root network or large woody debris (LWD) supply; and
6. provide shade and reduce bank microclimate change.

Streams are considered to be in a properly functioning condition if the impacts of forest development on a set of stream channel and riparian area health indicators are:

- small on average;
- within the range of natural variability; or
- beyond the range of natural variability in no more than a small portion of the stream and riparian habitat.

Resource Stewardship Monitoring Stream-Riparian Checklist and Protocol

The Resource Stewardship Monitoring (RSM) assessments of PFC are based on a checklist of 15 questions, each covering a principal indicator of individual stream channel and riparian area conditions (Tripp et al. 2009). For example, question one asks, "Is the channel bed undisturbed?" Question two asks, "Are the channel banks intact?" Other stream channel questions ask about substrate conditions, pool frequency, pool depth, wood characteristics, connectivity, the amount of moss on or along the channel bed, the amount of sand-sized and finer sediments present on the streambed, benthic invertebrate diversity, and fish cover diversity. Riparian area questions focus on windthrow, woody debris supply, soil exposure or compacted ground, bank microclimate, and vegetation composition, form, vigour, and recruitment.

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Figure 1. *Location of riparian sample sites, 2005–2008 (1441 sample streams).*

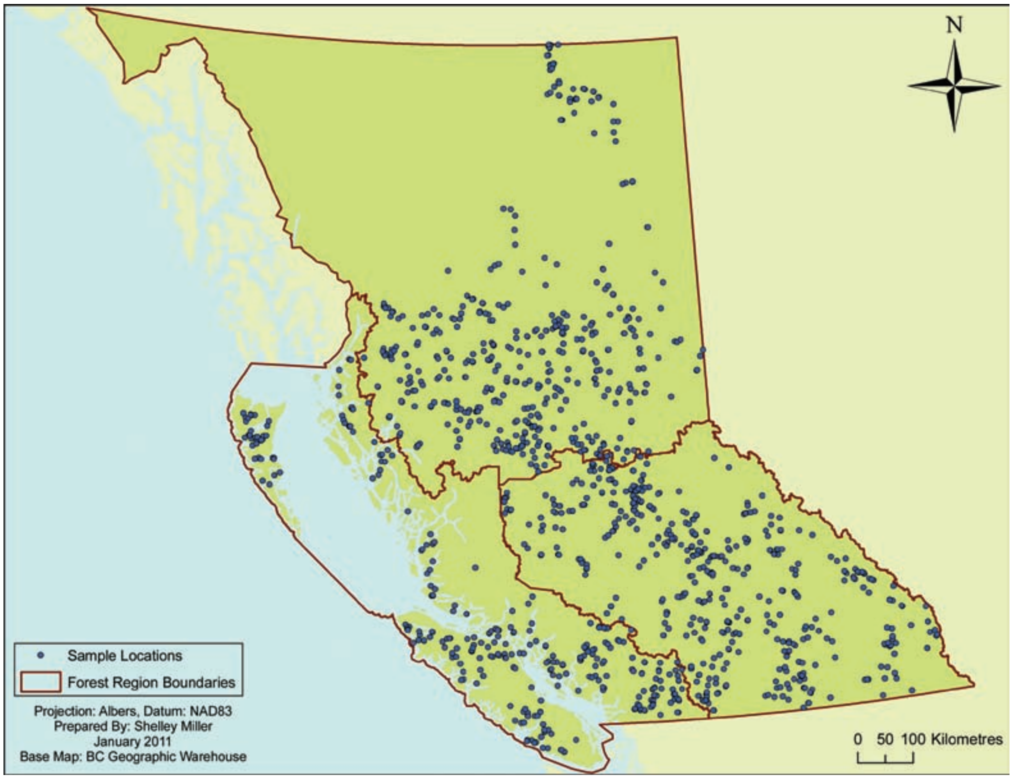

Figure 2. *Examples of streams in properly functioning condition: clockwise from upper left, an S3 and an S4 stream, and two S6 streams.*

Depending on channel morphology, substrate conditions, and fish use, 114–120 measurements, estimates, and observations are required to complete a stream-riparian assessment based on 38–60 specific indicators that cover 11–15 main checklist questions. Each assessment includes measurements of channel width, depth, and gradient as well as vegetation retention in the riparian area.

EVALUATION QUESTION AND INDICATOR THRESHOLDS

The riparian assessment requires a “yes” (pass), “no” (fail), or “not applicable” (NA) answer to each of the 15 questions. For most streams, nine of 15 questions require multiple “no” answers to a specific indicator before the question can also be answered “no”. Thresholds used for all indicators of acceptable stream and riparian condition represent 75–95% of the values typically recorded on streams undisturbed by humans. Conditions that exceed the thresholds indicate conditions beyond the normal range exhibited by streams undisturbed by humans. The assessment, by design, avoids comparing streams to an “average” or “ideal” undisturbed condition.

Thresholds for the indicators come from the scientific literature, a large base of research data collected from five physiographic regions and 10 major biogeoclimatic zones in British Columbia, and expert opinion to address data gaps. The range of natural variation for pre-harvest or pre-disturbance baseline conditions was identified from the data collected in multi-decade research projects on more than 100 streams where pre-harvest reference conditions were identified and compared to post-harvest changes. As a result, reference conditions were built into the assessment system so that alterations attributed to either forestry practices or other causes including natural disturbances could be identified.

DETERMINING FUNCTIONING CONDITION

Each stream was deemed to be in one of four possible outcomes based on the number of “no” answers to the 15 evaluation questions: (1) properly functioning condition, or PFC (0–2 “no” answers); (2) properly functioning with limited impacts, or PFC-L (3–4 “no” answers); (3) properly functioning with impacts, or PFC-I (i.e., intermediate-level effects; 5–6 “no” answers); and (4) not properly functioning, or NPF (> 6 “no” answers).

SAMPLE REACHES

The province-wide sample of assessed streams covered all six riparian management classes (Table 1).

Table 1. *Number of stream reaches assessed for post-harvest riparian and stream channel conditions between 2005 and 2008 for each riparian class and overall*

Sample size by riparian class							
Forest region	Fish-bearing streams				Streams without fish		Total
	S1	S2	S3	S4	S5	S6	
Coast	3	27	44	26	54	213	367
Northern Interior	1	25	137	150	17	207	537
Southern Interior	1	32	119	93	22	270	537
ALL	5	84	300	269	93	690	1441

RESULTS

The results of post-harvest monitoring over 4 years show that, across the province, 87% of the 1441 assessed stream reaches were in one of the three categories of properly functioning condition (Figure 3). Thirteen percent were deemed NPF.

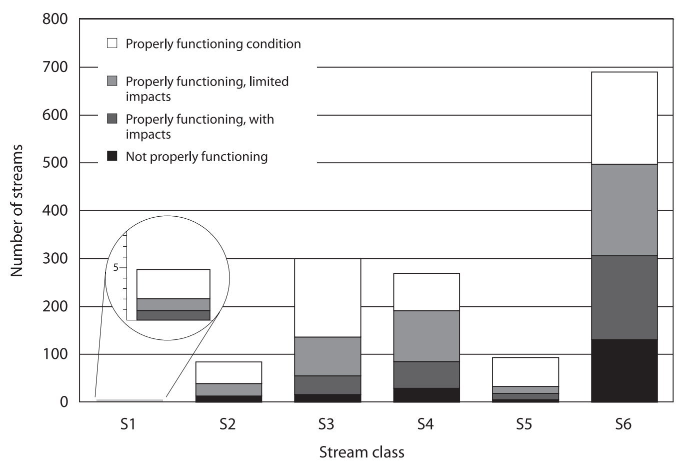

Figure 3 *Province-wide results of stream-riparian condition assessments for the six riparian stream classes.*

When results for stream reaches classified as fish bearing are considered alone, 93% of the 658 class S1–S4 streams were in one of the three properly functioning categories. About 77% were assessed as having limited to no observable impacts (PFC and PFC-L) and 16% were assessed as PFC-I. Seven percent were deemed NPF, and most of those were class S4. The highest frequencies of PFC outcomes were observed for fish-bearing streams provided with mandatory riparian reserves: 96% of class S1, S2, and S3 streams combined were in one of the three PFC categories, and 4% were deemed NPF.

Of the streams deemed NPF, 72% were small, non-fish-bearing class S6 of headwater areas followed by the smallest fish-bearing stream class (S4; 16%). Overall, 19% of all S6 and 11% of all S4 streams were determined to be NPF. Nine percent of all NPF stream reaches were fish-bearing class S3 and less than 3% were non-fish-bearing S5 streams.

The results of the present assessments correspond closely with those reported in 1998 by the B.C. Forest Practices Board, 2 years after the Forest Practices Code was implemented (Table 2). The results indicate that the B.C. Forest Practices Code was implemented consistently from 1996 to 2006. They also support the Board's conclusions that the effectiveness of riparian management resulting from the implementation of the Forest Practices Code represented a great improvement over pre-Code conditions because of "a marked reduction in the level of logging-related alterations to streams" (Forest Practices Board 1998).

Table 2. *Percentage of pre-code (coastal, 1988–1992) and code era (coastal, 1996; provincial, 2005–2008) British Columbia streams in NPF condition*

Riparian class	Pre-Code[a] (Percentage of streams equivalent to FREP NPF streams)	Code era[b] (Percentage of streams equivalent to FREP NPF streams)	FREP 2005–2008 (Percentage of NPF streams)
S1	5	0	0
S2	20	0.6	1.2
S3	41	4.4	5.3
S4	60	9.4	10.8
S5	45	3.3	5.4
S6	76	20.2	19.0

a Tripp, 1994.
b Forest Practices Board, 1998

Overall results varied between the coast and interior of the province. Of 1074 streams sampled in the Northern Interior Forest Region and Southern Interior Forest Region together, 40% were assessed as PFC and 71% were in the PFC and PFC-L categories combined (Figure 4). Another 19% were PFC-I. Therefore, 89% of interior streams were in one of three properly functioning condition categories. Eleven percent of interior streams were NPF.

Outcomes were more evenly distributed across the four stream-riparian functional categories in the Coast Forest Region. Eighty-one percent of these streams were in one of

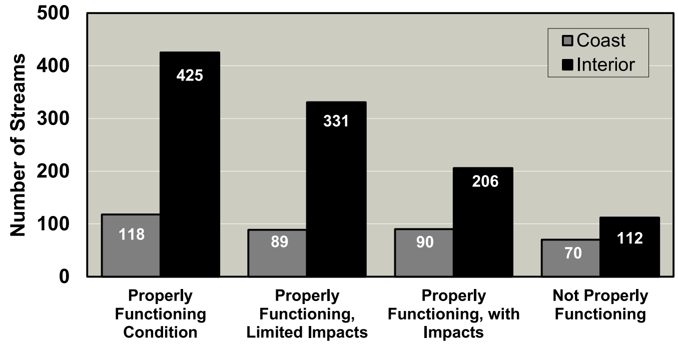

Figure 4. *Summary of stream-riparian condition assessments conducted in coastal and interior regions of British Columbia.*

three properly functioning condition categories with 32% in PFC, 24% in PFC-L, and 25% in PFC-I. Compared with the interior, the larger percentage of coastal streams assessed as NPF (19%) probably reflects the steeper terrain and higher precipitation levels present in coastal areas. It may also reflect varying levels of retention in riparian areas on small streams between regions.

Other differences may occur at the district level, especially among the northern and southern forest regions, which encompass a wider variety of physiographic regions or biogeoclimatic zones than the coastal region. While further district-level data analysis needs to be completed, preliminary inspection suggests that overall results were generally consistent among districts within each region (Figure 5). The one notable exception was the Chilcotin Forest District where none of the stream reaches sampled were NPF.

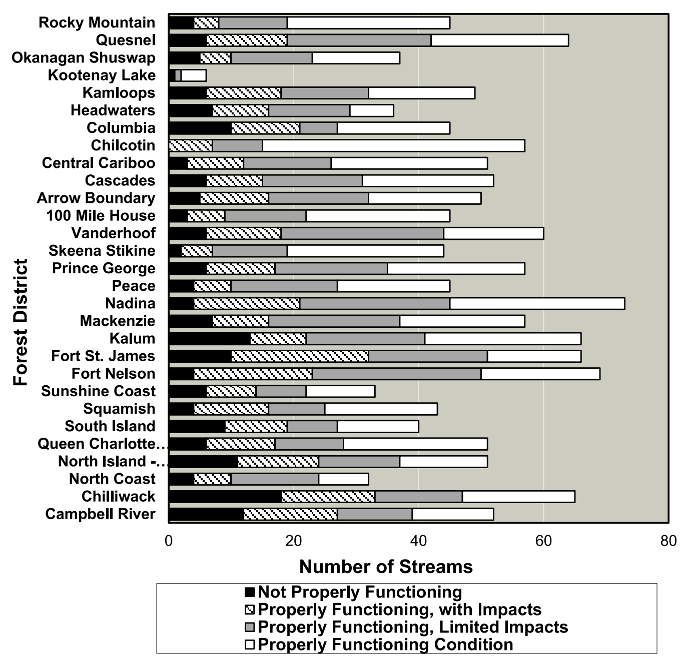

Figure 5. *Results of stream-riparian condition assessments in the 29 forest districts of the B.C. Ministry of Forests and Range (2005–2008).*

CAUSAL FACTORS

Streams that were assessed with PFC and PFC-L outcomes most frequently occurred in harvest areas where fine sediments were managed (road construction and maintenance), streamside retention consisted of overstorey trees managed for windthrow risk, and little or no disturbance was evident to the stream banks and adjacent riparian area.

Impacts from sources not related to site-level forestry practices resulted in 1.1 "no" answers on average for all streams combined. Site-level forestry practices added 2.5 "no" responses per stream on average (ranged from 0.9 to 1.6 for all stream classes except for S6 and S4 where it was 3.4 and 2.5, respectively; see Table 3 and examples in Figure 6). The primary forestry-related causes of impact reported were (in descending order of frequency): road-associated generation and transport of fine sediments (68%), low levels of Riparian Management Area (RMA) tree retention (48%), windthrow (32%), falling and yarding trees across streams (30%), and harvest-related machine disturbance in the RMA (26%). Non-forestry-related causes of impact included beetle infestations and fire (30% of all sites), livestock trampling (9%; access to streams may be forestry-related), and "other" human-caused disturbances (4% of all main causes). In addition, nearly 40% of "no" answers associated with fine sediment levels above the thresholds were attributed to a combination of naturally high background levels and delivery of fine sediments from human-related activity upstream.

Table 3. *Incremental effects of cutblock-level forestry practices on riparian-stream conditions*

Stream class	Number of "no" responses to indicator questions			
	Non-cutblock-related	Cutblock-related	Mean no. non-cutblock-related (per stream)	Mean no. cutblock-related (per stream)
S1	9	3	1.8	1.0
S2	142	73	1.7	0.9
S3	397	308	1.3	1.4
S4	352	567	1.3	2.5
S5	81	97	0.9	1.6
S6	555	1745	0.8	3.4
All	1536	2793	1.1	2.5

FINE SEDIMENTS

Fine sediment levels above threshold values for one or more of the four sediment-related indicators used in the assessment were widely encountered, and affected all stream classes regardless of the retention levels or buffer widths along the streams. Fine sediments affected 63% of the sample streams, ranging from 83% of S4 streams to 66% of S3 streams, 62% of S6 streams, 25% of S5 streams, and 55% of S2 streams.

Fine sediments resulting from forestry-related activities affected 38% of the sample streams. Roads and the associated stream crossings were by far the main forestry-related source of these fine sediments. However, 25% of the time upstream activities, natural disturbances, and background conditions were identified as the main sources of fine sediments, which indicates that factors elsewhere in the watershed were also important to consider.

Relatively minor forestry-related sources included eroding banks caused by new wood accumulations, or slumping banks and exposed soils caused by new windthrow. Non-forestry-related sources included naturally high background levels of fines in adjacent or upslope soils, trampling by livestock (although forestry could facilitate access to water), and non-forestry-related bank erosion, slumps, and windthrow.

TREE RETENTION

Measurements of riparian retention showed that all six stream classes were managed by the use of unharvested buffers at a frequency and extent substantially greater than required in regulations. Class S1, S2, and S3 fish-bearing streams, which require mandatory riparian reserves 50, 30, and 20 m wide, respectively, were provided (on average) with reserves of fully retained vegetation 67, 42, and 32 m wide, respectively. Class S4, S5, and S6 streams, which do not require any reserves, had unharvested buffers of 17, 28, and 11 m wide, respectively (on average).

The 17 m mean width of no-harvest strips adjacent to S4 streams was consistent with the findings of the post-harvest study of these streams in the British Columbia central interior in 2000 (Chatwin et al. 2001). In that study, 68% of S4 streams had some form of riparian reserve, and more than 30% of all class S4 RMAs received reserves 10–50 m wide; however, the widespread use and sizes of no-harvest buffers on non-fish-bearing streams was unanticipated. The presence of no-harvest buffers 28 m wide on average for S5 streams demonstrates that these relatively large, non-fish-bearing streams were generally managed with retention levels similar to class S2 and S3 fish-bearing streams. With 65% of class S5 stream reaches in the best category of properly functioning condition, it appears that the management strategy for these streams was effective.

Notwithstanding the overall higher than expected levels of retention along most streams, low riparian tree retention was the second most frequently cited problem, affecting 48% of streams as a main or secondary cause of impacts. This included a number of S2 and S3 streams

Figure 6. *S4 and S6 streams in properly functioning condition but with impacts (PFC-I) or not properly functioning (NPF).*

S6, NPF

S4, PFC-I

S6, PFC-I

S6, NPF

where mandatory reserves were left in place. On these streams, low retention as a cause of impacts refers to low retention in the management zone of the RMAs, primarily because low retention was the main factor contributing to excessive windthrow in the reserve zone. On streams without reserves, impacts associated with low retention were primarily attributed to reduced LWD supply to streams and (or) significant changes to the composition of the riparian vegetation and its form, vigour, or recruitment and the consequences for the aquatic environment. Retention strategies around S4, S5, and S6 streams varied considerably. A common approach was stream avoidance. Forest licensees often designed harvest areas to exclude these streams and much or all of the associated RMAs. Another common stream management approach was incorporating wildlife tree patches within RMAs of small streams for the dual purpose of stream channel protection and achieving wildlife and biodiversity objectives.

A third common approach was use of no-harvest buffers 10 m wide on S4 streams, a "best management practice" recommendation from the Riparian Management Area Guidebook (B.C. Ministry of Forests and B.C. Ministry of Environment, Lands and Parks 1995).

Stream reaches (all riparian classes combined) in the best category of properly functioning condition had the widest buffers followed sequentially by those in PFC-L, PFC-I, and NPF. In particular, class S4 and S6 stream reaches in PFC had wider buffers on average (24 and 18 m wide, respectively) than their counterparts in any other functional outcome.

Class S4 and S6 stream reaches with even narrow buffers (≤ 5 m wide) were in significantly better condition than those with harvesting up to the stream banks. The highest frequency of NPF outcomes and the lowest frequency of PFC outcomes occurred in class S4 and S6 reaches without a no-harvest buffer. Stream reaches receiving buffers in the 6–10 m category had significantly better post-harvest functional outcomes than streams with harvesting at the banks.

Nevertheless, streams of all classes with buffers wider than 10 m had functional outcomes that were not significantly different from reaches with buffers about 10 m wide. These results indicate that for buffer widths less than 10 m, the more retention the better, but any degree of retention is better than none.

It is important to understand that although 10 m reserve areas appeared to provide protection for stream-riparian function, wider buffers such as the riparian reserves on the larger fish-bearing streams in the province do provide a higher level of stream-riparian protection for a number of attributes and processes (e.g., water temperature, riparian microclimate, and aquatic primary production) and other values such as biodiversity. A growing body of experimental research has demonstrated that changes in these parameters can be detected where harvesting has occurred 30 m or more from the stream bank (Richardson et al. 2002, 2005; Kiffney et al. 2003).

OPPORTUNITIES FOR IMPROVEMENT IN THE MANAGEMENT OF RIPARIAN/FISH RESOURCE VALUES

The results of riparian (fish) monitoring show both positive results and areas for potential improvement. As discussed earlier, successful stream and riparian management is associated with five main management actions/outcomes:

1. Road-associated generation and transport of fine sediments;
2. Level of RMA tree retention;
3. Windthrow;
4. Falling and yarding trees across streams; and
5. Post-harvest machine disturbance in the RMA.

The following practices applied, in combination, result in higher functioning streams.

- Limiting the introduction of logging-related woody debris in channels (leave natural debris in place).
- Avoiding physical contact with the streambed and stream banks (e.g., through falling and yarding away from channels whenever feasible).
- Retaining riparian vegetation, at minimum, non-merchantable trees, understorey, and smaller vegetation within 10 m of the channel.
- Retaining some, or all, larger trees within 10 m of the RMA improves outcomes for small fish-bearing streams (S4) and non-fish-bearing tributaries (S5, S6) connected to fish bearing streams and drinking water sources
- Minimizing fine sediment delivery to channels from roads and stream crossings throughout the entire road life cycle.

Small streams, especially class S6, are challenging to manage in areas of steep terrain and high rainfall. Some of these areas are so highly dissected by the channel network that the 20 m wide RMA of one stream overlaps that of the next one, and this overlap may be repeated across large areas. Also, an extraordinary diversity of channels belong to riparian class S6. At one end of the spectrum are perennially flowing, well-defined streams 1.5–3 m wide that make significant contributions of water, debris, food, and nutrients to aquatic ecosystems downstream. At the other end of the spectrum are channels that barely satisfy the definition of a stream and deliver very little downstream. Although managing this variety of channels will continue to require difficult management decisions, focussing best practices on those S6 streams connected to downstream fish habitat and (or) downstream water quality concerns will likely result in the most improved outcomes for the least cost.

The Resource Stewardship Monitoring assessments have shown that much more riparian retention has been applied province-wide for all stream classes than is required by regulation, including class S4, S5, and S6 streams. Without further increasing riparian retention levels within a watershed or a landscape, this existing level of retention could be distributed where the greatest benefits for fish and aquatic values would be achieved with minimum additional cost. For example, additional retention, such as no-harvest buffers 10 m wide for fish-bearing class S4 streams and to some lengths of perennial S6 streams flowing directly into fish habitats, could be applied without increasing existing levels of riparian tree retention.

PLANS FOR RIPARIAN MONITORING UNDER FREP

Riparian monitoring will continue under FREP in 2011. The focus of monitoring has now shifted to practices under the *Forest and Range Practices Act*. It is anticipated that the full riparian report, which is the basis of this extension note, will be published in early 2011. The current FREP riparian monitoring protocol is undergoing a comprehensive continuous improvement review to identify possible efficiencies that may be gained through detailed statistical analysis.

THANK YOU

Thank you to the district staff who assisted in the development of this protocol, collected the data on which this extension note is based, and suggested ongoing improvements. Thank you to the individuals who conducted a peer review of the riparian report on which this note is based: Dr. Robert Bilby, Weyerhaeuser Company; Dr. Sherri Johnson, USDA Forest Service; Steve Smith, Leader, National Riparian Service Team, USDI Bureau of Land Management; Janice Staats, Hydrologist, National Riparian Service Team, USDI Bureau of Land Management; Dr. John Rex, B.C. Ministry of Forests and Range; Dr. Katherine Sullivan, Humboldt Redwood Company; Dr. Gordon Hartman, Consulting Fisheries Biologist and Fisheries and Oceans Canada (retired); and Dr. Todd Redding, FORREX and Okanagan College. A final thanks to Derek Tripp for his ongoing improvements to the FREP riparian monitoring indicators and protocol, field staff training and mentoring, significant contributions to this extension note, and overall dedication to the Forest and Range Evaluation Program.

For more information on FREP, please see: http://www.for.gov.bc.ca/hfp/frep/index.htm

REFERENCES

B.C. Ministry of Forests and B.C. Ministry of Environment, Lands and Parks. 1995. Riparian management area guidebook. Forest Practices Code of British Columbia, Victoria, B.C. Guidebook. http://www.for.gov.bc.ca/tasb/legsregs/fpc/fpcguide/riparian/rip-toc.htm (Accessed November 2010).

Chatwin, S., P. Tschaplinski, G. McKinnon, N. Winfield, H. Goldberg, and R. Scherer. 2001. Assessment of the condition of small fish-bearing streams in the central interior plateau of British Columbia in response to riparian practices implemented under the Forest Practices Code. B.C. Ministry of Forests, Research Branch, Victoria, B.C. Working Paper No. 61. http://www.for.gov.bc.ca/hfd/pubs/docs/Wp/Wp61.htm (Accessed December 2010).

Forest Practices Board. 1998. Forest planning and practices in coastal areas with streams. Victoria, B.C. Technical Report.

Kiffney, P. M., J. S. Richardson, and J. P. Bull. 2003. Responses of periphyton and insects to experimental manipulation of riparian buffer width along forest streams. Journal of Applied Ecology 40:1060–1076. http://faculty.forestry.ubc.ca/richardson/abstracts/Kiffney_etal2003.pdf (Accessed December 2010).

Richardson, J. S., P. M. Kiffney, K. A. Maxcy, and K. L. Cockle. 2002. An experimental study of the effects of riparian management on communities of headwater streams and riparian areas in coastal B.C.: How much protection is sufficient? In: Advances in forest management: From knowledge to practice. Proceedings, Sustainable Forest Management Network Conference, November 13–15, 2002. Edmonton, Alta. pp. 180–186. http://www.for.gov.bc.ca/hfd/library/ffip/Richardson_JS2002.pdf (Accessed December 2010).

Richardson, J. S., R. J. Naiman, F. J. Swanson, and D. E. Hibbs. 2005. Riparian communities associated with Pacific Northwest headwater streams: Assemblages, processes, and uniqueness. Journal of the American Water Resources Association 41:935–947.

Tripp, D. B. 1994. The use and effectiveness of the Coastal Fisheries Forestry Guidelines in selected Forest Districts of coastal British Columbia. D. Tripp Biological Consultants Ltd. report to the Ministry of Forests, Integrated Resources Branch, Victoria, B.C.

Tripp, D. B., P. J. Tschaplinski, S. A. Bird, and D. L. Hogan. 2009. Protocol for evaluating the condition of streams and riparian management areas (Routine riparian management effectiveness evaluation). B.C. Ministry of Forests and Range and B.C. Ministry of Environment, Forest and Range Evaluation Program, Victoria, B.C. http://www.for.gov.bc.ca/ftp/hfp/external/!publish/frep/indicators/Indicators-Riparian-Protocol-2009.pdf (Accessed December 2010).