Protocol for

Evaluating the Potential Impact of Forestry and Range Use on Water Quality

(Water Quality Management Routine Effectiveness Evaluation)

For the most current version of this document, please consult the FREP web site Indicators-WaterQuality-Protocol-2009.pdf

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March, 2009

British Columbia

Resource Stewardship Monitoring

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FREP Abstract

The Forest and Range Practices Act (FRPA) introduces the transition to a results-based forest practices framework in British Columbia. Under this new approach to forest management, the forest industry is responsible for developing results and strategies, or using specified defaults, for the sustainable management of the 11 resource values (subject areas) identified under FRPA. The role of government is to ensure compliance with approved results and strategies, and other practice requirements, and evaluate the effectiveness of forest and range practices in achieving government's objectives for FRPA's resource values.

Resource stewardship monitoring (RSM) is a key component of the provincial Forest and Range Evaluation Program (FREP).

Resource stewardship monitoring will help identify implementation issues regarding forest policies, practices, legislation, and Forest Stewardship Plan results and strategies. As a result, RSM will be a fundamental component for implementing continuous improvement of forest management in British Columbia.

FREP has been established as a multi-agency program to evaluate whether practices under FRPA are meeting not only the intent of the current FRPA objectives, but to determine whether the practices and the legislation itself are meeting government's broader intent for the sustainable use of resources.

FREP is a long-term commitment designed to:

- assess the effectiveness of FRPA and its regulations in achieving stewardship objectives
- determine if forest and range policies and practices are achieving government's objectives, with a priority on environmental parameters, and consideration for social and economic parameters, where appropriate
- identify issues regarding the implementation of forest policies, practices and legislation as they affect achieving stewardship objectives
- implement continuous improvement of forest management in British Columbia.

In order to accomplish these objectives, FREP will:

- develop specific monitoring and evaluation questions to be addressed
- document the status and/or trends of resource values over time through the use of detailed protocols
- identify causal factors where the status or trend is found to be undesirable
- determine whether resource values are being managed in a sustainable manner through proven or alternative forest practices
- communicate the results of evaluations
- recommend changes to forest and range policies and legislation, where required.

Foreword

British Columbia is a province of diverse landscapes, climates and soils as well as home to diverse forest management opportunities. The development of a standard water quality effectiveness evaluation system for Forest and Range Lands is challenging but potentially rewarding. The estimation of amount of fine sediment generated from roads and cutblocks, as a proxy for impact on streams, provides the means to evaluate the performance of forest and range managers in their objective to sustain water quality.

In order to maintain the brevity of this Field Manual, it is expected that Evaluators are familiar with the contents of the Forest Road Engineering Handbook printed by the Ministry of Forests and Range in 2002 and the Range Resources Assessment Procedure published by the Ministry of Forest And Range in 2006.

This manual is a work in progress and changes are likely to occur as new information comes to light through our verification trials. Feedback from hydrologists and forest technicians on problems encountered and their suggestions for improvement are welcomed. Please contact Brian Carson at brian_carson@dccnet.com or David Maloney at David.Maloney@gov.bc.ca.

Table of Contents

List of Figures

List of Tables

Document Purpose

The Forest and Range Practices Act (FRPA) makes provisions for independent assessments of the effectiveness of the Act to meet environmental objectives. Maintaining or improving water quality is one objective of the Act. Field procedures developed here provide a means to quantify the effect of forestry and range related disturbances on water quality and how that impact might be mitigated.[1]

Focus Used in Developing this Methodology

Using Turbidity as a Primary Characteristic of Water Quality

For the purpose of this evaluation, the primary characteristic of interest is turbidity, which is a measure of the cloudiness of water.[2] When forestry related disturbances generate fine sediment that is then transported to a stream, turbidity pulses occur which degrade water quality. Any process that transports fine sediment[3] is also capable of carrying any other pollutants that might be on site. Although the evaluation methodology focuses on fine sediment generating turbidity, it also acts as an indicator for other potential contaminants.

Identifying Point Sources of Sediment

Contrary to the assumptions of most hydrological models that consider forestry related sediment generation to be generated in a diffuse manner, virtually all sediment generated by forest activities comes from easy-to-identify point sources. Such sources or sites occur wherever roads, harvesting or livestock disturbed terrain come in close hydrological proximity with natural drainages.

1 This procedure has also been accepted as a Standard Methodology by the Forest Investment Account for the Land Base Investment Program. This standard is listed as an eligible activity under the "Information Gathering and Management" component of the program (http://www.for.gov.bc.ca/hcp/fia/landbase/info_gathering_eligible_activities.htm). When this manual is used for FRPA effectiveness evaluations, all "tasks" listed in this manual (Figure 1) must be completed as per the requirements of the manual. However, when used for the FIA program (e.g. for forest certification purposes), only the specific tasks and computations that are tailored to meet a particular Licensee's program are required.

2 More specifically turbidity can be defined as a " decrease in the transparency of a solution due to the presence of suspended and some dissolved substances, which causes incident light to be scattered, reflected, and attenuated rather than transmitted in straight lines; the higher the intensity of the scattered or attenuated light, the higher the value of turbidity. " (Ziegler, 2002)

3 Finer textured materials discussed here include particle size classes under 1 mm diameter – fine sand, silt and clay portion of the material matrix. Finer particle size classes will remain suspended with even slightly turbulent flow and contribute to turbidity of stream flow. Coarser particle sizes will fall out of suspension where any temporary quiet water occurs and generally not contribute to turbidity.

Assessing Both Mass Wasting and Surface Erosion

Research literature from the 1980s relates that most of the sediment generated from mountainous terrain was from mass failures associated with roads and cutblocks. In the last 10 years, with increasing attention to preventing mass failure, surface erosion has been recognized as increasingly important for fine sediment generation, this being a major cause of water quality degradation.[4] This methodology provides a means to randomly sample representative forestry and livestock disturbed sites, estimate fine sediment generated from mass wasting and surface erosion and determine if or how management could reduce that sediment load. Where livestock disturbed sites are noted, fine sediment generated by livestock will be evaluated as a component of the site. Fecal contamination by livestock is a primary concern with water purveyors and is evaluated separately.

Providing a Simple Means to Routine/Extensive Evaluation

The evaluation is meant to be conducted quickly by non specialists. It does not provide a rigorous account of all factors that contribute to sediment generation, nor does it profess to accurately predict exact quantities of sediment being generated for any particular site. To achieve such a goal, the methodology would become so cumbersome that it would negate its value as a Routine Evaluation. The methodology assumes its predictions are accurate to within an order of magnitude. For example, if the field evaluation predicts 1 m^3 of fine sediment will be generated by the site, this is an indication that the true sediment delivery from the site is likely to be much more than 0.1 m^3 and much less than 10 m^3. The methodology allows sites to be prioritized into very low, low, moderate, high, and very high water quality impact classes. The resultant management implications for different impact classes are both valid and concise.

Some water quality concerns associated with forestry and range management do not lend themselves to routine results based evaluation. Concerns such as pesticide use and hydrocarbon spills cannot be evaluated by one-off field observations and fall outside the scope of this methodology.[5]

4 Assessing downstream water quality effects of forestry operations is difficult. While on a watershed scale, modeling the sources as diffuse might be reasonable, on the cutblock level or road permit level, it is not. Most forestry related water quality effects are actually distinct “point” sources draining pre-selected disturbed sites. By estimating sediment generation at these discrete “points” one can infer the kinds of water quality changes expected in the receiving waters immediately downstream from sites generating sediment. In theory, should all these discrete sediment-generating sources for all forestry operations be considered together within one watershed, the evaluator would have amassed a reasonable assessment of the cumulative effect of forestry operations on water quality of a particular stream reach.

5 However most other potential water quality impacts associated with forestry activities (fertilization, pesticide/herbicide use, hydraulic oil contamination), if they occurred would be most likely associated with these same disturbed sites because of their potential to be transported to water.

Major tasks associated with this methodology are outlined in Figure 1.

Figure 1. Tasks Required to Complete Water Quality Effectiveness Evaluation.

Task I

Determine sampling area from randomly selected cutblocks and roads in district that will undergo field evaluation, select approximate boundary of sampling area associated with cutblock and roads and make preliminary selection of potential sediment generating sites. (Fill out Form 1 for each randomly selected cutblock or road).

Task II

Visit, characterize and finalize selection of sediment generating sample sites within sampling area. (Fill in first 3 columns of Form 2) Where livestock presence is noted, evaluate range condition using Checklist of Range Indicators. (Form 3).

Task III

For all sample sites selected, estimate fine sediment delivered to stream from mass failures and surface erosion. (Form 2, which is the Sample Site Field Card).

Task IV

Assess management practices associated with component or site in relation to sediment generation and fecal contamination. (Form 2 and 3).

Task V

Compile all results from Form 2s and Form 3s to complete Sampling Area Summary. (Form 4) Compile all results from all sampling areas to complete District Summary. (Form 5).

Getting Started

The following is a list of materials required to conduct a routine water quality effectiveness evaluation:

- List showing sampling areas chosen from those randomly generated by FREP
- 1:20,000 TRIM maps showing drainages within chosen Random Sampling Area
- Contour maps at available scale (1:20,000- 1:50,000) within chosen Random Sampling Area
- Forest Development maps showing up-dated roads, cutblocks and streams within chosen Random Sampling Area
- Water Quality Effectiveness Evaluation Checklists, Forms and Tables
- The Protocol for the Water Quality Effectiveness Evaluation
- A pocket calculator for completing field calculations required on Form 2
- Normal field gear (raingear, hard hat, vest, pencils, a field note book, clip board and safety/first aid supplies
- Suitable foot gear, which may or may not include steel toed caulk boots
- A range finder (optional as rough estimates of distance OK)
- A clinometer
- Digital camera (for taking photographs of Sample Sites)
- GPS receiver (for recording location of Sample Sites within Sampling Area)

When to do Water Quality Effectiveness Evaluations

The field inspection requires sufficient daylight to make observations and snow free ground within the site being sampled. There are some advantages in observing sites immediately post spring breakup before any road maintenance has been conducted as signs of erosion are most apparent at this time. However, the procedure does not depend solely upon observations of previously occurring erosion events; expected erosion events must also be recorded. Consequently, the results should not be overly sensitive to time of visit. Most evaluations are likely to be conducted between late spring, when all snow has left sampling area and mid autumn, before the snow returns.

Evaluators are encouraged to spend time along forest roads and active harvesting areas during spring breakup and during major rainstorms to become familiar with the processes by which sediment is generated and transported. Unless one has had this experience, there is a tendency to disbelieve the prediction of the amount of fine sediment that can be generated at a given site.

Basic Tasks of the Water Quality Effectiveness Evaluation

The methodology has been developed to proceed in a step wise fashion. Observations made during each task lead directly to the final evaluation results.

Selection of Sample Area and Preliminary Site Identification (TASK I)

The selection of the sampling areas is carried out as follows:

1. As with the other FREP Evaluations, a randomly selected list of cutblocks is generated using the provincial forestry database ("RESULTS") for each district. The evaluator proceeds down the list and selects between 15 and 20 cutblocks that were developed within the previous 2 years and where water features occur on, or along the road accessing the block. Generally, Non Classified Drainages (NCDs) will not be chosen as sampling sites because their connectivity to downstream water is uncertain. While range characteristics are not specifically considered in this initial selection, close proximity of water and roads will ensure that sampling sites are high use areas for livestock.
2. Once the cutblocks are selected, the location of each cutblock will be plotted (by MoFR GIS database) on a 1:400,000 base map for the District. For each of the selected cutblocks, 1:20,000 maps showing roads, drainages and cutblocks will be produced, again using "RESULTS" from the provincial data base.
3. Out of these 15 or 20 cutblocks, an undetermined number (preferably more than 10) will be chosen by district staff to become "sampling areas" requiring on site evaluation. Should two (or more) of the originally selected cutblocks share a majority of sample sites along common haul roads (branch and mainline) only one of the blocks will be sampled. The rest will be rejected as samples. The exact number of sampling areas chosen will depend on the availability of human resources, budgets, ease of access and other logistical considerations.
4. Once the sampling areas are determined, the evaluator will collect updated information for each of these areas by filling in Form 1. In addition, a map showing actual cutblock boundaries and streams as determined by ground survey[6] and the updated road network which will be required for the field evaluation.
5. Based on this updated field map, the evaluator will then select the initial sample sites to be visited. These sites are to be associated with each randomly selected sampling area as shown in Figure 2. This will include sites associated with the development of the cutblock (such as the mainline, branch roads, spur roads and harvested areas in proximity to natural drainage)[7] that have a high potential to degrade water quality, as shown in Table 1. Once in the the field, these sites will be assigned reference numbers and be located on 1:20,000 base maps

6 There are often discrepancies between Trim Data and field collected data. Streams shown on Trim maps may not exist and streams may exist that are not shown on Trim maps. Unless field observations prove otherwise, always take engineers' field notes to be correct.

7 All streams labelled S1 through S6. Non Classified drainages, (NCDs) only considered when observed to be directly connected with a larger stream or lake.

Table 1. TASK I. Typical Sample Sites Within Sampling Area that Require Evaluation.

Road Related	
1	All road stream crossings (bridge and culvert) Some streams may be missing from TRIM maps and, upon discovery of such streams in the field, will be added to sites requiring evaluation.
2	Inter-drainage culverts. Road segments located within 20 meters of stream or lake, or where there is a chance that road drainage reaches the natural water body.
3	Road generated slope failure. Any failure either immediately above or below road. (These will not generally be known until the field visit).
Harvesting Related	
4	Harvesting/yarding within or adjacent to riparian zone.
5	Skidder/mechanized harvester trails in proximity to riparian zone.
6	Harvesting generated slope failure (all new failures within or below cutblock).
7	Other forestry harvesting disturbances resulting in bare, unvegetated soil.
Silviculture Related	
8	Silvicultural-related-activities leading to water quality degradation.
Livestock Related	
9	Livestock presence noted within riparian zone and stream channel. Where livestock presence is noted, the site will require further evaluation using Range Checklist Indicator Sheet. (Form 3)

6. The number of required sampling sites associated with a particular sampling area is not fixed because of the great variability in drainage density found over the diverse terrain of British Columbia. On the coast, there might be 10 sampling sites within the targeted cutblock and the first 3 km of haul road radius. However, in Dawson Creek District there may be only 2 or 3 identifiable sites associated with a selected cutblock and 20 or 30 km of road driven to access the cutblock. The ideal number of sites to be sampled associated with a sampling area would be around 8. In many cases, reaching this ideal will not be possible. The length of road required to make up the number of sites that can be evaluated in one sampling day will vary considerably, depending on the nature of the terrain, condition of the road and drainage density. In most cases, the road accessing the cutblock, and not the cutblock itself, will provide most of the sites to be evaluated.

The evaluator will fill in Form 1 for each of the sampling areas chosen to undergo water quality evaluations. Most of the form can be filled in at the office and will help the evaluator to anticipate the nature of sampling sites while preparing to go into the field.

Form 1. Water Quality Sample Area Information Card (Side 1)

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Evaluation Program

Water Quality
Resource Stewardship Monitoring
Sample Area Information Card - Form 1 Side 1

1 Identification

page ____ of ____

Assessed by ______________________ Date M M / D D / Y Y Y Y
District __________________ Opening ID __________ Road ID __________
Watershed/Stream ____

2 Description

Is the watershed being used for drinking water? ☐ Yes ☐ No ☐ NA

Where is (are) the intake(s)? (Locate on map if known)

What is the distance and what is the connectivity
between intake and cutblock ______________________ km

Comments: ______________________________ ☐ Direct via stream
____ ☐ Indirect (lake, wetland)
____

Are there other special resource values associated with watershed? ☐ Yes ☐ No ☐ NA

If yes, explain: ____
____
____

Within the probable sampling areas, what are the approximate length, age and status of the access roads?

Type	Status[1]	Approximate Length (km)	Age of Road (years)
Main line			
Branch line			
Spur			
Winter use roads			

[1] active, inactive, temporarily or permanently deactivated

Areas of sensitive soils and unstable terrain associated with cutblock and access road? ☐ Yes ☐ No ☐ NA

FS 1247 HFP 2009/03 PAGE 1

Form 1. Water Quality Sample Area Information Card (Side 2)

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Sample Area Information Card - Form 1 Side 2

3 Reported Disturbance

page _____ of _____

Type of Disturbance	Year of Occurrence	Type of Disturbance	Year of Occurrence
☐ Landslide		☐ Road slump	
☐ Debris torrent		☐ Heavy gullying	

4 Report Use Of

	On Road right of way	Within Block
Fertilizer	☐	☐
Herbicide	☐	☐
Pesticide	☐	☐

5 Locate on 1:20,000 Map Showing Cutblocks, Roads and Streams

a. Approximate Extent of Sample Area (randomly selected cutblock or as-built road and access)
b. Sample Sites associated with forestry activities requiring field checking including: (check applicable)

☐ Stream crossings (bridges, culverts)
☐ Roads running parallel to stream (within 20 m)
☐ Potential unstable slopes along, in or down slope from road or cutblock
☐ Potential sensitive soils
☐ Harvesting adjacent to stream
☐ Potential livestock concerns
☐ Other ____

Travel mode:
☐ Truck
☐ Quad
☐ Helicopter
☐ Other

Time(hrs) to complete evaluation of area:
_____ travel time (hrs)
\+ _____ field time (hrs)
x _____ crew size
_____ total time (hrs)

6 Comments

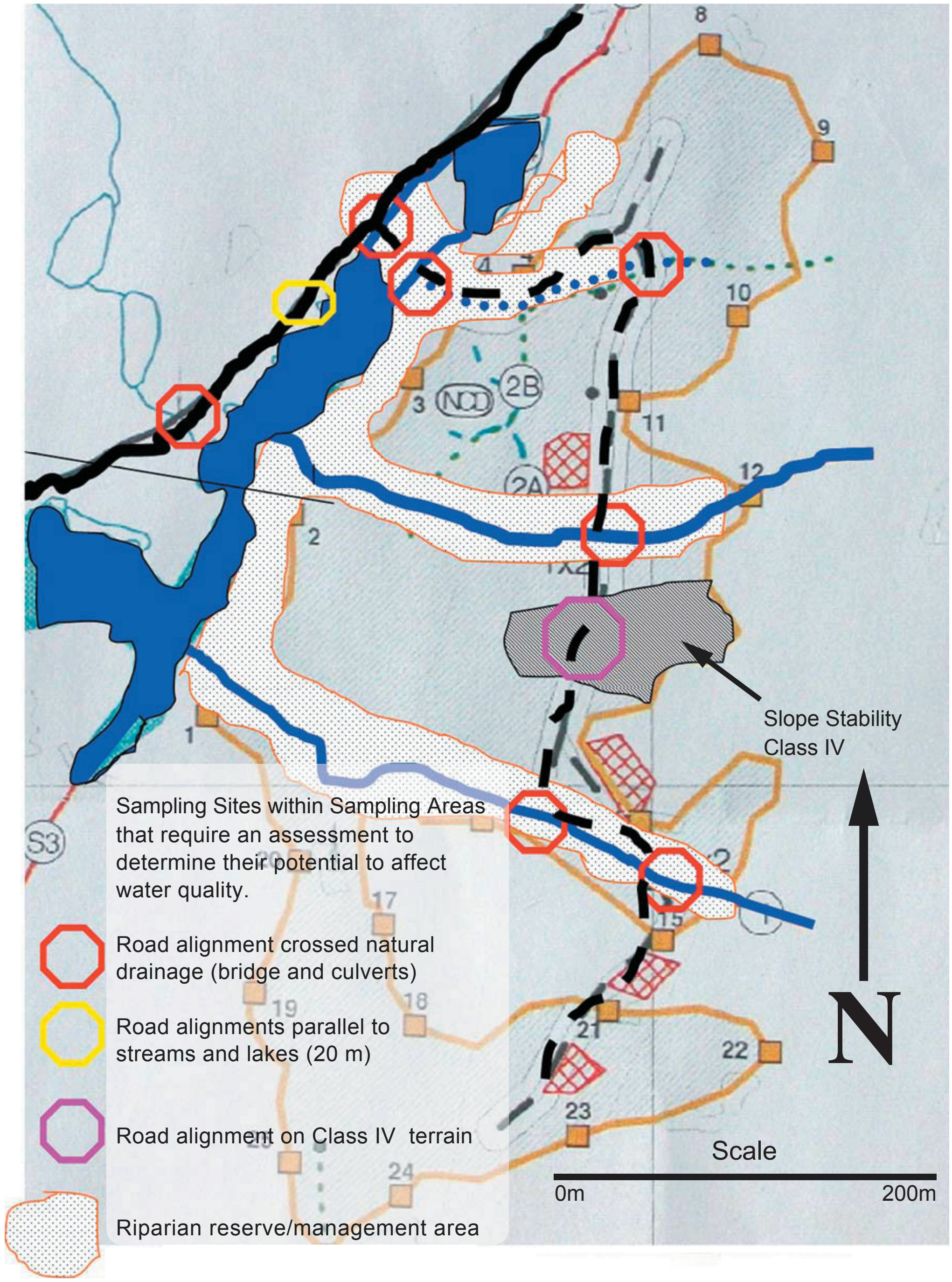
____

____

____

FS 1247 HFP 2009/03 PAGE 2

Figure 2. TASK I. An Example of a Coastal Sampling Area and Sites Requiring Inspection



Preliminary Description of Sample Sites (TASK II)

The evaluator will endeavour to visit all office-selected sample sites associated with randomly selected cutblock and road development on his field visit. In addition, other sites, not initially selected in the office but associated with the same cutblock and segment of road, may also require evaluation. For instance, unmapped streams may be found. Recent land failures may have occurred. Inter-drainage culverts may generate considerable storm flow and, if they drain particularly large road segments, storm discharge from them may travel much further than anticipated. Field selected sample sites may occasionally make up a substantial portion of the sites actually inspected. Conversely, some streams displayed on TRIM maps may not exist in the field and thus do not require sampling.

Road segments within 20 m of water bodies may require a slight modification to the procedure in order to capture situations where a road parallels a stream or lake for a considerable distance. In these cases, the evaluator should assess the connectivity of a number of inter-drainage culvert segments along the road to determine whether the road actually impacts water quality. Where inter-drainage culverts drain similar surface areas of road and pass through similar terrain below the road, the evaluator may choose to consider the whole segment with an average connectivity. In such a case the "site" may be a stretch of road 500 m or even 2 km long. This will avoid assigning separate sites to each inter-drainage culvert and greatly speed up the evaluation process.

The evaluation of each sample site requires the completion of a sample site field card. (Form 2) Once a site has been chosen for evaluation, Form 2 provides the framework upon which the assessment of each site is based. A sampling area may require completion of between 2 and 10 sample site field cards.

An example of this sample site field card is provided on the following page and in the Annex.

Form 2. Water Quality Sample Site Field Card (Side 2)

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Form 2 Side 1

Sample Site ID: ____________ Opening ID: ______________ District: ______________

UTM Zone: ____________ Easting: ________________ Northing: ________________ Road Ref: ________________

Watershed/stream: __________________ Known Domestic Intake Downstream (circle) Yes / No

Stream Channel Width (m) ________ Opening ID: ______________ Date Completed: M M / D D / Y Y Y Y

Site Type (Stream crossings, inter-drainage culverts, road failures, riparian harvesting/ yarding, skidder/harvester trails, other forestry disturbances)

Components and their Characteristics			**a. Mass Wasting Contribution (see back of card)**	**b. Surface Erosion Contribution**									
Column 1 Identify individual components of site within shared drainage. (Table 2) (road surface, road cutbank, road ditch, road sidecast, rills or gullies, mass failures, upturned root wads, livestock disturbance noted, etc)	*Column 2* Estimate connectiity between artificial and natural drainage (Table 3 & 4) Chose from: none (0) little (.2) half (0.5) a lot (0.8) all (1)	*Column 3* Estimate **portion of fine sediment** in matrix of eroded/ erodible material (Table 5) Chose from: none (0) little (.2) half (0.5) a lot (0.8) all (1) active road surfaces always 1	*Columns 4-7*	*Column 8* (Estimate erodible surface area of identified components within mini catchment) Gross area of component x portion erodible = Net area For portion erodible, choose from: None (0), a little (.2), half (0.5), a lot (0.8), all (1) (Portion of active road surface erodible always considered to be 1)			*Column 9a*	*Column 9b*	*Column 9c*	*Column 9d* Estimate depth of erosion expected for surface of each component	*Column 10* Calculate **volume** of material removed by surface erosion	*Column 11* Calculate **total sediment** contribution from surface erosion	*Column 12* Calculate **fine sediment** contribution from surface erosion
							Required for Road Surfaces only						
							Slope	***Road Use***	***Road Surface Quality***	Road Surfaces (Table 6 a, b, c)\			
							0-2 % 2-10 % >10%	Heavy, Moderate, Light, Deactivated	Paved, Good, Average, Poor	All other surfaces (Table 7)	C8(net) x C(9d)	C2 x C10	C3 X C11
				l x w (m^2)	Portion of surface erodible	Net (m^2)				(m^3)	(m^3)	(m^3)	(m^3)

FS 1247-2 HFP 2009/03

(SEE OVER)

Total Fine Sediment Generation from Surface Erosion for Site	

Form 2. Water Quality Sample Site Field Card (Side 2)

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Water Quality
Resource Stewardship Monitoring
Mass Wasting Contributions – Form 2 Side 2

Sample Site ID: ___________________ Opening ID: ______________________

Mass Wasting Contributions (> 1/2m³)

Column 1 Identify individual components of site Fill slumps (F) Gullys (rills) (G) Landslides (L)	*Column 3* Estimate portion of fine sediment in eroded/ erodible material Choose from none (0) little (.2) half (0.5) a lot (0.8) all (1) (Active road surfaces usually 0.2)	*Column 4* Estimate volume of material removed by mass wasting and gullying processes L x W x D of failure(s) gully(s) m³	*Column 5* Estimate volume of failed material still on site L x W x D of failure(s) gully(s) m³	*Column 6* Calculate total volume of sediment reaching stream C4-C5 m³	*Column 7* Calculate volume of fine sediment from mass wasting/ gullys reaching stream C6 x C3 m³

a. Total fine sediment generation from mass wasting at site	
b. Total fine sediment generation from surface erosion at site (from Side 1)	
Grand Total Fine Sediment for Site (a.+ b.)	

Site Diagram: Sketch of site components, drainage pathways and connectivity

Required Rating for FREP Evaluations

(CIRCLE)

Grand Total Fine Sediment	Rating
<0.2	Very Low
0.2–1	Low
1–5	Moderate
5–20	High
>20	Very High

(From Table 8)

Possible means to reduce stream sedimentation from this sample site (required if site rated moderate, high or very high (see Table 11)

1. ______________________
2. ______________________
3. ______________________
4. ______________________
5. ______________________

Comments on site

Optional
Rating of Water Quality Impact for fish bearing stream immediately downstream of site From Table 9

Optional
Rating of Water Quality Impact for domestic intake immediately downstream of site From Table 10

FS 1247-2 HFP 2009/03

Forestry- or Livestock-Disturbed sites are delineated by their disturbed drainage contributing areas. These are called “mini-catchments”. A mini-catchment encompasses the whole area of disturbance associated with any sample site that drains towards a recognized water body. It might include a portion of forest road drained by a particular culvert, cutbank faces along the road and the pathway of any concentrated water as it flows off a disturbed site toward an adjacent stream. It does not include surfaces where the forest floor, logged or not, is largely undisturbed.[8] A mini catchment boundary could be natural such as caused by a local swale in the topography or a result of management, where an existing water bar directs water away from a surface that would otherwise flow within the mini-catchment. Mini-catchments are usually small and simple with dimensions rarely greater than 200m x 10m. Occasionally they can be very large and complex, such as with massive slope failures or a long road segment drained by an uninterrupted road ditch. Field evaluation is mandatory to determine the boundaries and characteristics of any mini-catchment associated with a sample site. Standard topographic maps used by the forest industry with, 10 m or 20 m contours are of no use in delineating boundaries of mini-catchments. The difference in topography and consequential drainage resulting from a 10 cm deep water bar, which appears on no topographic map, may decisively direct surface drainage to a natural settling basin and thus avoid any impact on water quality.

In simple cases, Forestry- or Livestock-Disturbed Sites might be made up of only one type of disturbed surface requiring no further break down of its components. A yarding-induced stream bank slump may have failed directly into a stream. Here, the slump face may be the only surface requiring evaluation. In Figure 3, there is an example of a typical site with a number of components that will require evaluation.

8 Largely undisturbed forest floors, even when logged, will have an infiltration rate capable of absorbing high intensity rainfall. Storm drainage and any sediment it might be carrying, will be absorbed.

Column 1. Identify Individual Components of Site Within Mini-Catchment

Once the boundaries of the mini catchment are defined, its individual components (with differing actual or potential erosion capabilities) are identified. Typical components are shown on Table 2.

Table 2. (for Column 1) Individual Components[9] of Forestry Disturbed Sites.

Possible Components Found Within Sample Site (abbreviation on forms)	
a	Road surface (RS)
b	Road cutbank (RC)
c	Road ditch (RD)
d	Fill or sidecast (F)
e	Gullies or rills generated by artificially concentrated storm flow (G)
f	Landslides (L)
g	Upturned root wads (URW)
h	Livestock Disturbance Noted (LDN)
i	Other Disturbed Areas (ODA)

In order to facilitate writing entries on column 1 of the site field card, the use of the following short hand notations are recommended.

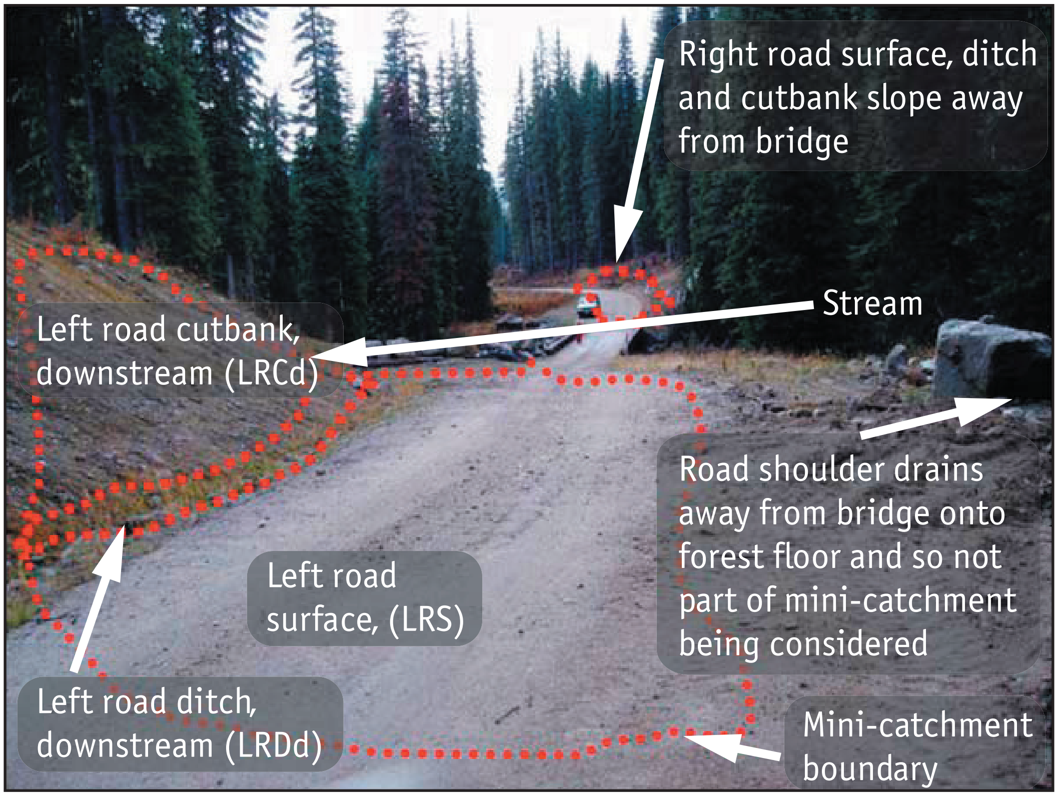
(All directions taken looking downstream from crossing).

Left Road Surface	LRS
Left Road Ditch	LRD
Left Road Ditch (upstream side of road)	$LRD_{(U)}$
Left Road Ditch (downstream side of road)	$LRD_{(D)}$
Left Road Cutbank	LRC
Left Road Cutbank (upstream side of road)	$LRC_{(U)}$
Right Road Surface	RRS
Right Road Ditch	RRD
Right Road Ditch (Upstream side of road)	$RRD_{(U)}$
(Other components can be entered as).	
Road Fill or sidecast	Road Fill or (F)
Landslide or slump	Landslide or (L)
Upturned root wad	Upturned root wad
Livestock disturbance noted	Livestock disturbance noted

9 A Forestry Disturbed Site can be made up of one or more components. Where there is only one component within a Forestry Disturbed Site, the component and site are the same.

An example of a site's delineated mini-catchment and partitioning of components is provided in Figure 3.

Figure 3. TASK II. Photograph of Site Showing Delineated Mini-Catchment and Components (lightly used forest road with bridge crossing)



The Water Quality Effectiveness sample site field card (Form 2) outlines the steps required to complete the evaluation. Once the sample site drainage has been delineated and the individual components identified, entries made in Columns 1 through 12 provide the framework upon which the assessment is based. Whenever a zero comes up for Column 2 or 3, there is no need to proceed with data collection of that component and a zero can be entered in Column 12. The final calculation of total fine sediment production is meant to be accurate only to within an order of magnitude, so estimates need not be exact.

Disturbance caused by the presence of livestock presents a special case for water quality degradation. In these cases, the main concern is usually not increased sediment generation but the much increased risk of fecal contamination of the water. Where livestock disturbance is noted within a mini-catchment and it is found to be connected to the receiving waters with downstream water licenses, a checklist indicating livestock disturbances (Form 3) must be completed for that site.

Column 2. Establish Connectivity

An assessment of connectivity between the disturbed site and a natural drainage is central to any water quality analysis. With no means to transport eroded material or fecal coliform from a disturbed site to the stream, there will be no effect on water quality. If the evaluator is certain that there is no chance that fine materials can be transported by the artificial drainage from the forestry- or livestock-disturbed site to the natural drainage, further evaluation of a site is unnecessary regardless of the magnitude of potential or actual erosion observed[10]. However, caution is advised when assessing the movement of fine sediments. The absence of obvious sediment lying along an apparent drainage course may not indicate that sediment transport is absent. In many fine textured soils, virtually all silts and clays, once entrained, do not settle out until they reach quiet standing water. They will flow through dense swards of grass without being trapped.

Positive connectivity can often be established conclusively by inspecting the discharge pathway between the forestry- or livestock-disturbed site and the receiving waters. If a recognizable continuous or discontinuous coarse sediment trail from the site reaches a stream, it is obvious that at least fine sediment laden water has traveled beyond that position during past storm events. Where a road ditch discharges directly into the stream, it has a connectivity of 1. In such cases there is no opportunity for drainage discharge to be reabsorbed into the ground and little opportunity for sediment to settle out or become trapped in ground vegetation. Ditch waters made turbid by silts and clays will not be cleared to any degree by the typical settling basin dug on the upper side of mid-drainage culverts. Such settling basins may remove coarser sediments and thus reduce potential blockages of culverts.

Partial connectivities must be estimated in instances where the pathway of drainage flows over irregular, vegetated surfaces before reaching the stream. Distances over vegetated surfaces between disturbed sites and streams, volume of discharge, density of ground cover, slope gradients and surface roughness will determine if and how much storm drainage will be absorbed down-slope before reaching a natural drainage. Estimates from visual observations can be directed by thresholds set in Table 3 and Table 4.

Mass wasting provides a special case because the evaluator assesses the amount of failed material and what is still on site. Consequently the connectivity column is not required to calculate Mass Wasting on Page 2 of Form 2.

10 To reiterate an important point from the text, the evaluator is to be cautioned when assuming how far fine textured materials carried by drainage water can and cannot travel. The larger the contributing area, the greater the volume of discharge and so the greater the distance travelled. Peak storm discharges from disturbed drainages can travel surprisingly long distances over vegetated surfaces. Texture classes of fine sand and especially silt and clay are not so likely to fall out of suspension during peak flows. The greater the intensity and duration of a rain storm event, the more likely that artificial drainage will reach a stream with their fine sediments. Coarser textured sediment (cobbles, pea-size gravel and coarse sand) often fall out before reaching a natural drainage but such particles do not have much effect on turbidity. Fine silts and clay size particles, once entrained usually move as far as surface water does.

Table 3. (for Column 2) Estimating Connectivity

Estimated Connectivity	Typical Example	Actual Range	Connectivity Value used in Column 2
none	Ditch-blocked interceptor culvert draining 70 m of road discharging onto long, hummocky forested slope	(<0.1)	0
a little	A 200 m^2 road surface collecting storm flow and dropping it onto forest floor within 15 meters of creek	(0.1-0.3)	0.2
about half	A small area of disturbed cutbank (50 m^2) with 2 meters of forest floor separation from stream	(0.3-0.7)	0.5
a lot	Ditch-blocked interceptor culvert draining 200m of road discharging onto a steep forested slope within 4 m of stream	(0.7-0.9)	0.8
all	Ditch drainage running directly into stream or road surface drainage running off road bridge	(>0.9)	1

For newly trained evaluators, a slightly more rigorous measure of connectivity is provided in Table 4 that considers the relationship between the size of the drainage area generating storm flow for a particular storm discharge[11] and the distance traveled over vegetated ground between disturbed site and stream. Connectivities are assigned to recognized portions of a mini-catchment that share a common drainage pathway. There may be more than one drainage pathway between the disturbed site and the receiving waters. For example storm drainage from a single sample site may flow to the stream along two inner road ditches, along a rill within a tire rut directly to a bridge deck and from an inter-drainage culvert. Once a drainage pathway has been identified, all components or portions of components drained by it, also share a common connectivity value.

11 Note that this disturbed drainage area may be considerably larger or smaller than that of a single component itself. For instance, half of a crowned road surface and a cutbank may all drain into a ditch so that the whole area of this drainage must be considered when estimating connectivity

Table 4. (for Column 2) Estimating Connectivity

Distance over Forest Floor between Ditch Outlet and Stream (m)	Approximate Area of Disturbed Drainage Upslope of Storm Drainage Outfall (m^2)							
	<10	10-50	50-100	100-250	250-500	500-1000	1000-2000	>2000
0.5-1	0.5	0.8	1	1	1	1	1	1
1-2	0.2	0.5	0.8	1	1	1	1	1
2-5	0	0.2	0.5	0.8	1	1	1	1
5-10	0	0	0.2	0.5	0.8	1	1	1
10-20	0	0	0	0.2	0.5	0.8	1	1
20-30	0	0	0	0	0.2	0.5	0.8	0.8
>30	0	0	0	0	0	0	0	0.5

The practical outcome of this table for management is straightforward. The greater the drainage area associated with any artificial catchment, the less likely that fine sediment generated by it can be recaptured. Storm drainage and the fine sediment generated from a 50 m^2 section of road may be effectively captured by five meters of rough forest floor. Conversely, it may be almost impossible to recapture storm drainage collected from a 300 meter stretch of uncrowned, unculverted mainline. There are a number of other factors that can influence connectivity that were not incorporated into this evaluation technique. Introducing them greatly increases the complexity of the evaluation, reducing its value as a quick field assessment.

Special Checklist of Range Indicators

For evaluators working in regions of the Province with extensive livestock utilization of rangeland and presence of domestic water intakes on local streams, it will be necessary to complete a separate form that considers a Checklist of Range Condition Indicators that may affect water quality. (Form 3) This form should be completed only if two conditions are met while completing the Sample Site Field Card. These being:

1. The evaluator is aware of a domestic intake downstream and
2. Livestock presence is noted around sampling site. Some districts such as in the Kamloops area, may be filling out Form 3 with every Form 2 completed. Other districts are unlikely to ever use Form 3 at all

This checklist was developed with the assistance of the Range Branch and is a subset of the range characteristics normally evaluated when assessing range conditions. The primary purpose of filling in this checklist is to provide a description of the nature of livestock disturbance when it might lead to water quality degradation.

Form 3. Checklist of Range Indicators Potentially Affecting Water Quality (Side 1)

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Forest and Range
Evaluation Program

Water Quality
Resource Stewardship Monitoring
Sample Area Information Card - Form 3 Side 1

1 Checklist of Range Indicators Potentially Affecting Water Quality

Opening ID ____________ Road ID ________ Sample Site ID __________

Observations of Livestock Disturbed Component of Sample Site with Demonstrated Connectivity of Receiving Waters
(refer to Range Resource Assessment Procedures, 2006)

Yes / No	Condition of Plant Community
☐ ☐	1. Riparian vegetation absent or highly modified by grazing or trampling
☐ ☐	2. Herbaceous stubble height < 10 cm noted (from 10 samples over 100 meters)
☐ ☐	3. Browsing of > 70% of leaders noted (from 10 samples over 100 meters)
Yes / No	**Condition of Ground Surface**
☐ ☐	4. Bare soil and compaction common (10% of component by area)
☐ ☐	5. Recent pugging and unvegetated hummocks common (10% of component by area)
Yes / No	**Condition of Stream Bank and Channel**
☐ ☐	6. Bank erosion/collapse apparent resulting from heavy livestock use
☐ ☐	7. Evidence of livestock standing in stream bed
☐ ☐	8. Macro-invertebrates[12] indicate degraded water quality
☐ ☐	9. Algal mats occur in receiving waters
☐ ☐	10. Water run-off along livestock trails
Yes / No	**Presence of Livestock Dung**
☐ ☐	11. Livestock feces noted within 3 m of water's edge, or on trails, ditch lines or other surface drainage features leading to water
Yes / No	**Specific Range Management Practices**
☐ ☐	12. Livestock drink directly from water source
☐ ☐	13. Absence of livestock control structures limiting access to water source
☐ ☐	14. Observed presence of calves (< 4 months old) in or adjacent to water source
☐ ☐	15. Salt, minerals, oilers within 100 m of water body

FS 1247 HFP 2009/03 PAGE 3

12 See Quick reference Guide to Macro Invertebrates in FREP Riparian Protocol Field Guide http://www.for.gov.bc.ca/hfp/frep/site_files/indicators/Indicators-Riparian-FieldGuide-Aug-19-2008.pdf.

Form 3. Checklist of Range Indicators Potentially Affecting Water Quality (Side 2)

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Forest and Range
Evaluation Program

Water Quality
Resource Stewardship Monitoring
Sample Area Information Card - Form 3 Side 2

1 Checklist continued

If at least three of the five preceding indicator classes receive at least one yes response, the possibility exists that livestock presence may be compromising water quality. The assessment of these 15 indicators provides a record of possible range management issues that may require further evaluation by the Range Division.

Are range conditions suggesting livestock is compromising water quality? ☐ Yes ☐ No
(risk will be proportional to distance downstream to water intake)

FS 1247 HFP 2009/03 PAGE 2

Column 3. Estimate Portion of Fine Sediments Eroded/Erodible Material

The portion of fine sand, silt and clay within any disturbed material matrix will strongly influence how any sedimentation event will influence water quality. A landscape dominated by shales, silty lacustrines or dispersible clays will tend to generate much more turbid waters when disturbed than a landscape dominated by coarse glacio-fluvial sands, rotted granites, competent bedrock or colluvium. With the exception of components made up of active road surfaces that are repeatedly disturbed by vehicular traffic and/or grading, all other surfaces require an assessment of matrix texture to provide an estimate of how much sediment is fine enough to be transported and actually contribute to water quality degradation. Sediment coarser than fine sands generally moves downstream as bed load and is often captured by various natural filters and traps within the mini-catchment or stream channel itself. When fishery values are of primary importance, this coarse textured sediment can play a significant role in degrading fish habitat although it is not primarily due to water quality decline. For instance, a landslide failing directly into a creek may include 10 % fines which will ultimately contribute directly to turbidity. The remaining 90% of the landslide material is destined to become bed load which can, in turn, affect hydraulic efficiency of the channel, composition of river bed and depth of pools. This coarse sediment may indirectly contribute to reduced water quality but is not a primary consideration of this evaluation. In any case, a licensee who manages for fine sediment generation will capture all sediment before it reaches a creek. A licensee who manages for coarse sediment by the inclusion of small settling ponds between ditches and a natural water body may fail completely to prevent water quality degradation. Most settling ponds placed to filter out sediment from long ditch lines have little or no effect on transport of fine sediments.

For this evaluation the determination of texture involves an estimate of the portion of the fine sediments (fine sand, silt and clay) within the matrix of the soil/material undergoing erosion. Hand texturing is preferred and should be conducted by those familiar with the technique. However, in lieu of hand texturing, a simple shaking of the dispersed soil material in a wide mouthed jar will give a reasonable estimate of the portion of fines within the soil under question. Any sediment still in suspension 15 seconds after shaking stops can be considered to be the fine portion and will influence turbidity. Once the evaluator has carried out texture measurements a few times and becomes familiar with the local materials found in their district, rapid visual estimates of textures become possible. To standardize the results, values for ranges are given on Table 5.

Table 5. (for Column 2) Estimating Fine Sediment Portion of Matrix

Estimate of portion of fine sand, silt and clay in eroded/ erodible material (excluding active road surfaces)	Actual Range	Value Used in Column 3
none	< 0.1	0
a little	0.1 - 0.3	0.2
about half	0.3 - 0.7	0.5
a lot	0.7 - 0.9	0.8
all	< 0.9	1

When assessing surface erosion, all active road surfaces are treated differently because they are constantly being disturbed by the passage of vehicular traffic to varying degrees. This repeated disturbance churns the road surface material, breaks down aggregates, liquefies fine materials at depth when the road is wet and constantly exposes new fines from below, making them available for erosion. So although a road might only have 10% fines distributed throughout the profile, these are selectively forced to the surface during wet weather and removed by surface erosion. Consequently when one estimates 1 mm erosion from an active road surface, it means 1 mm of fine material is expected to be eroded. No discounting for coarser materials that may be on the surface is required. The evaluator should assign even lightly used 4x4 road surfaces with a value of 1 for the portion of fines eroded. The relatively low rate of erosion that actually occurs on these lightly used roads will be reflected in low depth of surface erosion selected for Column 9 from Tables 6 a. b. and c.

However, if concentrated flow has created substantial landslides, slumps, rills or gullies (> ½ m^3 of material), they will be accounted for under mass wasting on the flip side of the card. In this specific case, it is necessary to estimate the portions of fines in the road prism because mass movement or concentrated flow will transport all particle size classes.

Estimate Sediment Contribution from Site (TASK III)

The evaluation is designed to be performed with a single visit to each site, during which sediment volumes reaching creeks are estimated. Sediment delivered from mass wasting and surface erosion, is considered separately. Besides the obvious differences in ease of recognizing their occurrence, it is important to separate mass wasting from surface erosion because of their different ability to transport different classes of sediments. A storm flow induced gully on a road surface will generate a large portion of coarse material as compared with non-channelized road surface erosion where only fines are transported.

Estimate Mass Wasting Contribution (if > 0.5 m^3) (Task IIIa)

If there is no mass wasting contribution or if volumes are small (< 0.5 m^3), the evaluator can ignore mass wasting and proceed immediately to the assessment of surface erosion contribution. Skipping mass wasting contributions will be the norm for many sites being evaluated. Occasionally, however, sediment delivered from mass wasting will overwhelm sediment generated from surface erosion. The back side of Form 2 will be used to record mass wasting when it is observed at a site. As mentioned previously, the mass wasting component does not require an assessment of connectivity because the portion reaching the stream is calculated differently. However, the mass wasting component does require a measure of the portion of fines within the matrix. Unlike road surfaces where fines are selectively removed, mass failures from roads do not selectively remove fines. The portion of fines selected for most roads that have experienced mass wasting will be (0.2) “a little”.

Column 4. Estimate Volume of Material Lost by Mass Wasting and Gullying Processes

To assess the contribution of mass wasting and gullying processes to water quality degradation, the evaluator must observe what obvious erosion (>1/2 m^3) has already occurred on site. Immediate past degradation of sites by slides and gullying is easy to recognize. The more recent the mass failure, the more obvious the remaining evidence. An estimate of length, width and depth (L x W x D) of landslide scars, gullies or rills provides the volume of the material eroded from the site. Approximations 20-30% above or below actual measurements will not influence outcome of evaluation. If the slide occurred more than one year before the visit, the evaluator can apportion the volume to give a sediment load per annum. (The volume estimated from a 5 year old slide would be divided by 5 to give a proxy for an annual contribution).

Column 5. Estimate Volume of Failed Material Still on Site

Depending on the nature of the terrain down slope from a failure, the volume of material recaptured can be substantial. Broad alluvial terraces may capture virtually all of the failed material from upslope. Failures on cutbanks may end up mostly on road surfaces and thus do not reach a natural drainage en masse.[13] These materials may be removed by road maintenance and not have the chance to impact water quality. On the other hand, fill slopes directly above a stream channel may send all failed material directly into a stream. The evaluator must determine the volume of failed material still on site by roughly estimating the dimensions of the failure run-out materials.

Column 6 Calculate Total Volume of Sediment Reaching Stream

To estimate how much sediment actually enters the stream, the evaluator must compare the volume of material estimated to have failed with the volume of material still on the site. This can be done by subtracting Column 5 from Column 4. Again we are interested in orders of magnitude (0.1 m^3, 1 m^3, 100 m^3, etc.).

13 However the disturbed surface material from a slide may be subject to surface erosion which is considered separately under Column 8.

Column 7. Calculate Volume of Fine Sediment from Mass Wasting/ Gullies Reaching Stream

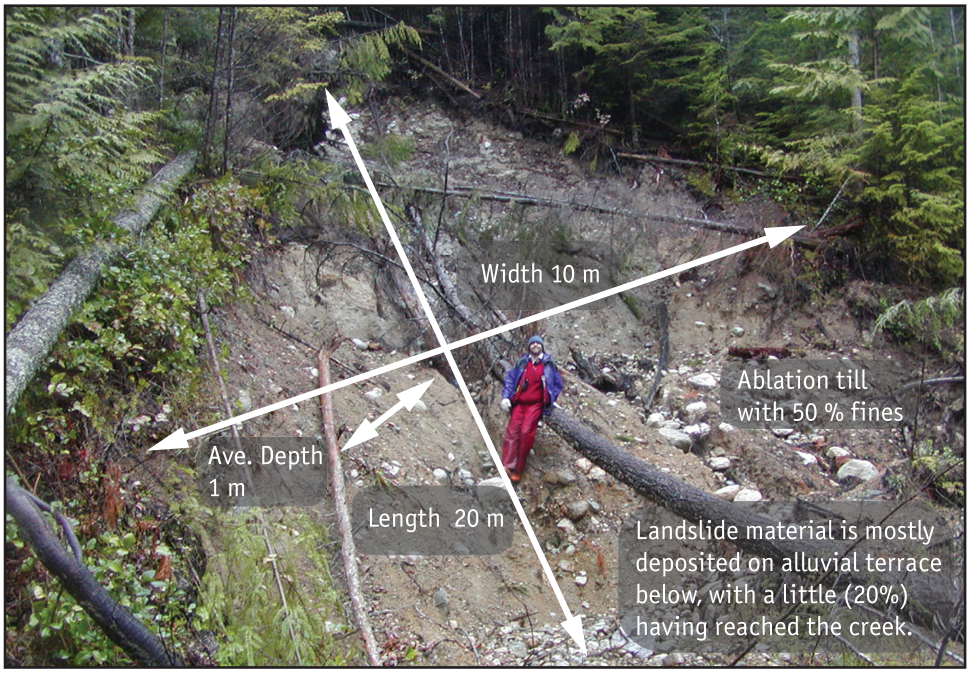
Unlike surface erosion, erosion by mass failures is not selective about the particle size classes that it transports. Large rocks, stones, and gravel as well as finer textured materials are transported down slope with landslides. Gullies incise downward until the base of the gully becomes armoured or a sufficiently low gradient is achieved to reduce discharge velocities. In any case, as with surface erosion, the coarser materials do not directly result in degradation of water quality. Consequently, in order to determine the effect that the sediment will have on water quality, it is necessary to consider the portion of fines in relation to the coarser material involved in the initial mass failure or gully incision. This is done by multiplying Column 3 with Column 6. The result is also expressed in m^3 of fine sediment.[14]

For some applications, where stream channel characteristics are considered important, the total sediment (column 6) minus the fine sediment (column 7) could be used to estimate the coarse sediment contribution to the creek from the site. This value may be of particular interest in Riparian Stream Channel Assessments where pool infilling is a concern.

A simple example of a landslide as a forestry-disturbed site is provided in Figure 4.

14 In the last stage of the evaluation the estimated volume is actually converted into a dimensionless index so as to emphasis the ball park nature of the estimate.

Figure 4. ***Example of Mass Failure: Landslide Adjacent to Creek Caused by Excess Road Drainage on Class V Slope***



Summary of Task IIIa for Site shown on Figure 4	
Site Type	**Landslide Caused by Excess Ditch Drainage (on "Shallow over Steep" Terrain)**
C1	Component is identified as a **landslide** surface
C2	Estimate Connectivity = **0.2** (used in Task IIIb to determine Surface Erosion Component)
C3	Portion of fine sediment = **50%** (estimated visually)
C4	Volume of surficial material moved = 20 x 10 x 1 = **200 m^3**
C5	Volume of failed material still on site = 40 x 2 x 2 = **160 m^3**
C6	Total volume of sediment reaching creek = 200 m^3 – 160 m^3 = **40 m^3**
C7	Volume of fine sediment from failure reaching creek = 40 m^3 x 0.5 = **20 m^3**

Note: Most new landslide surfaces will also have a surface erosion component that should be considered in the evaluation on Side 1 of Form 2.

Estimate Surface Erosion Contributions (TASK IIIb)

Surface erosion involves finer textured surface materials dislodged and segregated by the energy of raindrops[15] and moved via sheet erosion down slope. It is an estimate of potential surface erosion that would occur on the site in the upcoming year.[16] Surface erosion is estimated by assessing the area and erosivity of different types of disturbed surfaces. In addition to their mass wasting contribution, the surface areas of new slumps and gullies should be inspected for ongoing surface erosion.

Column 8. Estimate Surface Area of Identified Components

A surface area can be established by simply estimating lengths and widths of individual eroding surfaces of interest within the mini-catchment. Because of the order of magnitude nature of the evaluation results, estimations within 20-30 % of actual distances are still reasonable. Range finders might be used initially to help evaluators who are unfamiliar with estimating distances. Evaluators should estimate first the total surface area of the component and then estimate the portion of the total surface area that is actually bare and vulnerable to erosion. As in the completion of Column 3 which estimates portions of fines within the matrix , road surfaces must be considered differently from other components when assessing the erodible portion. An active road is subject to ongoing disturbance from differing degrees of traffic and grading. The whole surface is always assigned a value of 1 for proportion erodible. Only if the road becomes inactive to the point that it supports vegetation growth, then vegetated portions can be considered non erosive. For all other surfaces, this erodible portion measures the nature and condition of the surface material only and the degree to which the surface has become protected by gravel, stones, debris, or vegetation with the passage of time.

The Gross area (L x W) of component x Portion Erodible = Net Area (m^2).

15 These estimates of potential surface erosion are made without considering variation in climate throughout the province. This is because given the best climate data possible, the attempt to develop a meaningful provincial climatic erosion/sedimentation factor would be unrewarding. It is not yet possible to incorporate total rainfall, distribution of rainfall, intensity of rainfall, length of freeze up, number of thaws, nature of spring melt and how these factors interact with ongoing road management into any meaningful assessment of propensity to erode. On a practical note, if the evaluator is assessing the effects of forestry management in the Peace River on water quality, is it important or even relevant to be able to compare the result with some remote Coastal District?

16 This estimate also reflects, on average, the minimum amount of soil erosion that would have occurred over the previous year. This is a more realistic way of incorporating the sediment into the analysis as the licensee may have been planning to deactivate the road on the following day, in which case all predictions are meaningless. That is why the potential surface erosion and past mass wasting are added together to represent a reasonable assessment of the magnitude of sediment generation from a site over one year.

Column 9. Estimate Depth of Erosion for Surface of Each Component

High erosion hazard sites that are disturbed and improperly managed initially experience high rates of surface erosion. With some materials, erosivity can fall off dramatically as the site self-armours[17] or re-vegetates during the following growing season(s). For normal logging operations, the great majority of generated sediment occurs during the first year or two after road construction and harvesting. Eventually, road cutbanks, ditches and fill slopes either revegetate or self armour thus greatly reducing surface erosion from those sources. Where disturbances are ongoing, such as on active roads, erosion products can be generated indefinitely if there is no change in management. The greater the disturbance, the greater the amount of sediment generated.

Because of the wide variation in characteristics and processes contributing to surface erosion from forest roads, making accurate predictions of the amount of expected surface erosion from a gravel road is difficult. However it is not difficult to make order of magnitude estimates based on the wide range of literature dealing with sediment generation from gravel roads under a wide variety of conditions.

The estimates of surface erosion used in the methodology are anchored to research literature that show that gravel roads experience a wide range of sediment generation depending on their particular characteristics and management. Measured depths of surface erosion on gravel roads throughout North America fall into a range between 0.5 mm to 50 mm per year depending on climate, amount of traffic, condition of surfacing material and length and gradient of any road segment. (Coe, D.B. 2006, Dunne and Reid, 1984, Cederholm, 1980) In terms of volume of fine sediment generated per 100 meters of road, these erosion depths would generate between 0.25 m^3 to 25 m^3 of fine textured sediment (1/50th to 3 dump truck loads) per 100 meter segment of road each year. As a road's use increases, or with increased grader passage, the migration of fines to the surface increases, which in turn increases the potential rate of erosion. Less used road surfaces have greater opportunity for at least temporary self armouring and therefore reduced levels of surface erosion.

Based on simple verification techniques conducted over a wide range of locations throughout British Columbia, erosion rates between 0.0 mm and 20 mm depth were chosen to represent the range of surface erosion likely to occur on forestry roads under normal conditions throughout the province. This corresponds to a range of 0.0 m^3 to 10 m^3 of fine sediment generation per 100 meters of road. Most active road surfaces will fall somewhere between these two extremes.

Table 6a, b and c provide approximate rates of expected road surface erosion associated with roads located on different slope gradients with differing degrees of use and quality of materials.

Slopes are determined by measuring the average slope gradient of the road surface from the receiving waters to the farthest edge of the mini-catchment boundary. They are put into three classes: gentle (< 2%), moderate (2-10%) and steep (>10 %) in Column 9a. The

17 As finer materials are washed away by erosion, the coarser stony material within the soil matrix remains behind to protect the surface from further erosion.

proportional erosion values determined from these thresholds (0.5, 1.0 and 2) were based on the average values for Revised Universal Soil Loss Equation (RUSLE) LS factors for a road segment of 100 meters (which reflects average culvert spacing density).

Road use categories include heavy, moderate, light and deactivated and are input in Column 9b)

Road capping quality depends on the relative amount and nature of materials laid down. A 15 cm crushed granite capping on a firm road bed is best, native material made up from fine textured soils, the worst. (Column 9c) In the event that the evaluator is not familiar with how to assess road surface material quality on a given road system, they should default to average values. This is important to remember because less experienced evaluators tend to rate dry roads as good and wet roads as poor based solely on the how the road looked on the day the observation was made. To be effective, the assessment must come up with the same numbers regardless of the weather.

Table 6a. (for Column 9) Showing Predicted Depths of Surface Erosion (m) from Road Surface of <2% Slope Gradient under Differing Conditions[18]

<2% Slope	**Road Surfacing Quality**[19]			
Road Use	**Paved or Coarse Ballast**	**Good**	**Average**	**Poor**
Heavy use, all season road	0	0.001	0.002	0.005
Moderate use, all season road	0	0.0005	0.001	0.002
Light seasonal use (4x4 and occasional logging truck)	0	0.0002	0.0005	0.001
Deactivated (and unused)	0	0.0001	0.0002	0.0005

Table 6b. (for Column 9) Showing Predicted Depths of Surface Erosion (m) from Road Surface of 2-10% Slope Gradient under Differing Conditions

2-10% Slope	**Road Surfacing Quality**			
Road Use	**Paved or Coarse Ballast**	**Good**	**Average**	**Poor**
Heavy use, all season road	0	0.002	0.005	0.01
Moderate use, all season road	0	0.001	0.002	0.005
Light seasonal use (4x4 and occasional logging truck)	0	0.0005	0.001	0.002
Deactivated (and unused)	0	0.0002	0.0005	0.001

18 Note: Estimates are based in part on the Revised Universal Soil Loss Equation (RUSLE) combined with observations of behaviour of wide range of forestry-disturbed surfaces and their sediment generating capacity. It is the relative rate of sediment generation between different surfaces that is important to the evaluation. The absolute numbers given here for annual rates of surface soil erosion should be treated as indicators only.

19 Wet roads always will look worse than dry roads. If not familiar with rating road surface quality, use average values.

Table 6c. (for Column 9) Showing Predicted Depths of Surface Erosion (m) from Road Surface of >10% Slope Gradient under Differing Conditions

>10% Slope	Road Surfacing Quality			
Road Use	Paved or Coarse Ballast	Good	Average	Poor
Heavy use, all season road	0	0.005	0.01	0.02
Moderate use, all season road	0	0.002	0.005	0.01
Light seasonal use (4x4 and occasional logging truck)	0	0.001	0.002	0.005
Deactivated (and unused)	0	0.0005	0.001	0.002

Components other than road surfaces are treated differently because they are usually only disturbed in the construction phase and thereafter slowly “heal”.

Table 7 provides estimates of rates of erosion from disturbed surfaces other than road surfaces. For any component, only that portion of exposed, bare, fine textured soil is considered to be erodible and assigned an erosion rate of 1cm (0.01m). Cobble, gravel or even coarse sand surfaces, if undisturbed, are considered to be non-eroding and are not counted in the evaluation. For a newly excavated cutbank, 100% of the surface could be subject to a high rate of surface erosion, whereas over time, as the surface is either re-vegetated or armoured, the portion of bare, eroded soil will drop proportionally and usually dramatically. After a few seasons, most cutbanks are covered by at least moss or algae and such coatings also indicate that the surface is no longer erosive. It is apparent from this table why heavy sediment generation is skewed towards new road construction and other recent disturbances.

On landscapes with a soil matrix with a high silt content (or very fine sand) repeated needle ice formation can act as a continual disturbance of cutbank surfaces and result in chronic, long term sediment generation.

Table 7. (for Column 9) Annual Surface Erosion Expected on Surfaces Commonly Found Associated with Mini-Catchments

Choose surface erosion rating that provides the best match for condition of surface being evaluated.[20]

Surface Erosion Ratings	Typical Surface (other than road running surfaces) within Mini-Catchments Draining Forestry-Disturbed Sites.	Estimated Annual Depth of Surface Erosion Expected under Existing Conditions[21] (m)
Nil	Forest floor, cutbanks, sidecast, fill slopes or ditch lines with good moss, grass or litter cover or naturally or artificially armoured.[22] (Generally associated with well established roads).	0
	Bedrock outcrop in any location.	0
	Colluvial/morainal stone rubble gravel in any location.	0
High	Disturbed forest floor, cutbanks, sidecast, fill slopes or ditch lines with bare, unvegetated, unarmoured unconsolidated surface material (other than lacustrine). (Generally associated with new roads and other recent disturbances. After a road becomes established, often only a small portion of a cutbank or road ditch is subject to erosion.).	0.01
	Natural or artificial surface with heavy livestock use and presence of compacted bare soil.	0.01
Extreme	Cutbanks, sidecast, fill slopes and ditches with no vegetation cover on stone-free, very fine sandy and silty lacustrine.	0.02+

20 Where gullying/slumping or massive slope failure is noted, any expected ongoing surface erosion from the scarp face is included in the analysis under surface erosion contribution, but the material already lost by mass failure is considered separately.

21 In most cases, any disturbed surface will be made up of a portion of non-eroding (vegetated or armoured) (0 mm surface erosion) or eroding (non-vegetated or non-armoured) (10 mm erosion). The evaluator should estimate the portion of bare soil within the component being considered and pro-rate the actual expected sediment generated from that slope. (ie a 50 x 3 meter cutbank with 60 % unarmoured and unvegetated = (150 m^2 x 0.6 x 0.01 m) = 0.9 m^3

22 A surface can be armoured artificially by placement of rip-wrap or naturally by selective removal of fines during rainfall leaving coarser material on surface.

Column 10. Calculate Volume of Material Removed by Surface Erosion

By multiplying the results from Column 8 and 9 together, we can get a value for the expected annual volume in m^3 of sediment removed by surface erosion of the component under consideration. This estimate is based on what might be expected to happen to the given component averaged over a few years to take into account normal variation in weather and management.

Column 11. Calculate Total Sediment Contribution from Surface Erosion

The product of Column 2 (giving the portion of sediment bearing artificial drainage reaching the stream) and Column 10 (which gives the total volume of material removed by erosion) provides an estimate of the total sediment load received by the water body from surface erosion.

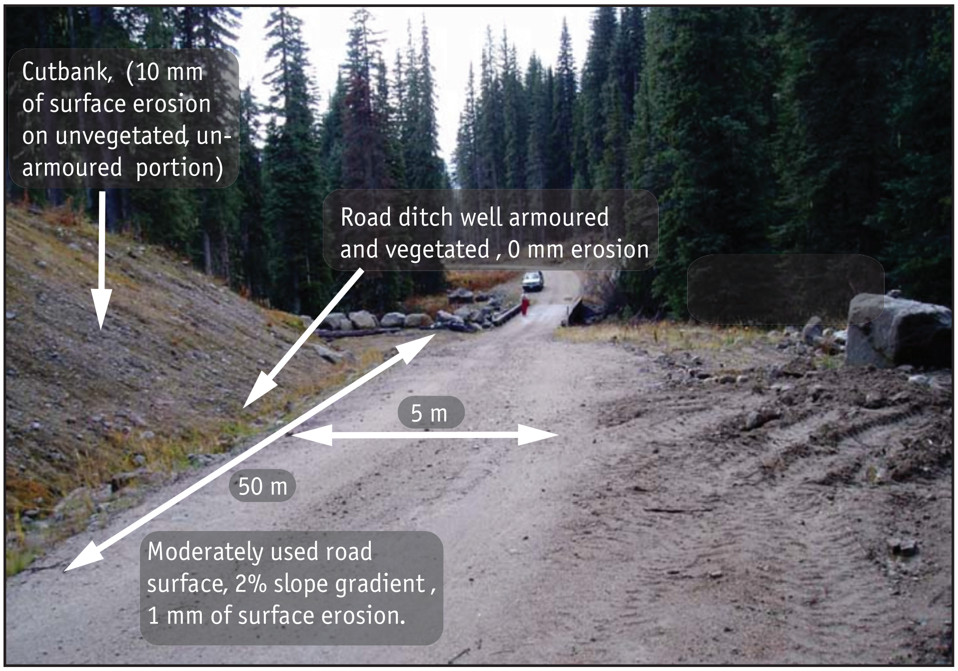
Column 12. Calculate Fine Sediment Contribution from Surface Erosion

When considering water quality degradation caused by sediment, it is only the finer particle classes that contribute to turbidity.[23] In low gradient streams, all particles larger than medium sands are transported as bed loads and do not influence turbidity. In more turbulent streams, coarse sand size fraction may be temporarily suspended. Column 12 makes an adjustment for those surfaces that are less likely to be able to transport larger particles sizes to the stream.

By adding the total fine sediment contribution from mass wasting components in Column 7 (taken from Side 2 of Form 2) to the total fine sediment contribution from surface erosion components of Column 12, we get the total fine sediment contribution for the site.

23 Medium sand and coarser sediments may have a serious effect on fish habitat (spawning grounds, infilling of natural pools etc.)

Figure 5. TASK IIIb. Example of Surface Erosion Contribution



Rating of Total Fine Sediment Generation from Site

The indices of fine sediment generation are then assigned to different classes as shown in Table 8. Indices range from very low, (< 0.2 m^3 of fine sediment generated) to very high, (>20 m^3 of fine sediment being generated at the site). Sediment Generation Potential Classes reflect the absolute magnitude of impact on forestry-related disturbances upon the whole drainage network being considered. The thresholds chosen for site sediment generating potential classes broadly reflect levels of management undertaken at the site. With better management, we expect to lower the sediment generating potential from evaluated sites.

Table 8. Rating of Total Fine Sediment Generation from Site (independent of stream size)

Total Volume of Fine Sediment Generated (WQ Index)	Site Sediment Generation Potential Classes	General Level of Management
< 0.2 (m^3)	very low	Good
0.2 - 1 (m^3)	low	↑
1 - 5 (m^3)	moderate	
5 - 20 (m^3)	high	↓
> 20 (m^3)	very high	Poor

The break down of the Site Sediment Generation Potential into these classes provides the appropriate detail for rating water quality impacts at a routine/extensive level of evaluation. These general classes were used to rate the outcome of the 2006, 2007 and 2008 water quality effectiveness evaluation field seasons. Based on numerous discussions with district staff, licensees and water purveyors, the classes used are consistent with site assessments made by a diverse range of qualified professionals. These results provide the Ministry of Forests and Range and the Licensee with a means to prioritize water quality impacts of specific sites requiring improvements to management.

The Water Quality Protocol as a framework for more rigorous evaluations beyond FREP's mandate

If a land manager is particularly interested in the impact of water quality immediately downstream of a site, the size of the stream must also be considered. The smaller the stream, the larger the impact of a given quantity of sediment will be. Sensitive fish bearing streams and streams with intakes immediately downstream require special consideration. Even small sediment additions into very small streams can cause significant local elevation of turbidity levels.

Table 9 shows a measure of potential water quality impact of a given quantity of sediment on a fish stream with a defined channel width[24] immediately downstream from the sample site. The table shows that the smaller the stream, the larger the effect of a given volume of fine sediment will be on the water quality of that stream. This table will provide a reasonable estimate of change in water quality experienced on different sized streams below that site.[25] However, if the affected stream is non-fish bearing, but eventually flows into a larger stream that becomes fish bearing, the impact on fish would be best reflected by considering the size of the larger stream, not the size of the tributary at the site itself. For example, imagine a small stream (channel 1 m wide) with a water quality evaluation indicating 0.5 m^3 of fine sediment is being generated. From Table 8 we determine that this would be considered a "low" site sediment generating potential. However, from Table 9 we determine that the water quality impact immediately downstream of that site for this size of stream would be "moderate". If, however, the actual fish habitat was some kilometers downstream, with a channel width of 10 meters, the impact of sediment generation at the site would be "very low" by the time the sediment pulse reached the fish bearing portion of the stream. At present, cumulative effects of multiple sites on a single stream are not considered within the Water Quality Effectiveness Evaluation. They may however, be considered during a more rigorous, intensive evaluation, should one be conducted.

Table 9. Rating of Water Quality Impact for Fish Bearing Stream Immediately Downstream from Site

	Width of Stream Channel in Fish Bearing Watershed				
WQ Index	**< 0.5 m wide**	**0.5 to 1.5 m wide**	**1.5 to 5 m wide**	**5 to 20 m wide**	**> 20 m wide**
< 0.2	Variable	Low	Very Low	Very Low	Very Low
0.2 - 1	High	Moderate	Low	Very Low	Very Low
1 - 5	Very High	High	Moderate	Low	Very Low
5 - 20	Very High	Very High	High	Moderate	Low
> 20	Very High	Very High	Very High	High	Moderate

24 The following discharges have been assigned to matched streams of a given channel width.

Stream Channel Width (m)	Implied Range of Discharge for Stream during Sedimentation Events (m^3/sec)
< 0.5	0.001 - .01
0.5 - 1.5	0.01 - 0.1
1.5 - 5	0.1 - 1
5 - 20	1 - 10
> 20	10 - 100

25 These tables were developed considering the sediment concentration/duration tables developed by Newcome (1996)

Likewise, Table 10 presents a rating of water quality impact for drinking water for a given volume of sediment introduced to a stream of a specific stream channel width. However, the severity of impact on drinking water for any given volume of sediment is one class higher than for fish streams. The effect of downstream dilution is the same as for fish streams. An impact of a tributary that flows into a much larger stream, on which an intake is located, is attenuated proportionally to the size of the stream it enters.

Table 10. *Rating of Water Quality Impact for Drinking Water Intake Immediately Downstream from Site*

	Width of Stream Channel in Community Watershed				
WQ Index	**< 0.5 m wide**	**0.5 to 1.5 m wide**	**1.5 to 5 m wide**	**5 to 20 m wide**	**> 20 m wide**
< 0.2	Variable	Variable	Low	Very Low	Very Low
0.2 - 1	Very High	High	Moderate	Low	Very Low
1 - 5	Very High	Very High	High	Moderate	Low
5 - 20	Very High	Very High	Very High	High	Moderate
> 20	Very High	Very High	Very High	Very High	High

Regardless of whether Table 8, 9 or 10 is chosen to determine the effects of fine sediment generation at a site, management must then be assessed in light of the rating assigned to a site.

For the FREP routine/extensive water quality evaluation, only Table 8 need be considered. When sites from the relevant tables are assigned very low and low classes, the evaluator is assured that the management within the watershed is good, water resources are being protected and little in the way of remedial action is required. If the sites are rated high or very high, water resources are not being protected and remedial action should be considered. Sites with moderate ratings may or may not receive attention, depending on the sensitivity of the stream and District priorities.

Assessment of Management Practices Associated with Sample Site (TASK IV)

The selection of appropriate management options to reduce or prevent sediment entering streams strongly influence if, and how much water quality degradation will occur. This Task will help the evaluator to determine how management has influenced fine sediment generation and how changes to management at a site could reduce fine sediment delivery to streams.

The assessment of water quality effectiveness requires that the evaluator be familiar with forestry operations associated with roads and harvesting. They must recognize what sort of practices put water quality at risk and what management opportunities are available to minimize that risk. A tentative list practices that might reduce sediment generation are considered in Table 11.

Checklist of Possible Solutions to Reduce Fine Sediment Generation

When ratings from Table 8 (or in more intensive evaluations using Table 9 and Table 10) are very low or low, management has avoided impacting water quality and consequently the Licensee's management can be considered to be effective. When moderate, high or very high levels of sedimentation were observed at a site, management has been proportionally less effective.

Whenever a moderate, high or very high water quality impact was observed, what practices could have reduced the level of sedimentation? Suggestions of opportunities for improvement are provided in Table 11. The evaluator will choose one or more means to mitigate the water quality impact at the site. Other observations may also be desirable and should be noted under "comments" on the second Page of Form 2.

Table 11. Checklist of Possible Solutions to Reduce Fine Sediment Generation

Activity of Concern	Possible Means to Reduce Stream Sedimentation
Location of road (To be considered in future road alignments)	1. Seek alternate alignment
	2. Avoid steep, unstable slopes
	3. Avoid long greadients approaching streams
Design of road and cutblock (To be considered in future road drainage and cutblock boundary design)	4. Avoid deep ditches in proximity to streams
	5. Increase number of strategically located culverts
	6. Place deck higher than road
	7. Use narrow road that follows natural breaks
	8. Ensure riparian zone wind firm
Construction of road/ harvesting of cutblock (To be considered during construction of road and harvesting of cutblocks)	9. Minimize soil disturbance
	10. Armour, seed and protect bare soil
	11. Avoid wet areas or use brush mat
	12. Use better quality materials
	13. Armour areas of concentrated flow
	14. Construct sediment trap
Management/ Maintenance (To be considered during ongoing management and maintenance of road and cutblock)	15. Use good quality materials and crown road
	16. Remove berms
	17. Avoid road use when wet or thawing
	18. Restrict traffic
	19. Fall away, yard away from stream
	20. Improve range management
Deactivation (Seasonally or permanently)	21. Use cross ditches, kickouts, etc.
	22. Pull back unstable material
	23. Pull culverts and armour crossing
Other	24

Compile Sampling Area and District Summary Forms. (TASK V)

Once the evaluator has visited all priority sites in the selected sample area and completed site field cards for each, the final step in the evaluation is to gather information together in the form of a cumulative review for the particular sampling area. Form 4 is used to summarize all the information related to fine sediment generation and forest and range management from the inspected sites in any sampling area. Where livestock presence is noted, range indicators potentially affecting water quality are summarized. At a glance, the evaluator knows something about the magnitude of water quality degradation caused by forestry operations and range management associated with the selected sampling area. For sites where fine sediment generation is anything above a low Index rating (> 1) recommendations for reducing water quality degradation are provided. With increasing proportions of sites with moderate, high and very high classes of water quality degradation attributable to shortcomings in management, the evaluator has the basis for a negative assessment about the effects of forest operations on water quality.

Form 5 provides a district summary of a. Forestry and b. Range impacts on water quality.

Form 4. Summary of Sample Sites Evaluated Within Sampling Area

BRITISH COLUMBIA
The Best Place on Earth

Forest and Range
Evaluation Program

Water Quality
Resource Stewardship Monitoring
Summary of Water Quality Sample Sites within Sample Area – Form 4

District ID: ______________________ Opening ID: ______________________ Date Completed: M M / D D / Y Y Y Y

Summary of Sample Sites Evaluated Within Sampling Area

Sample Site ID	Type of Disturbance	Total volume of fine sediment generated at Site (m3)	Fine sediment generation potential class (VL, L, M, H, VH)	Management opportunities to reduce negative water quality impact of forestry	Range form 3 completed and showing compromised water quality (check if compromised)	Indicators observed that suggest water quality has been compromised

FS 1247-4 HFP 2009/03

Form 5. District Performance Tables

BRITISH COLUMBIA
The Best Place on Earth

Forest and Range
Evaluation Program

Water Quality
Resource Stewardship Monitoring
Summary of Water Quality Sampling Sites Within District – Form 5

District ID: ________________ Year: Y Y Y Y Total # of Sample Sites Evaluated: ________________

Sediment Generation Potential Rating	VERY LOW		LOW		MODERATE		HIGH		VERY HIGH	
Number of sample sites with assigned fine sediment generation potential class.	# of sites	% of total	# of sites	% of total	# of sites	% of total	# of sites	% of total	# of sites	% of total

Leading management opportunities to reduce negative water quality impact of forestry operations (with moderate or higher impact rating)	1.
	2.
	3.
	4.
	5.
Total number of range sample sites evaluated:	
Number of sample sites showing range characteristics compromising water quality:	
% of range sites showing compromised water quantity:	
Indicators observed that suggest water quality has been compromised	1.
	2.
	3.
	4.
	5.

FS 1247-5 HFP 2009/03

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Annex: Water Quality Effectiveness Evaluation Reference Tables for Form 2

Table 1. Site Type: Requiring Evaluation within Sampling Area

Road Related
All road stream crossings (bridge and culvert)
Road segments located within 20 meters of stream or lake (inter-drainage culverts)
Road generated slope failure. Any failure either immediately above or below road. (These will not generally be known until the field visit)
Harvesting Related
Harvesting/yarding within or adjacent to riparian zone (windthrow)
Skidder/mechanized harvester trails in proximity to riparian zone
Harvesting generated slope failure (all new failures within or below cutblock)
Other forestry harvesting disturbances resulting in bare, unvegetated soil
Silvicultural related
Silvicultural-related activities leading to water quality degradation
Livestock Related
Livestock presence noted within riparian zone and stream channel. If component is recognized and found to have any connectivity to stream, that portion of site will require further description using Range Checklist Indicator Sheet. (Form 3)

Table 2. (for Column 1) Individual Components of Sampled Sites.

Possible Components Found within Sample Site
Road surface (RS)
Road cutbanks (RC)
Road ditches (RD)
Road Fill and sidecast (F)
Gullies or Rills generated by artificially concentrated storm flow (G)
Landslides or other mass failure scars (L)
Upturned root wads (URW)
Livestock disturbance noted (LDN)
Heavy machine tracks: exposed, compacted, gouged or incised forest floor
Other disturbed areas (ODA)

In order to facilitate writing entries on column 1 of the site field card, the use of the following short hand notation are recommended. (All directions taken looking downstream from crossing)

Left Road Surface	LRS
Left Road Ditch	LRD
Left Road Ditch (upstream side of road)	$LRD_{(U)}$
Left Road Ditch (downstream side of road)	$LRD_{(D)}$
Left Road Cutbank	LRC
Left Road Cutbank (upstream side of road)	$LRC_{(U)}$
Right Road Surface	RRS
Right Road Ditch	RRD
Right Road Ditch (Upstream side of road)	$RRD_{(U)}$
(Other components can be entered in longhand)	
Fill	(F) or Fill
Landslide or slump	(L) or Landslide or slump
Upturned Root Wad	(URW) or Upturned root wad
Livestock disturbance noted	(LDN) Livestock disturbance noted
Other Disturbed Areas	(ODA) or Other Disturbed Areas

Table 3. (for Column 2) Estimating Connectivity

Estimated Connectivity	Typical Example	Actual Range	Connectivity Value used in Column 2
none	Ditch-blocked interceptor culvert draining 70 m of road discharging onto long, hummocky forested slope	(<0.1)	0
a little	Landslide with majority of failed material captured by alluvial terrace below	(0.1-0.3)	0.2
about half	A small area of disturbed cutbank (50 m^2) with 2 meters of forest floor separation from stream	(0.3-0.7)	0.5
a lot	Ditch-blocked interceptor culvert draining 200 m of road discharging onto a steep forested slope within 4 m of stream	(0.7-0.9)	0.8
all	Ditch drainage running directly into stream or road surface drainage running off road bridge	(>0.9)	1

Table 4. (for Column 2). Estimating Connectivity (area of disturbed drainage generating storm flow vs. distance between outlet and stream)

Distance over Forest Floor between Ditch Outlet and Wetted Width of Stream (m)	Approximate Area of Disturbed Drainage Upslope of Storm Drainage Outfall (m^2)							
	<10	10-50	50-100	100-250	250-500	500-1000	1000-2000	>2000
0.5-1	0.5	0.8	1	1	1	1	1	1
1-2	0.2	0.5	0.8	1	1	1	1	1
2-5	0	0.2	0.5	0.8	1	1	1	1
5-10	0	0	0.2	0.5	0.8	1	1	1
10-20	0	0	0	0.2	0.5	0.8	1	1
20-30	0	0	0	0	0.2	0.5	0.8	0.8
>30	0	0	0	0	0	0	0	0.5

Table 5. (for Column 3) Estimating Fine Sediment Component

Estimate of Portion of Fine Sand, Silt and Clay in Eroded/ Erodible Material Matrix (excluding active road surfaces)	Actual Range	Value used in Column 3
none	< 0.1	0
a little	0.1-0.3	0.2
about half	0.3-0.7	0.5
a lot	0.7-0.9	0.8
all	< 0.9	1

Note: All road surfaces are always assigned a fine sediment portion value of 1 because surface is being reworked by vehicular traffic.

Estimating Surface Erosion on Roads

Table 6a. (For Column 9) Showing Predicted Depths of Surface Erosion from Road Surface of <2% Slope Gradient under Differing Conditions

<2% Slope	Road Surfacing Quality[26]			
Road Use	Paved or Coarse Ballast	Good	Average	Poor
Heavy use, all season road	0	0.001	0.002	0.005
Moderate use, all season road	0	0.0005	0.001	0.002
Light use (4 x4)	0	0.0002	0.0005	0.001
Deactivated (and unused)	0	0.0001	0.0002	0.0005

Table 6b. (For Column 9) Showing Predicted Depths of Surface Erosion from Road Surface of 2-10% Slope Gradient under Differing Conditions

2-10% Slope	Road Surfacing Quality			
Road Use	Paved or Coarse Ballast	Good	Average	Poor
Heavy use, all season road	0	0.002	0.005	0.01
Moderate use, all season road	0	0.001	0.002	0.005
Light seasonal use (4x4 and occasional logging truck)	0	0.0005	0.001	0.002
Deactivated (and unused)	0	0.0002	0.0005	0.001

Table 6c. (For Column 9) Showing Predicted Depths of Surface Erosion from Road Surface of >10% Slope Gradient under Differing Conditions

>10% Slope	Road Surfacing Quality			
Road Use	Paved or Coarse Ballast	Good	Average	Poor
Heavy use, all season road	0	0.005	0.01	0.02
Moderate use, all season road	0	0.002	0.005	0.01
Light seasonal use (4x4)	0	0.001	0.002	0.005
Deactivated (and unused)	0	0.0005	0.001	0.002

26 Wet roads always will look worse than dry roads. If not familiar with rating road surface quality, use average values.

Estimating Surface Erosion on Non-Road Surfaces

Table 7. ***(for Column 9d) Annual Surface Erosion Expected on Surfaces Commonly Associated with Sites.***

Note: Only bare portion of surface subject to surface erosion is considered. Net down to account for self armouring and/or revegetation (0, 0.2, 0.5, 0.8, 1.0).

Typical Surface (other than road surfaces) within Mini-Catchments Draining Forestry-Disturbed Sites.	Estimated Annual Depth of Surface Erosion Expected under Existing Conditions (m) (1mm – 0.001m)
Forest floor, cutbanks, sidecast, fill slopes or ditch lines with algae sheen, moss, grass or litter cover or naturally or artificially armoured. (Generally associated with well established roads)	0
Bedrock outcrop, colluvial/morainal, fluvial stone rubble in any location	0
Disturbed forest floor, newly opened cutbanks, recent sidecast, fill slopes or ditch lines with bare, unvegetated, unarmoured, unconsolidated surface material. Also older surfaces with on-going needle ice formation	0.01
Natural or artificial surface with heavy livestock use and presence of compacted bare soil and cow pies present	0.01
Cutbanks, sidecast, fill slopes and ditches with no vegetation cover on stone-free very fine sandy and silty lacustrine	0.02

Table 8. ***Rating of Total Fine Sediment Generation from Site (independent of stream size)***

Total Volume of Fine Sediment Generated (WQ Index)	Site Sediment Generation Potential Classes	General Level of Management
< 0.2 m^3	very low	Good
0.2 - 1 m^3	low	↑
1 - 5 m^3	moderate	↕
5 - 20 m^3	high	↓
> 20 m^3	very high	Poor

Table 9. Rating of Water Quality Impact for Fish Bearing Stream Immediately Downstream from Site

	Width of Stream Channel in Community Watershed				
WQ Index	**< 0.5 m wide**	**0.5 to 1.5 m wide**	**1.5 to 5 m wide**	**5 to 20 m wide**	**> 20 m wide**
< 0.2	Variable	Low	Very Low	Very Low	Very Low
0.2 - 1	High	Moderate	Low	Very Low	Very Low
1 - 5	Very High	High	Moderate	Low	Very Low
5 - 20	Very High	Very High	High	Moderate	Low
> 20	Very High	Very High	Very High	High	Moderate

Table 10. Rating of Water Quality Impact for Drinking Water Intake Immediately Downstream from Site

	Width of Stream Channel in Community Watershed				
WQ Index	**< 0.5 m wide**	**0.5 to 1.5 m wide**	**1.5 to 5 m wide**	**5 to 20 m wide**	**> 20 m wide**
< 0.2	Variable	Variable	Low	Very Low	Very Low
0.2 - 1	Very High	High	Moderate	Low	Very Low
1 - 5	Very High	Very High	High	Moderate	Low
5 - 20	Very High	Very High	Very High	High	Moderate
> 20	Very High	Very High	Very High	Very High	High

Table 11. ***Checklist of Possible Solutions To Reduce Fine Sediment Generation***

Activity of Concern	Possible Means to Reduce Stream Sedimentation
Location of road (To be considered in future road alignments)	1. Seek alternate alignment
	2. Avoid steep, unstable slopes
	3. Avoid long greadients approaching streams
Design of road and cutblock (To be considered in future road drainage and cutblock boundary design)	4. Avoid deep ditches in proximity to streams
	5. Increase number of strategically located culverts
	6. Place deck higher than road
	7. Use narrow road that follows natural breaks
	8. Ensure riparian zone wind firm
Construction of road/ harvesting of cutblock (To be considered during construction of road and harvesting of cutblocks)	9. Minimize soil disturbance
	10. Armour, seed and protect bare soil
	11. Avoid wet areas or use brush mat
	12. Use better quality materials
	13. Armour areas of concentrated flow
	14. Construct sediment trap
Management/ Maintenance (To be considered during ongoing management and maintenance of road and cutblock)	15. Use good quality materials and crown road
	16. Remove berms
	17. Avoid road use when wet or thawing
	18. Restrict traffic
	19. Fall away, yard away from stream
	20. Improve range management
Deactivation (Seasonally or permanently)	21. Use cross ditches, kickouts, etc.
	22. Pull back unstable material
	23. Pull culverts and armour crossing
Other	24

Help

If you require assistance on the use of the water quality RSM forms and/or protocol, please contact one of the following people:

David Maloney	(250) 828-4173 or David.Maloney@gov.bc.ca
Brian Carson	(604) 886-3282 or brian_carson@dccnet.com
Peter Bradford	(250) 356-2134 or Peter.Bradford@gov.bc.ca
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