

Riparian Effectiveness Evaluations

The evaluation of the effectiveness of riparian management practices implemented under the BC Forest Practices Code or the new Forest and Range Practices Act can be conducted at three levels of intensity. In ascending order of detail, these evaluations are respectively termed *routine*, *extensive*, and *intensive*. Each level of evaluation uses a set of field indicators to identify forestry-related effects upon riparian and aquatic ecosystem conditions or functions. Routine indicators are relatively simple measures that can be obtained at most sites (e.g., 80 %) subjected to a regime of riparian management. Extensive indicators include more rigorous measures that require more effort (time and cost) to obtain; therefore, they are used to assess a smaller population of managed sites (e.g., 20 % of the total) which can be a subset of those initially covered by a routine assessment. Intensive measures involve the most detailed levels of assessment, and are appropriate only at a limited number of locations (e.g., 1 % of all sites).

I. Routine Indicators

Routine indicators can be used as a “primary-level” of assessment at any site identified within a defined area of study. Auditors have the option of implementing the more detailed extensive-level assessments if meaningful forestry-related changes to stream, lake, wetland, or riparian habitats are visually apparent.

The following two tables contain routine indicators. Table 1 indicators can be obtained from an aerial overview (i.e., by helicopter reconnaissance) when the aquatic features in question are not unduly obscured by the riparian canopy. The Table 2 indicators are always ground based. The aerial reconnaissance is an overview survey performed first. The observation of forestry-related alterations from the air may then trigger further assessments on the ground. Alternatively, if no management-related impacts or changes are apparent from an overflight, the assessment team has the option of moving on to the next site.

The overview indicators can thus be used in a decision-making sequence to determine whether further investigation is warranted on the ground. The advantage of an aerial overview is the ability to quickly compare upstream control or reference areas with managed or "treatment" areas.

Two summary questions are addressed in the aerial overview on the basis of answers to specific questions (indicators). The first summary question (Table 1, Question 1) represents the most generalized level of assessment. This question concerns the overall appearance of the Riparian Management Area (RMA) with its Riparian Management Zone (RMZ), and Riparian Reserve Zone (RRZ) if the latter is required by the riparian classification. Specific questions (indicators) for Question 1 include the level of windthrow relative to reference sites; whether full RMZ tree retention occurs within 10 m of the stream channel; presence of canopy disturbances; cattle use; ground disturbances

(exposed sediment sources), channel appearance on-site versus upstream; and, the presence of roads, trails, and stream crossings.

The second summary question (Table 1, Question 2) is intended to further examine from the air those sites with minor alterations; that is, those so slight that observers may conclude that the riparian management treatment is still effective. Specific indicator questions include generalized observations of stream substrates and large woody debris (LWD); the locations of ground disturbances and their potential direct connection with aquatic habitats; the location of roads and trails and their association with apparent disturbances and sediment sources; whether roads and trails have isolated aquatic habitats (e.g., from main stream habitats); and, the extent and apparent impact of windthrow. For example, windthrow may occur but only at a low level (e.g., $\leq 5\%$ of stems). Furthermore, the windthrown stems may not expose any extra soil other than the rootwad scar, and no impacts to the stream channel are apparent. The RMA alteration is then small, and the riparian treatment may still be considered effective (i.e., if the treatment was intended to reduce windthrow and its impacts on streams, other aquatic habitats, and other attributes).

Table 1. Aerial (helicopter) overview of riparian management effectiveness.

Question 1. Is the aquatic habitat and associated riparian area intact, and free of any disturbances attributable to on-site or adjacent forestry activity?	Yes ☐	No ☐
a) The RRZ is as wide as required, with no evidence of any cattle use or windthrow above what would normally be expected in unlogged areas.	☐	☐
b) Where no RRZ is required, the first 10 m of the RMZ is unlogged, with no cattle use and no evidence of any windthrow above what would normally be expected in unlogged areas.	☐	☐
c) There are no unusual or unexpected breaks in the canopy cover of the RMA.	☐	☐
d) There are no roads or trails present within the RMA, nor any stream crossings.	☐	☐
e) There is no evidence of any ground disturbance, or exposed mineral soil in the RMA, or any adjacent area outside the RMA that is hydrologically linked to the RMA.	☐	☐
<i>If answer is “No” to 1 or more statements, check the “No” box for Question 1, then go to Question 2 and do a closer inspection while hovering. Otherwise, go to the next site.</i>		

Question 2. Are the changes in the RMA noted in Question 1 of a minor nature, sufficient to consider the RMA treatment effective?	Yes ☐	No ☐
a) The amount of windthrow present accounts for < 5 % of the mature trees still standing.	☐	☐
b) None of the windthrow involves trees considered to be wildlife trees, or trees on the edge of the stream.	☐	☐
c) None of the windthrow has entered a stream channel, or increased the amount of stream bank or side slope disturbance present.	☐	☐
d) Any ground disturbance or exposed mineral soil present constitutes < 1 % of the RMA, none of which appears to be directly linked to the aquatic habitat.	☐	☐
e) Roads or trails within the RMA are confined to the outer edge of the RMA, with no evidence of any slides, sloughing, rilling or sediment delivery to the aquatic habitat.	☐	☐
f) There are no off-channel areas evident that may be cut-off from the main habitat by roads or trails in the RMA.	☐	☐
g) There is only one stream crossing, the stream crossing is stable with no evidence on any erosion on the surface or approach slopes, and no encroachment on the channel.	☐	☐
h) Channel form within the treatment area (no. of channels, channel width, location and size of gravel bars, meander frequency) is generally the same as conditions upstream.	☐	☐
i) The average size, distribution and quantity of substrates visible in the aquatic habitat is generally the same upstream of (streams) or outside (lakes, wetlands) the treatment area. The management activity has not introduced any additional sediment.	☐	☐
j) The amount, average size and distribution of LWD visible in the aquatic habitat is generally the same as upstream (streams) or outside (lakes, wetlands) the treatment area. Small localized increases in LWD loads at crossings are not considered significant if the stream lacks the energy to move the debris.	☐	☐
<p><i>If the answer is “Yes” for all statements, check the “Yes” box for Question 2 and go to the next site. If the answer is “No” or questionable for any statements, then a routine ground assessment is warranted.</i></p>		

When ground-based assessments appear warranted on the basis of the aerial overview indicators, the subsequent ground-based survey might use the routine-level, ground-based indicators (Table 2) as one set of all indicators, including some or all of the more detailed *extensive* indicators, that would be needed for a more thorough investigation of riparian management effectiveness.

The ground-based routine indicators are divided into (1) Channel Physical, (2) Channel Biological, and (3) Riparian (physical plus biological) categories. Separate indicators are provided for different types (morphologies) of stream channels: (1) riffle-pool and cascade-pool channels, (2) channels with step-pool morphology, and (3) steep, non-alluvial watercourses. Threshold values for the channel and riparian indicators were most frequently taken or adapted from those referring to Proper Functioning Condition (PFC) as used in the Forest Practices Board Special Report on the effect of cattle grazing near streams lakes and wetlands (FPB Special Report 11 2002).

Table 2. Routine ground-based assessments of riparian effectiveness.

(1) Channel Physical Indicators.

Question 1. Is the channel <i>bed</i> disturbed?	Yes ☐	No ☐
A) Riffle-pool or cascade-pool channels		
a) Are there abundant mid-channel bars (observed along > 50% of the reach)?	☐	☐
b) Are multiple channels and/or braids prevalent (observed along > 50% of the reach)?	☐	☐
c) Are there long stretches of channel with little or no gravel bars (observed along > 50% of reach)?	☐	☐
<i>If answer "Yes" to 2 or more, check Yes box in Question 1.</i>		
B) Step-pool channels		
a) Are stable steps infrequent (< 50% span the channel either in a perpendicular or diagonal orientation relative to the banks)?	☐	☐
b) Are steps devoid of moss (> 25%)?	☐	☐
c) Are multiple channels and/or braids prevalent (observed along > 25% of the reach)?	☐	☐
<i>If answer "Yes" to 2 or more, check Yes box in Question 1.</i>		
C) Steep non-alluvial channels		
a) Is the channel bed devoid of moss (> 25%)?	☐	☐
b) Is the channel "full" of sediment and debris with little or no additional storage opportunities (i.e., sediment and/or LWD fill the channel volume and may spill over the bank)?	☐	☐
c) Are sediments stored in a few relatively large compartments (e.g., wedged behind an accumulation of immobile rocks or organic debris)?	☐	☐
<i>If answer "Yes" to 2 or more, check Yes box in Question 1.</i>		

Question 2. Are the channel <i>banks</i> disturbed?		Yes ☐	No ☐
A) Riffle-pool or cascade-pool channels			
a)	Is there any evidence of recent bank erosion (> 10 % of bank eroded along one side of channel—do not include outside bends)?	☐	☐
b)	Is the bank area immediately adjacent to the channel devoid of deeply rooted vegetation (observed along > 25 % of reach)?	☐	☐
c)	Are there limited overhanging or undercut banks (observed along < 50% of reach)?	☐	☐
d)	Are root wads (wind thrown) upturned along the channel banks (observed along > 10% of reach)?	☐	☐
<i>If answer “Yes” to 2 or more, check Yes box in Question 2.</i>			
B) Step-pool channels			
a)	Is there any evidence of recent bank erosion (> 5 % of bank eroded along one side of channel—do not include outside bends)?	☐	☐
b)	Is the bank area immediately adjacent to the channel devoid of deeply rooted vegetation (observed along > 75 % of reach)?	☐	☐
c)	Are there limited overhanging or undercut banks (observed along < 50% of reach)?	☐	☐
d)	Are root wads (wind thrown) upturned along the channel banks (observed along > 25% of reach)?	☐	☐
<i>If answer “Yes” to 2 or more, check Yes box in Question 2.</i>			
C) Steep non-alluvial channels			
a)	Is the bank area immediately adjacent to the channel devoid of deeply rooted vegetation (observed along > 75 % of reach)?	☐	☐
b)	Is there any evidence of recent bank erosion (> 5 % of bank eroded along one side of channel—do not include outside bends)?	☐	☐
c)	Are root wads (wind thrown) upturned along the channel banks (observed along > 25% of reach)?	☐	☐
<i>If answer “Yes” to 2 or more, check Yes box in Question 2.</i>			

Question 3. Are LWD processes disturbed?		Yes ☐	No ☐
A) Riffle-pool or cascade-pool channel			
a)	Are most debris jams recently formed (i.e., accumulations of woody debris span the channel and appear freshly deposited)?	☐	☐
b)	Are most recently formed debris jams relatively large and frequent (occurring more than twice every 5 channel widths)?	☐	☐
c)	Do most debris jams contain logging debris (e.g., branches, treetops, bark, small logs and LWD with saw-cut ends)?	☐	☐
d)	Is there abundant woody debris oriented parallel to the channel banks (particularly small logs and limbs with lengths << bankfull channel width)?	☐	☐
<i>If answer "Yes" to 3 or more, check Yes box in Question 3.</i>			
B) Step-pool channel			
a)	Are most debris jams recently formed (i.e., accumulations of woody debris span the channel and appear freshly deposited)?	☐	☐
b)	Are most recently formed debris jams relatively small but frequent (occurring more than twice every 5 channel widths)?	☐	☐
c)	Do most debris jams contain logging debris (e.g., branches, treetops, bark, small logs and LWD with saw-cut ends)?	☐	☐
d)	Is there abundant woody debris oriented parallel to the channel banks (particularly small logs and limbs with lengths << bankfull channel width)?	☐	☐
<i>If answer "Yes" to 3 or more, check Yes box in Question 3.</i>			
C) Steep non-alluvial channel			
a)	Are most debris jams recently formed (i.e., accumulations of woody debris span the channel and appear freshly deposited)?	☐	☐
b)	Do most debris jams contain logging debris (e.g., branches, treetops, bark, small logs and LWD with saw-cut ends)?	☐	☐
c)	Is there abundant woody debris oriented parallel to the channel banks (particularly small logs and limbs with lengths << bankfull channel width)?	☐	☐
<i>If answer "Yes" to 2 or more, check Yes box in Question 3.</i>			

Question 4. Has channel morphology been disturbed?		Yes ☐	No ☐
A) Riffle-pool or cascade-pool channel			
a)	Are riffles and/or cascades much more abundant than pools (riffles and/or cascades observed along > 75 % of the reach)?	☐	☐
b)	Is the surface sediment texture highly homogeneous (consider assessment over size range from sand to large cobbles)?	☐	☐
c)	Are deep pools absent (< 10 % of all pools are as deep as the stream banks are high)?	☐	☐
<i>If answer "Yes" to 2 or more, check Yes box in Question 4.</i>			
B) Step-pool channel			
a)	Are deep plunge pools infrequent (< 75 % of steps associated with a plunge pool with depths similar to the size of the largest rock in a step) and/or in-filled to near the top of the next downstream step?	☐	☐
b)	Does >25% of the channel consist of relatively long cascades (i.e., the channel does not alternate almost exclusively between steps and pools)?	☐	☐
c)	Are deep pools absent (< 10 % are as deep as the stream banks are high)?	☐	☐
<i>If answer "Yes" to 2 or more, check Yes box in Question 4.</i>			

(2) Channel Biological Indicators.

Question 5. Are all aspects of the aquatic habitat sufficiently connected to allow for normal, unimpeded movements of fish, organic debris, and sediments?	Yes ☐	No ☐
a) Temporary blockages because of new debris jams or landslides are absent.	☐	☐
b) Down cutting that blocks the entrance to tributary streams or off-channel areas is absent.	☐	☐
c) Build-ups of sediment or debris above any crossing structures are absent.	☐	☐
d) There is no down cutting present below any crossing structure that blocks fish movements upstream by any size fish at any time.	☐	☐
e) On fish bearing streams, all crossing structures are open bottom structures.	☐	☐
f) Dewatering over the entire channel width due to excessive new accumulations of sediment is absent.	☐	☐
g) Off-channel or overland flow areas have not been isolated, cut off or covered by any roads or trails.	☐	☐
<i>If answer is "No" to any statements, check the "No" box for Question 5. Otherwise, check the "Yes" box.</i>		

Question 6. Does the stream, lake or wetland support a good diversity of fish cover attributes?	Yes ☐	No ☐
(Note: To qualify as cover, each cover attribute should have at least one dimension equal to 10 % of the channel width. Thus, only one dimension of the cover in a 1m wide channel has to be 10 cm. In a 10 m wide stream, then one dimension of the cover has to be at least 1 m.)		
a) Deep, quiet water (pools in streams) is available.	☐	☐
b) Large, immovable boulders are present.	☐	☐
c) Stable woody debris or rootwads are present in the channel.	☐	☐
d) Stable, deep-rooted undercut banks are present.	☐	☐
e) Submerged or emergent aquatic vegetation is present.	☐	☐
f) Overhanging vegetation is present within 1 m of the top of the channel (streams) or water surface (wetlands, lakes).	☐	☐
g) There is a stable substrate present with void spaces for fish to hide in.	☐	☐
<i>For streams, if the answer is "Yes" for three statements, check the "Yes" box. Otherwise, check the "No" box. For wetlands, check the "Yes" box if two statements are true.</i>		

Question 7. Does the amount of moss present on the substrates indicate a stable and productive system?	Yes ☐	No ☐
a) The number of moss patches present on the substrate is best described as frequent or abundant.	☐	☐
b) Patches of moss on the streambed are best described as lacking, little or occasional, not frequent or abundant.	☐	☐
<i>If the answer is "Yes" to Statement a), check the "Yes" box for Question 7. If the answer is "Yes" to Statement b), check the "No" box.</i>		

Question 8. Has the introduction of fine sediments been minimized?	Yes ☐	No ☐
a) Wetted riffle bed areas that a stick or heel can be easily pushed into are absent.	☐	☐
b) Recent fine sediment deposits that blanket the substrates in flowing water are absent.	☐	☐
c) The sides of gravels and cobbles can generally be seen touching each other, i.e. individual gravels and cobbles are not embedded in a matrix of sand or finer size particles.	☐	☐
d) Insects use the undersides of rocks in riffles.	☐	☐
<i>If the answer is "Yes" to all statements, check the "Yes" box for Question 8. Otherwise, check the "No" box.</i>		

Question 9. Does the stream, lake or wetland support a satisfactory diversity of aquatic invertebrates? (For example; insects, molluscs such as clams or snails, annelids such as worms or leeches, and crustaceans such as shrimp or water fleas)?	Yes ☐	No ☐
a) Three of the above major taxonomic groups (insects, mollusks, annelids, and crustaceans) are present.	☐	☐
b) At least four recognizably different taxa within any one of the above major groups are present.	☐	☐
c) At least five recognizably different taxa from all the above major groups are present.	☐	☐
d) Particularly sensitive invertebrates such as caddisflies or freshwater clams are present.	☐	☐
<i>Check the "Yes" box for Question 9 if any of the statements are "Yes". Otherwise, check "No".</i>		

(3) Riparian Indicators.

Question 10. Have riparian reserves and designated wildlife trees or wildlife patches in RMAs been protected from windthrow?	Yes ☐	No ☐
a) The incidence of windthrow in reserve zones, or management zones with wildlife trees or wildlife patches is less than 5 % more than what would occur naturally.	☐	☐
b) Designated wildlife trees are still standing, or if windthrown, still functional as wildlife trees (e.g., above-ground bear dens).	☐	☐
c) Others?	☐	☐
<i>If answer is "Yes" to any statements, check the "Yes" box for Question 10. Otherwise, check the "No" box.</i>		

Question 11. Has the amount of bare ground or soil disturbance in the riparian area been minimized?	Yes ☐	No ☐
b) Total bare erodible ground or soil disturbance present in the first 10 m of the riparian zone, plus all other areas hydrologically linked to the first 10 m of riparian zone is less than 5 %.	☐	☐
b) Total bare erodible ground or soil disturbance that is directly linked to a stream in the first 10m of the riparian zone is less than 1 %.	☐	☐
c) Total area affected by cattle pugging and hummocking in the first 10 m of the riparian zone, plus all other areas hydrologically linked to the first 10 m of riparian zone is less than 15 %.	☐	☐
c) Total area affected by cattle pugging and hummocking that is directly linked to a stream, wetland or lake in the first 10m of the riparian zone is less than 5 %.	☐	☐
<i>If the answer is "Yes" for all statements, check the "Yes" box. Otherwise, check the "No" box.</i>		

Question 12. Has streambank integrity been maintained?	Yes ☐	No ☐
a) The length of streambank or shoreline negatively affected by cattle (hoof shear, watering sites, cattle trails and crossings) is less than 15 %.	☐	☐
b) The length of streambank or shoreline negatively affected by crossings, roads, trails, falling, yarding, or windthrow is less than 15 %.	☐	☐
c) The length of bank or shoreline present with deep-rooted vegetation exceeds 65 %.	☐	☐
<i>If the answer is "Yes" to all statements, check the "Yes" box. Otherwise, check the "No" box.</i>		

Question 13. Has sufficient vegetation been retained to provide shade, reduce bank microclimate change, and maintain an adequate root network or LWD supply?	Yes ☐	No ☐
e) On all streams, nonmerchantable conifer trees, understory deciduous trees, shrubs, and herbaceous vegetation were retained to the fullest extent possible within 5 m of the channel.	☐	☐
f) On S1 to S3 size streams, the first 10 m of the riparian reserve zone is intact, including windthrown trees, thereby providing for 99 % of the LWD normally supplied to streams with no additional inputs from upstream or the adjacent hillslopes.	☐	☐
g) On S4 streams, where windthrow hazard is not high, all windfirm trees with roots embedded in the bank, and 50% of all other trees (excluding dominant conifers) within 10 m of the stream bank were retained.	☐	☐
h) On S4 streams, where the windthrow hazard is high, all conifers < 30 cm DBH were retained within 10 m of the stream bank.	☐	☐
i) On valley bottom S5 streams with alluvial banks and a floodplain, 50 % of dominant and codominant windfirm stems within 30 m of the stream bank were retained.	☐	☐
j) On non-valley, LWD dependent S5 streams, all leaners within 10 m of the channel and all conifer stems < 30 cm DBH within 5 m of the stream bank were retained.	☐	☐
k) On LWD dependent S6 streams, or S6 that flow directly into fish-bearing waters, at least 10 trees < 30 cm DBH per 100 m of streambank were retained within 5 m of the stream bank.	☐	☐
<p><i>Check the “Yes” box for Question 13 if there are only “Yes” answers. Otherwise, check the “No” box.</i></p>		

Question 14. For streams with moderate to high transport capability, has the risk of impacts to downstream fisheries resources or water quality remained unchanged as a result of management activities in the riparian zone?	Yes ☐	No ☐
a) The amount of transportable debris or sediments present in the channel has not increased.	☐	☐
b) The potential for additional debris or exposed sediments to enter the channel is remote.	☐	☐
c) Steep slopes adjacent to the stream are stable, and unlikely to fail and enter the stream because of lost root strength.	☐	☐
d) Bare ground subject to surface erosion and movement to the stream is less than 1 % of total area hydrologically linked to the stream.	☐	☐
e) Temporary stream crossings have been satisfactorily deactivated.	☐	☐
<p><i>Check the “Yes” box for Question 14 if all of the statements are “Yes”. Otherwise, check “No”.</i></p>		

Question 15. Have the number of disturbance-increaser plants or noxious weeds present been limited to a satisfactory level?	Yes ☐	No ☐
a) Riparian area occupied by disturbance-increaser plants (e.g. domestic grasses, dandelions) is less than 25 % of total area.	☐	☐
b) Riparian area occupied by noxious weeds is less than 5 % of total area.	☐	☐
<i>Check the “Yes” box for Question 15 if all statements are “Yes”. Otherwise, check “No”.</i>		

General Methods

Observations made during an aerial overview of streams are intended to incorporate the entire length of homogenous sections of stream; that is, the assessment is based on the entire stream reach. When the choice has been made to perform ground-based assessments, the study area should be a representative segment of the stream consisting of a 100 m long section or a length equivalent to 50 channel bankfull widths, whichever is greater.

Study section lengths should be feasible to survey within reasonable amounts of time because the majority of streams identified for further ground-based study will likely be the relatively small class S4 – S6 streams where riparian reserves are not mandatory by regulation. For each indicator, all relevant counts, or measures by percentage or proportion (e.g., by hip chain or fibre tape) needed to answer questions 1 – 15 in Table 2 are performed within the defined study section and where specified, within the specified RMA band measured perpendicularly from the channel (or wetland or lake) margin. Generally, all observations, regardless of question, are made well within 20 m of the waterbody.

The progression from the ground-based, routine indicators to the more detailed extensive indicators represents increased frequency or level of measurement. For example, for the routine indicators, aquatic invertebrates in streams are assessed by kick (or Surber) samples or from 1 – 2 riffles. When further assessed by extensive-level surveys, the frequency of sampling is increased to represent riffles throughout the entire 100-m study section.

Similarly, assessing substrate quality for fish spawning and rearing is performed by answering four questions at one or two riffle-pool breaks for a routine assessment, but is increased systematically to include most or all riffle breaks in an extensive-level assessment (see Methods for extensive indicators).

II. Extensive Indicators

A total of 18 indicators were accepted for use in extensive monitoring for Riparian Effectiveness by participants in an experts workshop held on 21 July 2003 (Table 3). Participants included representatives from provincial agencies (Ministry of Forests, Ministry of Water, Land and Air Protection, Forest Practices Board), the Department of Fisheries and Oceans Canada, the University of British Columbia, and private

consultants. The final list of indicators was condensed from an initial list of about 60 candidate indicators contemplated prior to the workshop.

Indicators were eliminated because they were either (1) considered redundant with others (e.g., sheared banks, unstable banks, well-rooted banks), (2) not directly applicable to the restricted focus of forestry effects on fish and aquatic values (e.g., number of wildlife signs, wildlife sightings, wildlife tree attributes), (3) unfeasible or impractical (e.g., water quality, terrestrial invertebrate diversity, and similarity to natural forest structure), or (3) recommended for intensive monitoring, range-use investigations, or assessments at the landscape level (see Appendices).

Six additional indicators were recommended for possible use in special circumstances (see Appendices) where either a more intensive study was warranted (fish abundance, periphyton abundance), range use was being assessed specifically (increaser-invader species coverage, plant vigor, similarity to the natural plant community), or effectiveness at the landscape level was being evaluated (riparian connectivity).

Field Assessment Questions, Indicator Descriptions, and Rationale

1. *Bank Erosion*

Question:

Is stream bank disturbance (erosion) within the expected range of that in an undeveloped watershed?

Indicator Description:

Eroding stream banks are a direct indicator of bank stability. All streams have banks that are actively or historically eroding (e.g., on the outside of a channel bend), but there is a

Table 3. Extensive indicators with proposed scoring system (where available). Measurement targets are provisional for SBS BEC zone.

Indicator	Measure	Scoring System			
		Nonfunctioning	Functioning – High Risk	Functioning – At Risk	Proper Functioning
1. Bank erosion	Proportion sloping or vertical banks (per 1 W_b interval)	> 0.60	0.50 to 0.60	0.39 to 0.49	= 0.39
2. Sediment variability	Estimate of D_{95} per 1 W_b interval	100% of values in 1 size class	75% of values in 1 size classes	75% of values in 2 size classes	75% of values in >2 size classes
3a. Bar frequency	Presence/absence of bar per 1 W_b interval	> 0.81	0.63 to 0.81	0.45 to 0.62	=0.45
3b. Bar type	Ratio of mid-channel bar or wedge to total number of bars	> 0.59	0.53 to 0.59	0.46 to 0.53	=0.46
4. Degraded channel	Proportion of D2 and D3 CAP states	> 0.060	0.033 – 0.060	0.022 – 0.032	= 0.021
5. Channel depth variability	Bankfull channel depth per $\frac{1}{5} W_b$ interval	Omit for now.	Omit for now.	Omit for now.	Omit for now.
6. Logjam frequency	No. of logjams	> 0.23	0.17 – 0.23	0.12 – 0.16	=0.12
7.a LWD volume ($W_b < 3m$)	Percent cover of LWD	> 80	61 – 80	41– 60	= 40
7.b LWD volume ($W_b 3$ to 6 m)	Percent cover of LWD	> 35	26 – 35	16 – 25	= 15
7.c LWD volume ($W_b > 6 m$)	Percent cover of LWD	> 30	21 – 30	11 – 20	= 10
8.a LWD supply – reserve band	Width of buffer	< 1 m	1 – 3 m	4 – 14 m	=15 m
8.b LWD supply – RMZ	Level of retention	< 25 %	25 – 49 %	50 – 74 %	= 75 %
9. Substrate embeddedness	Mean of “Yes” vs. “No” answers to 4 questions	0 Yes / 4 No	2 Yes / 2 No	3 Yes / 1 No	4 Yes / 0 No
10. Fish cover types	Count of cover types	0 – 1	2	3	≥ 4
11. Aquatic connectivity (was Fish access)	Presence of blockages or barriers	Any seasonal or year-round barriers	Any partial year-round barriers	Any partial seasonal barriers	No barriers
12. Stream moss cover	Presence/absence categories	Little or none	Occasional	Frequent	Abundant
13. Benthic invertebrate diversity	Count of taxa	< 3	3 – 5	6 – 7	> 7
14. Riparian vegetation (canopy) cover	Percent canopy cover	< 75	75 – 85	86 – 95	> 95
15. Bare, disturbed ground	Percent bare ground	> 10	6 – 10	1 – 5	< 1
16. Deep rooted streambanks	Percent of bank with deep-rooted vegetation	< 35	35 – 65	66 – 85	> 85
17. Shade cover over stream	Percent canopy cover	< 75	75 – 85	86 – 95	> 95
18. Streamside moss cover	<i>Omit for now.</i>	<i>Omit for now.</i>	<i>Omit for now.</i>	<i>Omit for now.</i>	<i>Omit for now.</i>

typical spatial extent of erosion where values outside the range represent a disturbed state. Stable banks are often indicated by either an overhang or an undercut and usually associated with a heavy turf mat (i.e., no exposed mineral soil). Unstable banks are frequently indicated by either a vertical or sloping bank profile, and usually are associated with exposed mineral soil.

Rationale:

Riparian zones are influenced by both direct and indirect factors related to harvesting. Stream banks can be eroded at sites of physical disturbance, such as a road crossing, because bank material strength is reduced with vegetation removal or because sediment loads have increased. Whether the factors are direct or indirect, the result is bank erosion. The occurrence of bank erosion is obvious and unmistakable to the field observer. Measurement of the spatial extent of bank erosion is quantifiable and repeatable.

2. *Sediment Variability*

Question:

Is the texture of the sediment covering the channel bed highly variable (e.g., ranging from sand to cobbles) or homogeneous (e.g., extensive coverage of gravel)?

Indicator:

A common feature of streams that have been disturbed by altered sediment supply and/or LWD supply from either the riparian zone, upstream, or both is a noticeable reduction in the sizes of sediment exposed on the streambed surface. Although the determination of fluvial sediment texture distributions is difficult and labour intensive, measurement of the apparent largest stone moved during flood flows, commonly referred to as the “D₉₅”, can be rapidly and consistently accomplished by different field workers.

Rationale:

Sediment texture variability decreases when sediment supplies to the stream are altered. Variability decreases when the sediment load increases, and the channel aggrades (the textural distribution is narrowed, usually becoming finer). Similarly, the variability also decreases when the sediment supply decreases and causes the channel to degrade, which results in the streambed becoming progressively coarser. Measurement of the D₉₅ is quantifiable and repeatable.

3. (a) *Bar Frequency* and (b) *Bar Type*

Question:

Is the number of channel bars, especially mid-channel bars, greater than normally expected? Are the sediment accumulations that form the channel bars in a stable configuration?

Indicator:

The indicators are the total number of bars and the proportion of mid-channel bars and sediment wedges along a 50 Wb longitudinal survey transect. The measures identify the

amount of exposed sediment relative to the flowing stream during low-flow summer conditions. The indicators are flow-stage dependant.

Rationale:

A hierarchy of physical stabilities, ranging from highly unstable mid-channel bars to stable diagonal and alternating bars, characterizes stream channel bars. As sediment supply to the stream is increased and/or LWD supply is altered the frequency and spatial extent of the unstable forms increase. Counting the number of mid-channel bars is quantifiable and repeatable; however, care must be taken when estimating the spatial extent of mid-channel bars because the surface area exposed will vary with streamflow stage. Higher flows in the same stream will appear to have a lesser amount of mid-channel bar because more of the bar is covered by water and not visible to the observer.

In addition to bar stability, the frequency of individual bars is important because a channel characterized by many small bars is more mobile than one that has a wider distribution of bar sizes. The number of channel bars in undisturbed streams is normally restricted to a fairly narrow range. As sediment supply to the stream is increased, and instream LWD function is altered, the number of small bars increases. Counting the number of bars is quantifiable and repeatable and somewhat less stream flow stage dependant than the other bar indicators.

4. Degraded Channel (Proportion CAP Channel State D2 and D3)

Question:

In streams with either riffle-pool and step-pool morphologies, are the sediment accumulations that form the channel bars and steps devoid or lacking along the channel? What is the length of degraded channel?

Indicator:

The indicator is the relative extent of severely scoured channel along a 50 Wb longitudinal survey.

Rationale:

A significant reduction in the supply of sediment to the stream system can lead to severely degraded channels. As the local channel sediment is moved downstream by normal fluvial processes, and not replaced by sediment from upstream or the proximal banks, the morphology will progressively simplify due to sediment loss and ultimately result in severe fish habitat loss. Measurement of degraded stream channel length is quantifiable and repeatable. In most cases, a degraded channels occur downstream of some interruption to normal fluvial transport of sediment. This may include a logjam, lake/wetland, culvert, or other blockage.

5. Channel Depth Variability

Question:

In streams with either riffle-pool and step-pool morphologies, is channel depth relatively uniform throughout the longitudinal profile, or are there alternating deep and shallow sections of channel?

Indicator:

The indicator is depth variance measured systematically along the thalweg. Depth variance is expressed as the Coefficient of Variation, or the standard deviation as a percentage of the mean $((SD/X)*100)$.

Rationale:

A significant decrease in the supply of sediment to the stream system can lead to severely degraded channels. As the local channel sediment is moved downstream by normal fluvial processes, and not replaced by sediment from upstream or the proximal banks, the morphology will progressively simplify due to sediment loss and ultimately result in severe fish habitat loss. Simplified channel morphology is also caused by increases in sediment supply and channel aggradation. Riffles will consequently extend longitudinally into pools and/or pools become filled with sediment. In both cases, the result can be a reduction in relatively deep or shallow sections of channel (i.e., channel depth becomes uniform). Measurement of depth variability is quantifiable and repeatable.

6. Logjam Frequency**Question:**

Are logjams present along the survey reach. Are they more frequent or less frequent than expected in a stream not subjected to forestry or other developments?

Indicator:

The indicator is the frequency of logjams.

Rationale:

In the absence of any post-logging landslides, logging debris will usually enter the stream channel during or immediately after logging and operations. Generally, logging debris contains slash, bark, and LWD pieces with detached root wads that are easily floated downstream at high flows and can accumulate into logjams. Newly formed logjams, especially those formed with logging debris, are usually effective sediment traps and relatively impermeable to sediment transport, and can adversely affect fish habitat in the short-term (i.e., < 10 years). Following streamside logging, logjams may become larger and more frequent (especially in riffle-pool streams), or smaller and more frequent (especially in step-pool streams).

7. LWD Volume in (a) Small ($W_b < 3\text{ m}$), (b) Medium ($W_b 3 - 6\text{ m}$), and (c) Wide ($W_b > 6\text{ m}$) Channels**Question:**

Has logging slash been introduced to the channel? Has LWD been removed from the channel? Has the supply of LWD to the channel been reduced?

Indicator:

The indicator is the volume of logs stored in the channel.

Rationale:

Streambank logging can alter the LWD budget of a stream by changing the size and amount of LWD pieces delivered to the channel. These changes can occur if the transfer of large trees from the riparian area to the channel is interrupted following logging operations. These changes can also occur if existing LWD pieces are salvaged from the channel and/or logging debris is delivered to the channel during logging operations. Overall, this can result in an increase in LWD volume (e.g., logging slash) or a decrease in LWD volume (LWD salvage and/or a reduction in supply). For purposes of this assessment, we expect the later not to be an expected scenario (i.e., LWD is not normally salvaged from the stream and the reduction in supply may take several decades before influencing current channel conditions). Changes in LWD cover and quality can severely affect fish habitat.

8. LWD Supply by (a) Riparian Reserve Width and (b) Level of Tree Retention**Question:**

Has a supply of LWD to the channel been maintained?

Indicator:

The indicator is the condition of the LWD supply corridor in the adjacent riparian area. “Condition” refers to the presence of any harvesting (relative to the level of retention) in the corridor. Riparian sources for LWD depend upon the width of the riparian reserve zone (RRZ), if a reserve is required for the stream class (or implemented even where no mandatory RRZ is required), and (or) the level of tree retention in the riparian management zone (RMZ).

Rationale:

LWD supply from the riparian area occurs through bank erosion and tree mortality. If a channel is decoupled from surrounding hillslopes (i.e., there are no landslide inputs of LWD) and if the channel is relatively narrow and low in stream power (i.e., there is no input of LWD from upstream reaches), then the riparian area will be the source of all LWD supplied to the channel. The volume of LWD supplied from this zone to a given channel is a function of tree height, diameter, species, stems per hectare, rate of bank erosion, and distance from the streambank. The first five factors have been generalized for each biogeoclimatic zone to establish average supply corridors (distances from the streambank) that maintain a given volume of LWD supplied to a channel.

9. Substrate Embeddedness**Question:**

How much of the channel bed is covered in fine-textured sediment?

Indicator:

The indicator is the relative proportion of the channel with fine-sediment infilling of the substrate matrix. Consider the interstitial spaces of the stream substrate that are infilled with fine gravel or finer material (sand) such that the subsurface habitats are unusable by juvenile fish or stream invertebrates. Also consider the compactness of the sediment deposit.

Rationale:

A change in sediment supply can lead to channel aggradation or degradation. If the sediment supplied is fine textured, it can lead to harmful impacts on inter-substrate fish and invertebrate habitats by filling the streambed matrix zones. Estimation of the degree of embeddedness is difficult but the ecological importance of the fine textured fraction of the channel bed sediment warrants its inclusion.

10. Number of Fish Cover Types**Question:**

Is the diversity of fish cover present and available to fish indicative of healthy, undisturbed streams, lakes, or wetlands?

Indicator:

The indicator is the count of broad categories of fish habitat cover. Basic types of cover include: overhanging vegetation within 1 m of the channel surface; overhanging LWD; in-channel LWD; stable small woody debris (SWD); stable undercut banks; non-embedded boulders and cobbles that are stable at high flows; deep, quiet water; and, aquatic vegetation.

Rationale:

A diversity of fish cover types is typical of undisturbed aquatic systems with well developed riparian habitats. Land use practices frequently reduce the number of cover types available; for example, when riparian vegetation is reduced or removed altogether, stream banks erode, or channels exhibit excessive aggradation or degradation. Fish cover can be difficult to quantify quickly, but the number of different types present can be easily recognized and enumerated. Stable, undisturbed aquatic habitats rarely have no cover or only one type of cover present including that provided directly from the riparian zone. Most aquatic habitats have at least three types of fish cover present.

11. Aquatic Connectivity**Question:**

Has fish access been maintained to all upstream sites or “off-channel” areas (fisheries sensitive zones) that any fish species present in the system would reasonably be expected to use at some time of the year as part of their normal migration patterns?

Indicator:

The indicator is the presence of blockages or barriers within a channel network, or between main stream or lake habitats and fisheries sensitive zones which may contain water only seasonally. Logging slash and sediment deposits are examples of impediments to fish movements (see Rationale). Unimpeded access to upstream, tributary, or off-channel areas is characteristic of most fish-bearing waters. Temporary barriers such as beaver dams, logjams, stream diversions or avulsions, or landslides that completely block fish movements do occur naturally in fish bearing waters. However, these blockages are usually short-lived.

Rationale:

Many aspects of forest harvesting can compromise or block fish access to upstream, tributary, or off-channel habitats. Bridges or culverts can constrict flows and create velocity barriers or impassable jumps. Falling and yarding can introduce excessive debris into aquatic habitats that further impede fish passage at road crossings or in stream channels. Off-channel areas can be directly blocked by roads that lack drainage structures. Access to tributaries or off-channel areas from the main channel can also be blocked if the streambed degrades as a result of a constriction or blockage that impedes sediment movements downstream. Excessive aggradation may similarly block fish access upstream of the blockage due to streambed aggradation.

12. Streambed Moss Cover**Question:**

Is there a healthy growth of moss on the stream substrates as would be expected from the channel type and setting?

Indicator:

The indicator is moss cover category: little or lacking (1), occasional (2), frequent (3), or abundant (4).

Rationale:

A healthy growth of moss on stream channel substrates and in-stream LWD indicates clean water, stable flows and bedload, and adequate shading and nutrient levels. It is an indicator that is also easily observed and categorized into cover classes under most conditions. Forest practices and grazing activities can disturb the streambed and reduce the moss cover on stream substrates directly (e.g., trampling, skidding, and yarding) or indirectly (e.g., water diversions, increased sediment loads, reduced shading, siltation, increased turbidity, and increased scouring).

13. Benthic Invertebrate Diversity**Question:**

Is there a healthy diversity of benthic invertebrates present?

Indicator:

The indicator is a simple count of the visibly different aquatic invertebrate taxa present in a kick sample (from a streambed) or net sweep sample (from lake or wetland littoral substrate).

Rationale:

Like all direct assessments of living organisms, the diversity (i.e., in this case, richness) of the benthic invertebrate community is a potentially direct assessment of PFC. Benthic invertebrate assessment can be costly and time consuming; therefore, the main challenge for extensive-level surveys is to identify suitable methods to collect, analyze, and score benthic invertebrate data. Quick visual inspection 3 – 5 simple samples, ideally with a hand lens, should reveal most of the broadly recognizable taxa which would be present, and which represent important functional groups within aquatic benthic ecosystems.

14. Riparian Vegetation (Canopy) Cover

Question:

Is there enough riparian canopy cover (shrubs and trees) to provide shade in the RMA and reduce erosion from rainfall?

Indicator:

The indicator is percent canopy cover estimated at pre-determined points along the length of a standard transect in the RMA on one side of a stream, wetland, or lake. Canopy closure can be measured in categories with an angular canopy densiometer or visually by comparison with standardized cards.

Rationale:

The vegetation canopy consisting of trees and shrubs in riparian areas moderates the direct impacts of rainfall on exposed soils. The canopy also provides shade, which lowers air, ground, and water temperatures, and reduces the rate of evaporation from waterbodies. Trees and shrubs also supply food and habitat for terrestrial and aquatic invertebrates, both of which are critical food sources for many vertebrates, including fish. Canopy cover by trees and shrubs along streams, wetlands, and lakes can be reduced by harvesting or intensive cattle grazing.

15. Bare, Disturbed Ground

Question:

How much of the RMA, by percent or proportion, is bare ground?

Indicator:

The indicator is a direct estimation of percent or proportion of bare ground in the Riparian Management Area. Bare ground is exposed soil resulting from the activities of livestock or forestry. For cattle, examples are cattle trails, pugging, hummocking, trampling, and wallows. Forestry-related examples include roads, wheel or track ruts, bladed trails, gouges and scalps due to yarding, windthrow scars, slides, and slumps. Wildlife-caused bare ground is not included as disturbed, bare ground.

Rationale:

Exposed soil is subject to erosion, can contribute to stream bank erosion, reduces sediment entrapment, alters rainfall run-off rates, and provides an opportunity for invasion by weeds. Assessments should include any exposed ground on adjacent slopes that have a gradient >10 % because of the direct hydrologic linkage to the streamside area in question.

16. Deep Rooted Streambanks

Question:

Are the root masses of trees, shrubs and grasses on the banks developed enough to withstand high stream flows or wave action and allow the development of overhanging banks?

Indicator:

The indicator is the percent or proportion of a given length of streambank containing deep-rooted plant species.

Rationale:

The margins of most waterbodies frequently exhibit varying degrees of bank erosion. However, the banks of most streams, lakes, and wetlands in their natural, undisturbed state are protected from excessive fluvial erosion or wave action by vegetation with well-developed root systems. Most trees, shrubs, and grasses will serve this function. These plants also trap sediments to build and restore banks. Herbaceous species such as Kentucky bluegrass are often shallow rooted and not effective in binding streambank soils. Mosses are similarly poor bank stabilizers. Cattle grazing or forest harvesting can reduce or eliminate the amount of deep rooted vegetation present on the banks of aquatic habitats, thereby reducing the ability of the banks to withstand erosion through fluvial erosion or wave action.

17. Shade Cover Over Stream**Question:**

Is there enough vegetation cover from the riparian canopy and understory vegetation combined, to provide the shade needed to moderate water temperatures to within the ranges similar to nearby unmanaged sites?

Indicator:

The indicator is percent total shade cover at water height estimated at pre-determined points along the length of a study transect along a stream reach or lake/wetland shore. Total shade at water height can be measured in categories with an angular canopy densiometer or by visual estimation of the canopy with standardized cards, combined with estimates of the contribution made by streamside understory vegetation and overhanging banks and LWD.

Rationale:

Shade cover is critical for moderating water temperatures and also plays a role in maintaining riparian soil moisture. Shade cover varies with plant species, plant height, plant density, time of year, aspect, and latitude. This indicator differs substantially from canopy cover (for protection of bare soil from rainfall), which varies mainly by plant species, plant height and plant density. Shade cover is a direct indicator of riparian effectiveness that may be more meaningful than overhead canopy cover, though it may require two measurements. One measurement would be for the riparian zone where shade cover would help reduce air temperatures and maintain soil moisture. The second measurement would be for shade cover on the stream, and would include in addition to the shade provided by a canopy, the shade provided by overhanging banks, vegetation, and LWD.

18. Streamside Moss Cover

This indicator is deferred pending further development by the Riparian Effectiveness Evaluation Working Group.

Methods

Riparian Survey Area Width

The width of RMAs the Forest and range Practices Act vary by waterbody type and class. For class S1 fish-bearing streams, the RMA may be 70 m wide including a 50 m reserve zone and 20 m management zone. Small streams without fish (class S6) have only a 20 m management zone. In spite of this variation, for the purpose of effectiveness evaluations, the riparian area of study should be restricted to a band 20 m wide as measured from the shore of the waterbody given that most of the functional attributes to be studied occur predominantly within this width. This band usually includes most off-channel aquatic habitats, and is the full width of the RMZ of the smallest classified streams without fish (class S6).

Control Sites

Field surveys of riparian management effectiveness that employ extensive indicators should include, whenever possible, assessment of riparian conditions upstream of the treatment section, or outside of the riparian treatment area to provide reference or “control” conditions. Observations made in similar but unmanaged reaches within the geographic region studied will provide reference information useful for comparison with managed reaches.

Field Procedures

1. *Bank Erosion*

Determine average bankfull channel width to establish a survey interval. Measure a cross section (using a fibre tape and measuring to ± 0.1 m) at five locations spaced approximately evenly along the reach. Each measurement should be spaced a distance equal to about 1/5 the overall reach (i.e., beginning and end of the reach and three locations in-between). Calculate the average width from the five individual measurements.

A number of standard criteria can be used to determine bankfull width in the field. Only those relevant to the field site need be used. Look for:

- A change in vegetation from bare ground with no trees to vegetated ground with trees, from no moss to moss covered ground or from bare ground to grass covered ground, particularly in range lands
- A topographic break from vertical bank to flat floodplain
- A topographic break from steep bank to more gentle slope
- The highest elevation below which no fine woody debris (needles, leaves, cones or seeds) occurs
- A change in texture of deposited sediment from clay to sand, or sand to pebbles, or boulders to pebbles

Once the survey interval is established, run a hip-chain line along the thalweg (generally, the deepest portion of the channel) for a distance equivalent to 50 times the average bankfull channel width. At each survey interval (one bankfull channel width), determine if the banks are either (a) undercut and/or overhanging, or (b) vertical and/or sloping. In a sinuous channel, bank erosion is expected to alternate from one side of the channel to the next. For the purpose of this procedure, one bank is chosen for assessment (usually the bank adjacent to management activities if only one bank is managed). However, both sides would be measured if there were management activities of concern on both sides of the habitat.

2. *Sediment Variability*

Over a longitudinal transect of stream length equivalent to 50 channel bankfull widths (as previously described), stop at each survey interval and measure the b-axis diameter of the largest stone moved by fluvial processes. To determine the size of the largest sediment particle on the channel bed:

- Measure the b-axis (intermediate length) diameter of the biggest visible stone. Refer to Figure 4 of the BC Forest Practices Code Field Guidebook Channel Assessment Procedure (Anon 1996) for additional information.
- Measurement need be to the nearest 10%. For instance, if the largest stone is 1m in b-diameter, then measurement to ± 10 cm is appropriate. If the largest stone is 10 cm, then the measurement should be ± 10 mm.
- The largest stone does not include large lag boulders deposited during periods with very different streamflow regimes (e.g., immediately post-glacial) or those that have fallen into the channel from surrounding glacial moraines or colluvial fans/cones.
- The largest stone should not be covered in old moss and organic stains and should be rounded or sub-rounded but not angular. It should have evidence of movement by flowing water during the past few decades. It should also be incorporated into the channel bed (other sediment knitted around the larger stones) and not be an isolated stone distinctly different than all others in the near vicinity (within several bankfull channel widths upstream and downstream).

Sediment sizes are then grouped into size classes as described in Table 4.

Table 4. Sediment size classification following the Wentworth system.

Sediment texture	Wentworth size class (mm)
Boulder	> 256
Cobble	64 – 256
Medium and coarse gravel	8.0 – 64
Fine gravel	4.0 – 8.0
Granules	2.0 – 4.0
Very coarse sand	1.0 – 2.0
Coarse sand	0.5 – 1.0
Medium sand	0.25 – 0.5
Fine sand	0.064 – 0.25
Silt and finer	< 0.064

3. (a) Bar Frequency and (b) Bar Type

Over a longitudinal transect of stream length equivalent to 50 channel bankfull widths (as previously described), stop at each survey interval and determine if a bar is present. For operational use, a channel bar is identified by an accumulation of sediment with length = one bankfull width and height ~ bankfull depth. If a bar is identified, it is classified as one the following types:

- Side channel bar
- Point bar
- Mid-channel bar
- Sediment wedge

Refer to Figure 9 of the BC Forest Practices Code Guidebook Channel Assessment Procedure (Anon 1996) for additional information describing bar types. If a single bar extends beyond one survey interval, it is counted at each interval (e.g., if a bar extends for five bankfull channel widths, it is counted and classified five times).

4. Degraded Channel (Proportion CAP Channel State D2 and D3)

Over a longitudinal transect of stream length equivalent to 50 channel bankfull widths (as described above), measure the length of degraded channel with a hipchain. Definition and identification of degraded channels (classified as D2 and D3) are detailed in the BC Forest Practices Code Field Guidebook Channel Assessment Procedure (Anon 1996). Walk upstream (or downstream) along the channel thalweg (deepest point along the cross-section if wading is possible) or along the bar tops if the water is too deep or the stream flow velocities are too fast for safe wading. Record the distance (from the hip chain) corresponding to the channel condition as determined from the list of field indicators of disturbance and appropriate keys as described in the BC Forest Practices Code Field Guidebook Channel Assessment Procedure (Anon 1996).

5. Channel Depth Variability

Although quantifiable and repeatable, determinations of channel depth variability require a large number of individual depth measurements. For small streams (classes S4 to S6), experienced personnel should be able to obtain these measurements, plus those for other physical indicators, in approximately two hours. This time requirement should be considered in assessment planning for decisions on specific indicators to use, and (or) what proportion of the total population of study sites should be targeted for elevated levels of measurement such as those associated with determining depth variability.

Over a longitudinal transect of stream length equivalent to 50 channel bankfull widths (as previously described), measure depth at five equally spaced locations within each survey interval.

- Place the stadia rod on the channel bed and, holding the stadia rod vertical, estimate the height of bankfull stage using the hand level to sight off the bank (read the stadia at that point that corresponds to level from bankfull height).
- Measurement should be to the nearest 10%. For instance, if the channel depth is 1 m, then measurement to ± 10 cm is appropriate. If the depth is only 10 cm, then the measurement should be ± 10 mm.
- Channel depth should be measured at the thalweg (generally, the deepest portion of the channel).

6. Logjam Frequency

Over a longitudinal transect of a stream length equivalent to 50 channel bankfull widths (as described above), count the number of log jams encountered. For the purposes of this assessment, log jams are identified as an accumulation of several logs that span (or nearly span) the channel and are tightly packed together (i.e., there are no obvious holes in the structure). A sediment wedge is usually present. Additional details for making this assessment are given in Figure 9d of the BC Forest Practices Code Field Guidebook Channel Assessment Procedure (Anon 1996).

7. LWD Volume in (a) Small ($W_b < 3$ m), (b) Medium ($W_b 3 - 6$ m), and (c) Large ($W_b > 6$ m) channels

Over a longitudinal transect of a stream length equivalent to 50 channel bankfull widths (as described above), estimate the percent cover of LWD at each survey interval for each width category of stream. Refer to a cover class chart to aid in this assessment.

8. LWD Supply by (a) Riparian Reserve Width and (b) Level of Tree Retention

Over a longitudinal transect of a stream length equivalent to 50 channel bankfull widths (as described above), measure the width of the riparian supply corridor at every fifth survey interval. This corridor may or may not include a reserve zone immediately adjacent to the stream channel depending on the FRPA riparian class of the reach.

Extend a fibre tape normal to the channel, starting from the banktop and extending into the riparian area, for approximately 20 m (actual distance will vary with biogeoclimatic

zone). Identify the presence of any harvesting encountered along the riparian transect and record the distance where management activities begin. Estimate the level of retention (if any) as a percentage of total stems along the managed portion of the riparian transect.

9. *Substrate Embeddedness*

Four statements are considered for routine assessments of whether benthic substrate quality for fish spawning and rearing has been adversely affected by fine sediments (i.e., sands):

- (a) Wetted riffle bed areas that a stick or heel can be easily pushed into are absent.
- (b) Recent fine sediment deposits that *blanket* the substrates in flowing water are absent.
- (c) The sides of gravels and cobbles can generally be seen touching each other, i.e., individual gravels and cobbles are not embedded in a matrix of sand or finer size particles.
- (d) Insects use the undersides of rocks in riffles.

By recording “yes” or “no” answers to each statement at a number of riffle transects along a 100-m long (or 50 Wb section, whichever is greatest), the frequency distribution of “yes” and “no” for each statement can be used to categorically assess Properly Functioning Condition.

This following scoring scheme is tabled for field testing. Each mean score should be rounded to the nearest integer.

- 4 “Yes” answers (i.e., 0 “No” answers) = PFC
- 4 “No” answers = Nonfunctioning Condition
- 3 “Yes” answers = Properly Functioning but at Risk
- 2 “Yes” answers = Properly Functioning but at High Risk.

10. *Number of Fish Cover Types*

Number of different fish cover types present can be enumerated over the length of the riparian zone inspected; e.g., 50 channel bankfull widths. Basic types of cover include overhanging vegetation within 1 m of the channel surface, overhanging LWD, in-channel LWD, stable SWD, stable undercut banks, non-embedded boulders and cobbles that are stable at high flows, deep quiet water, and aquatic vegetation.

To be counted as cover, at least one dimension of the area encompassed by the cover should be 10 % of the channel width. For wetlands and lakes, at least one dimension of the area encompassed by the cover should be 10% of the riparian area’s zone of influence. The latter is interpreted as being equal to the edge of the overhanging canopy in undisturbed areas. The survey score is by ranking the number of different cover types present (Table 3): 0 – 1 = 1 (nonfunctioning), 2 = 2, 3 = 3, 4 or more = 4 (proper functioning).

11. Aquatic Connectivity

A standard length of stream and associated riparian habitat will be visually inspected for any forestry-related fish blockages to upstream, tributary, or off-channel areas. In particular, look for:

- accumulations of logging slash;
- sediment deposits (e.g., from roads or slope failures);
- roads without adequate drainage structures which cut off seasonal or permanent aquatic habitats from the main stream or other principal waterbody;
- isolation of off-channel areas due to channel aggradation or degradation;
- channel constrictions or blockages at road crossings .

Total length of stream and riparian habitat to be inspected should be at least 100 m or a distance equal to 50 bankfull channel widths, whichever is greatest. Sections of lakeshore or wetland margin studied should be at least 100 m long. This method represents a quantitative summation of general observations made for the routine-level inspection.

12. Streambed Moss Cover

Moss typically grows in patches on stable substrates. At regular intervals along a transect parallel to the stream margin, record the relative abundance of moss patches as little or lacking (1), occasional (2), frequent (3) or abundant (4). This indicator is difficult to translate into rigorous quantitative categories. Professional judgement is required based on site conditions and reference to reaches in unmanaged adjacent sites.

Overall moss abundance is the average of all individual estimates of abundance. Total stream length inspected should be a standard transect length based on a minimum distance equal to 100m or 50 channel widths, whichever is greatest.

13. Benthic Invertebrate Diversity

Recommended sample methods included kick samples or Surber samples at 3 – 5 pool-riffle breaks in streams, or net sweeps of the aquatic vegetation, shallow open water and substrate surface at 3 – 5 sites in lakes and wetlands. Each sample should be examined in the field by placing the samples in white trays, examining the sample with a hand lens, and recording the number of recognizably different taxa present. PFC would then be assessed based on the number of recognizably different taxa present in all 3 – 5 samples combined. Field processing will underestimate the true number of taxa present, but that 3 – 5 samples should capture most of the recognizably different taxa present at pool-riffle breaks.

Finalizing a scoring system will require field testing of this method. Initially the following ranking is proposed: < 3 taxa = 1 (non-functioning), 3 - 5 taxa = 2 (functioning, but at high risk), 5 - 7 taxa = 3 (functioning, some risk), > 7 taxa (properly functioning). Ideally, expert judgement is needed to assign taxa number (or broad type; e.g., mayflies, caddisflies) to riparian functioning condition.

14. Riparian Vegetation (Canopy) Cover

Percent canopy cover can be estimated at pre-determined points along the length of a standard transect in the riparian zone on one side of a stream, wetland, or lake. The transect is located a standard distance (e.g., 3 m) from the edge of the rooted vegetation, and should be 100 m long or 50 bankfull channel widths, whichever is greatest.

Percent canopy cover at each point can be estimated by comparison with standardized percentage-cover cards. Alternatively, an angular canopy densiometer can be used to obtain measurements of canopy closure. Overall percent canopy cover is the average of the percent canopy cover estimates made at each point. Scoring is as shown in Table 3: percent canopy cover < 75 % = 1, 75 – 85 % = 2, 86 – 95% = 3, > 95 % = 4.

15. Bare, Disturbed Ground

A transect parallel to the stream, 5 m wide at minimum, and 100 m long or 50 channel widths (whichever is greatest) is used to visually estimate the proportion or percentage of bare, exposed ground in four categories: bare ground > 10 % = 1, 6 – 10 % = 2, 1 – 5% = 3, < 1 % = 4. The approximate contribution of different types of disturbance (e.g., windthrow scars, bladed trails, cattle pugging or hummocking, etc.) can also be estimated. All exposed ground within the transect area is included, plus any exposed ground on adjacent slopes that have a gradient >10%, and thus are hydrologically linked to the transect sample.

16. Shade Cover Over Stream

Percent shade cover at water height be estimated in categories at pre-determined intervals over a 100-m long or 50 Wb segment of stream. These estimates are more difficult to make than those for canopy cover alone, because the estimates need to include the contributions made by the riparian canopy, streamside understory vegetation, and overhanging banks and LWD respectively.

An angular canopy densiometer can be used to obtain measurements of shade at water height. Alternatively, canopy cover can be estimated visually by comparison with standardized percentage-cover cards. The additions of other cover contributions need to be made by professional judgement to assign shade into one of the four categories listed here. Overall percent shade cover is the average of the percentages estimated at each point. Scoring is as shown in Table 3 and is the same as that for riparian canopy cover: percent shade cover < 75 % = 1, 75 – 85 % = 2, 86 – 95% = 3, > 95 % = 4.

17. Deep Rooted Streambanks

Percent of the banks protected by deep rooted vegetation is estimated by recording the length of the bank inspected with deep rooting vegetation present within 1 m of the unvegetated edge of the bank. Total bank length inspected should be a standard transect length based on a minimum distance equal to 100 m or 50 channel widths, whichever is greatest. The scoring system suggested is: percent of bank with deep rooted vegetation < 35 % = 1, 35 – 65 % = 2, 66 – 85 % = 3, > 85 % = 4.

18. Streamside Moss Cover

This indicator is deferred pending further development by the Riparian Effectiveness Evaluation Working Group.

Appendix 1.

Intensive, Range, or Landscape Level Riparian Effectiveness Indicators

1. Fish Abundance – Intensive-level Indicator

Question:

In fish bearing streams, are the numbers of resident fish present within expected limits, and indicate healthy, undisturbed stream ecosystems?

Indicator:

Numbers of fish per second of electrofishing or meter of stream electrofished are straightforward indicators of fish abundance. Either measure is an expression of Catch Per Unit Effort (CPUE).

Rationale:

CPUE is a simple, direct assessment of riparian Properly Functioning Condition because resident fish, especially salmonids, require high water-quality and stable, complex habitats.

Methods and Scoring:

Most routine electrofishing in BC streams is probably conducted at frequencies of 60-90 Hz, a pulse width of 4 – 8 ms, and voltages of 300 – 500V. Wading depth for fishing is in most cases less than 0.5 m. Sampling times are mainly during summer and autumn. The electrofisher settings and conditions listed here are recommended for determining fish catch per unit of sample effort. Minimum sample effort recommended is 100 m of stream length or 300 seconds, whichever is greatest.

Data on fish CPUE is available for all BEC zones, but database analysis is needed to develop rigorous scoring systems. Fish catch data may not be readily sorted by land use activity.

Scoring for CPUE can be rigorously developed from the large datasets on electrofishing CPUE in FDIS for BC by stream width, gradient, hydrographic regime, and physiographic region. Presently, the following catches per 300 seconds of electrofishing are suggested for use in field tests (based on CPUE data for the Gold, Memekey and Benson river drainages on north Vancouver Island):

- < 1 fish = Nonfunctioning;
- 1 fish = Functioning but at high risk;
- 2 – 3 fish = Functioning but possibly some risk; and
- > 3 fish = Properly Functioning Condition

2. Periphyton – Intensive-level Indicator

Question:

Is there a healthy diversity of benthic algae (periphyton) present?

Indicator:

Chlorophyll A concentration is the best measure of algae activity and waterbody health, followed by ash-free dry weight from standardized algae collections.

Rationale:

Periphytic algae have a long history of use as biological indicators. The main issues concern the most efficient methods for collecting, analyzing, and scoring the periphyton data for an extensive riparian effectiveness evaluation.

Methods and Scoring:

Periphyton can be easily collected from hard surfaces with a tooth-brush head mounted on the plunger of a large syringe. Other simple methods are also available for sampling the fine sediments layers typical of wetlands or lakes. Composite samples can be quickly collected at separate pre-determined sites, and preserved for later analysis of taxonomic diversity, biomass or ChlA (a measure of live algae) level by commercial labs or contractors.

Final assignation of taxa number, biomass or Chl A level to riparian functioning condition could be based on expert opinion combined with thresholds derived from available literature. A conservative approach should be taken initially, followed by a reassessment of the scoring after all other indicators have been compiled. Scoring remains to be developed.

3. Increaser-Invader Species – Range Sites

Question:

Has there been an increase in the number of disturbance-related increaser-increaser plants present?

Indicator:

Amount of cover occupied by disturbance increaser-invader species in the RMA (as per cover categories from the BC Forest Practices Board Report (2002), “Effects of Cattle Grazing near Streams, Lakes and Wetlands”).

Rationale:

From the FPB 2002 report, increaser-invader species are native or introduced plants that are absent, or present in low numbers, in undisturbed habitats. Populations of these species can become more prevalent with certain kinds of disturbances, including grazing. Examples are Kentucky bluegrass and dandelions. These plants may indicate a trend away from PFC in riparian areas. Most of these species provide less soil-holding and sediment trapping capability and less desirable forage and wildlife value than native species. Noxious weeds counted in the previous indicator are not reconsidered here.”

Methods and Scoring:

Percent disturbance increaser-invader vegetation is assessed by listing all undesirable species and estimating their cover class in the riparian zone over the area of riparian zone inspected. A transect 5 m wide and 100 m long (or 50 channel widths, whichever is greatest) is recommended.

Scoring follows the following categories from nonfunctioning to PFC respectively: percent of transect area with increaser-invader species > 50 % = 1, 26 – 50 % = 2, 5 – 25 % = 3, < 5 % = 4 (PFC).

4. Similarity to Natural Plant Community – Range Sites

Accepted for range sites only. Similar to Increaser-Invader species indicator. No recommendations provided for scoring, so scoring below is assumed to be satisfactory.

Question:

Is the existing riparian plant community the same as or similar to the Desired Plant Community?

Indicator:

Index of similarity to the “Desired Plant Community” as specified for the vegetation site series.

Rationale:

This indicator is similar to increaser-invader species. The maintenance of the Desired Plant Community (DPC) is a key objective of almost all Range Use Plans. In most cases, the desired DPC is the same as the Natural Plant Community (NPC) as specified for the site series. Maintenance of forest structure for the NPC is often also the goal of RMA objectives where maintenance of satisfactory LWD supply and CWD attributes is desired. As an indicator it is assumed that the DPC or NPC best approximates what is required to maintain Properly Functioning Condition of riparian zones.

Methods and Scoring:

Assess plant community composition and structure according to standard procedures at 5 – 10, circular plots that are systematically located along a linear transect in the riparian zone. Recommended length of each transect is 100 m or a length equal to 50 channel widths, whichever is greatest. Overall plant community composition and structure is the average of the 5 – 10 plots.

Range Use target conditions in Tables 17-19 of the BC Forest Practices Code RMA Guidebook were consulted for guidance on scoring. Tables 17 – 19 on target conditions for range use of riparian areas in the RMA Guidebook provide information on DPC for wetlands and moist riparian habitats only, not streams. To assess PFC, the target for DPC at the wetlands is recommended for the riparian areas adjacent to all other aquatic habitats. The target is stated as follows: “Vegetation structure and composition should be at least 75 % similar to the DPC”.

From the target conditions for moist riparian habitats, the guidebook further states that “areas with vegetation less than 50 % similar to the DPC should not occupy more than 10 % of the range habitat unit DPC”. Consistent with this recommendation, it may not be appropriate for more than 25 % of the vegetation composition to be completely (i.e., 100 %) different from the DPC. The same limits are recommended for forest structure, and each is scored separately as a “Yes” or “No”.

For scoring, riparian zones that achieve a “Yes” on both composition and forest structure could be scored as Properly Functioning Condition (= 4). Riparian zones that are “No” on achievement of DPC and natural forest structure could be scored as Nonfunctioning (=1). Where DPC is maintained but forest structure is not maintained, or vice versa, an intermediate score could be assigned depending on the relative importance of each attribute to the riparian zone. This scoring scheme is tentative, and requires further development.

5. Plant Vigor - Range Sites

Question:

Has the vigor of the plants in the riparian zone decreased as a result of forest harvesting or cattle grazing?

Indicator:

The indicator is a standardized plant vigor index for ecological sites.

Plant “vigor” is a measure of plant health that is usually easily recognized but frequently difficult to quantify because of the wide variety of symptoms indicative of poor plant health (e.g. changes in height, biomass, new growth, colour, turgidity, leave integrity, stem integrity, brittleness, reduced growth rates, etc.). Excessive browsing or foraging can directly reduce plant vigor. Plant vigor can also be reduced indirectly if soil moisture characteristics are altered by forest practices within or adjacent to the riparian zone.

Rationale:

Plant vigor is a good indicator because it can be directly related to management practices in or adjacent to the riparian area. An index for plant vigor is available in standard published methods for describing ecological sites, complete with a general description of each vigor class.

Methods and Scoring:

Assess plant vigor at 5 – 10, 3.9m² circular plots systematically located along a linear transect in the riparian zone. The recommended length of the transect is 100 m or a length equal to 50 channel widths, whichever is greatest.

The proposed scoring scheme recommended for assessing plant vigor at each plot is 1 = species dead, 2 = vigor poor, 3 = vigor fair, 4 = vigor good to excellent. Overall plant vigor for the riparian zone is the average of all individual plots.

6. Forest Connectivity – For Landscape-level Assessments

Question:

Is the riparian habitat well integrated with or physically connected with other undisturbed riparian areas and upland areas?

Indicator:

The indicator is an index of connectivity to rank the degree of forest fragmentation (see scoring below).

Rationale:

To be fully effective, management of riparian areas should be well integrated with or physically connected with other undisturbed riparian and upland areas. Riparian connectivity should be assessed and reported on if overall riparian effectiveness is being evaluated. Achieving connectivity is an important objective of the FPC Biodiversity Guidebook.

The use of connectivity as an indicator of PFC requires further testing for developing measurement and scoring protocols. The definition of a forest break also needs to be developed given that breaks vary according to the dispersal abilities of animals and plants. Breaks that prevent or reduce the ability of the least mobile organisms impacts on connectivity and PFC. Aquatic habitat type may also be an important factor. For example, streams may be an important dispersal route for some organisms, but lakes and wetlands may be an obstacle to the same species.

Methods and Scoring:

No existing methods are available that measure or quantify connectivity, but connectivity might be studied analogously to fish passage. For example, a single road could represent a given level of blockage or break in connectivity, a second road and adjacent cutblock another type of break, and a road and adjacent cutblocks on both sides of the stream a third type. Adjacency could be defined as locations within 200 m of a stream, at which point interior forest conditions are compromised. Similar criteria could be applied for disturbed areas upstream and downstream of the stream reach in question.

This landscape-level concept requires further development to systematically define fragmentation. It is suggested that connectivity be should be recorded for each site, but this information is presently not considered mandatory for field surveys. Data on connectivity or riparian fragmentation could just as easily be collected from GIS-linked data.

The following scoring system is suggested for field tests. The riparian feature in question is modelled as a four-sided polygon.

PFC - no openings, or one road crossing/small opening in the riparian zone (no breaks in connectivity)

Functioning, at Risk – one crossing plus one opening on no more than 50% of one side, interior forest conditions still present on opposite side (1 – 2 breaks in connectivity)

Functioning, at High Risk – no interior forest conditions adjacent to riparian zone, plus one break (road) across riparian zone (3 breaks in connectivity)

Nonfunctioning - no interior forest conditions adjacent to riparian zone, plus breaks (roads or openings) above and below riparian zone (4 breaks in connectivity)

Appendix 2.

REE Indicators for Background and Supporting Information Only

1. Windthrow

Question:

Is windthrow present in the riparian zone and are there alterations or impacts to aquatic habitats as a result of windthrow?

Indicator:

The indicators are counts of windthrown trees in the RMA and along the banks of streams, lakes, or wetlands.

Rationale:

One of the main objectives of a riparian management zone is to protect riparian reserves from excessive windthrow. The amount of windthrow present is therefore a direct indicator of how successful or effective the management zone is in protecting riparian reserves.

On habitats that lack riparian reserves, management zones are mainly for retaining key wildlife habitat attributes characteristic of natural riparian systems, providing some shade to reduce bank microclimate changes, and maintaining bank and stream stability. In these cases, windthrow is a direct indicator of management success (or failure) mainly if trees that were to remain standing blow over, key wildlife attributes are disrupted, and the integrity of the stream and streambank environment has been compromised.

Methods:

The occurrence of windthrow is usually obvious and unmistakable to field observers. Windthrow is also very quantifiable and repeatable. Where the number of windthrown trees is low, all windthrow can be counted directly and compared to the number of trees still standing. Where windthrow is extensive, numbers of stems can be counted over 3 – 4 short segments of a transect along the riparian zone and compared to the number of stems still standing in the segments. Alternatively, windthrow can be enumerated in the RMA and along the streambanks (separate subtotals) along the entire transect length equal to 100 m or 50 channel widths, whichever is greatest.

Presently, no scoring scheme is recommended. While a direct measure of riparian management effectiveness, there is no clear link between wind throw and Properly Functioning Condition. Riparian impacts due to windthrow (bare ground, eroded banks, stream blockages, introduction of fines) are covered by more direct indicators.

Some useful background information to collect and questions to consider where windthrow occurs include:

- Tree height, DBH, diameter where top is broken
- What is the distance from rootwad to opposite bank, or toe of slope on fall line?
- What is slope distance from rootwad to stream on fall line?
- Is the level within the range of windthrow expected in undisturbed riparian areas?
- How extensive? (no. of stems down)
- What is the cause?
- How many stems hit the stream (number of stems in the creek)?
- How many stems bridge the stream?
- How many stems were part of the streambanks?
- If stems do not bridge the stream, or hit the stream, did they fall on the slope and remain in place, or did they slide down the slope?
- Has the windthrown trees changed the function of the riparian zone?