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WATER QUALITY EFFECTIVENESS EVALUATION

Water Quality Data Summary for 2008-2020

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BRITISH COLUMBIA

FREP Forest & Range Evaluation Program

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EXECUTIVE SUMMARY

Under the Forest and Range Evaluation Program (FREP), the Water Quality Effectiveness Evaluation (WQEE) protocol evaluates the propensity of forestry disturbed sites to generate and transport fine sediment to natural water bodies.[1] The outcome provides a means of ranking sampled sites into "Very Low", "Low", "Moderate"," High" and "Very High" fine sediment generation classes. Based on discussions with sedimentologists, hydrologists, district staff, licensees and water purveyors, the classes reflect a general consensus of the severity of water quality impacts that a site may have on a watershed. When sites are evaluated to have "Moderate" or higher impact ratings, management opportunities to reduce sediment loading are determined as part of the assessment. The protocol also provides a simple and repeatable means of flagging potential faecal contamination from rangelands where domestic water intakes occur downstream.

Between 2008 and 2020, 8411[2] randomly selected sample sites were investigated in 23 forest districts in British Columbia. Water quality impact ratings were determined to be "Very Low" at 27% of sites, "Low" at 43%, "Moderate" at 24%, "High" at 5%, and "Very High" at 1 % of sites.

At the 937 sites located upstream of a drinking water intake, the results were surprisingly similar to the provincial data set - "Very Low" at 21% of sites, "Low" at 42%, "Moderate" at 32%, "High" at 4%, and "Very High" at 1 % of sites.

A total of 171 sites located upstream of a drinking water intake were considered impacted by free-ranging livestock. Over 65% of these impacted sites were centred in the Okanagan, Kamloops and East Kootenay Districts, with higher population densities and the presence of free-grazing animals.

A more specific water quality evaluation was initiated in 2017 on a trial basis and has now been incorporated into the protocol. This evaluation estimated the impact of the fine sediment load on fish immediately downstream. Between 2017 and 2020, 1147 sites were evaluated using this methodology. The results suggest that 902 sites did not represent a risk to fish (79%), 127 sites were a slight risk (11%), 82 sites were a moderate risk (7%), and 36 sites were high risk of impairment for fish (3%). The two rating systems have been compared and their differing utility in watershed management discussed. Unlike the more general water quality rating, the fish risk of impairment rating only focuses on sites above known or assumed fish streams.

An evaluation is being developed to consider the impact of fine sediment on drinking water at a site and how it might impact water quality at a downstream intake. Thresholds of concern are roughly an order of magnitude more sensitive than those developed for fish. A drinking water quality rating would apply only to those streams where drinking water intakes occur downstream of the evaluated site.

The results of the WQEE highlight the importance of addressing fine sediment impacts through all stages of a road's life – location, design, construction, maintenance, and deactivation. Proper management techniques throughout these stages can mitigate most conditions that lead to negative water quality impacts associated with industrial operations.

The top four management recommendations to reduce fine sediment impacts from roads are: ensuring strategically placed culverts, spreading out logging debris on exposed soils, managing grader berms, and using good quality

1 Excessive fine sediment generation is unquestionably the primary reason for degraded water quality attributed to forestry operations. In addition, the quantification of fine sediment from a site provides a reasonable proxy for other water quality contaminants that are transported in a similar fashion (faecal coliform, pesticides, hydrocarbons, etc.) Basically, any contaminant that is generated within these defined mini catchments is much more likely to impact water quality. Other areas within the watershed, without surface water connectivity to streams, are heavily buffered by forest soil filtration.

2 There are 8411 sites that have sufficient information entered via the WQEE App between 2008 and 2020 to use in this analysis. Thirteen sites were removed from analysis because they only contained location data and no other information.

road materials. Some recognized problems that lead to water quality impacts, such as locating a road too close to a stream, are difficult if not impossible to address without paving or relocating the road. Others, such as the frequency of culvert placement or management of grader berms can be corrected relatively simply in a cost-effective manner by licensees.

The Ministry of Forests, Lands, Natural Resource Operations and Rural Development is presently developing a modified version of the FREP WQEE protocol to address cumulative impacts of forestry disturbances on water quality within priority watersheds.

A newly constructed bridge in DSC that employed best management practices. These include good road base and surfacing materials on approach, bridge deck higher than road grade, rock armouring everywhere that storm drainage might concentrate and diverted ditch drainage onto forest floor. The WQEE indicates a "Low" water quality impact.

1.0 INTRODUCTION

The Water Quality Effectiveness Evaluation (WQEE) protocol was developed to provide district stewardship staff a means to characterize and evaluate the impact of forestry operations on water quality. Values for different fine sediment impact classes were assigned to sites where eroded sediment could reach a stream. Where levels of sedimentation exceeded a defined threshold, the evaluator provided recommendations for management options to reduce the impact of forestry operations (mostly roads) on water quality.

This report summarizes the Forest and Range Evaluation Program (FREP) water quality data collected for 2020, as well as a compilation of all data collected between 2008 and 2020. Both provincial and district summaries are presented. A total of 8411 sites were evaluated in eight regions and 23 districts over the last 12 years. Some district boundary changes resulted in a reassignment of some evaluated sites to new districts and consequently resulted in some discrepancies in district data compilations. Up-to-date boundaries as well as the latest region and district names have been used throughout this report. See Appendix 1 for a list of forest districts and their abbreviations.

2.0 METHODOLOGY

The WQEE methodology is described in detail on the Ministry of Forests, Lands, Natural Resource Operations and Rural Development website:

https://www2.gov.bc.ca/gov/content/industry/forestry/managing-our-forest-resources/integrated-resource-monitoring/forest-range-evaluation-program/frep-monitoring-protocols/water-quality

Additional information on the WQEE is provided in Appendix 2.

Pamphlets are available for viewing on the site and training videos are available on the WQEE Field App 2021.

3.0 RESULTS

3.1 Provincial Water Quality Impact Ratings Summary

Figure 1 provides a breakdown of the water quality impact rating at all 565 sites evaluated over the 2020 field season. Twenty-six percent (26%) of the sites were rated "Very Low" for water quality impact (144 sites with average fine sediment volume of 0.04 m^3), 47% were rated "Low" (268 sites with average fine sediment volume of 0.46 m^3), 23% were rated "Moderate" (129 sites with average fine sediment volume of 2.430 m^3), 3% were rated "High" (17 sites with average fine sediment volume of 8.5 m^3) and 1% were rated "Very High" (7 sites with an average fine sediment volume of 105 m^3).

Figure 2 provides the compiled set of water quality data collected between 2008 and 2020. As shown in Table 1, the proportions of water quality impact classes for sites evaluated between 2008 and 2020 are similar to those data collected in 2020. The average values calculated within each class helps to understand the significance of the actual thresholds used in defining water quality ratings. Relatively consistent proportions of each water quality impact class were found from year to year within and between districts. This provides assurance that the data provides a reasonable overview of the water quality situation in British Columbia. No attempts were (or should be) made to establish trends or make comparisons between years, districts or regions. This is because the sample population was too sparse to account for the diversity of terrain, variable intensity of forest harvesting, and differing levels of road management.

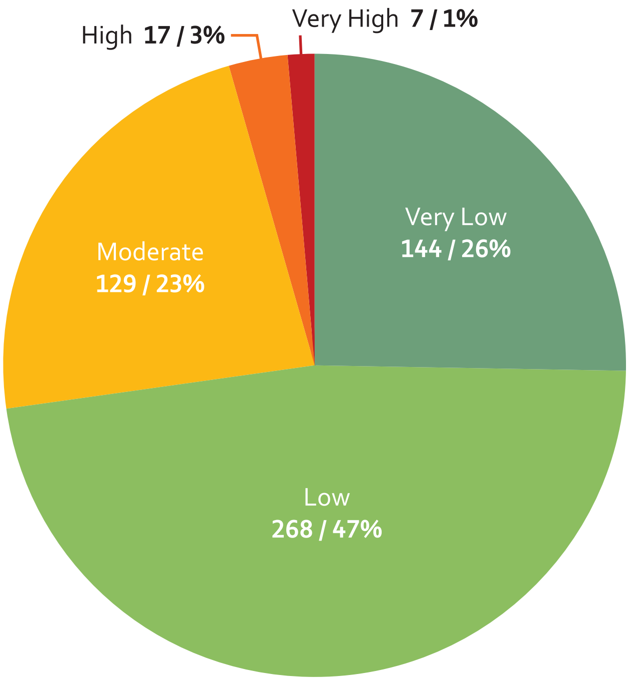


Figure 1. *Provincial water quality ratings (number of sites and %) for 2020.*

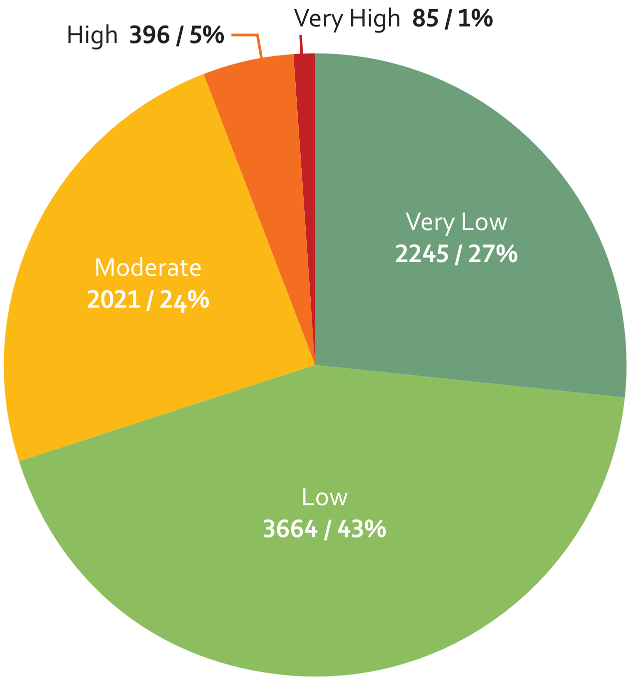


Figure 2. *Provincial water quality ratings (number of sites and %) for 2008-2020.*

Table 1. *Provincial WQEE results for 2020 and 2008-2020*

Sampling interval	Very Low	%	Low	%	Moderate	%	High	%	Very High	%	Total # of sites evaluated
2020	144	25.5	268	47.4	129	22.8	17	3.0	7	1.2	565
2008-2020	2245	26.7	3664	43.6	2021	24.0	396	4.7	85	1.0	8411

Table 2 shows the various water quality ratings for all years evaluated (2008-2020). This table shows that the relative proportions of each water quality impact class are similar between years. Given the small sampling size, however, any differences between years cannot be used to establish trends.

Table 2. *Provincial WQEE summary evaluation results for 2008-2020*

Year	Very Low	%	Low	%	Moderate	%	High	%	Very High	%	Total # of sites
2008	149	24.5%	252	41.5%	179	29.5%	26	4.3%	1	0.2%	607
2009	249	27.2%	396	43.2%	215	23.5%	45	4.9%	11	1.2%	916
2010	216	24.3%	405	45.6%	224	25.2%	34	3.8%	9	1.0%	888
2011	208	29.0%	339	47.3%	145	20.2%	21	2.9%	4	0.6%	717
2012	168	26.5%	289	45.6%	147	23.2%	24	3.8%	6	0.9%	634
2013	203	28.0%	304	41.9%	184	25.3%	28	3.9%	7	1.0%	726
2014	191	27.1%	312	44.2%	170	24.1%	29	4.1%	4	0.6%	706
2015	113	24.8%	215	47.1%	99	21.7%	27	5.9%	2	0.4%	456
2016	117	19.8%	245	41.5%	164	27.8%	58	9.8%	6	1.0%	590
2017	138	30.5%	163	36.0%	115	25.4%	29	6.4%	8	1.8%	453
2018	173	33.5%	187	36.2%	130	25.2%	20	3.9%	6	1.2%	516
2019	176	27.6%	289	45.4%	120	18.8%	38	6.0%	14	2.2%	637
2020	144	25.5%	268	47.4%	129	22.8%	17	3.0%	7	1.2%	565
	Total 2245	**Average % 26.7%**	**Total 3664**	**Average % 43.6%**	**Total 2021**	**Average % 24.0%**	**Total 396**	**Average % 4.7%**	**Total 85**	**Average % 1.0%**	**Total 8411**

3.2 District Water Quality Impact Ratings Summary

In Table 3, district summaries of water quality ratings are provided for all sites evaluated in 2020.

Table 3. *District summaries of water quality ratings for sites evaluated in 2020*

Districts	Very Low	%	Low	%	Moderate	%	High	%	Very High	%	Total for district
DCC	11	50.0%	11	50.0%	0	0.0%	0	0.0%	0	0.0%	22
DCK	14	30.4%	27	58.7%	5	10.9%	0	0.0%	0	0.0%	46
DCR	20	37.0%	25	46.3%	9	16.7%	0	0.0%	0	0.0%	54
DCS	6	11.3%	29	54.7%	18	34.0%	0	0.0%	0	0.0%	53
DHG	8	32.0%	11	44.0%	5	20.0%	1	4.0%	0	0.0%	25
DKA	2	66.7%	1	33.3%	0	0.0%	0	0.0%	0	0.0%	3
DKM	9	27.3%	14	42.4%	9	27.3%	1	3.0%	0	0.0%	33
DMH	5	20.0%	6	24.0%	8	32.0%	5	20.0%	1	4.0%	25
DMK	4	16.0%	10	40.0%	7	28.0%	3	12.0%	1	4.0%	25
DND	7	41.2%	2	11.8%	7	41.2%	1	5.9%	0	0.0%	17
DNI	13	28.3%	22	47.8%	7	15.2%	2	4.3%	2	4.3%	46
DOS	6	18.8%	11	34.4%	15	46.9%	0	0.0%	0	0.0%	32
DPG	8	40.0%	4	20.0%	3	15.0%	3	15.0%	2	10.0%	20
DQU	11	40.7%	8	29.6%	8	29.6%	0	0.0%	0	0.0%	27
DSE	2	5.1%	22	56.4%	15	38.5%	0	0.0%	0	0.0%	39
DSI	6	13.3%	36	80.0%	3	6.7%	0	0.0%	0	0.0%	45
DSN	4	18.2%	11	50.0%	5	22.7%	1	4.5%	1	4.5%	22
DSQ	8	25.8%	18	58.1%	5	16.1%	0	0.0%	0	0.0%	31
	Total 144	**Average % 25.5%**	**Total 268**	**Average % 47.4%**	**Total 129**	**Average % 22.8%**	**Total 17**	**Average % 3.0%**	**Total 7**	**Average % 1.2%**	**Total 565**

Table 4 presents water quality ratings by district for sites evaluated between 2008 and 2020. Once again, the results are quite uniform between districts.

Table 4. *District summaries of water quality ratings for sites evaluated between 2008-2020*

District	Very Low	%	Low	%	Moderate	%	High	%	Very High	%	Total
DCC	88	28.9%	148	48.7%	52	17.1%	15	4.9%	1	0.3%	304
DCK	68	13.5%	207	41.2%	196	39.0%	30	6.0%	1	0.2%	502
DCR	222	27.6%	401	49.9%	171	21.3%	6	0.7%	3	0.4%	803
DCS	34	13.2%	117	45.3%	89	34.5%	18	7.0%	0	0.0%	258
DFN	1	9.1%	9	81.8%	0	0.0%	1	9.1%	0	0.0%	11
DHG	125	33.1%	167	44.2%	71	18.8%	12	3.2%	3	0.8%	378
DKA	104	22.6%	205	44.5%	128	27.8%	20	4.3%	4	0.9%	461
DKM	145	27.3%	239	45.0%	121	22.8%	20	3.8%	6	1.1%	531
DMH	49	31.2%	54	34.4%	37	23.6%	15	9.6%	2	1.3%	157
DMK	53	22.9%	77	33.3%	68	29.4%	28	12.1%	5	2.2%	231
DND	76	20.6%	100	27.1%	149	40.4%	39	10.6%	5	1.4%	369
DNI	195	35.1%	250	45.0%	89	16.0%	11	2.0%	11	2.0%	556
DOS	87	16.0%	241	44.4%	187	34.4%	23	4.2%	5	0.9%	543
DPC	47	21.9%	70	32.6%	49	22.8%	36	16.7%	13	6.0%	215
DPG	56	26.7%	62	29.5%	61	29.0%	25	11.9%	6	2.9%	210
DQU	125	43.1%	112	38.6%	44	15.2%	5	1.7%	4	1.4%	290
DRM	93	25.6%	188	51.8%	70	19.3%	11	3.0%	1	0.3%	363
DSC	145	34.4%	207	49.1%	68	16.1%	2	0.5%	0	0.0%	422
DSE	121	27.1%	196	43.8%	102	22.8%	22	4.9%	6	1.3%	447
DSI	131	30.5%	224	52.2%	64	14.9%	8	1.9%	2	0.5%	429
DSN	89	24.0%	148	39.9%	100	27.0%	30	8.1%	4	1.1%	371
DSQ	96	25.4%	184	48.7%	86	22.8%	10	2.6%	2	0.5%	378
DSS	95	52.2%	58	31.9%	19	10.4%	9	4.9%	1	0.5%	182
	Total 2245	**Average % 26.7%**	**Total 3664**	**Average % 43.6%**	**Total 2021**	**Average % 24.0%**	**Total 396**	**Average % 4.7%**	**Total 85**	**Average % 1.0%**	**Total 8411**

3.3 Provincial Level Water Quality Impact Ratings for Sites Upstream of Drinking Water Intakes

Figure 3 and Figure 4 compare the water quality results at sites with a known drinking water intake within 10 km downstream (937 sites out of a total of 8411 sites evaluated) verses no drinking water intake downstream. The data sets appear to show worse overall water quality condition in drinking water watersheds than non-drinking water watersheds. This result was somewhat unexpected as one would assume a higher level of management associated with watersheds used for drinking water. One possible explanation is that most watersheds used for drinking water were located near historic population centres and thus were logged long before more distant watersheds. Consequently, the inherited road network from older, harvested watersheds may have been built to a lower standard, particularly where haul roads were located too close to streams. Roads close to population centres are also more likely to receive considerable recreation traffic and increased degradation of cross ditches on deactivated roads. Such problems are frequently observed in these types of areas. As is discussed later, historic poorly located roads are not easily remediated by present road permit holders, even those employing best management practices. Operationally, such results stress the importance of locating new roads where they will have the least effect on natural drainage.

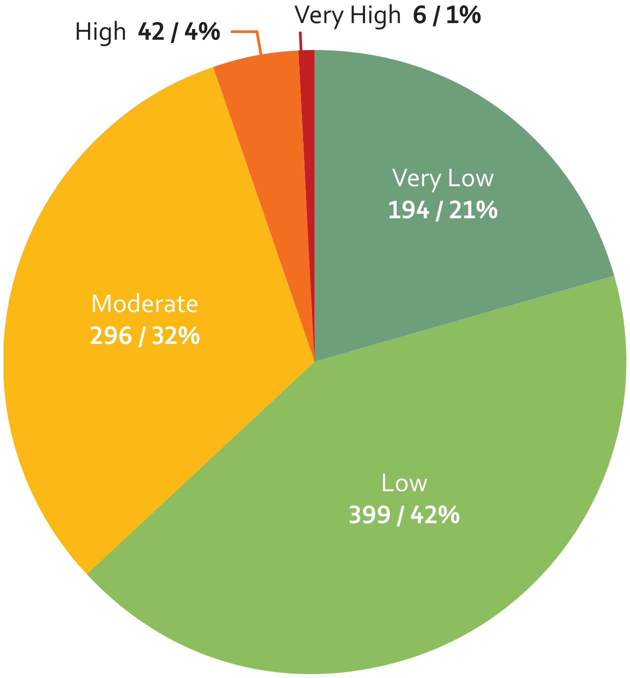


Figure 3. *Water quality results for sites with a known domestic intake within 10 km downstream (number of sites and %, n=937 sites).*

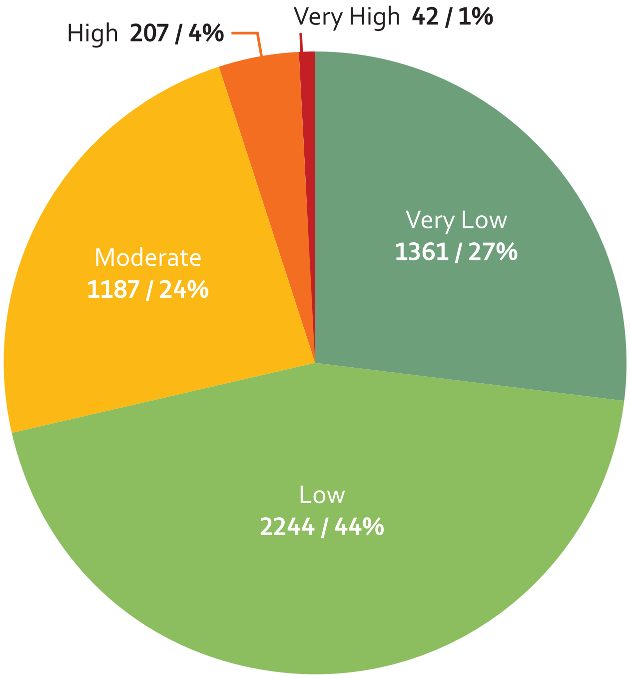


Figure 4. *Water quality results for sites with no domestic intake downstream (number of sites and %, n=5041 sites).*

3.4 Site Types Evaluated

As shown in Table 5, 86.9% of sites evaluated were categorized as stream crossings, 3.1 % were inter-drainage culverts, and the remaining other site types ranged from 0.7% down to zero. Nine percent (9.1%) of the evaluated sites had no data on site type.

Table 5. *Site types evaluated from 2008-2020*

Site types	Very Low	Low	Moderate	High	Very High	Total	%
Stream crossings	1954	3148	1778	353	72	7305	86.9%
No data on site type	200	368	161	25	9	763	9.1%
Inter-drainage culverts	62	123	61	13	1	260	3.1%
Other forestry disturbances	20	17	16	2	2	57	0.7%
Road failures	5	7	3	3	1	19	0.2%
Riparian harvesting or yarding	2	1	2	0	0	5	0.1%
Skidder or harvester trails	2	0	0	0	0	2	0.0%
Total	**2245**	**3664**	**2021**	**396**	**85**	**8411**	**100.0%**

At each evaluated site, the WQEE requires an estimate of how much erosion is occurring, how much of eroded sediment reaches the stream and what the discharge of the stream will be during normal storm flows. This permits a means to estimate the expected change in turbidity of the stream over natural levels.

3.5 Range Results

Since its inception, the range portion of the WQEE protocol has focussed on faecal contamination rather than fine sediment generation as an indicator for water quality degradation. In the early years, as the protocol was being developed, the range evaluation did not differentiate whether a site had a drinking water intake downstream. Since 2010, the criteria to initiate an on-site evaluation were adjusted to require that the site be located within 10 km of a downstream intake. Province wide, over the course of evaluations conducted to date (2010-2020), 171 sites were observed where livestock faecal contamination was considered a concern further downstream. Table 6 indicates the specific field observations used to determine the impact of livestock.

Table 6. *Observations used to determine livestock impacts (data collected from 2010-2020)*

Indicator of livestock causing water contamination	# of instances observed at evaluated sites
Absence of livestock control structures	212
Livestock faeces on site	205
Livestock found drinking from stream	201
Evidence of livestock standing in stream	183
Recent pugging noted	117
Bank erosion collapse noted	97
Bare soil compaction	82
Riparian vegetation damaged	77
Water runoff	34
Algal mats found in stream	28
Herbaceous stubble reflecting heavy grazing	25
Browsing	16
Observed presence of calves	7
Macro invertebrates indicated	2
Salt minerals oilers within 100m of stream	1

Table 7 provides a list of those districts with sites exhibiting potential water quality impacts related to range. Districts that reported potential range impacts[3] on water quality are those with substantial areas of range land and higher human population densities, such as the Okanagan, Kamloops and the east Kootenays, where over 65 % of observations were made. In less populated districts with larger free-ranging livestock populations, such as the Chilcotin, the lack of intakes downstream made sampling unnecessary. As noted in Table 6, a wide range of observations were used to determine livestock impacts on water quality.

[3] The FREP WQEE weighs the presence or possibility of faecal contamination, whereas range specialists consider over grazing of riparian vegetation as their major concern.

Table 7. *Districts with range-related water quality impacts (2008-2020 data[4])*

District	# of sites with potential faecal contamination impacting drinking water
DOS	65
DKA	31
DCC	21
DRM	18
DSE	11
DCS	8
DMH	6
DND	4
DPC	3
DSN	3
DQU	1
Total # of sites where water quality was impacted by faecal contamination	171

3.6 Use of the WQEE to Determine Impairment of Fish Habitat

When the WQEE was originally developed, its role was to determine whether forestry activities were impacting water quality and, if so, by how much. The evaluation was of a low level, routine nature, meaning that an assessment could be performed by technicians and that the results would be of a "general" nature, useful for district and provincial planning purposes. While the evaluation has performed that role effectively, there was interest in a more specific analysis that would determine the local impact of fine sediment on a particular stream. At a minimum, such an analysis requires an estimate of local stream discharge to determine what sort of increase in turbidity could be expected downstream for a given level of disturbance at a site. Newcombe (1991)[5] investigated the magnitude and duration of turbidity events on fish health and survival. See Table 8.

Table 8. *Effect of a given turbidity increase (in ntu)[6] on fish health and survival*

Effect on sensitive fish	Sediment duration of 10 days
Not impaired (Impact Class 0)	<10 mg/l (<5 ntu)
Slightly impaired (Impact Class 1,2,3)	10-40 mg/l (5-20 ntu)
Moderately impaired (Impact Class 4,5,6,7,8)	40-400 mg/l (20-200 ntu)
Severely impaired (Impact Class 9,10,11,12)	>400 mg/l (>200 ntu)

4 In the WQEE, the presence of faecal contamination indicators invariably triggers the threshold for concern. Most districts may have extensive rangelands or many downstream water intakes, but rarely both.

5 Newcombe, C.P. and D.D. MacDonald. 1991. Effects of suspended sediments on aquatic ecosystems. North American Journal of Fisheries Management. 11: 72-82.

6 ntu (nephelometric turbidity units); a measure of cloudiness of water.

By estimating how a given site would increase the turbidity downstream, the impact on fish health and survival could be determined using Newcombe's table. The protocol was modified in 2017 to include an estimate of stream discharge. This added information was then used to estimate changes to downstream turbidity, which in turn, provided a measure of potential impairment to local fish populations.

1147 sites were evaluated between 2017 and 2020 for the potential severity of impairment for fish as a result of fine sediment additions. The results (Figure 5) indicated that 79% of the sites were not at risk of impairment, 11% were slightly impaired, 7% moderately impaired, and 3% at severe risk of impairment for fish. This evaluation provides a measure of local on-site stream impairment.

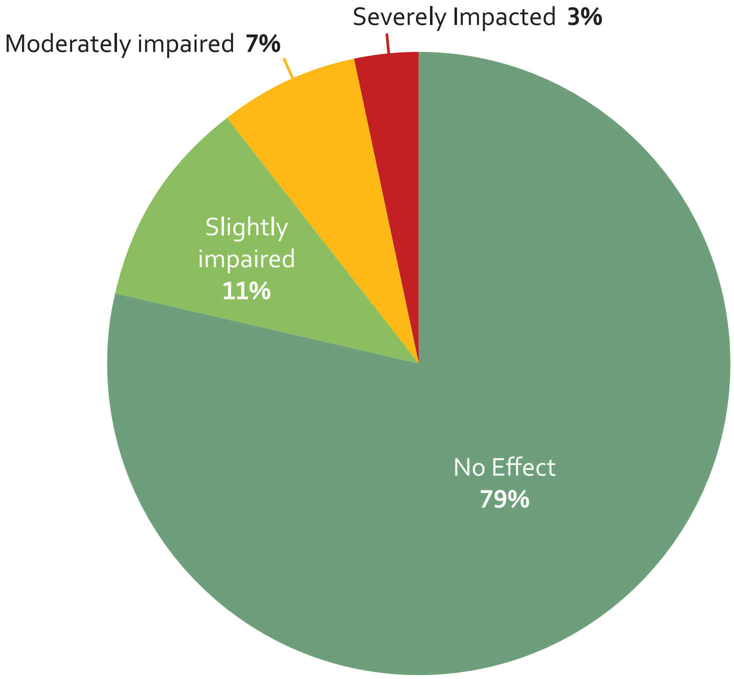


Figure 5. *Percentage of sites evaluated with given fish risk impairment rating (1147 sites evaluated between 2017-2020).*

How does this result compare with the actual FREP water quality rating ("Very Low", "Low", "Moderate", "High" and "Very High") for the same sites?

Table 9 compares the general water quality ratings for a site verses the "severity of impairment" of that site on fish immediately downstream. The water quality rating considers the amount of fine sediment generated at a site, independent of creek size. This measure relates to the magnitude of site disturbance and overall impact of sediment generation on the watershed as a management unit. The lower the WQ rating value, the better the overall sediment management of the road and the less impact on the watershed. Representative and properly weighted sites with FREP water quality ratings provides the basis for determining cumulative impacts on water quality in watersheds. The "severity of risk to fish", on the other hand, includes a local determination of stream discharge which allows an estimate of the potential change in turbidity that might be expected immediately downstream from the site and how that may impact local fish habitat should fish be present.

__Table 9.__ Comparing water quality impact ratings with fish risk impairment ratings (1058 sites, 2017-2020)

Water quality rating	# of sites with given WQ rating	No effect (0-5 ntu increase)	Slightly impaired (5-20 ntu increase)	Moderately impaired (20-200 ntu increase)	Severely impaired (>200 ntu increase)	% of sites with given water quality rating
Very Low	333	328	2	3		29.0%
Low	457	387	51	11	8	39.8%
Moderate	265	159	52	39	15	23.1%
High	71	25	15	25	6	6.2%
Very High	21	3	7	4	7	1.8%
Total sites with given rating	1147	902	127	82	36	100.0%
% of sites with given fish impairment rating	100.0	78.6%	11.1%	7.1%	3.1%	

Note on Table 9 that the 21 "Very High" water quality ratings have a range of differing fisheries risk impairment ratings. Although in each case, a substantial amount of fine sediment enters the stream, its net effect on the stream differs, depending on the discharge of the stream during the sediment generating event. In this case, one of the streams rated as having experienced "No effect" had a discharge of >20 m^3/sec, greatly diluting the impact of that specific site disturbance on the stream. The total potential increase in turbidity of the stream was less than 5 ntu, a value considered of little consequence to fish downstream. The 7 sites labelled severely impaired that had a "Very High" water quality rating occurred on very small streams with an estimated storm discharge of <100 l/sec. With much less dilution, the sediment contributions have the potential to cause the turbidity to increase dramatically during a sediment generating event(s).

3.7 Stream Widths and Risk of Fish Impairment Where Discharge was Measured

In Table 10, all sites that collected stream discharge data (1474) were rated for fish impairment based on stream size (calculated bankfull discharge). The general FREP WQEE protocol does not incorporate the size of stream when assigning the water quality impact rating. This is because the evaluation is meant to provide a sort of cumulative impact on water quality for the watershed as a whole. It is assumed that fine sediment generated at any site will work its way downstream and a given volume of fine sediment will have the same impact on the main channel regardless of the order or size of stream into which the fine sediment initially flows. (Note that this will be different for coarse sediment generation as a certain stream velocity and volume threshold is required to move larger size particles.)

Simply put, the smaller the stream and discharge, the larger the detrimental effect a given amount of fine sediment will have on fish immediately downstream. This reflects the observations of riparian assessments that smaller streams are most often severely impacted by logging disturbance.

Table 10. Provincial fish risk impairment ratings for streams of differing bankfull discharge (2008-2020)

Bankfull discharge (m^3)	No effect	Slightly impaired	Moderately impaired	Severely impaired	Undefined	Total
<0.05	270	84	42	7	138	541
.05 to.5	139	10	5	1	44	199
.5 to 1	30	23	34	26	56	169
1 to 5	245	8	1	1	67	322
5 to 50	164	2			21	187
>50	54				2	56
Total	**902**	**127**	**82**	**35**	**328**	**1474**

3.8 Use of the WQEE to Determine Impacts on Drinking Water Intakes

Where community watersheds and drinking water are a concern, a combination of both evaluations (water quality and fish risk impairment) should be considered. Standards for drinking water are much more stringent than that for fish. Small increases in turbidity over short periods may have little or no impact on fish but may severely impact water quality at a drinking water intake. In evaluating a stream with a drinking water intake just downstream of the site, and treatment involving chlorination only, the Ministry of Health considers an increase of 1 ntu to be a concern and an increase of over 5 ntu to be unacceptable. Above 5 ntu, a boil water notice would be required. These thresholds are provided in Table 11.

Table 11. Impact of increases in turbidity on drinking water intakes (where water treatment involves chlorination only)

Turbidity increase	<1 ntu	1-5 ntu	>5 ntu
Drinking water impact rating	No effect	Boil water advisory	Boil water notice

3.9 Management Implications Derived from the Evaluation

Once an evaluation has determined there is a potential negative impact to water quality, whether by the general water quality rating or the fish risk impairment rating, (or ultimately by impacts to drinking water), the next step is to determine what, if any, action is required to remediate the situation or at least make improvements to management to reduce the chance of the impact happening again in the future. The most common recommendations to improve the management of fine sediment impacts from roads are listed in Table 12.

Table 12. *Most common recommendations for improving the management of fine sediment impacts from roads (2008-2020)*

Recommendations	Number of times recommendations sited in database
Install strategically placed cross ditches	867
Use good quality road materials	725
Spread out logging debris	644
Manage grader berms	615
Avoid stream crossings	416
Avoid deeply dug ditches	192
Plan for a sufficient number of culverts	192
Construct a sediment basin	189
Design the bridge deck higher than the road grade	145
Place rock armouring over areas of concentrated flow	117

The top four recommendations offered to reduce fine sediment from active roads are: installing strategically placed culverts, using good quality road materials, spreading out logging debris on exposed soils, and managing grader berms.

The life of a road can be divided into five stages - location, design, construction, maintenance, and deactivation. Table 13 provides a summary of all recommendations forwarded by evaluators for the period 2008-2020 for possible improvements to water quality during the life of a road. Note that 6976 of the 8411 sites sampled (82.9% of total) were considered to have had little or no impact on water quality so no management concerns were noted during the evaluation. Recommendations for improvement were provided for sites where the water quality impact rating could be improved. In all, 5014 recommendations were made for 1435 sites. "Problem" sites had, on average, 1.5 specific recommendations for reducing fine sediment.

While the WQEE protocol does evaluate the impact of industrial road networks and harvesting on water quality, it does not assign responsibility. The nature of the sampling procedure is based on using a randomly selected harvested area by a known licensee. However, the actual sampling transect of the water quality protocol follows the road used to transport the timber to the sorting station or mill. This route may follow a road with limited or even no responsibilities associated with the licensee that harvested the block. Even when the road use permit is assigned to the licensee over the length of the haul road used in the transect, the water quality impacts noted may be the result of limitations inherited from historic road location and design and be unrelated to the present road permit holder. Non-forestry use of roads for exploration, hunting, fishing, and other recreational activities can also have profound impacts on fine sediment generation from a road. Sediment generation associated with roads paralleling within 5 m of a stream, or steeply incised bridge approaches perpendicular to a stream, may not be easily corrected. There were

572 observations (11.4% of) that were associated with the original road location. Along many old mainlines, short of relocating the road or paving it, there are few options to reduce sediment reaching a stream.

Road design problems were frequently observed and usually associated with insufficient or improperly placed inter-drainage culverts to permit safe dispersal of road drainage water to the forest floor rather than into the stream. The greater the density of culverts, the less discharge from individual culverts and the greater the opportunity for sediment to be filtered out in forest buffers. Bridge decks installed at the lowest point on the road grade also caused higher water quality impacts that might not have occurred with an elevated bridge deck. When water runs away from a bridge deck rather than towards it, there are more options to filter generated road sediment before it reaches the stream. Altogether, design problems impacting water quality were observed 627 times, accounting for 12.5% of total provincial observations between 2008 and 2020.

Road construction issues were noted 1912 times or 38.1 % of total provincial observations between 2008 and 2020. Using good road base and surfacing materials was recommended 773 times. The next highest observations were the protection of bare soils by revegetation, rock armouring, or covering with logging slash.

Road maintenance and management concerns were noted 862 times (17.2 % of total provincial observations between 2008 and 2020). These were most often associated with road grading (management of grader berms and elimination of road ruts). One of the most effective means to reduce water quality impacts caused by road networks (also the least expensive) is by encouraging closer attention to routine road maintenance.

Finally, road deactivation was mentioned 1041 times (20.8% of total provincial observations in the 12-year data collection period). These were associated with roads that were no longer in active industrial use although many were still being used by recreational vehicles. Greater use of ditch blocks and cross ditches would have decreased water quality impacts significantly. There were a considerable number of comments stating that originally functioning cross ditches had been compromised by recreation traffic and thus were not directly related to the licensee's road deactivation procedures.

Where cattle are present at stream crossings and drinking water intakes occur downstream, a range evaluation is conducted. In these evaluations the propensity for faecal contamination is investigated, and not fine sediment generation as in normal WQEE sites.

Table 13. Summary of management recommendations during the five stages of a road's life (2008-2020)

Stage in road life	Specific recommendation for site	# of times observed out of 8028 sites evaluated between 2008-2020	Total # and %
Location	Locate road away from stream	89	
	Avoid steep unstable slopes	77	
	Avoid stream crossing	406	
	Recommendations related to location		572 (11.4%)
Design	Avoid deeply dug ditches	196	
	Plan for sufficient number of culverts	196	
	Design bridge deck higher than road grade	154	
	Design narrower road	81	
	Recommendations related to design		627 (12.5%)
Construction	Ensure that remaining trees are wind firm	20	
	Avoid soil disturbance wherever possible	107	
	Spread out logging debris	663	
	Avoid compaction of skid trails	7	
	Use good quality road materials	278	
	Place rock armouring over areas of concentrated flow	136	
	Construct sediment basin	206	
	Ensure good quality road fill	495	
	Recommendations related to construction		1912 (38.1%)
Maintenance	Manage grader berms	646	
	Reduce vehicular traffic during wet weather	119	
	Reduce vehicular traffic on road	22	
	Clean stream to former conditions	9	
	Improve range management	66	
	Recommendations related to maintenance		862 (17.2%)
Deactivation	Install strategically placed cross ditches	915	
	Move unstable road fill to safe location	50	
	Pull culverts armour crossing	76	
	Recommendations related to deactivation		1041 (20.8%)
		Total number of recommendations	**5014**

Figure 6 depicts the proportions of different stages of a road's life with observed sediment delivery issues. Construction issues account for the highest proportion, followed by deactivation and then maintenance.

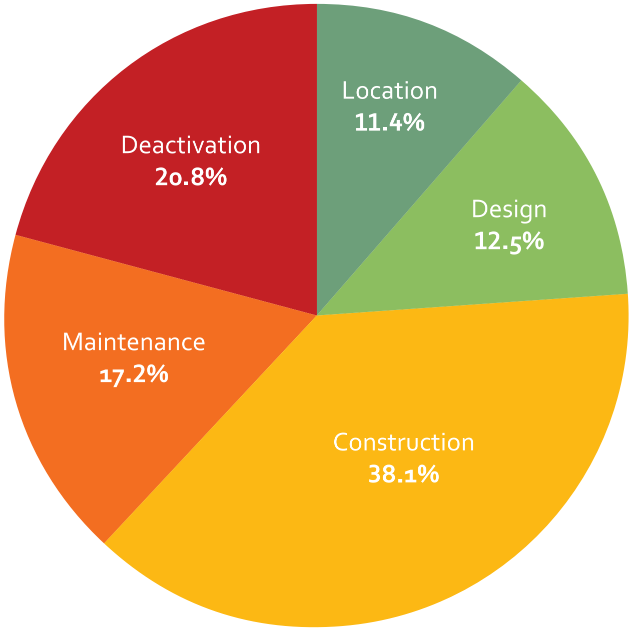


Figure 6. *Proportion of different stages of a road's life with observed sediment delivery issues.*

The most common evaluation site of the WQEE is where the forestry road crosses a stream. It is here that there is the greatest potential for road derived fine sediment to impact a stream.

4.0 CONCLUSIONS AND RECOMMENDATIONS

The FREP WQEE protocol has been used to assess forestry related site disturbances on water quality across the province. The majority of these disturbances are associated with roads. Evaluations showed substantial differences in the impacts of specific sites on water quality. Those differences in impact were invariably tied to differences in road location, design, construction, maintenance and deactivation. With this baseline data collected from across the province, it is recommended that the program now focus on more targeted and intensive evaluations that address local management needs. An example of a simple district summary of water quality data for one year is presented in Appendix 3.

Based on the analysis of the water quality data collected so far, several issues have come to light. These are considered below.

4.1 Target Selection Process for WQEE Sample Sites

Random sampling methods to determine sample site location may address FREP objectives but not necessarily meet the needs of local district managers who have specific management goals in mind. Future WQEEs undertaken by the Province, districts or licensees might consider focusing on the management issues raised by the large volume of data already collected or recognized local district issues. For example, sampling specific watersheds rather than randomly located sites will better meet the needs of watershed managers whether focused on fish health or drinking water quality. To reduce fine sediment generation, licensees might focus their attention and resources on problems of particular concern in their operating area. This might be associated with bridge approach design, location of new roads under development, training of grader operators, and/or road deactivation - whatever has been identified as important issues. Provincial legislation might be considered to encourage improved forest management where deficiencies have been noted. Recognized potential turbidity issues within community watersheds might need to receive more attention. Such a directed approach would be well received by district managers, provided it offers clear operational recommendations.

4.2 Use the FREP WQEE Protocol to Enhance an Environmental Certification Process

Possibly one of the most effective uses of the FREP WQEE is in the implementation of a company's environmental certification program. All licensees are working towards defining environmental goals that are quantifiable and establish a means to show that measurable improvements are being made over time. The WQEE methodology provides such a tool. It is both simple and effective to quantify changes to water quality impacts through changes in management. As an example, pre-selected sites along a major haul road may be evaluated using the WQEE in year 1. The results could provide a baseline upon which future evaluations would be conducted. The year 1 data could be analysed and individual sites and or specific management techniques might be singled out as "lessons learned" if no easily implemented improvements are forthcoming. On the other hand, the results might point towards improved environmental training for workers or possibly a focus on practical upgrades to the road network under review.

At a future date, the original road transect could be reassessed to evaluate whether the changes in management resulted in commensurate changes to water quality. Finding lower water quality impact ratings along the re-sampled route would confirm that the desired continuous improvement program was working. In order to "fine tune" the evaluation procedure, the evaluator could use actual volumes of fine sediment generated in evaluations rather than the broad water impact classes ("Very Low", "Low", "Moderate", "High", "Very High") as they are now defined. For instance, the "Moderate" impact class encompasses sites with a fine sediment generation of between 1 and 5 m^3. By employing actual volumes instead of one of the five impact classes, a reduction of 2 m^3 on a site with a measured sediment generation of 4.5 m^3 might not change the WQ rating but would nevertheless be a measurable improvement.

4.3 Use the WQEE as a Framework for a Cumulative Impact Assessments of Priority Watersheds[7]

With the recognized limitations of the Coastal Watershed Assessment Procedure (CWAP) and Interior Watershed Assessment Procedure (IWAP) as a means of evaluating forestry activities within watersheds, forest development planners need a more effective means of evaluating how their operations impact water quality for drinking water and fisheries. The Equivalent Clearcut Area (ECA) is still the most popular concept for watershed assessment employed almost universally by hydrological investigations since 1995. The ECA is well known and almost universally adopted as a standard benchmark to measure hydrological impacts in community watersheds; however, it rarely leads to practical operational recommendations. With a broadly based, systematic provincial database now completed using the WQEE protocol, managers can pinpoint issues that have been observed to impact water quality in priority watersheds. Issues identified by the WQEE are easily recognized and quantified on the ground, as are solutions to recognized problems.

4.4 Be Aware of the Limitations of the WQ Data

The FREP WQ database, as it is presently collected, is unsuited for establishing spatial or temporal trends in management for licensees, districts, or regions. The random location of sample sites, the low sampling densities, the highly variable landscape, and the diversity of road networks and their management in BC limit any trend analysis. This constraint can be overcome by implementing targeted, recurring evaluations focussing on priority watersheds.

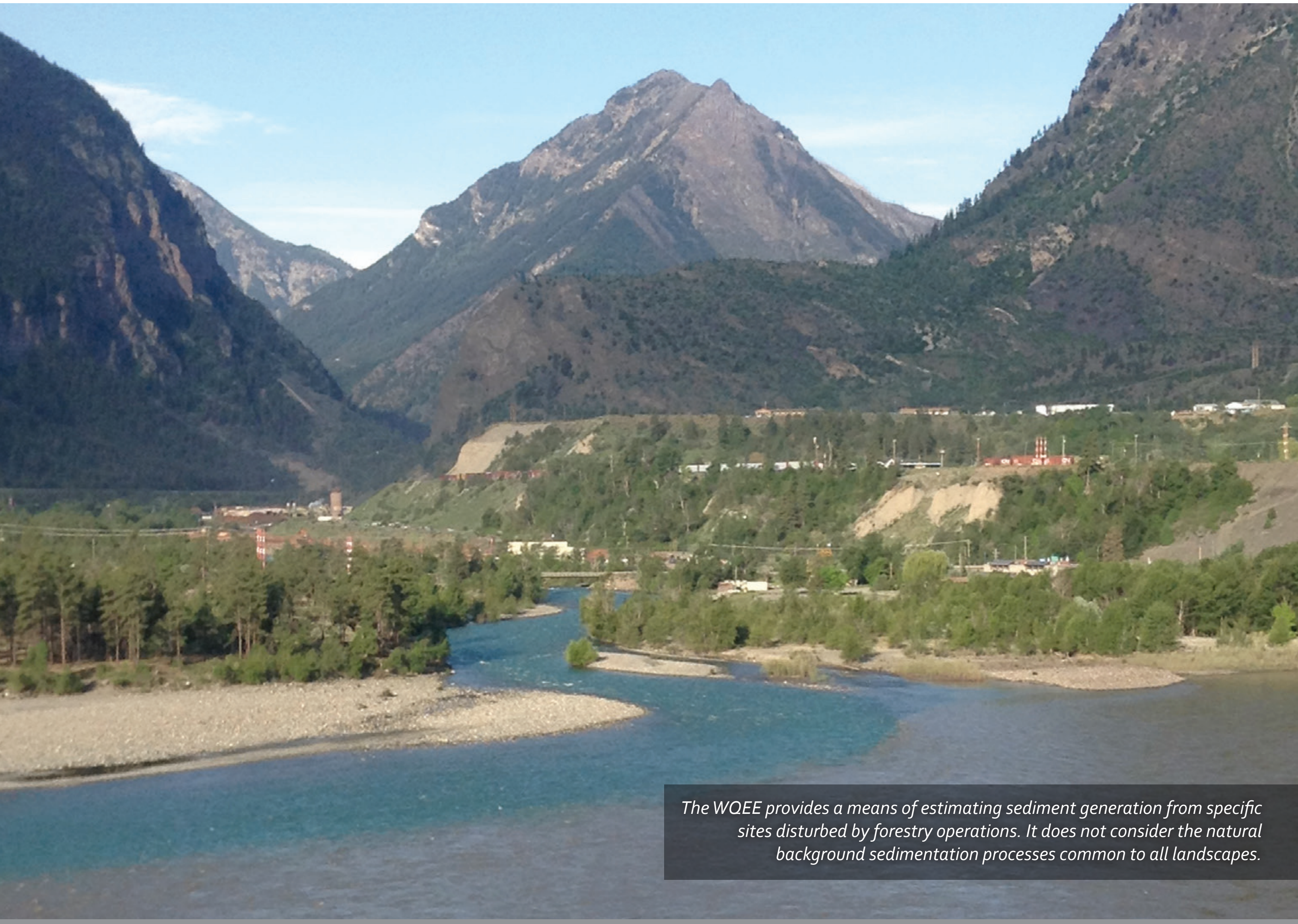
The original purpose of the FREP WQEE protocol was to evaluate whether formal government environmental objectives mandated by the existing regulatory framework were being met. Thus, the evaluation was not designed, nor is it particularly useful for assigning responsibility to specific agencies for observed water quality impacts. The present road licensee may have neither the responsibility nor the authority to address the reason the road is generating high levels of fine sediment. A historically badly located, designed, and constructed road may cause long-term liabilities for water quality but be outside the responsibility of the present road permit holder. The heaviest traffic generated on an industrial road may be unrelated to activity of the forest industry. The licensee may have done an excellent job implementing a deactivation plan on a road but since deactivation, recreation users may have re-opened the road and destroyed the erosion control structures that had been installed. In other cases, the Province may have primary responsibility for a road used by licensees, therefore evaluators must be cautious about assigning responsibility for any site generating excess sediment. However, one area where the licensee or road permit holder is clearly responsible for road sediment generation is during the design and new construction phases and the condition

7 A FLNRORD draft report dealing with cumulative impacts of water quality on watersheds is presently under review.

with which the new road is left to "harden up". A road manager must also take responsibility for the management and maintenance of their active haul roads.

Because of these concerns, district reports should be written with a clear understanding of the limitations of the FREP sampling procedure as a "Report Card". The evaluation is not meant to initiate compliance and enforcement[8] actions. The report card evaluation associated with a site, a road, or a district should be solely viewed as a report on whether long-term government policy has met the objective of maintaining water quality. Recommendations for improved management will be given but how and by who they are implemented will depend on other factors. There may be instances where clearer delegation of responsibility and authority to a road permit holder might be required to avoid confusion when conflicts arise. Rewriting of regulations associated with letting of road contracts might be appropriate. In any case, the solution to the range of water quality impacts encountered requires a more integrated approach to overall watershed management.

[8] Although some of the WQEE tools may be invaluable to a C&E officer to calibrate water quality impacts.



The WQEE provides a means of estimating sediment generation from specific sites disturbed by forestry operations. It does not consider the natural background sedimentation processes common to all landscapes.

5.0 APPENDICES

Appendix 1 – Abbreviations of regions and districts

South Coast (RSC)

DSC	Sunshine Coast
DSQ	Sea to Sky
DCK	Chilliwack

Skeena (RSK)

DKM	Coast Mountains
DSS	Skeena Stikine
DND	Nadina

Northeast (RNO)

DFN	Fort Nelson
DPC	Peace

Omineca (ROM)

DMK	Mackenzie
DNS	Stewart Nechako
DPG	Prince George

Thompson-Okanagan (RTO)

DKA	Thompson Rivers
DCS	Cascades
DOS	Okanagan Shuswap

Cariboo (RCB)

DQU	Quesnel
DCC	Cariboo- Chilcotin
DMH	100 Mile House

Kootenay-Boundary (RKB)

DSE	Selkirk
DRM	Rocky Mountain

Appendix 2 – Further reading on the Water Quality Effectiveness Evaluation

http://www.for.gov.bc.ca/ftp/hfp/external/!publish/FREP/extension/FREP_Extension_Note_12.pdf

http://www.for.gov.bc.ca/ftp/hfp/external/!publish/FREP/extension/FREP_Extension_Note_29.pdf

The following website will be upgraded for the 2021 field season:

https://www2.gov.bc.ca/gov/content/industry/forestry/managing-our-forest-resources/integrated-resource-monitoring/forest-range-evaluation-program/frep-monitoring-protocols/water-quality

Appendix 3 – Examples of simple district reports generated with an iPad

District staff are increasingly being asked to prepare simple rapid reports. Data presented here can be generated almost instantaneously directly from an iPad and emailed to interested parties. The figures in this appendix show iPad screenshots to illustrate what can be generated using the WQEE App. Additionally there is a link to a tutorial video showing how to complete this under the 'Video Tutorials' section in the WQEE Field App 2021.

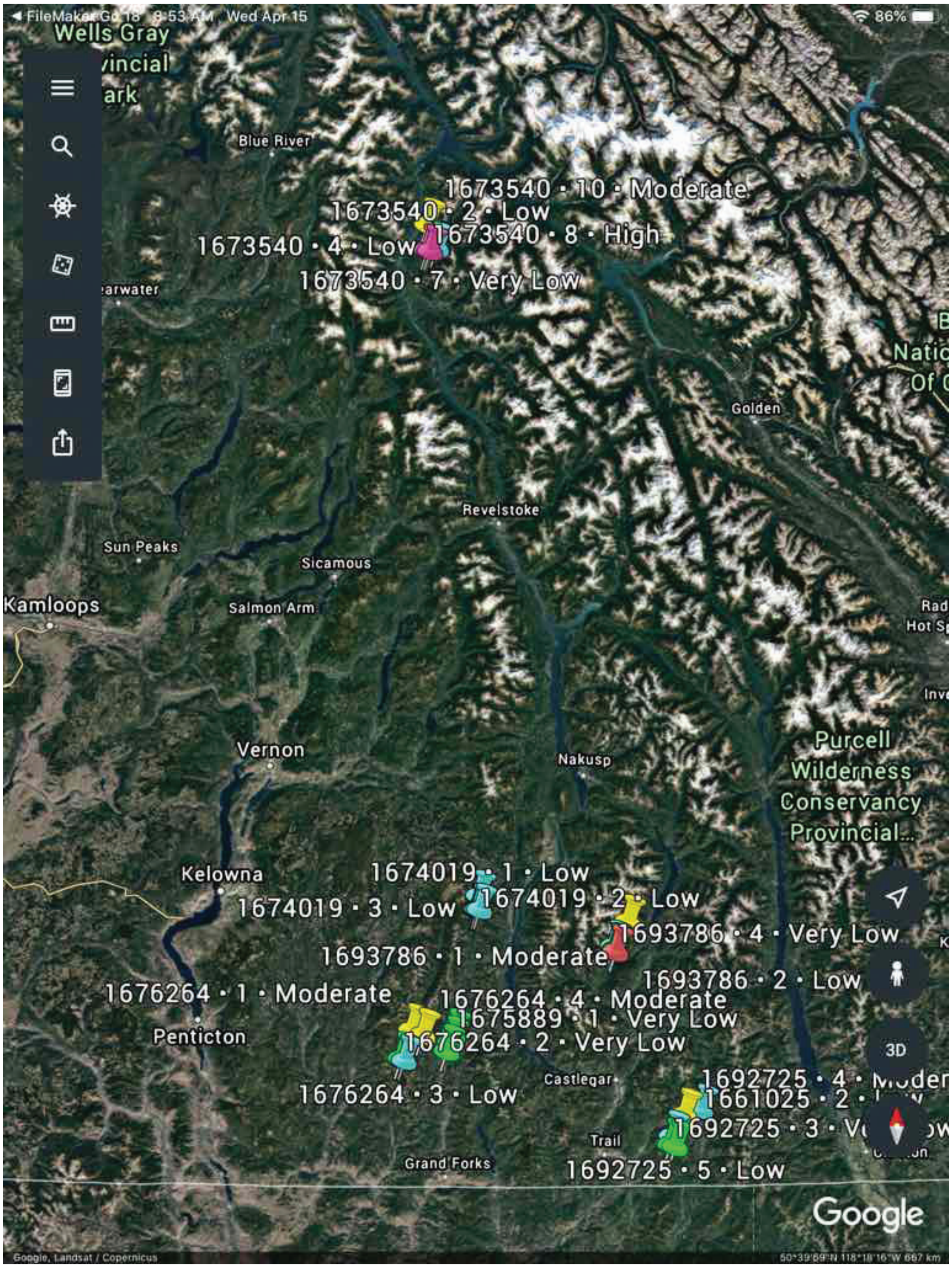


Figure A3.1. *KML file plotted on Google Earth of all FREP water quality sites evaluated in 2019 (34) in the Selkirk District. (Green, Very Low; Blue, Low; Yellow, Moderate; Red, High).*

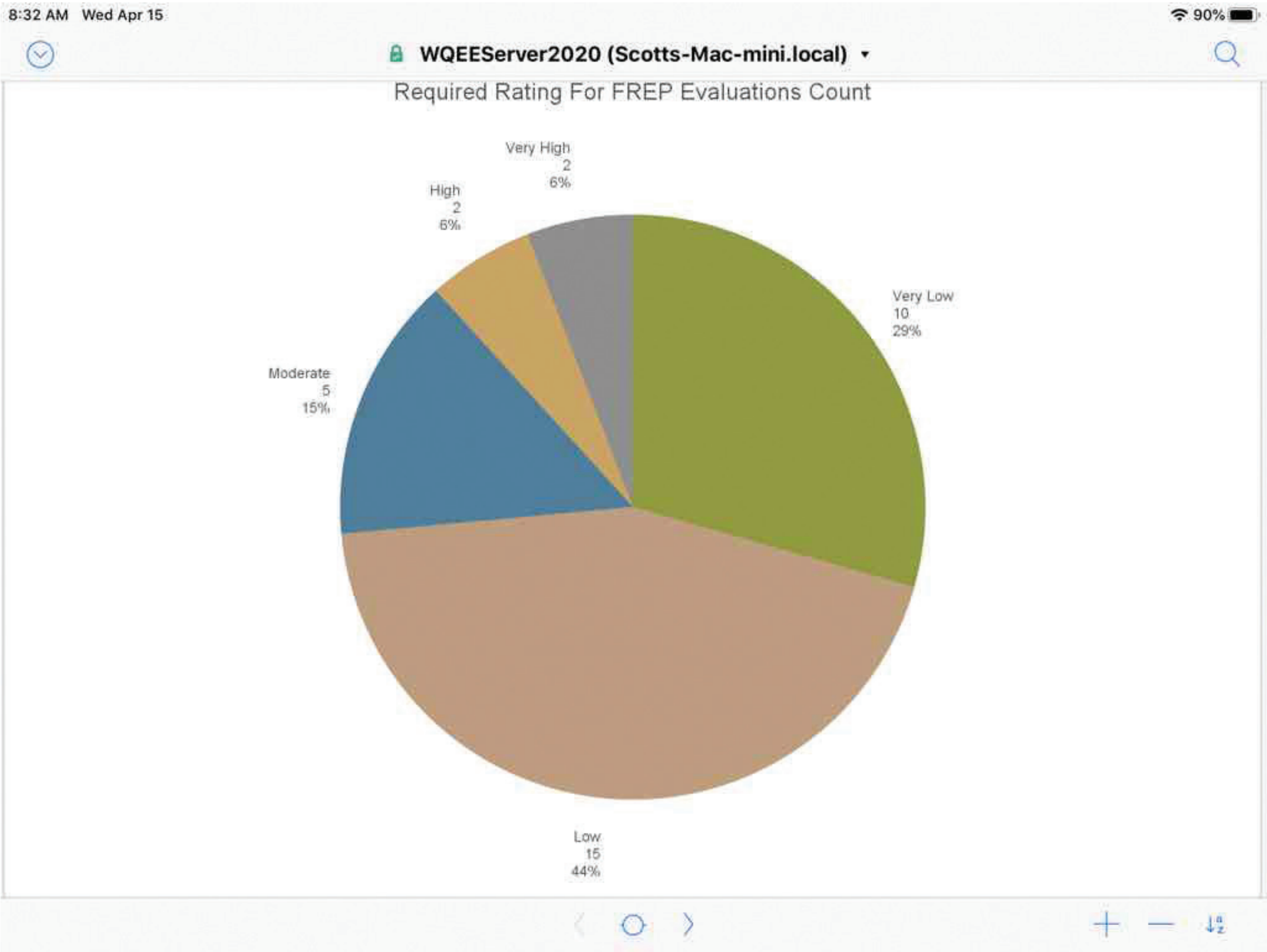


Figure A3.2. *Breakdown of ratings for all 34 water quality sites evaluated in 2019 in the Selkirk District.*

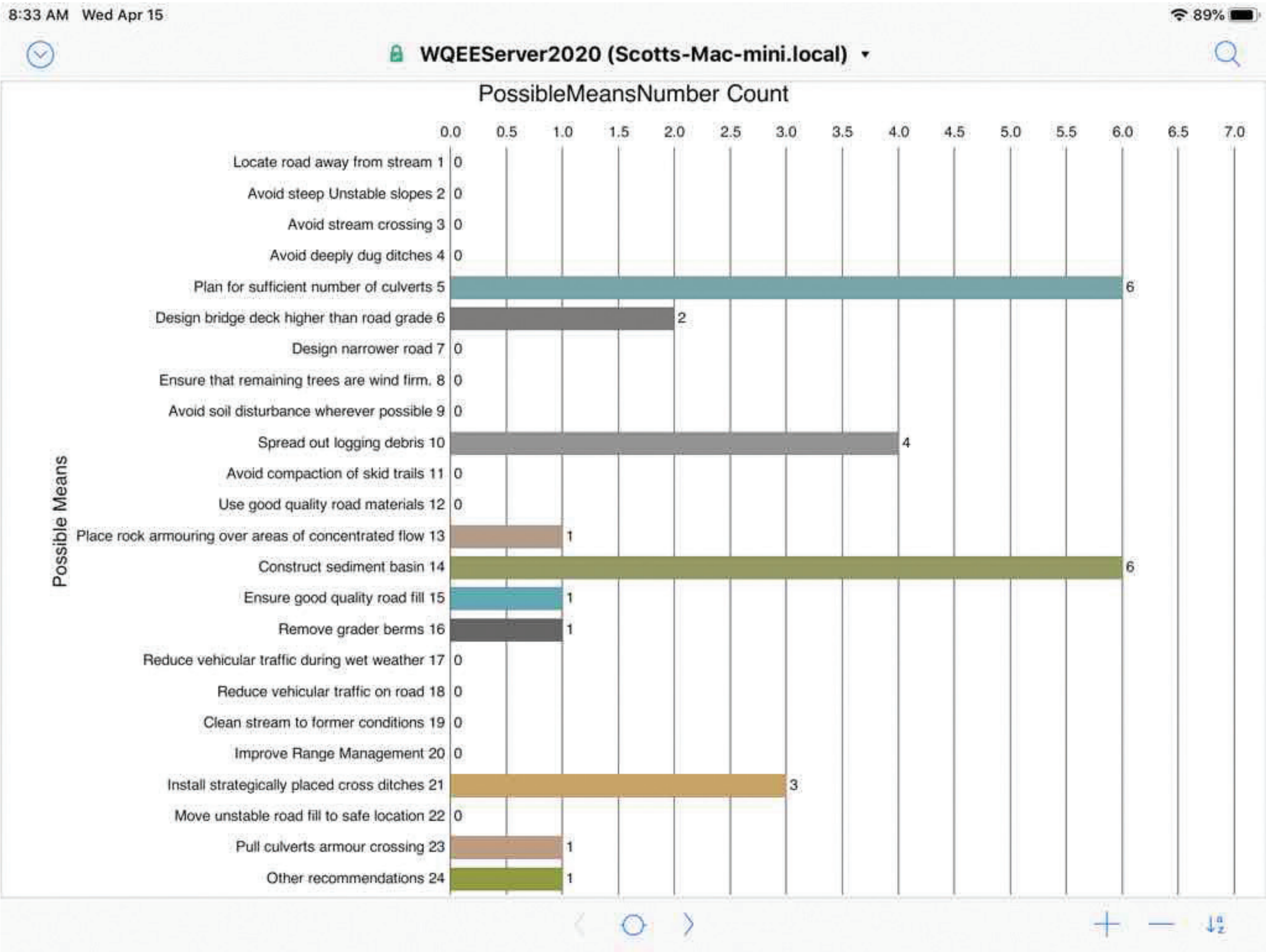


Figure A3.3. *Chart showing recommendations given for sites where the water quality rating was 1m³ or higher for fine sediment generation (Selkirk District 2019 data).*

Figure A3.4. *This map shows a transect initiated with a starting point at cutblock 1673540 with all 10 sites evaluated during this transect (DSE, 2019).*

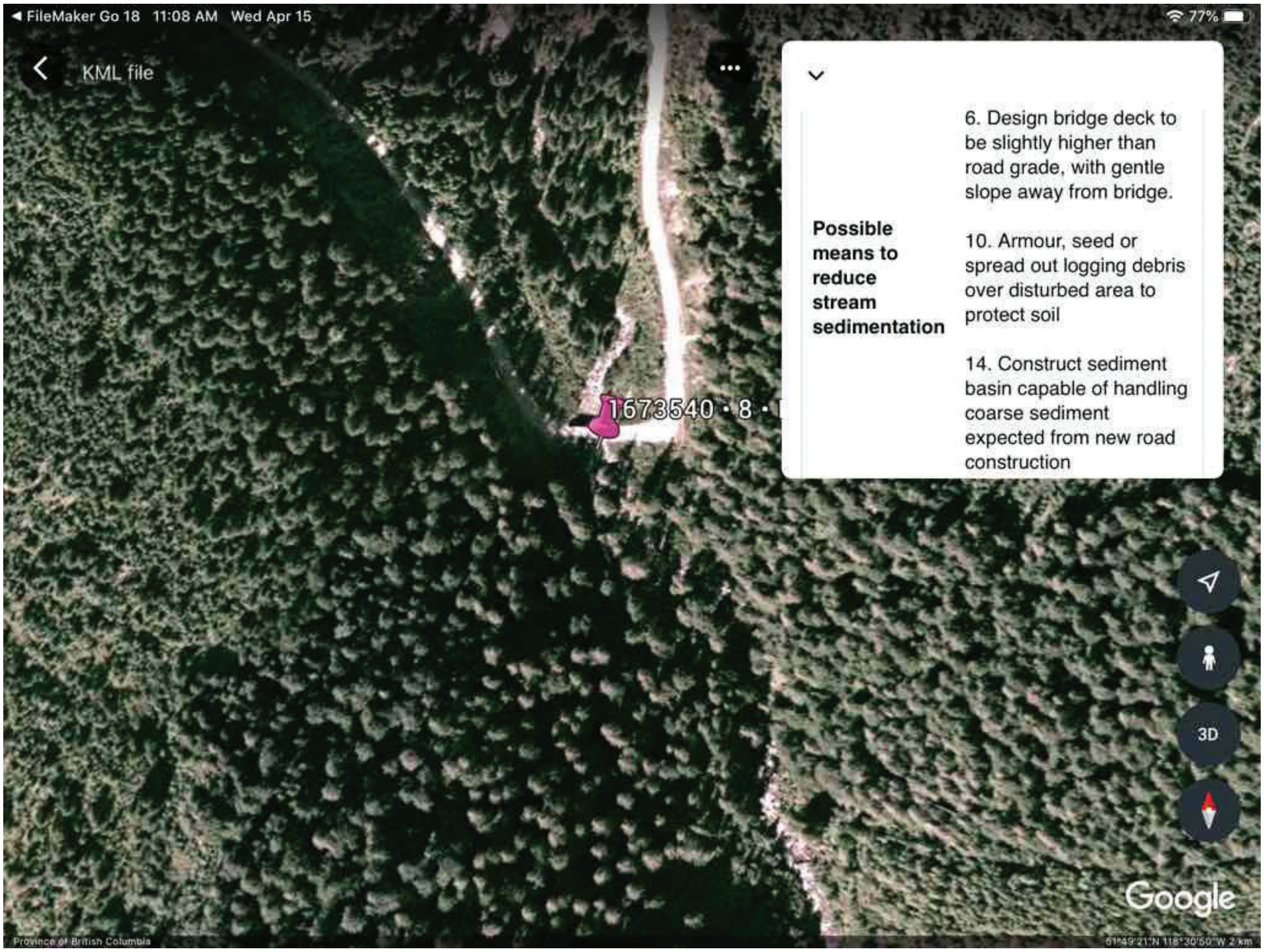


Figure A3.5. *Focusing on site 8 within the transect. The pin denotes a "High" water quality rating. Tapping on the site brings up more information on recommendations to reduce the sediment load (or prevent the problem from happening elsewhere).*

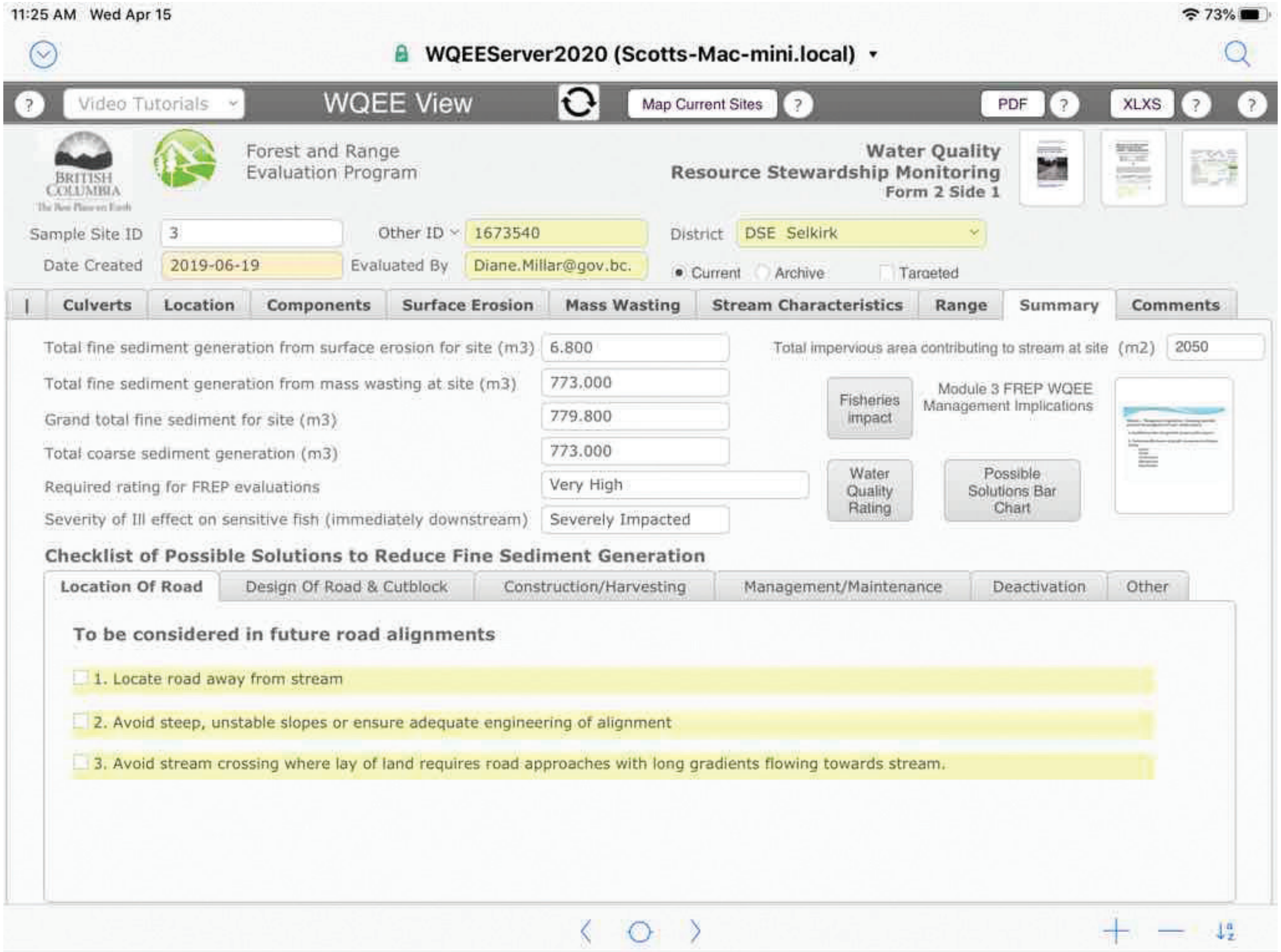


Figure A3.6. *A view of field data on site 3 from the WQEE App that specifies the nature and characteristics of the site leading to a fine sediment rating.*

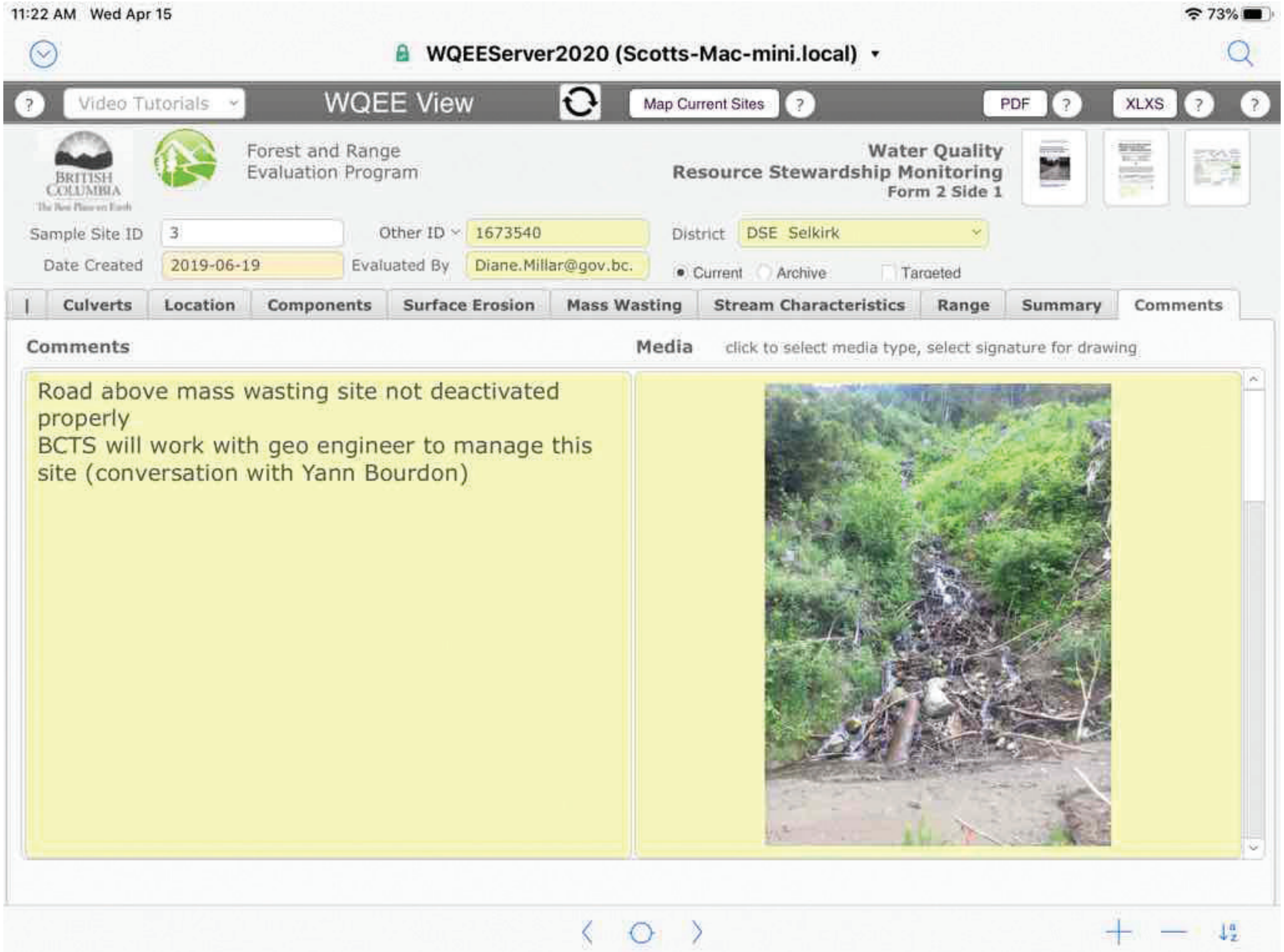
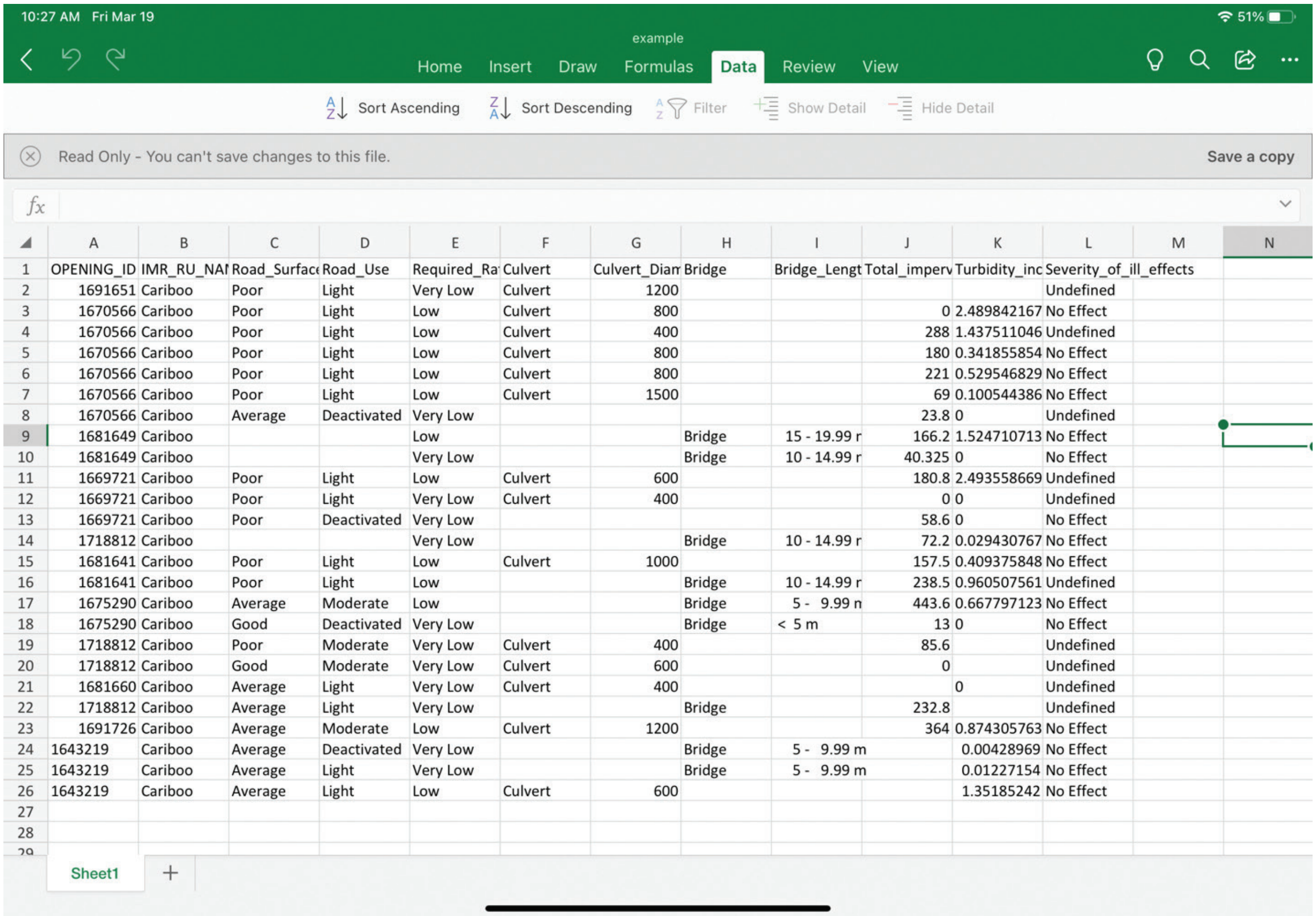


Figure A3.7. *Photographs of a site can be retrieved from the iPad database. The photograph substantiates severe disruption to the stream by a landslide on site.*



	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	OPENING_ID	IMR_RU_NAI	Road_Surface	Road_Use	Required_Ra	Culvert	Culvert_Diam	Bridge	Bridge_Lengt	Total_imperv	Turbidity_inc	Severity_of_ill_effects		
2	1691651	Cariboo	Poor	Light	Very Low	Culvert	1200					Undefined		
3	1670566	Cariboo	Poor	Light	Low	Culvert	800			0	2.489842167	No Effect		
4	1670566	Cariboo	Poor	Light	Low	Culvert	400			288	1.437511046	Undefined		
5	1670566	Cariboo	Poor	Light	Low	Culvert	800			180	0.341855854	No Effect		
6	1670566	Cariboo	Poor	Light	Low	Culvert	800			221	0.529546829	No Effect		
7	1670566	Cariboo	Poor	Light	Low	Culvert	1500			69	0.100544386	No Effect		
8	1670566	Cariboo	Average	Deactivated	Very Low					23.8	0	Undefined		
9	1681649	Cariboo			Low			Bridge	15 - 19.99 r	166.2	1.524710713	No Effect		
10	1681649	Cariboo			Very Low			Bridge	10 - 14.99 r	40.325	0	No Effect		
11	1669721	Cariboo	Poor	Light	Low	Culvert	600			180.8	2.493558669	Undefined		
12	1669721	Cariboo	Poor	Light	Very Low	Culvert	400			0	0	Undefined		
13	1669721	Cariboo	Poor	Deactivated	Very Low					58.6	0	No Effect		
14	1718812	Cariboo			Very Low			Bridge	10 - 14.99 r	72.2	0.029430767	No Effect		
15	1681641	Cariboo	Poor	Light	Low	Culvert	1000			157.5	0.409375848	No Effect		
16	1681641	Cariboo	Poor	Light	Low			Bridge	10 - 14.99 r	238.5	0.960507561	Undefined		
17	1675290	Cariboo	Average	Moderate	Low			Bridge	5 - 9.99 n	443.6	0.667797123	No Effect		
18	1675290	Cariboo	Good	Deactivated	Very Low			Bridge	< 5 m	13	0	No Effect		
19	1718812	Cariboo	Poor	Moderate	Very Low	Culvert	400			85.6		Undefined		
20	1718812	Cariboo	Good	Moderate	Very Low	Culvert	600			0		Undefined		
21	1681660	Cariboo	Average	Light	Very Low	Culvert	400				0	Undefined		
22	1718812	Cariboo	Average	Light	Very Low			Bridge		232.8		Undefined		
23	1691726	Cariboo	Average	Moderate	Low	Culvert	1200			364	0.874305763	No Effect		
24	1643219	Cariboo	Average	Deactivated	Very Low			Bridge	5 - 9.99 m		0.00428969	No Effect		
25	1643219	Cariboo	Average	Light	Very Low			Bridge	5 - 9.99 m		0.01227154	No Effect		
26	1643219	Cariboo	Average	Light	Low	Culvert	600				1.35185242	No Effect		
27														
28														

Figure A3.8. *For more detailed analysis, all data can be selectively sorted and quickly converted to an Excel spreadsheet. This spreadsheet shows a portion of data for sites evaluated in 2020 in DCC. For more detailed analysis, pivot tables can easily be generated.*

BRITISH COLUMBIA

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