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Mountain pine beetle and salvage harvesting influence on small stream riparian zones

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Abstract

We investigated the influence of the mountain pine beetle infestation and salvage harvesting on small stream and riparian zone ecological function, shade, and temperature. Small streams (less than a 2 m bankfull width) were selected because they are the most prominent stream type within a watershed and they determine many ecological characteristics of larger downstream channels. Due to their prominence, they are also the most frequently encountered channel type during forest-harvesting activities, and they have no legislated riparian reserve zones. Riparian areas within the pine-dominated watersheds studied here were primarily comprised of spruce, whereas upland areas were comprised of pine.

Field assessment of 39 small streams (n = 19 control and 20 treatment) indicated that grey attack channel reaches had properly functioning riparian areas and streams, whereas salvage-harvested areas were functioning with some level of impairment. Shade levels were significantly lower in harvested areas, which allowed greater light penetration compared to the higher-shade mountain pine beetle-affected streams. Air temperature was also significantly higher above streams with salvage-harvested riparian zones. Stream temperature, in contrast, showed a variable response. Small streams of groundwater origins did not exhibit significant differences in warming trends between control and treatment reaches. Small streams with surface-water origins, such as those from lakes and wetlands, exhibited a significant decrease in cooling in harvested reaches compared to their control reaches.

Keywords: mountain pine beetle, small streams, riparian zone, retention, aquatic ecology, temperature, habitat

Résumé

Nous avons étudié l’influence de l’infestation de dendroctone du pin ponderosa (DPP) et de la coupe de récupération sur la fonction écologique, l’ombrage et la température des zones riveraines et des petits cours d’eau. Les petits cours d’eau (< 2 m de largeur à pleins bords) ont été choisis parce qu’ils constituent le type de cours d’eau le plus fréquent dans un bassin versant et déterminent de nombreuses caractéristiques écologiques des canaux plus grands en aval. Étant donné leur domination, ils sont aussi le type de cours d’eau rencontré le plus fréquemment durant les activités de déforestation; ils n’ont pas de zone riveraine juridiquement réservée. Les zones riveraines des bassins versants dominés par les pins étudiés étaient principalement peuplées d’épinettes, tandis que les zones des hautes terres étaient occupées par les pins.

L’évaluation sur le terrain de 39 petits cours d’eau (19 soumis au contrôle et 20 soumis au traitement) a indiqué que les tronçons au stade gris avaient des zones riveraines et un débit corrects, tandis que les zones de coupe de récupération fonctionnaient avec une certaine difficulté. L’ombrage était bien plus faible dans les zones de coupe, ce qui permettait une pénétration de la lumière plus importante que dans les secteurs plus ombragés touchés par le DPP. La température de l’air était aussi bien plus élevée au-dessus des cours d’eau dont les zones riveraines avaient subi une coupe de récupération. La température de l’eau, en revanche, montrait des réactions variables. Les petits cours d’eau issus des eaux souterraines ne montraient pas de différence significative de chaleur entre les tronçons contrôlés et les tronçons traités. Les petits cours d’eau issus d’eaux de surface, par exemple des lacs et des zones humides, montraient un rafraîchissement nettement moins important dans les tronçons de coupe que dans les tronçons contrôlés.

Mots clés : dendroctone du pin ponderosa, petits cours d’eau, zone riveraine, rétention, écologie aquatique, température, habitat

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1 INTRODUCTION

This research identifies how small streams and their riparian zones are affected by the mountain pine beetle (MPB) infestation and salvage harvesting in British Columbia. The current MPB epidemic in British Columbia began in the late 1990s and had spread to over 14 million hectares (around 50% of merchantable pine) by 2008. At the current rate of spread, it is estimated that 80% of the mature pine in British Columbia will be dead by 2013 (BCMoFR 2008). Accelerated harvesting has been the primary strategy to slow the spread of the beetle and recover the greatest economic value from the dead timber before it burns or decays. Although upland areas contain the majority of beetle-killed timber, riparian forests also contain infected trees, providing rationalization for their harvesting. The question remains whether the beetle infestation is significant in riparian zones and if removing this infected timber from the riparian zone will adversely affect the stream and riparian zone.

Small streams comprise up to 60%–80% of the total channel length within a watershed (Shreve 1969). They play a significant role in the stream continuum by contributing organic matter, nutrients, and energy to downstream environments and their aquatic communities (Vannote et al. 1980). Accordingly, the disturbance of small stream riparian forests through infestation and harvesting is an important issue because these small stream riparian forests contribute to overall watershed health and are the most commonly encountered stream type during forest development. The Forest and Range Practices Act (2002) allows complete harvesting of riparian zones of small fish-bearing streams—less than a 1.5 m bankfull width according to Forest Planning and Practices Regulation (FPPR) Sec. 47(4)—as an approved activity in a forest stewardship plan (FSP).

The beetle infestation of riparian pine stands and/or subsequent riparian harvesting can alter riparian structure by changing microclimate conditions, decreasing litterfall to streams, and opening previously shaded streams to higher levels of direct solar radiation. To address the likelihood of this scenario occurring over the expansive sub-boreal spruce (SBS) biogeoclimatic ecological zone (BEC) in the Northern Interior Forest Region, a series of investigations were initiated to identify riparian stand structure and the influence of the mountain pine beetle and salvage harvesting on riparian zones and small streams. The initial studies described here were implemented in the Vanderhoof Forest District because it was already heavily affected by the beetle and had correspondingly seen increased levels of salvage harvesting.

This project assesses post-beetle and salvage-harvesting influences on small stream and riparian function, shade, and air and water temperature, including:

1. identifying current levels of stream and riparian function as well as air and water temperature in beetle-affected and recently salvage harvested small stream watersheds.
2. identifying retention strategies for these beetle-susceptible sites and addressing the potential for small stream riparian zones as sites for retention at the stand and landscape scale identified in the Chief Forester's document (Snetsinger 2005).

To meet these objectives, we addressed the following research questions:

- What is the small stream riparian zone structure in beetle-affected watersheds?
- How is the mountain pine beetle influencing small stream riparian zone overstorey?
- How does beetle-affected riparian overstorey alter stream ecology?
- How does salvage harvesting influence or alter small stream ecology?
- What level of riparian retention is required to minimize the effect of salvage harvesting?

2 MATERIALS AND METHODS

2.1 Basal Area Study

To assess riparian-stand structure, basal-area studies were completed in unharvested riparian zones of 45 small streams, 15 in each of the SBSmc (2/3), SBSdw (2/3), and SBSdk biogeoclimatic zones in 2006/07 (Figure 1). The forest cover of these sites was identified as pine leading by the Vegetation Resources Inventory database (VRI). For each stream, field-based basal area estimates were gathered along four transects perpendicular to the stream channel, spaced at 50-m intervals along a representative reach 200 m in length. Sample plots were located along each transect 0 m, 10 m, and 20 m from the channel bank as well as an upslope location outside the riparian zone. At each plot, tree species were identified and basal-area measurements were made with a BAF-7 prism. Basal-area values across sites and distance from the stream were compared using an analysis of variance (ANOVA) of arc-sin transformed basal area data assuming a randomized block design with distance from the stream acting as blocks and tree type as the main plot factor.

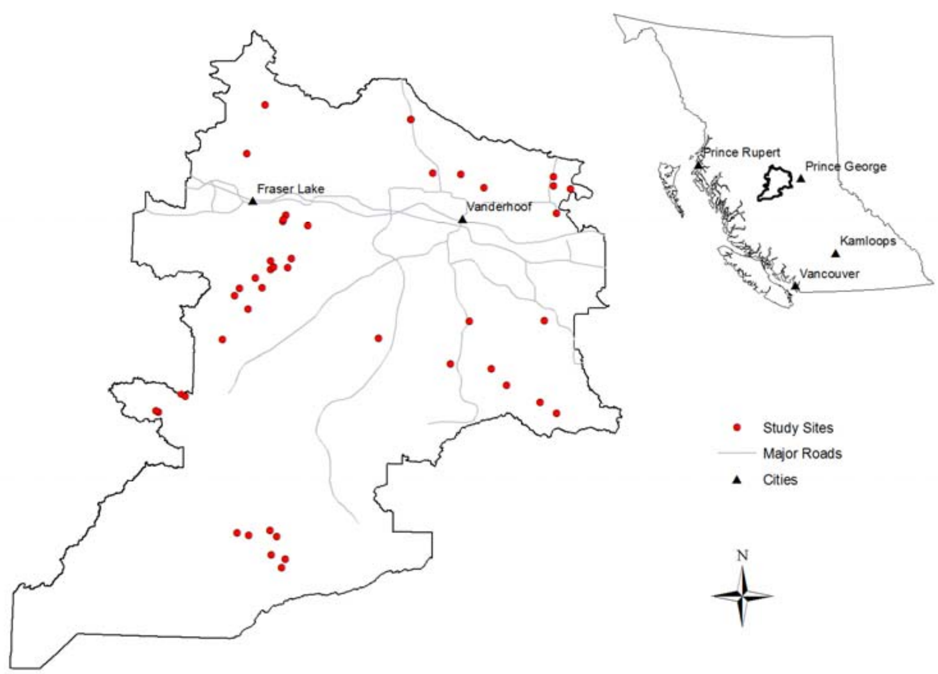

Figure 1. General location map for the 45 small streams basal area surveys conducted in 2006/07 within the Vanderhoof Forest District.

2.2 Small Stream and Riparian Zone Study

2.2.1 Site selection

Study sites used for the small stream and riparian zone study were selected from the 45 small-stream watersheds used during the basal-area study. Each of these watersheds was reviewed by air photo inspection and GIS interpretation to select similar channel reaches that were in beetle-attack polygons (control) and salvage harvesting polygons (treatment). Following office review, approximately 25 candidates were observed in the field, from which 18 were selected. The 18 watersheds selected had well-established channels that were expected to flow perennially. Seventeen of the watersheds had at least one treatment and control reach that was 150 m or longer, while one had a control reach that was at least 150 m long. The treatment reaches were within or adjacent to recent cutblocks (less than five years) and most control reaches were immediately upstream of a treatment reach. When a control reach was not available upstream of the treatment reach, a control stream with similar stream/riparian characteristics near the treatment reach was selected. Treatment streams of various buffer widths were chosen, ranging from 3 m to greater than 40 m. Streams with the narrowest buffers were typically smaller systems with easily accessible riparian zones, while those with wider buffers were generally larger and/or below a topographic break such as a below a terrace or in a gully.

Three of the 17 treatment/control watersheds had two treatment stream reaches because two separate streams were within harvested areas, bringing the total treatment stream sample size to 20. One of these three watersheds had two proximal control streams, bringing the total control reach sample size to 19 (Figure 2). Each stream reach was assessed using the Routine Riparian Effectiveness Evaluation (RREE) procedure, shade estimation, and temperature monitoring.

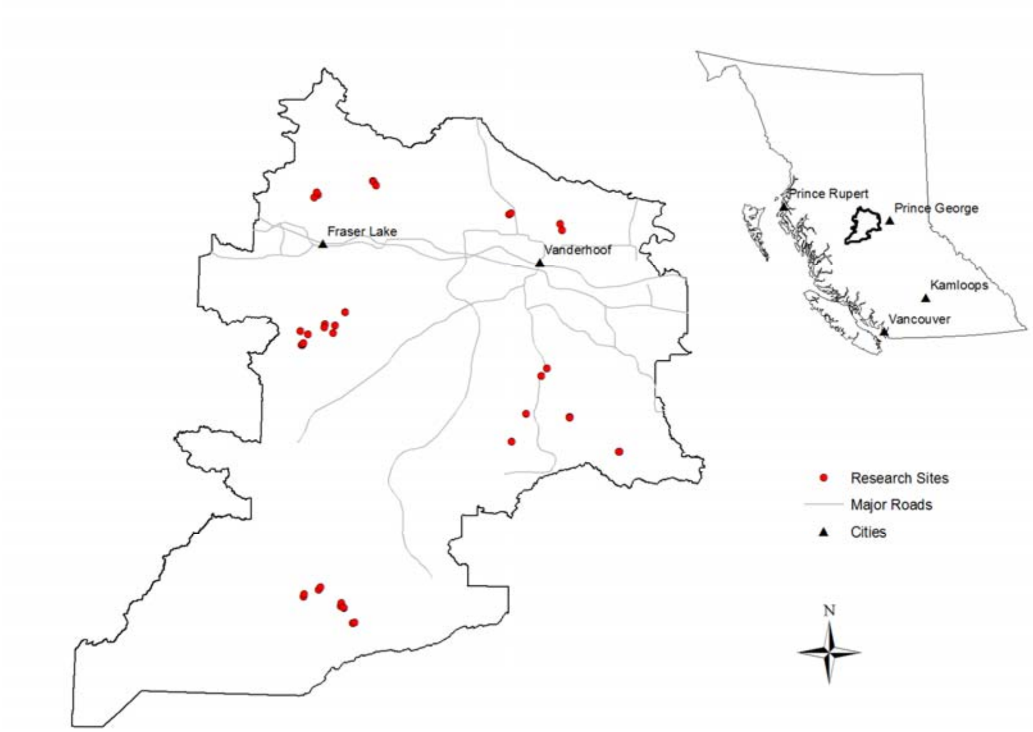

Figure 2. General location of the 2008 small stream study reaches in the Vanderhoof Forest District.

Note: Research sites overlap due to map scale, so 39 markers are not visible.

2.2.2 Routine riparian effectiveness evaluation

The Routine Riparian Effectiveness Evaluation (RREE) was used to assess the level of ecosystem function for each stream reach (Tripp et al. 2007). A properly functioning stream, wetland, or lake and its riparian area is defined as the ability of that system to:

(1) withstand normal peak flood events without experiencing accelerated soil loss, channel movement, or bank movement;

(2) filter runoff;

(3) store and safely release water;

(4) maintain the connectivity to and among fish habitats in streams and riparian areas so that these habitats are not lost or isolated as a result of management activity;

(5) maintain an adequate riparian root network or large woody debris (LWD) supply;

(6) provide shade and reduce bank microclimate change.

Small-stream and riparian-zone function was assessed in 2008 for the 18 small-stream watersheds using the RREE protocol (Tripp et al. 2007). The RREE is a monitoring strategy developed for and employed by the Forest and Range Evaluation Program (FREP) to identify if harvesting practices meet the sustainable management goals set forth in the British Columbia Forest and Range Practices Act (FRPA). The RREE protocol requires the measurement of 15 principal indicators by answering either "yes" (pass) or "no" (fail) questions that guide the user toward a recommendation on the relative health and functionality of a stream and its riparian area. Specifically, the protocol requires that nine stream indicator and six riparian zone indicator questions are answered. To familiarize the reader with these indicators an abridged explanation from Nordin et al. (2009) is provided.

STREAM INDICATOR QUESTIONS

Question #1 • Is the channel bed undisturbed?

Disturbance such as aggradation or degradation can simplify a stream channel and reduce productive fish habitat. Impacts from logging can cause either too much sediment (e.g., from eroding roads or collapsing banks) or too little (traps caused by log jams or inappropriately sized culverts). Either situation will result in a less complex morphology characterized by a reduction in pools and a more uniform channel depth. Attributes that may lead to a failure for this indicator question include mid-channel bars, sediment wedges, multiple channels and lack of lateral bars.

Question #2 • Are the channel banks intact?

Forest harvesting can alter the amount and type of vegetation on stream banks, thereby reducing resistance to fluvial erosion. Disturbed banks contribute fine and/or coarse sediments to the stream. Fine sediments fill in void spaces between gravels and affect invertebrate diversity and fish-spawning potential. Coarser sediments cause channel aggradation and can lead to a reduction of pools and possible dewatering. Attributes that may lead to a failure for this indicator question include notable bank disturbance; the absence of deep-rooted vegetation; the lack of stable, undercut banks; and recently upturned root wads.

Question #3 • Are channel LWD processes intact?

Large woody debris (LWD) in the stream channel provides fish habitat, regulates sediment transfer, and controls channel morphology. Impacts from harvesting can be gauged by examining the type, abundance and position of LWD accumulations. Attributes that may lead to a failure for this indicator question include abundant post-harvest LWD, excessive accumulations which span the channel, parallel LWD in the stream, and removal of LWD by equipment or weather events.

Question #4 • Is the channel morphology intact?

Pools and riffles are important to fish streams. Reducing either one by harvesting activities diminishes fish habitat. Attributes that may lead to a failure for this indicator question include lack of pools, absence of deep pools (twice the riffle depth), and sediment texture homogeneity.

Question #5 • *Are all aspects of the aquatic habitat sufficiently connected to allow for normal, unimpeded movements of fish, organic debris, and sediments?*

In addition to logging, harvest-related structures can cause excessive aggradations, log jams and other obstructions to fish, which can compromise their use of important habitat. Roads contribute sediment to streams, and roads without proper drainage systems can directly block habitat. Improperly installed or inadequately sized culverts can constrict flow, and create velocity barriers and/or insurmountable jumps for fish. Inadequately sized bridges can be a bottleneck for LWD and sediment movement. Built-up sediment often leads to dewatering or downcutting, further impeding fish passage. Attributes that may lead to a failure for this indicator question include recent blockages, downcutting, crossing structure related accumulations, dewatering, and channel diversion.

Question #6 • *Does the stream support a good diversity of fish-cover attributes?*

Fish-cover diversity indicates an undisturbed stream with a well developed riparian area. Although actual amounts of cover can vary, a properly functioning system rarely has fewer than five types. Attributes that may lead to a failure for this indicator question include fewer than five of the following seven kinds of fish cover: deep pools, boulders, organic material, undercut banks, aquatic vegetation, overhanging vegetation and a stable mineral substrate with void spaces.

Question #7 • *Does the amount of moss in the substrate indicate a stable and productive system?*

The relative abundance of a healthy growth of moss can be linked to fish and invertebrate productivity. The presence of moss in vigorous condition indicates moderate flows, clean water, a stable streambed, sufficient shading and adequate nutrient levels. If any of these qualities are altered, the abundance or health of moss will decline. Attributes that may lead to a failure for this indicator question include absence or poor condition of moss.

Question #8 • *Has the introduction of fine inorganic sediments been minimized?*

Fine-textured sediment can influence the spawning and rearing habitat for fish by filling in the spaces between gravels and blanketing the substrate. Invertebrate habitat will also be affected and sensitive species (those with external gills) will be limited. Attributes that may lead to a failure for this indicator question include the abundance of fines, single large areas of particularly soft patches of sediment, embedded substrate, and the absence of sensitive invertebrates.

Question #9 *Does the stream support a diversity of aquatic invertebrates?*

Invertebrates are sensitive to sand, silt, toxic compounds and pollutants, and are good indicators of a healthy stream with clean water. The number of invertebrates is less important than the diversity of species considering that a larger community requires a wider range of stable environmental conditions. When harvesting impacts cause large fluctuations in water temperature or turbidity, species numbers will decline until only those that can adapt persist. Attributes that may lead to a failure for this indicator question include low numbers of sensitive invertebrate species, major invertebrate groups, insects, and the total invertebrate species.

RIPARIAN INDICATOR QUESTIONS

Question #10 *Has the vegetation retained in the riparian management area been sufficiently protected from windthrow?*

Windthrow in the riparian area over and above what is naturally expected is a direct sign of an ineffectively managed zone. The objective of reserve and management zones is to protect riparian areas from excessive windthrow and retain key wildlife attributes. Extensive windthrow in the riparian area can compromise the integrity of the stream bank, the functioning condition of the stream and the health of the aquatic and terrestrial biota. Attributes that may lead to a failure for this indicator question include: more post-treatment windthrow than naturally occurs and the absence of functional wildlife trees.

Question #11 • *Has the amount of bare, erodible ground or soil disturbance in the riparian area been minimized?*

Soil disturbance includes both bare and disturbed (vegetated) ground. Soil exposed by harvesting is usually present on spur roads, skid trails, recent root wads, and old landings, and can also result from recent hillslope slides and slumps. Areas of bare soil can erode and add sediment to streams. The bare ground also reduces the ability to filter and regulate runoff, and it helps disturbance-increaser plants get established. Disturbed ground is similar in that it is also compacted and sheds water rapidly, but it is more resistant to erosion because it is vegetated. Disturbed ground can result from mechanical or animal disturbance and includes pugging, hummocking, vegetated deactivated roads and heavy equipment tracks, animal trails, and paved surfaces. Attributes that may lead to a failure for this indicator question include both bare and disturbed ground within 10 m of the channel bank or otherwise hydrologically connected to the stream.

Question #12 • *Has sufficient vegetation been retained to maintain an adequate root network or LWD supply?*

The root network is considered an essential criterion because it is the major contributor to bank stability. LWD is important not only for fish, but also to maintain channel form and function. Although harvesting may inadvertently increase woody debris in the stream in the short term, removing too much riparian vegetation will eventually cause a shortage of LWD. It can take decades for a new plantation to provide woody contributions to the channel. Until then, the stream will remain LWD poor. Attributes that may lead to a failure for this indicator question include the absence of vegetation within 5 m for bank-root network and insufficient woody debris supply.

Question #13 • *Has sufficient vegetation been retained to provide shade and reduce bank microclimate change?*

Streamside vegetation is necessary to mitigate direct impacts of storm events as well as to moderate stream bank and water temperatures. Harvesting or intensive grazing can remove the protection provided by riparian vegetation and open the canopy to expose the stream to weather and temperature fluctuations. Attributes that may lead to a failure for this indicator question include bare ground exposed to rain, insufficient shade, the absence of moisture-loving plant species, and hot or dry soil.

Question #14 • *Have the number of disturbance-increaser species or noxious weeds been limited to a satisfactory level?*

Disturbance–increaser and invasive plant species often thrive in disturbed areas. These plants are typically shallow-rooted and suppress the growth of natural deep-rooted vegetation. Once established, the shallow-root systems cannot provide adequate root networks for channel bank strength. Most of these species lack sediment-trapping capabilities and have low value as wildlife forage. Attributes that may lead to a failure for this indicator question include the abundance of disturbance-increaser plants and noxious weeds (species lists are provided in protocol).

Question #15• *Is the riparian vegetation within 10 m of the stream edge characteristic of nearby healthy unmanaged riparian plant communities?*

A healthy riparian area is one that contains a diversity of trees, shrubs, herbaceous plants and ground cover (mosses, lichens) in vigorous condition and in various age classes. Intensively managed riparian areas may still contain trees, but the structural diversity associated with a typical unmanaged forest is absent. Similarly, structural diversity will be diminished if heavy browsing or grazing has reduced or eliminated the shrub or ground-cover layer. Attributes that may lead to a failure for this indicator question include absence of major vegetation layers, poor health, form or recruitment of vegetation, and the occurrence of heavy browsing or grazing.

To answer the above questions, 53 observations and/or measurements were made (Appendix 1). These continuous and point measurements were taken along the 150 m homogenous channel section referred to as the sample reach. Attribute measurements were compared to specific threshold values that led to a “yes” or “no” answer (i.e. pass/fail) for the indicator question. The thresholds represented values expected for undisturbed conditions (Tripp et al. 2007). Conversely, the LWD supply and riparian vigour/structure questions did not have measurements specific to them and indicator responses were based on field observations of the vegetation. The number of indicator “no” answers in the evaluation determined the overall level of functioning condition of the site according to the following guidelines:

- properly functioning condition (0–2 failed indicators),
- properly functioning but at low risk (3–4 failed indicators),
- properly functioning but at high risk (5–6 failed indicators), and
- not properly functioning, (> 6 failed indicators).

RREE final scores for each site were ranked for comparison among sites using Pearson’s Chi-Square test as 1 - properly functioning, 2 - low risk, 3 - high risk, and 4 - not properly functioning.

2.2.3 Spherical angular canopy densiometer

Riparian shade measurements were collected along each treatment and control reach using the spherical angular canopy densiometer (ACD)—see Teti and Pike (2005). Measurements were made at 10 equally spaced locations along the 150 m sample reach while facing south with the ACD approximately 1 m above the stream surface (Figure 3). Angular canopy densiometer measurements provide an estimate of canopy density between 10 a.m. and 2 p.m. solar time in August, when solar radiation is highest (Teti and Pike 2005). Angular canopy densiometer data was compared among sites by averaging the 10 measurements (a percentage between 0 and 1) collected along each stream reach. Stream-reach averages were arc-sin transformed and then compared between harvested and control sites as well as across BEC zones using a two-way ANOVA (Sokal and Rohlf 1995).

2.2.4 Air temperature and light

Air temperature and light levels were recorded at 1 h intervals within 0.5 m of the stream surface using Hobo Pendant Loggers (accuracy 0.47˚C; resolution 0.10˚C at 25˚C). Air temperature data were collected at all 39 sites; light was measured at only 35 sites due to available equipment. Air temperature and light data were taken at 20% and 80% of the total reach length (Figure 4). Data loggers were mounted on top of wooden stakes to ensure light sensors faced upward (Figure 5).

The data from these loggers were used to identify how buffer presence and/or width moderates air temperature and light penetration to the stream surface. Light data were summed and averaged for each reach to provide an average daily accumulation, and daily median values were also determined. Daily median, maximum, and minimum air temperatures were also calculated for each reach. Some probes experienced more heating than others because they were in open areas. As a result of this positive bias for some probes, maximum air temperatures were not used to compare sites. Instead, average daily median and minimum temperature values were compared across sites and treatment conditions using a general linear model (GLM) approach in SYSTAT 11. Median air temperatures were used instead of mean values because they are less affected by the extreme values caused by preferential heating (Sokal and Rohlf 1995).

Figure 3. Shade measurement using the spherical angular canopy densiometer at one point along a small stream control reach, August 2008.

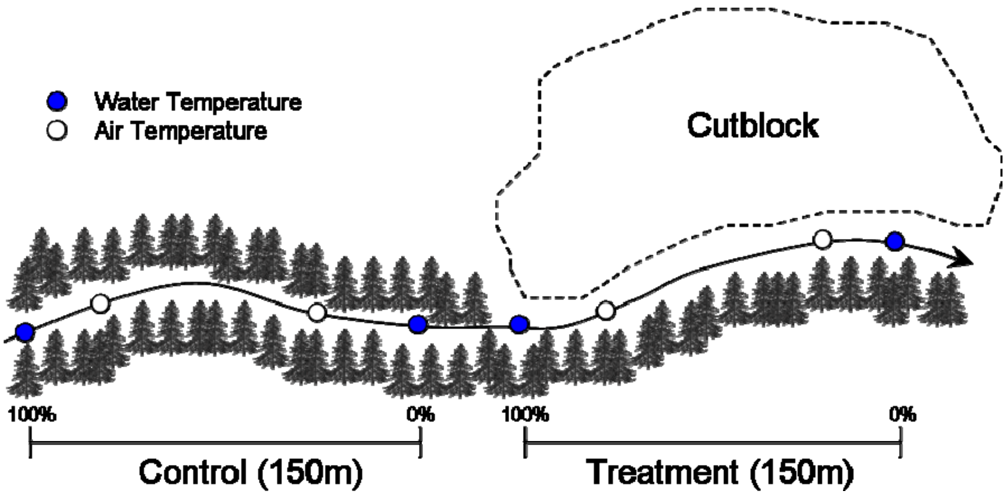

Figure 4. Field deployment of air and water temperature probes in an upstream-control reach and a downstream-treatment (cutblock) reach. Water-temperature probes deployed at 0% and 100% and air temperature/light probes at 20% and 80% of reach length.

Figure 5. Field deployment of Hobo Pendant Logger on top of a stake approximately 50 cm above the stream surface, August 2008.

2.2.5 Stream temperature

Stream temperature was recorded in 15-minute intervals between May and October 2008 using Onset StowAway Tidbit™ v2 temperature loggers (accuracy 0.2˚C; resolution 0.02˚C at 25˚C). Temperature loggers were installed at 0% and 100% of reach length as identified in Figure 4. Loggers were placed in deep channel sections such as a deep run or pool inside a solar shield to reduce preferential heating of the probes in open areas (Figure 6).

Stream temperature was compared between upstream and downstream locations and between treatment and control reaches to identify whether stream temperature was influenced by adjacency to harvested areas. Daily values, mean weekly maximum, and the difference between downstream (DS) and upstream (US) temperatures were calculated. Several of the study streams experienced very low flow and/or dry periods during the monitoring period. Data that were abnormally high due to low water volumes were removed prior to statistical analysis.

Average daily median, minimum, and maximum stream temperatures were compared using a GLM in Systat 11. Mean weekly maximum temperature (MWMT) was calculated for the most upstream and downstream locations of each treatment and control reach. Reach average values of MWMT were compared across streams and conditions using GLM. The MWMT index was selected because it is more biologically meaningful than analyzing daily maximum temperatures (Wilkerson et al. 2005). MWMT is used to gauge the potential for cumulative effects on fish, occurring when maximum temperature criteria are repeatedly exceeded over a brief period.

Figure 6. Field deployment of Tidbit™ temperature logger and solar shield in a pool, August 2008.

3 Results

3.1 Basal Area Study

The riparian zone within 10 m of the channel bank is predominantly composed of spruce regardless of the BEC zone (Table 1, Figure 7). ANOVA results identified:

Significant differences between basal area values for each tree type ($F_{3,\ 117}$ = 40.5 p <0.05). Specifically, pine and spruce comprise the largest proportion of total basal area at all study sites, while deciduous trees and balsam fir comprised a smaller proportion.

A significant difference in basal area with distance from the channel ($F_{3,\ 117}$, = 9.3 p <0.05). Basal area was generally lowest near the channel and increased going upslope.

A significant interaction between distance and tree type ($F_{9,\ 351}$ = 19.1, p <0.05) indicating the riparian zone within 10 m of the channel bank was typically spruce dominant while the 20 m and upslope locations were typically pine dominant (Figure 7).

A significant interaction between BEC zone, distance and tree type ($F_{36,\ 351}$ = 1.6, p <0.05) indicating that while there is typically a transition from spruce dominance closer to the stream and pine dominance further from the stream, the proportions are variable between BEC zones.

Table 1. Total basal area values for study sites in 2006-2007 by BEC zone and tree type 0 m, 10 m, and 20 m from the channel bank, and an upslope location (values reported are percent of total).

BEC	Tree Type	0 m	10 m	20 m	Upslope	N
SBSdw2	Spruce	62	52	30	29	3
	Pine	17	46	55	63	
	Balsam	0	0	15	8	
	Deciduous	21	2	0	0	
SBSdw3	Spruce	37	36	25	18	12
	Pine	6	35	58	76	
	Balsam	1	0	1	0	
	Deciduous	56	29	16	6	
SBSmc2	Spruce	56	36	22	15	8
	Pine	26	55	63	77	
	Balsam	9	0	2	0	
	Deciduous	9	9	13	8	
SBSmc3	Spruce	75	64	30	17	7
	Pine	24	33	60	79	
	Balsam	0	0	5	3	
	Deciduous	1	3	5	1	
SBSdk	Spruce	74	57	48	39	15
	Pine	9	31	39	55	
	Balsam	0	0	0	0	
	Deciduous	17	12	13	6	

3.2 Small Stream and Riparian Zone Study

3.2.1 Routine riparian effectiveness evaluation

Significantly more treatment sites than control sites were functioning with some level of impairment (chi-square = 11.1, d. f. = 3, $p < 0.05$). Generally, control sites were properly functioning and harvested sites ranged between properly functioning and not properly functioning (Figure 8). Harvested sites generally failed for riparian indicators such as shade and bank microclimate, riparian vegetation, fish cover diversity, and LWD supply rather than in-stream indicators. Harvested sites with buffers greater than 10 m generally had better RREE scores because they failed fewer riparian indicators than harvested sites with buffers less than 10 m.

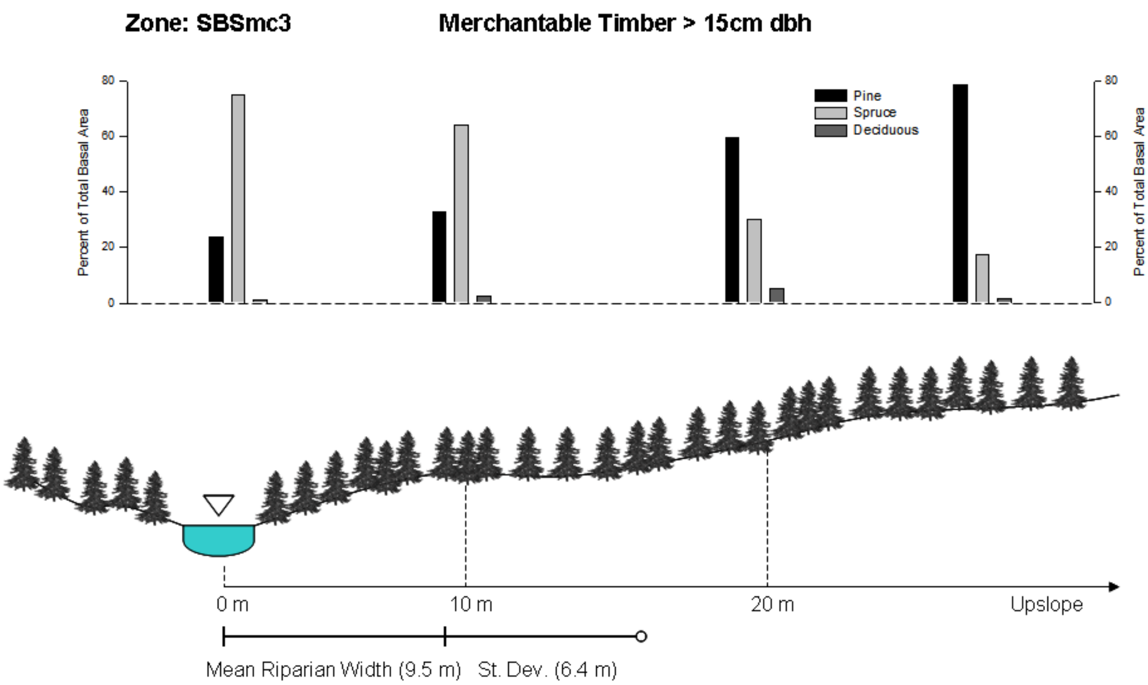

Figure 7. Basal area percent composition by tree type in the SBSmc3 study sites 0 m, 10 m, and 20 m from the channel bank, and at an upslope location (n = 7). Mean riparian width and the standard deviation are also provided.

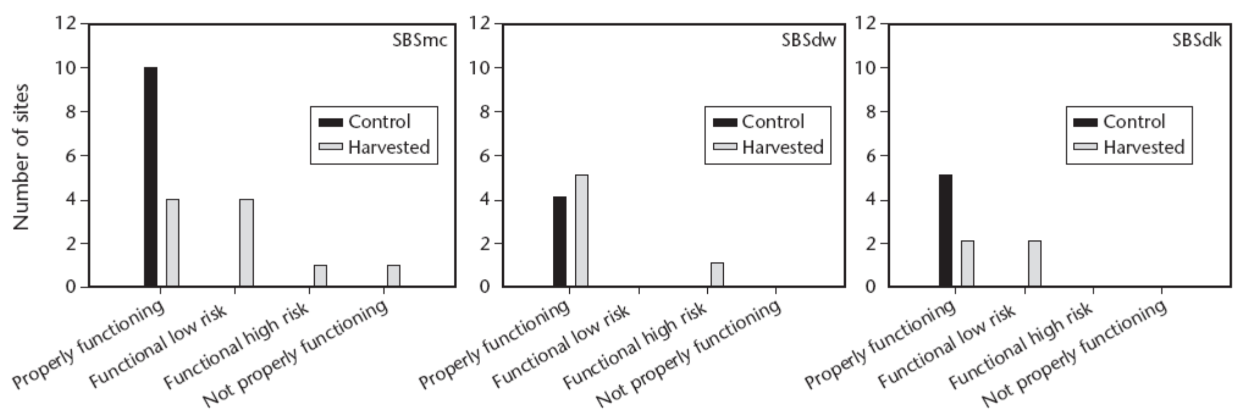

Figure 8. RREE scores for control and harvested sites in the SBSdw, SBSmc, and SBSdk, summer 2008.

3.2.2 Spherical angular canopy densiometer

Control sites had significantly higher ACD levels than treatment sites across all BEC zones (Figure 9, $F_{1,\,29}$ = 6.8, p < 0.05). Although harvested sites generally had lower ACD values, it varied based upon the width of retained buffer zones. The buffer zone width class of 0-5 m had significantly lower ACD values than those of 5-10 m and wider (Figure 10).

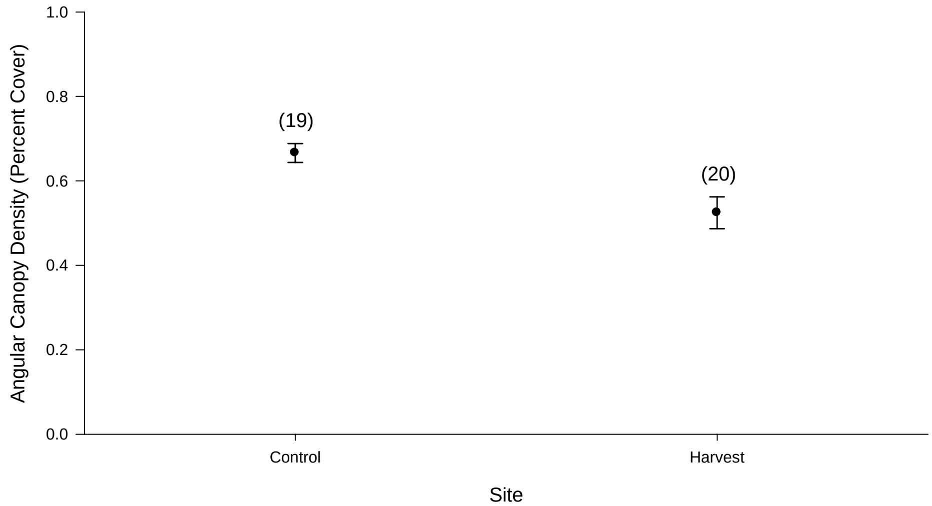

Figure 9. Mean angular canopy density for control and harvested areas in the Vanderhoof Forest District. Error bars represent mean square error (n= 19 control and 20 treatment sites).

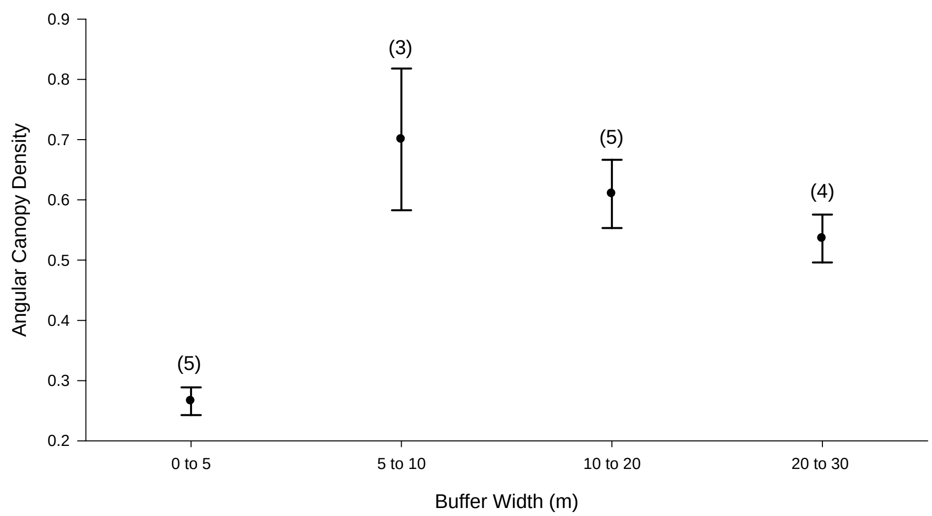

Figure 10. Mean angular canopy density for specified buffer width categories at harvested sites in the Vanderhoof Forest District. Error bars are mean square error and sample numbers are provided in brackets (n = 17 treatment sites, buffer width class 30–40 m (n=2) and > 40 m (n=1) were excluded due to small sample sizes).

3.2.3 Air temperature and light intensity

Median air temperatures were higher and minimum temperatures were significantly lower at harvested sites than control sites ($F_{1, 36} = 6.5$ $p < 0.01$ Figure 11). Treatment sites had higher cumulative light levels than control sites (Figure 12). Buffer width, when divided into four size classes, had an effect on light intensity (Figure 13) and air temperature near a stream's surface. Median daily light intensity and median daily air temperatures were highest for treatment streams with buffer widths less than 5 m (Figures 13, 14). Minimum daily air temperatures were also less for those streams with the narrowest buffer widths.

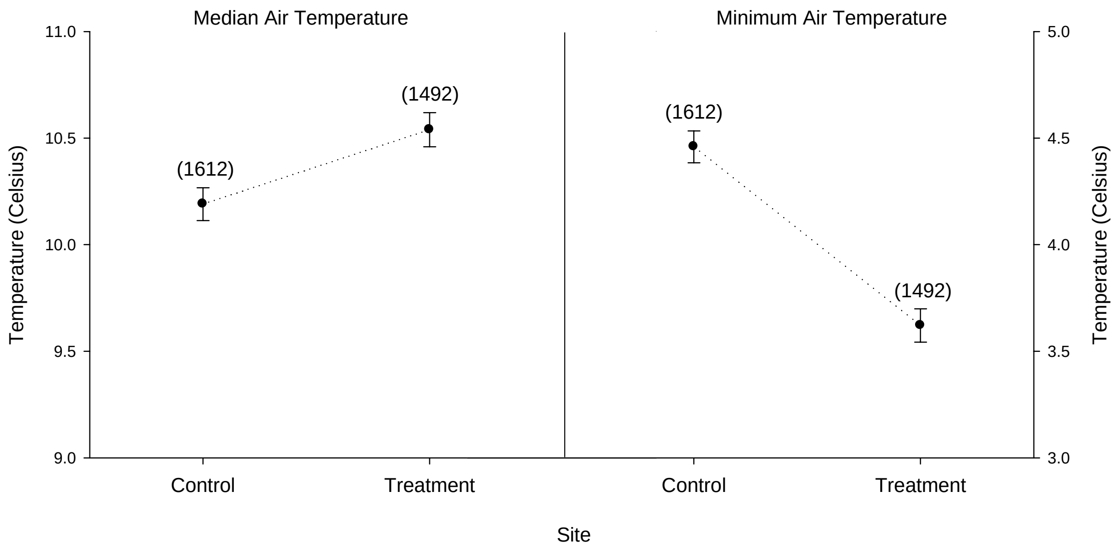

Figure 11. Median and minimum air temperature by site. Error bars represent mean square error. The number of records are included in brackets (n = 19 control and 20 treatment sites).

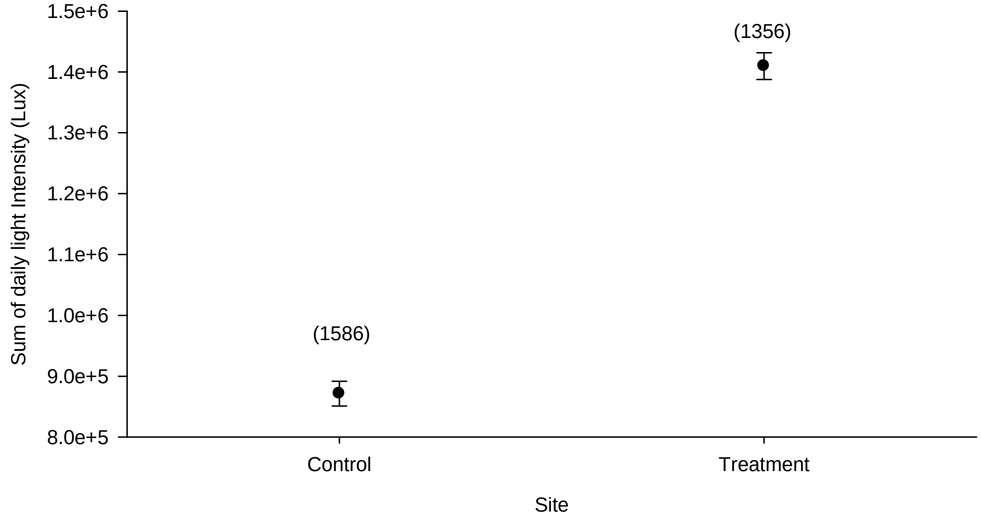

Figure 12. Least square mean estimates of the sum of daily light intensity by site. Error bars are mean square error. The number of records are included in brackets (n = 18 control and 17 treatment sites).

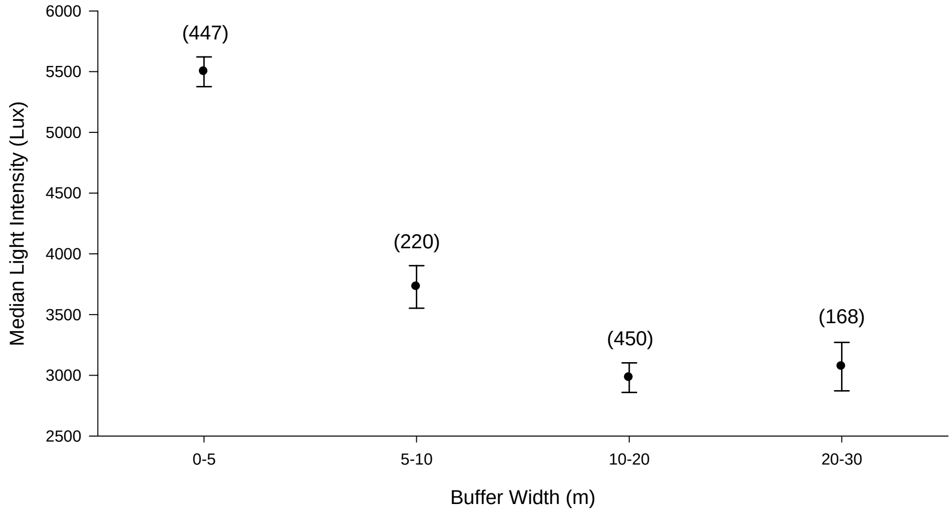

Figure 13. Least square mean estimates of median daily light intensity by buffer width. Error bars are mean square error. The number of records are included in brackets (n = 17 treatment sites).

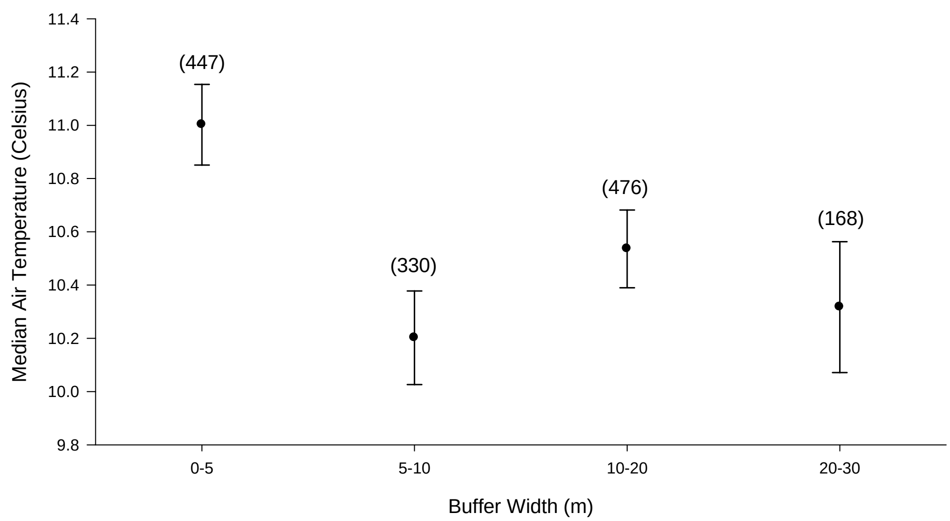

Figure 14. Least square mean estimates of median daily air temperature by buffer width. Error bars are mean square error. The number of records are included in brackets (n = 17 treatment sites).

3.2.4 Stream Temperature

Preliminary analysis identified differences between the thermal regimes of headwater streams (lotic) and streams headed by lentic waterbodies (lakes and wetlands). To address this difference, stream reaches were analyzed according to source water type. Average stream temperatures were significantly warmer ($F_{1, 34} = 8.9$, Tukeys HSD $p < 0.01$) for lentic-headed stream reaches than for lotic-headed reaches. Downstream cooling was most commonly observed in streams headed by lentic waterbodies, while headwater streams generally warmed downstream. Treatment reaches of lentic-headed streams cooled less than control reaches, and temperature increases were not significantly different between treatment and control reaches of lotic-headed streams (Figure 15).

Mean weekly maximum temperature (MWMT) was significantly higher for lentic-headed streams (lakes and wetlands) than for headwater streams ($F_{1, 34} = 10.3$, $p < 0.01$) (Figure 16).

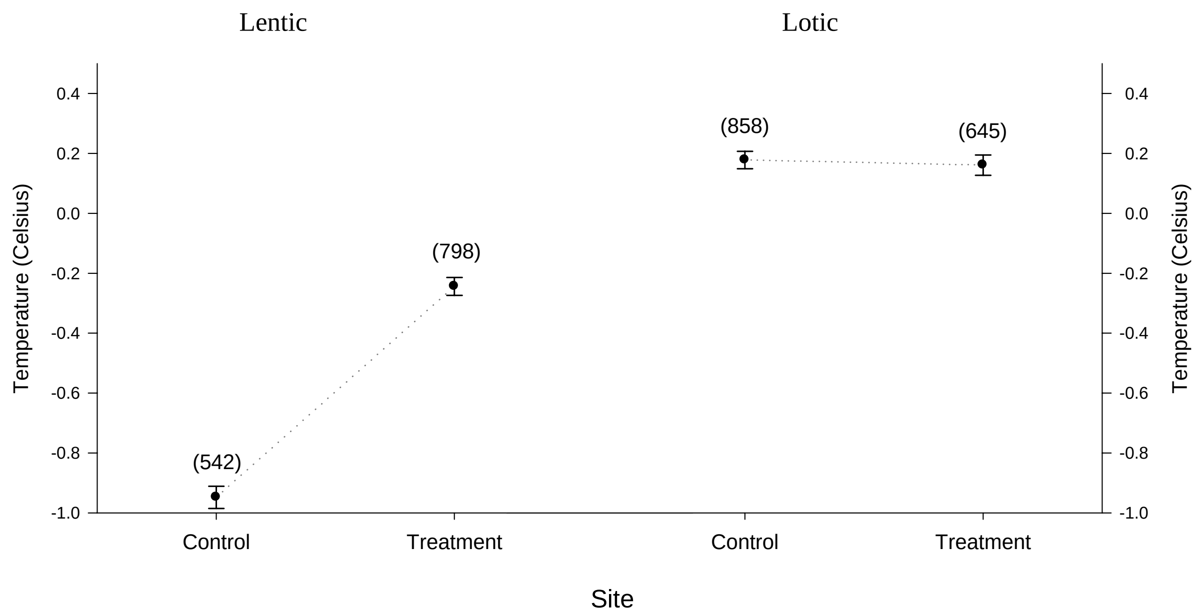

Figure 15. Least square mean estimates of downstream change in maximum daily stream temperature (US-DS) by site. Error bars are mean square error. The number of records are provided in brackets (n= 18 control and 17 treatment sites).

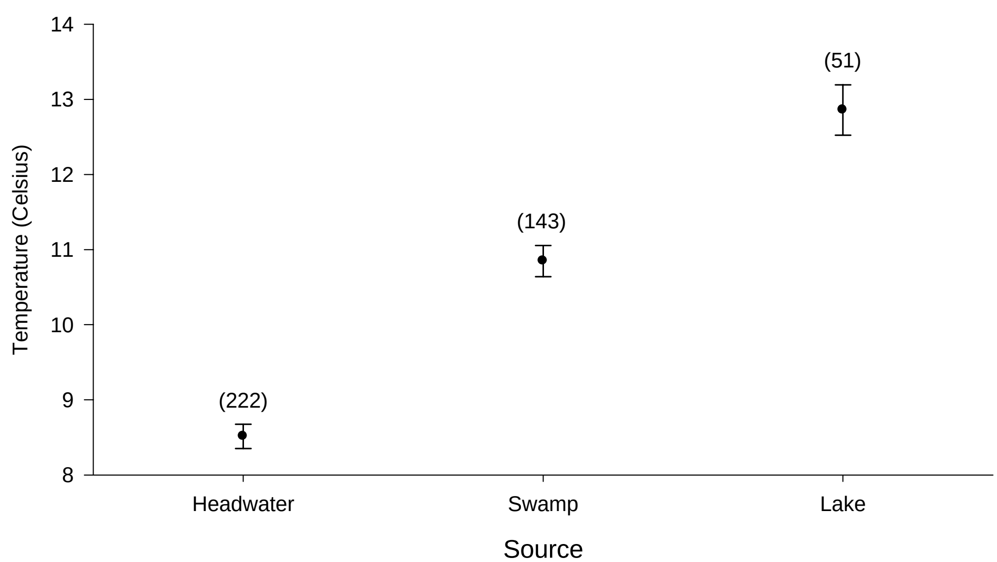

Figure 16. Least square mean estimates of mean weekly maximum temperature (MWMT) by source. Error bars are mean square error. The number of records are provided in brackets (n= 18 control and 17 treatment sites).

4 Project Summary and Management Considerations

The series of studies was designed to address five research questions, answered below.

What is the small stream riparian zone structure in beetle-affected watersheds?

Basal area surveys from 45 small streams study sites in the SBSmc (2/3), SBSdw (2/3), and SBSdk indicate that riparian zones can be predominantly composed of spruce within the first 10 m of the channel bank while upslope areas are comprised of pine. The VRI tree species information at the polygon level did not reflect overstorey riparian composition at the study sites.

How is the mountain pine beetle influencing small stream riparian zone overstorey?

The riparian overstorey at study sites was predominantly spruce so the mountain pine beetle has a minor influence. As observed in the control sites, grey-attack pine within the riparian zone did not negatively influence the riparian zone's functional condition.

How does beetle- affected riparian overstorey alter stream ecology?

Beetle-affected riparian areas were properly functioning as identified by RREE scores. Similarly, shade levels recorded by the ACD were highest in unharvested riparian stands. Light levels and median air temperature were lowest in small streams with unharvested riparian stands, indicating they had higher levels of effective shade than harvested areas despite the presence of beetle-affected pine. Stream temperature response was variable depending upon source-water. Streams that originated from surface-water sources such as lakes and wetlands had higher rates of cooling in reaches with unharvested riparian stands than they did in salvaged areas. In contrast, groundwater-sourced systems generally warmed in a downstream direction and the rate of warming was similar between control and treatment reaches at our study sites.

How does salvage harvesting influence or alter small-stream ecology?

Salvage harvesting in the riparian zone was found to have a variable response on RREE scores depending upon the riparian buffer width retained. Salvage-harvested areas with large buffers (i.e. wider than 10 m) were generally functioning properly or with slight impairment. As buffer width decreased, the level of impairment increased. Reaches that were salvage harvested had lower shade levels and higher levels of light penetration and air temperature than un-harvested areas. Small stream temperature response varied depending upon stream source water.

What level of riparian retention is required to minimize compound effects of the beetle and salvage harvesting?

Findings from this program indicate that small stream riparian zones of beetle-affected watersheds can be dominated by trees other than pine. These small streams and their riparian zones may be functioning properly despite the beetle-affected pine. Salvage harvesting these sites can reduce ecosystem function and shade as well as increase air temperature. Harvesting effects on shade and RREE scores were reduced when buffers were close to or exceeded a 10 m width. As such, retention should be maximized within the first 10 m.

Many studies have shown that harvesting within 10 m of the channel bank alters the riparian environment, increasing the air and stream temperature (Adams and Sullivan 1990; Gomi et al. 2006; Moore et al. 2005), solar radiation (Kiffney et al., 2003), and wind speed and advection from clearings to the riparian zone (Moore et al. 2005a). The diurnal fluctuation of stream temperature is strongly influenced by solar radiation, riparian vegetation, and diurnal fluctuations in air temperature (Adams and Sullivan 1990). Increases in air, soil, and stream temperatures with reductions of relative humidity are typical when riparian zones are harvested (Moore et al. 2005), which can lower the biodiversity value of the riparian zone (Naiman and Décamps 1997).

In accordance with the findings of this study and the literature, it is recommended that riparian retention be increased within the 10 m zone closest to the stream. The data presented here indicate that retention within the 0-5 m zone was ineffective at keeping functional condition and shade levels similar to control (grey-attack) areas. Salvage harvesting within beetle-affected areas should include the retention of sufficient riparian vegetation to maintain stream channel and aquatic habitat function. The 10 m reserve suggested here complements existing best management practices for S4 streams as identified in the Riparian Management Area Guidebook (BC Ministry of Forests 1995). The 10 m riparian reserve should also be considered for substantial non-fish streams that flow directly into fish-bearing streams. If the reserve zone is predominantly composed of dead pine that pose a windthrow risk, selective harvest methods can be used to preserve some pine for short-term LWD recruitment. Further, all non-pine species should be retained and machine-free zones should be established to minimize soil disturbance.

The findings presented here and the riparian retention recommendations made support the retention guidance provided by the Chief Forester regarding potential hydrologic impacts and landscape and stand level structural retention (Snetsinger 2005, 2007). They do so by identifying the value of increasing retention in small stream riparian zones without compromising the intent of salvage harvesting pine for sanitation and forest health purposes.

5 ACKNOWLEDGEMENTS

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8 APPENDIX 1

Routine riparian effectiveness evaluation field cards

BRITISH COLUMBIA — Forest and Range Evaluation Program

Riparian Management Routine Effectiveness Evaluation

Sample No ____________ Date ____________ Evaluator(s) ____________

Stream/Opening Identification

District ____________ Opening ID ____________ Licensee ____________

Licence ____________ Block ____________ Harvest Year ____________

Range Use Plan ____________ Pasture ID ____________

Stream Name ____________ Stream Location In Block ☐ Beside Block ☐

Stream Class on Plans ____________ Stream Class in Field ____________

Reach Location _____ to _____ m US ☐ DS ☐ from ____________

UTM at US ☐ DS ☐ end of reach East ________ North ________ Zone ________

Channel Width(m) ________ Channel Gradient(%) ________ RMA Assessed (looking downstream) L ☐ R ☐ Both ☐

Channel Morphology Rifle-pool or Cascade-pool ☐ Step-pool ☐ Non-alluvial ☐

Riparian Retention Information in RMA (Distance to harvest edge(m)________)

	Dominants & codominants in plans	Dominants & codominants in field	Understory retention in plans	Understory retention in field
% Retention in first 10m of the RMA (all classes)				
% Retention in rest the of the RRZ (for S1,S2, S3)				
% Retention in the rest of the RMZ (all classes)				

Photo Section

Photo #	Photo Description

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Sample No ____________

Field Data

Question No.	Point Indicators (Measure at 6 equidistant points along the reach)							Threshhold	Mean
	Transect No.	1	2	3	4	5	6		
Q7	% Moss							1%	
Q8	% Fines/sands							10%	
Q9	# of sensitive invertebrate types							1	
Q9	# of major invertebrate groups							2	
Q9	# of insect types							3	
Q9	Total # of invertebrate types							4	
Q13	% Shade							60%	
Q14	% Disturbance - increaser species							25%	
Q14	% Noxious weeds							5%	

Number of Different Invertebrate Groups & Types Sampled

"Group"	"Type"	Sensitivity	Transect Number 1	2	3	4	5	6
Insect	# of mayfly types	Yes						
Insect	# of stonefly types	Yes						
Insect	# of caddisfly types	Yes						
Insect	# of midge types	No						
Insect	# of other diptera types	No						
Insect	# of riffle beetle, water penny types	Yes						
Insect	# of other beetle types	No						
Clams	# of clam types	Yes						
Snails	# of right snail types	Yes						
Snails	# of left snail types	No						
Flatworms	Flatworms ("Planaria")	No						
Nematodes	# of nematode types	No						
Worms	# of other "worm" types	No						
Crustaceans	# of crustacean types	No						
Arachnids	# of spider or mite types	No						
	# of "other" types	Unknown						

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Sample No ____________

OTHER INDICATORS TO NOTE

Q1 Channel Spanning Steps (For Step-Pool Channels Only). 50% or more of the boulder steps do or do not span the channel. 25% or more do or do not have moss.

Q1 Sediment and LWD Storage (For Non-Alluvial Channels Only). Sediments and/or LWD do or do not completely fill the channel up to the top of the banks at any point or points together representing more than 5% of the reach length.

Q1 Moss Along the Channel Bed (For Non-Alluvial Channels Only). More than 25% of the channel bed length does or does not have some moss on the substrate.

Q2 Non-erodible Banks. Banks that are non-erodible on both sides of the stream at the same time are or are not present. Thresholds for stable undercut banks or deeply rooted banks are based on the length of erodible banks present only. Base the percent of undercut bank or deeply rooted bank present on total reach length minus the length of non-erobible bank present, if any.

Q3 Main Woody Debris Characteristics. Is the channel woody debris mainly new or old, natural or logging related, across or parallel, intact or not, recently removed or not by hand, catastrophic floods, or debris torrents?

Q4 Surface Sediment Texture. The texture is homogeneous or heterogeneous.

Q4 Steps and Pools (For Step-Pool Channels Only). Cascades lacking steps account for more or less than 25% of the sample reach.

Q4 Plunge Pool Characteristics (For Step-Pool Channels Only). More than 25% of the steps at stone lines do or do not have a plunge pool as deep as the largest rock in the step. More than one step is or is not completely infilled.

Q5 Connectivity is or is not good; i.e., open-bottom structures present or not on fish streams, no temporary blockages, no down cutting, no sediment or debris buildups, no dewatering, overland flow areas not isolated, generally free movements of sediments and debris possible.

Q6 Fish Cover Types Present include deep water, boulders, void spaces, undercut banks, woody debris, aquatic vegetation, overhanging vegetation.

Q8 Fine Sediments. Check if there are any fine or sand-sized sediment deposits that "blanket" the stream anywhere or not, whether the substrate is embedded in sand/fines or not, or whether "quicksand" or "quickgravel" is present or not.

Q13 Bank Soils are cool or warm, moist or dry, unchanged or not. Moisture-loving plants are present or absent, are or are not in good condition.

Q15 Vegetation. All vegetation layers and the structure expected of a healthy, unmanaged forest are or are not present (e.g., gaps, snags, trees, tall shrubs, low shrubs, herbaceous plants, mosses, lichens)

Q15 Vegetation. Is form normal or not, vigor normal or not, recruitment normal or not?

Q15 Browse, Grazing. Heavily browsed shrubs are or are not present. Heavy grazing is or is not present on more than 10% of the available forage.

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Sample No _______________

Field Data

Question No.	Continuous indicators (Measure along the total length of the reach)		Threshhold	Total
Q1	Mid-channel bars, wedges (m, measure all but no overlap)		50% of reach	
Q1	Lateral bars (m, measure all but no overlap)		50% of reach	
Q1	Multiple or braided channels (m, measure all but no overlap)		50% of reach	
Q2	Recently disturbed bank (m, always measure both sides, but no overlap)		10,15% of reach*	
Q2	Stable undercut bank (m, always measure both sides, but no overlap)		50% of reach	
Q2	Deep rooted bank (m, only measure the side(s) affected by the treatment)		65,75% of reach*	
Q2	Upturned bank root wads (m, always measure both sides, but no overlap)		10,25% of reach*	
Q3	Number debris accumulations		NA	
Q3	Number debris accumulations with recent debris		50% of all accumulations	
Q3	Number debris accumulations with recent debris that span the channel		12 per reach	
Q4	Pool length (m)		25% of reach	
Q4	Deep pools (number)		2 per reach	
Q10	Recent windthrow (number)		5% in RRZs otherwise 10%	
Q10	Old windthrow (number)		NA	
Q10	Standing trees (number)		NA	
Q11	Bare soil in first 10m (m^2)		1% of area	
Q13	Bare soil exposed to rain in first 10m (m^2)		1% of area	
Q11	Bare soil hydrologically connected to first 10m (m^2; include with bare soil in first 10m to decide if threshold is exceeded)		5% of area	
Q11	Disturbed ground in first 10m (m^2)		10% of area	
Q11	Disturbed ground hydrologically connected to first 10m (m^2; include with disturbed ground in first 10m to decide if threshold is exceeded)		15% of area	

*Threshold varies depending on channel morphology

Sample No _______________

Notes, Diagrams

Sample No _______________

"TIPS"

Non-Alluvial Channels - In steep areas where the stream gradient is often more than 13%, almost all small S4 or S6 streams will be non-alluvial. This means that the cobbles and boulders in these streams are rarely moved by water. The boulders, cobbles and sometimes even gravel size particles present are typically colluvial materials that are washed out of the bank by the stream. Since they don't move very far after being washed out, they usually have rough or sharp edges. Smaller particles like pea sized gravels, sand or finer sized particles will move downstream as alluvium, but not the larger particles. Because they don't move, these cobbles and boulders frequently have a good growth of moss on them in forested areas. Roots of adjacent trees and tall shrubs are also able to grow across non-alluvial channels. In logged areas, moss may be buried by new sediments or debris.

1. Gravel Bars and Multiple/Braided Channels - Measure the total length of channel present with these indicators, but do not count the length twice where the indicators overlap.

2. Recently Disturbed Banks, Stable Undercut Banks, and Recently Upturned Bank Rootwads - For each of these indicators, determine the total length present on both banks, even if just one side of the riparian area is being assessed. Do not double up on the length of stream affected by these indicators where the indicators overlap.

3. Deep Rooted Banks - Only measure the side(s) with the riparian treatment(s) being assessed. Where both sides of the stream are being assessed, record the length of bank with the least amount of deep rooted vegetation. Deep-rooted banks are vegetated with trees, shrubs and deep rooted grass species, not herbs, forbs, or mosses.

4. Fine Sediments - Fine and sand-sized sediments include inorganic (i.e., mineral) sediments <5mm diameter.

5. Pools and Riffles - Only measure the length of pools that go from bank to bank. Do not measure pools that are small pockets in the middle of riffles or cascades, or that are back eddies or back water pools off to the side. When the boundary between a pool and a riffle is diagonal to the main axis, measure from the center of the diagonal to the next boundary.

Please refer to Figure 5 in the Riparian Protocol

6. Deep pool - To see if you have a "deep" pool, measure pool depth from the deepest part of the pool to the top of the bank (A to B). Then measure riffle depth at the pool/riffle break below the pool from the deepest part of the riffle to the top of the bank (A' to B'). A deep pool needs to be at least twice as deep as the riffle.

Please refer to Figure 6 in the Riparian Protocol

7. "Sensitive" Invertebrates - Stoneflies, mayflies, caddisflies ("case builders"), riffle beetles, clams, Dobson flies ("helgrammites"), snails with the opening on the right when held toward you with the open end of the shell on the bottom.

8. "Major" Invertebrate Groups - Insects, segmented worms (oligochaetes, earthworms, leeches), molluscs (e.g., snails and clams), flatworms, nematodes, spiders and mites, crustaceans (daphnia, water shrimp).

Windthrow calculation:

1) % Old windthrow = (No. Old windthrow X 100)/(No. Old windthrow + No. New windthrow + No. Standing trees).
2) % New windthrow = (No. New wind throw x 100)/(No. New windthrow + No. Standing trees).

To calculate % new windthrow over and above the old windthrow, subtract (1) from (2).

Sample No ______________

Question 1. Is the channel bed undisturbed? (Yes ☐ No ☐)

Note: For Questions 1-4, decide what the predominant channel morphology is and then complete the section for that morphology only (i.e., Part A, B or C, not all three).

A) Riffle-pool or cascade-pool channels

a) Less than 50% of the reach length is occupied by active sediment wedges or mid-channel bars. ☐ ☐

b) Less than 50% of the reach has active multiple channels and/ or braids. ☐ ☐

c) More than 50% of the reach has lateral bars. ☐ ☐

If answer "Yes" to 2 or more, mark Yes box in Question 1

B) Step-pool channels

a) More than 50% of the steps present span the channel. ☐ ☐

b) More than 25% of the steps have moss. ☐ ☐

c) Less than 25% of the reach has active multiple channels and/ or braids. ☐ ☐

If answer "Yes" to 2 or more, mark Yes box in Question 1.

C) Non-alluvial channels

a) Over 25% of the channel bed length has some moss on the substrate. ☐ ☐

b) The channel has space for storage of sediments and debris; i.e., sediment and/or LWD do not fill the channel volume or spill over the banks for any significant distance. ☐ ☐

c) Sediments are widely distributed throughout the channel. Sediments are not stored in a few relatively large compartments (e.g., wedged behind an accumulation of immobile rocks or organic debris). ☐ ☐

If answer "Yes" to 2 or more, mark Yes box in Question 1.

Stream Channel Morphology - General Characteristics for Small to Medium Size Streams

Channel Type	Typical Gradient (%)	Dominant Type of Stones	Main Pool Types
Riffle-pool	0-3	small; gravel and cobbles smoothed by water	lateral, under, backwater
Cascade-pool	>3-5	medium; cobbles and boulders smoothed by water	small plunge, pockets
Step-pool	>5	large; boulders arranged in lines by stream flow	plunge pools below boulder steps
Non-alluvial	>13	varied; cobbles and boulders come from the bank and are not smoothed or organized by stream flows. Roots often span the channel.	plunge pools below boulders, roots or LWD

TIP: When measuring the length of overlapping bars or multiple channel segments, only record the total length of the reach occupied by these features. Don't increase the length by measuring zones of overlap twice.

Sample No ______________

Question 2. Are the channel banks intact? (Yes ☐ No ☐)

A) Riffle-pool or cascade-pool channels

a) Less than 15% of the shoreline or streambank on one side of the stream is recently disturbed by stream flows, windthrow, infilling, animals (hoof shear, watering sites, crossings), roads, or harvest and silviculture activities. ☐ ☐

b) More than 65% of the bank area immediately adjacent to the channel has deeply rooted vegetation (e.g., deep rooting grass species, shrubs, and trees - not moss, shallow rooting grass species, small herbs or forbs). ☐ ☐

c) More than 50% of the potentially erodible reach length has stable (usually vegetated) undercut banks. ☐ ☐

d) Less than 10% of the reach length has recently upturned (wind thrown) root wads along the banks. ☐ ☐

If answer "Yes" to 3 or more, mark Yes box in Question 2.

B) Step-pool channels

a) Less than 10% of the shoreline or streambank on one side of the stream is recently disturbed by stream flows, windthrow, infilling, animals (hoof shear, watering sites, crossings), roads, or harvest and silviculture activities. ☐ ☐

b) More than 75% of the bank has deeply rooted vegetation (e.g., deep rooting grass species, shrubs, and trees - not moss, shallow rooting grass species, small herbs or forbs). ☐ ☐

c) More than 50% of the potentially erodible reach length has stable (usually vegetated) undercut banks. ☐ ☐

d) Less than 25% of the reach length has recently upturned (wind thrown) root wads along the banks. ☐ ☐

If answer "Yes" to 3 or more, mark Yes box in Question 2.

C) Non-alluvial channels

a) More than 75% of the bank has deeply rooted vegetation (e.g., deep rooting grass species, shrubs, and trees - not moss, shallow rooting grass species, small herbs or forbs). ☐ ☐

b) Less than 10% of the shoreline or streambank on one side of the stream is negatively affected by stream flows, windthrow, infilling, animals (hoof shear, watering sites, crossings), roads, or harvest and silviculture activities. ☐ ☐

c) Less than 25% of the reach length has recently upturned (wind thrown) root wads along the banks. ☐ ☐

If answer "Yes" to 2 or more, mark Yes box in Question 2.

Please refer to Figures 3 and 4 in the Riparian Protocol. Figure 3 shows a stable, vegetated undercut bank. Figure 4 is an example of an unstable, overhanging bank that should not be considered undercut.

Sample No ______________

Question 3. Are channel LWD processes intact? (Yes ☐ No ☐)

Note: The words "recent" and "recently" refer to the age of the riparian management activity being assessed.

A) Riffle-pool or cascade-pool channel

a) Most woody debris is old and does not appear to have been recently deposited. ☐ ☐

b) Fewer than 12 recently formed accumulations of woody debris span the channel. ☐ ☐

c) Half or more of all woody debris accumulations lack recent debris (e.g., branches, treetops, bark, small logs and LWD with cut ends, recently crushed or shattered logs). ☐ ☐

d) Woody debris oriented parallel to the channel banks (particularly small logs and limbs with lengths much less than the bankfull channel width) is not abundant. ☐ ☐

e) There is no indication that natural debris was recently removed from the channel by hand, slides, torrents, or catastrophic floods. ☐ ☐

If answer "Yes" to 4 or more, mark Yes box in Question 3

B) Step-pool channel

a) Most woody debris is old and does not appear to have been recently deposited. ☐ ☐

b) Fewer than 12 recently formed accumulations of woody debris are present in the channel. ☐ ☐

c) Half or more of all woody debris accumulations lack recent debris (e.g., branches, treetops, bark, small logs and LWD with cut ends, recently crushed or shattered logs). ☐ ☐

d) Woody debris oriented parallel to the channel banks (particularly small logs and limbs with lengths much less than the bankfull channel width) is not abundant. ☐ ☐

e) There is no indication that natural debris was recently removed from the channel by hand, slides, torrents, or catastrophic floods. ☐ ☐

If answer "Yes" to 4 or more, mark Yes box in Question 3.

C) Non-alluvial channel

a) Most woody debris is old and does not appear to have been recently deposited. ☐ ☐

b) Half or more of all woody debris accumulations lack recent debris (e.g., branches, treetops, bark, small logs and LWD with cut ends, recently crushed or shattered logs). ☐ ☐

c) Woody debris oriented parallel to the channel banks (particularly small logs and limbs with lengths much less than the bankfull channel width) is not abundant. ☐ ☐

d) There is no indication that natural woody debris was recently removed from the channel by hand, slides, torrents, or catastrophic floods. ☐ ☐

If answer "Yes" to 3 or more, mark Yes box in Question 3.

TIP: "Old" debris is debris that was present before the treatment (i.e., the most recent harvesting or road building). "Recently deposited" debris means debris that was deposited after road building and harvesting was completed.

TIP: To be considered "debris in the channel," the debris must actually extend into the channel. Logs that are suspended on the banks above the channel are not included, but any branches associated with the log could be in the channel.

TIP: Post-harvest windthrow-related debris (including branches) is considered "recently deposited debris" if it extends into the channel.

Sample No ______________

Question 4. Is the channel morphology intact? (Mark NA if the channel is non-alluvial, and therefore lacking a riffle-pool, cascade-pool or step-pool morphology). Yes ☐ No ☐ NA ☐

A) Riffle-pool or cascade-pool channel

		Yes	No
a)	Pools are present along > 25 % of the reach.	☐	☐
b)	Surface sediment texture is heterogeneous and well sorted; i.e., the number and range of main sediment classes present(fines and sands, gravels, small and large cobbles, small and large boulders) is large and non-randomly distributed.	☐	☐
c)	At least two deep pools are present. (A deep pool is a pool with a channel depth twice the average channel depth at riffle crests).	☐	☐

If answer "Yes" to 2 or more, mark Yes box in Question 4.

B) Step-pool channel

		Yes	No
a)	Plunge pools are frequent (>25% of steps are associated with a plunge pool with depths similar to the size of the largest rock in the step). Few pools are infilled to near the top of the next downstream step.	☐	☐
b)	The channel alternates almost exclusively between steps and pools (i.e., less than 25% of the channel consists of relatively long cascades).	☐	☐
c)	At least two deep pools are present. (A deep pool is a pool with a channel depth twice the average channel depth at riffle crests)	☐	☐

If answer "Yes" to 2 or more, mark Yes box in Question 4.

TIP: A stream reach can have aspects of both a cascade-pool and a step-pool morphology. Use the predominant morphology to decide which set (A or B) of indicator statements to use.

TIP: If you cannot decide what the predominant channel morphology is, try completing both sections. More often than not the answer to Question 4 will be the same, in which case it is not necessary to decide what the predominant channel morphology is.

TIP: Steep streams (with gradients between approximately 5-15%) that look like long cascades are probably step-pool streams that are filled in with abundant sediment. Even steeper streams (with gradients much greater than 15%) are probably non-alluvial, especially small streams.

TIP: Only measure the lengths of the main pools present. These are the pools that extend from one side of the wetted channel to the other. Do not include the small pools that are often present behind boulders in riffles or cascades or the small backwater or back eddy pools that might be present along the margins of riffles and cascades.

Sample No ______________

Question 5. Are all aspects of the aquatic habitat sufficiently connected to allow for normal, unimpeded movements of fish, organic debris, and sediments? Yes ☐ No ☐ NA

		Yes	No	NA
a)	Temporary blockages to fish, debris, or sediments because of new accumulations of debris or sediments are absent.	☐	☐	
b)	Down cutting in the main channel that now isolates the floodplain from normal flooding or blocks access to tributary streams or off-channel areas is absent.	☐	☐	
c)	Build-ups of sediment or debris above or within any crossing structures are absent.	☐	☐	☐
d)	There is no down cutting present below any crossing structure that blocks fish movements upstream by any size fish at any time.	☐	☐	☐
e)	On fish bearing streams, all crossing structures are open bottom structures.	☐	☐	☐
f)	Dewatering over the entire channel width due to excessive new accumulations of sediment is absent.	☐	☐	
g)	Off-channel or overland flow areas have not been isolated or cut off by roads or levees.	☐	☐	
h)	Water in the stream has not been withdrawn or diverted elsewhere.	☐	☐	

If answer "No" to any statements, mark the "No" box for Question 5.

TIP: For Question 5, part (a), beaver dams should only be considered temporary blockages to fish, sediment, and debris if they were constructed after the block was logged.

TIP: "Down cutting" refers to channel incisement; i.e., the vertical movement of the channel downwards into the floodplain

Question 6. Does the stream support a good diversity of fish cover attributes? To qualify as cover, each cover attribute should represent at least 1% of the total stream area observed. (Mark NA if the stream is non-fish bearing; i.e., classes S5 or S6). Yes ☐ No ☐ NA ☐

		Yes	No
a)	Deep pool habitat is available.	☐	☐
b)	Stable, unembedded boulders are present.	☐	☐
c)	Stable rootwads, woody debris, or other organic material that fish can hide in is present.	☐	☐
d)	Stable, deep-rooted, undercut banks are present.	☐	☐
e)	Submerged or emergent aquatic vegetation is present.	☐	☐
f)	Overhanging vegetation is present within 1 m of the top of the channel (streams) or water surface (wetlands, lakes).	☐	☐
g)	A stable mineral substrate with void spaces for fish to hide in is present.	☐	☐

If the answer is "Yes" for five or more statements, mark the "Yes" box. Otherwise, mark the "No" box.

TIP: Question 6 is "NA" if the stream is non-fish bearing. Also, if there are no deep pools, there is no deep pool habitat.

Sample No ______________

Question 7. Does the amount of moss present on the substrates indicate a stable and productive system? Yes ☐ No ☐ NA ☐

		Yes	No	NA
a)	Moss patches are easily observed from almost any point along the margins, riffles, or shallow pools of the stream. Average coverage on mineral substrates only is 1% or more of the channel bed, from the toe of one bank to the toe of the other bank.	☐	☐	
b)	Half or more of the moss present, even uncommon, occasional or rare patches are generally intact, not embedded with sediments, buried or damaged by scouring. Mark "NA" if no moss is present.	☐	☐	☐
c)	Moss not scoured, silted, or buried in sediment is generally vigorous, not stressed or dead. Mark "NA" if no moss is present.	☐	☐	☐

If the answer is "No" for any statement, mark the No box for Question 7. Otherwise, mark the Yes box.

Question 8. Has the introduction of fine inorganic sediments been minimized? Yes ☐ No ☐ NA ☐

		Yes	No	NA
a)	Inorganic ("gritty" feeling) fine and sand-sized sediments on the substrate are best described as little or lacking. Average coverage is less than 10%, with no single areas over 50%.	☐	☐	
b)	Wetted areas of gravel, sand, or fine sized sediments that a foot can be easily pushed or wiggled into represent less than 1% of the total wetted area. Mark "NA" if the stream is dry.	☐	☐	☐
c)	Gravels and cobbles are not embedded or buried in a matrix of sand or finer sized particles. The sides of individual gravel and cobble particles can generally be seen touching each other.	☐	☐	
d)	An average of one invertebrate sensitive to the effects of sedimentation is present at most sample sites. Mark "NA" if the stream is dry.	☐	☐	☐

If the answer is "No" to any statement, mark the "No" box for Question 8. Otherwise, mark the "Yes" box.

Question 9. Does the stream support a diversity of aquatic invertebrates? (Mark "NA" if the stream is dry) Yes ☐ No ☐ NA ☐

		Yes	No
a)	An average of one sensitive invertebrate (e.g., a caddisfly, stonefly, mayfly, freshwater clam, etc.) is present at each sample site.	☐	☐
b)	An average of two different major invertebrate groups (e.g., insects, worms, mollusks, crustaceans, etc.) is present at each sample site.	☐	☐
c)	An average of three recognizably different insects is present at each sample site.	☐	☐
d)	An average of four recognizably different invertebrates is present at each sample site.	☐	☐

Mark the "Yes" box for Question 9 if two of the statements are "Yes". Otherwise, mark "No".

Sample No ______________

Question 10. Has the vegetation retained in the RMA been sufficiently protected from windthrow?	Yes	No	NA
	☐	☐	
a) The incidence of post-treatment windthrow in S1-S3 RRZs or S4-S6 RMZs with WTPs does not exceed 5% of the stems, over and above what occurs naturally in the area. Mark NA and answer 10 b) if there is no reserve zone, or management zone with wildlife trees or wildlife tree patches.	☐	☐	☐
b) The incidence of post-treatment windthrow in S4-S6 RMZs that are not part of a WTP does not exceed 10% of the stems, over and above what occurs naturally in the area. Mark NA if there is a reserve zone or wildlife tree patch adjacent to the stream, and answer 10 a).	☐	☐	☐
c) Designated wildlife trees are still standing, or if windthrown, still functional as wildlife trees (e.g., above-ground bear dens). Mark NA if there are no designated wildlife trees.	☐	☐	☐

If the answer is "No" to any statement, mark the "No" box for Question 10. Otherwise, mark the "Yes" box.

Calculating % Windthrow:

1) % Old Windthrow = [(# Old Windthrown Trees)/ (# Standing Trees + # Old Windthrown Trees + # New Windthrown Trees)] X 100
2) % New Windthrow = [(# New Windthrown Trees)/ (# Standing Trees + # New Windthrown Trees)] X 100

To calculate % new windthrow over and above the natural pre-treatment windthrow, subtract (1) from (2).

Question 11. Has the amount of bare erodible ground or soil disturbance in the riparian area been minimized?	Yes	No
	☐	☐
a) Total bare erodible ground in the first 10m of the riparian zone is less than 1%.	☐	☐
b) Total bare erodible ground present in the first 10 m of the riparian zone, **plus** all other bare erodible ground hydrologically linked to the first 10 m of riparian zone, is less than 5%.	☐	☐
c) Total area disturbed by animals or machinery in the first 10m of the riparian zone is less than 10%.	☐	☐
d) Total area disturbed by animals or machinery in the first 10 m of the riparian zone, **plus** all other disturbed areas hydrologically linked to the first 10 m of riparian zone is less than 15%.	☐	☐

If the answer is "Yes" for all statements, mark the "Yes" box. Otherwise, mark the "No" box.

TIP: Sediment deposited on the ground from upslope sources is considered bare ground for Question 11, but not if the sediment is deposited due to flooding (i.e., overbank deposits).

Sample No ______________

Question 12. Has sufficient vegetation been retained to maintain an adequate root network or LWD supply?	Yes	No	NA
	☐	☐	
a) On all streams, nonmerchantable conifer trees, understory deciduous trees, shrubs, and herbaceous vegetation were retained to the fullest extent possible within 5 m of the channel.	☐	☐	
b) On S1 to S3 size streams, the first 10 m of the riparian reserve zone is intact (regardless of windthrow), thereby providing for 99 % of the LWD normally supplied to streams with no additional inputs from upstream or the adjacent hillslopes.	☐	☐	☐
c) On S4 streams, where the windthrow hazard was not assessed, or where windthrow hazard as assessed on the Silviculture Prescription is not high, all windfirm trees with roots embedded in the bank, and 50% of all other trees (excluding dominant conifers) within 10 m of the stream bank were retained.	☐	☐	☐
d) On S4 streams, where the windthrow hazard as assessed on the Silviculture Prescription is high, all conifers < 30 cm DBH were retained within 10 m of the stream bank.	☐	☐	☐
e) On valley bottom S5 streams with alluvial banks and a floodplain, 50 % of dominant and codominant windfirm stems within 30 m of the stream bank were retained.	☐	☐	☐
f) On non-valley, LWD-dependent S5 streams, all leaners within 10 m of the channel and all conifer stems < 30 cm DBH within 5 m of the stream bank were retained.	☐	☐	☐
g) On LWD-dependent S6 streams, or S6 that flow directly into fish-bearing waters, at least 10 trees < 30 cm DBH per 100 m of stream bank were retained within 5 m of the stream bank.	☐	☐	☐

Mark the "No" box for Question 12 if there are any "No" answers. Otherwise, mark the "Yes" box.

TIP: All streams require an answer to indicator statement 12 (a). At most, only one other indicator statement will be applicable.

TIP: Stream crossing right-of-ways should not be considered a factor for this question unless the right-of-ways represent more than 25% of the riparian habitat.

Question 13. Has sufficient vegetation been retained to provide shade and reduce bank microclimate change?	Yes	No
	☐	☐
a) With the exception of active roads at stream crossings, bare ground directly exposed to rain is less than 1% of the riparian habitat in plan view.	☐	☐
b) Shade (the average amount of sky not visible due to vegetation) averages more than 60%, as estimated visually for any two of the east, south and west aspects at 60° above the horizontal, or as estimated with a "Teti" angular canopy densiometer.	☐	☐
c) Moisture loving macrophytes, mosses, ferns, or other bryophytes are present and in vigorous condition, with no indication of stress due to sunburn, drought or desiccation.	☐	☐
d) Soil in the riparian habitat is moist or cool to the touch.	☐	☐

Mark the "Yes" box for Question 13 if 3 or more answers are "Yes". Otherwise, mark the "No" box.

TIP: All four indicator statements should be answered. This question needs two or more "No" answers to the indicator statements before the Question can be answered "No".

Sample No ______________

Question 14. Have the number of disturbance-increaser species or noxious weeds present been limited to a satisfactory level?	Yes	No
	☐	☐
a) Disturbance-increaser plants (domestic grasses, dandelions, pineapple weed, buttercups, etc.) occupy less than 25% of total area in the first 10m of the riparian zone.	☐	☐
b) Noxious weeds (Canada thistle, sowthistles, toadflax, knapweed, etc.) occupy less than 5% of total area in the first 10m of the riparian area.	☐	☐

Mark the "Yes" box for Question 14 if all statements are "Yes". Otherwise, mark "No".

TIP: To estimate coverage by disturbance-increaser plants or weeds at a sample site, try estimating the percentage of a 10m-long line transect that is occupied by these plants. Start the line transects at the edge of the stream and go 10m at right angles to the main axis of the stream reach.

Question 15. Is the riparian vegetation within the first 10m from the edge of the stream generally characteristic of other healthy unmanaged riparian plant communities in the area?	Yes	No
	☐	☐
a) The major vegetation layers expected of healthy unmanaged riparian plant communities in the area (e.g., snags, tall trees, tall shrubs, low shrubs, herbaceous plants, mosses, and lichens) are present over more than 75% of the stream reach.	☐	☐
b) The dominant species in the tree and shrub layers generally exhibit high vigour, normal growth form, and good recruitment of seedlings or saplings. Mark "No" if more than 25% of the specimens in these layers are stressed, dying, dead, burned, "mushroomed", windthrown, or harvested. Mark "No" if there is also no recruitment.	☐	☐
c) Heavy browse is absent on a preferred browse species in the shrub layer. Heavy browse on a plant is browse down to second year wood over most (>50% of the branches) of the plant.	☐	☐
d) Heavy grazing occupies <10% of the available grazing area. Heavy grazing is defined as less than the recommended target stubble height for the dominant forage species present.	☐	☐

Mark the "Yes" box for Question 15 if 3 or more answers are "Yes". Otherwise, mark the "No" box.

TIP: All four statements can always be answered "Yes" or "No". There are no NA statements.

TIP: If more than 25% of the first 10m of the riparian area is logged, then 15(a) and 15(b) should be marked "No". This means that for most S6 streams and many S4 streams that are logged to the stream edge, the answer to Question 15 will automatically be "No".

TIP: A preferred browse species may be altogether absent if browsing is intense or prolonged. Their presence may be restricted to inaccessible sites. Huckleberry plants in many locations on the Queen Charlotte Islands/Haida Gwaii, for example, are frequently restricted to the tops of high stumps or other inaccessible sites out of reach of the local deer.

Please refer to Figure 12 in the Riparian Protocol for a description of "heavy browse".

Sample No ____________

Summary

	Question	Yes	No	NA
Question 1	Is the channel bed undisturbed?	☐	☐	
Question 2	Are the channel banks intact?	☐	☐	
Question 3	Are channel woody debris processes intact?	☐	☐	
Question 4	Is the channel morphology intact?	☐	☐	☐
Question 5	Are all aspects of the aquatic habitat sufficiently connected to allow for normal, unimpeded movements of fish, organic debris, and sediments?	☐	☐	
Question 6	Does the stream support a good diversity of fish cover attributes?	☐	☐	☐
Question 7	Does the amount of moss present on the substrates indicate a stable and productive system?	☐	☐	
Question 8	Has the introduction of fine sediments been minimized?	☐	☐	
Question 9	Does the stream support a diversity of aquatic invertebrates?	☐	☐	☐
Question 10	Has the vegetation retained in the RMA been sufficiently protected from windthrow?	☐	☐	
Question 11	Has the amount of bare ground or soil disturbance in the riparian area been minimized?	☐	☐	
Question 12	Has sufficient vegetation been retained to maintain an adequate root network or LWD supply?	☐	☐	
Question 13	Has sufficient vegetation been retained to provide shade and reduce bank microclimate change?	☐	☐	
Question 14	Have the number of disturbance-increaser plants or noxious weeds present been limited to a satisfactory level?	☐	☐	
Question 15	Is the riparian vegetation within the first 10m from the edge of the stream generally characteristic of other healthy unmanaged riparian plant communities in the area?	☐	☐	

No. of "Yes" answers:_____ + No. of "No" answers:_____ + No. of "NA" answers:_____ = Total No. of answers:_____

Conclusion on Functioning Condition (check one):

☐ Properly Functioning (0-2 "No's")
☐ Properly Functioning but at Risk (3-4 "No's")
☐ Properly Functioning but at High Risk (5-6 "No's")
☐ Not Properly Functioning (>6 "No's")

List the questions that had a "No" answer below, and check what you believe was the main reason for the problem. A "No" answer due to natural causes would include any natural event such as insects, fires, floods, slides, diseases etc. that were clearly unrelated to man's activities in the stream or adjacent riparian area. Check Logging, Cattle, Roads or Other Manmade as a cause if these factors directly affected the stream or riparian area assessed in this evaluation. Check Upstream Factors if the No answer was the result of some event or condition that occurred upstream, regardless if it was manmade or natural.

"No" answer questions	Cause of "No" Answers: Logging	Cattle	Roads	Other Manmade	Natural Factors	Upstream Factors
	☐	☐	☐	☐	☐	☐
	☐	☐	☐	☐	☐	☐
	☐	☐	☐	☐	☐	☐
	☐	☐	☐	☐	☐	☐
	☐	☐	☐	☐	☐	☐
	☐	☐	☐	☐	☐	☐

Sample No ____________

Checklist of Specific Impacts for All "NO" Answers Combined

	Stream Impacts that Apply: Within Stream Reach	Above Stream Reach
Logging Related Impacts		
Falling and yarding	☐	☐
Machine disturbance during harvesting	☐	☐
Machine disturbance during site preparation	☐	☐
Windthrow	☐	☐
Low retention	☐	☐
Old logging	☐	☐
Slides/sloughs	☐	☐
Torrenting	☐	☐
Water courses diverted	☐	☐
Roads, Crossings		
Running surface eroding into stream	☐	☐
Ditches eroding into stream	☐	☐
Fill or cut slopes eroding into stream	☐	☐
Road lens failing/collapsing	☐	☐
Cross ditching inadequate	☐	☐
Ditch blocks inadequate	☐	☐
Cross drains inadequate	☐	☐
Sediment traps inadequate	☐	☐
Berms/ruts trap water on road	☐	☐
Crossing leaks fines into stream	☐	☐
Water courses diverted	☐	☐
Crossing opening too small	☐	☐
Crossing misaligned	☐	☐
Crossing not open-bottomed	☐	☐
Culvert evert too high	☐	☐
Culvert damaged	☐	☐
Culvert plugged	☐	☐
Animal Disturbance		
Excessive grazing/browsing (cattle)	☐	☐
Excessive grazing/browsing (other ungulates)	☐	☐
Excessive grazing/browsing (beavers)	☐	☐
Trampling (cattle)	☐	☐
Trampling (other animals)	☐	☐
Stream dammed (beavers)	☐	☐
Excessive manure	☐	☐
Natural Impacts		
High natural background sediment levels	☐	☐
Organic stream bed	☐	☐
Fire	☐	☐
Beetle kills	☐	☐
Other diseases, epidemics	☐	☐
Wind	☐	☐
Slides	☐	☐
Torrents	☐	☐
Floods	☐	☐
Unknown	☐	☐
Other Impacts (List)	☐	☐
	☐	☐
	☐	☐
	☐	☐
	☐	☐
	☐	☐

Sample No ____________

Final Comments

Does the conclusion on functioning condition generally agree with your personal opinion on the functioning condition of this stream reach? If not, why not?

Describe more specifically what the reasons were for the "No" answers.

All No answers are weighted equally. Were any specific problems identified that affected the assessment more than others?

Have you marked the stream reach assessed on a map in a way that will be legible when photocopied?

Does the leave strip appear as indicated in plans or on plan maps?

Do you have any recommendations for improving the Riparian Effectiveness Routine Evaluation Checklist or Protocol?

9 APPENDIX 2

Site Cards

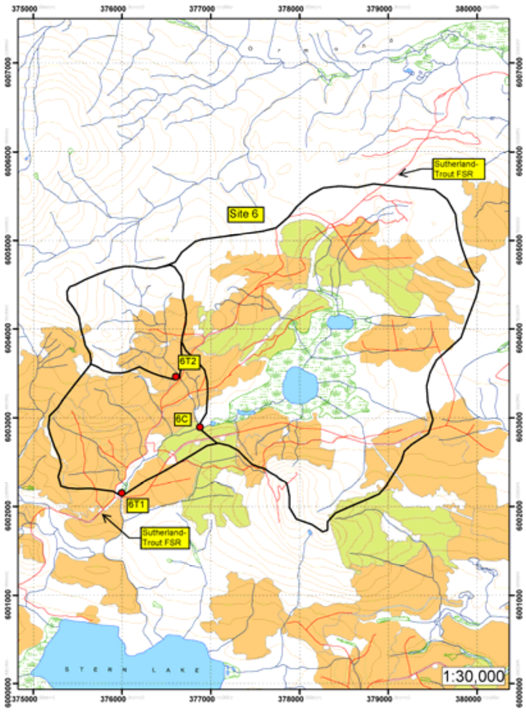
Legend

- Reach location
- Watershed boundary
- Roads
- Waterbodies
- Wetlands
- Streams
- Contour lines
- Cutblocks (pre-2008)
- Cutblocks (post-2008)

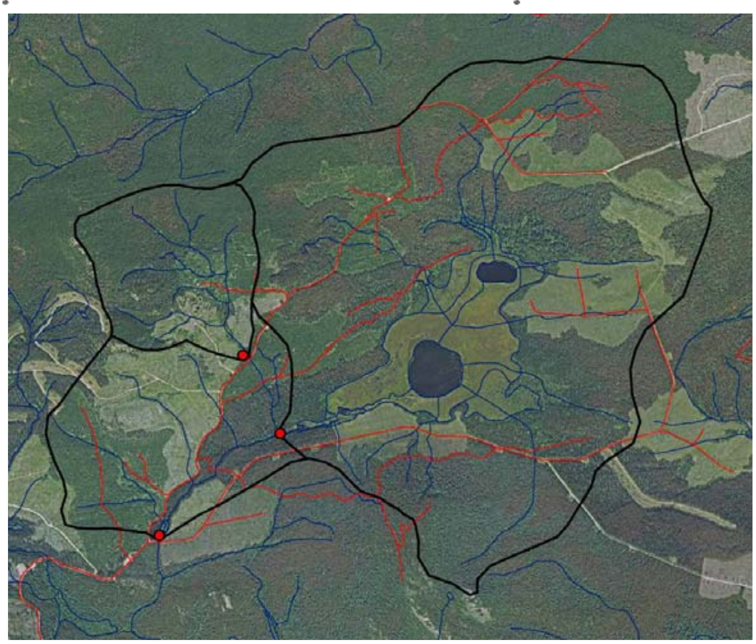
* Orthophotos are from Summer/Fall 2006

* Coordinate system was NAD 1983 UTM Zone 10

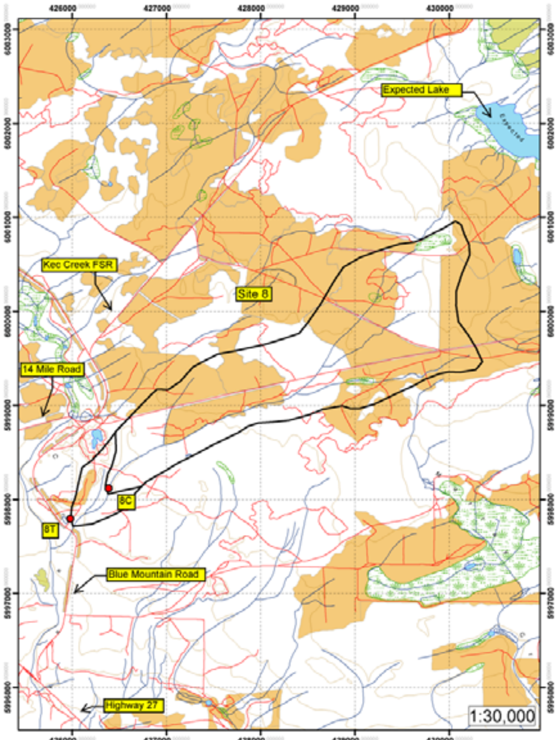
Site 6



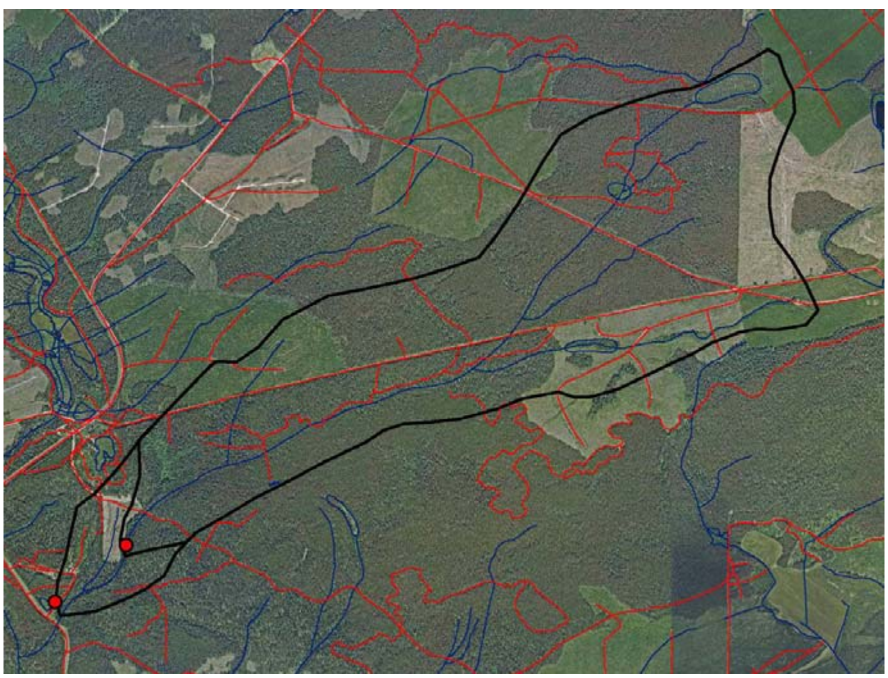
	6C	6T1	6T2
Watershed Area (km^2):	8.88	12.25	1.34
Aspect:	SW	SW	SW
BEC Zone:	SBS dw3	SBS dw3	SBS mc2
Treatment Condition:	Red Attack	Red Attack	Red Attack
Source water:	Lake/Swamp	Lake/Swamp	Headwater
Drainage Density (km/km^2):	1.69	2.18	4.04
Road Density (km/km^2):	1.96	1.92	0.41
Standing Water Area (%):	1.98	1.44	0
Wetland Area (%):	10.68	7.79	0
Elevation (Mean):	960	956	1044
Geology (primary):	Volcanic	Volcanic	Volcanic
Harvested Area (%):	35.7	59.8	77.25
Dominant Forest Cover:	Pine	Pine	Pine



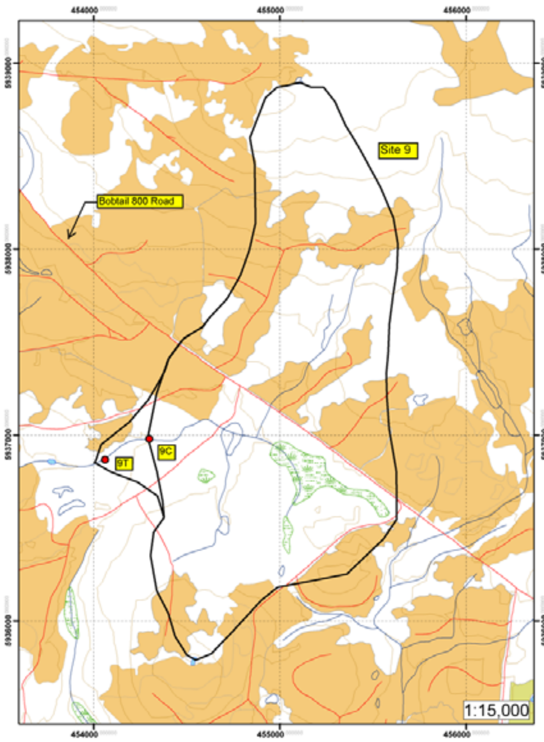
Site 8

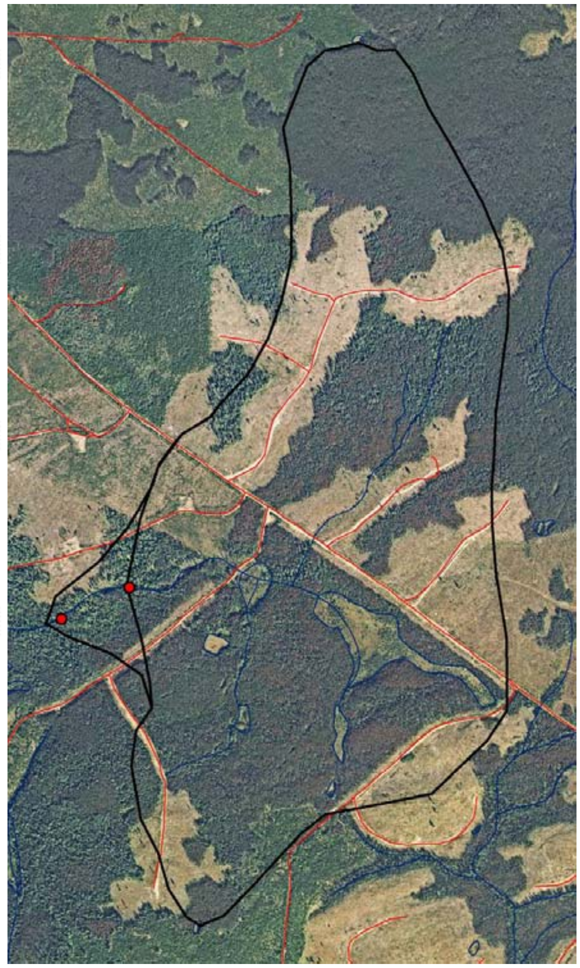


	8C	8T
Watershed Area (km2):	4.60	4.29
Aspect:	SW	SW
BEC Zone:	SBS dw3	SBS dw3
Treatment Condition:	Red Attack	Red Attack
Source water:	Headwater	Headwater
Drainage Density (km/km2):	2.21	2.12
Road Density (km/km2):	3.97	3.88
Standing Water Area (%):	0	0
Wetland Area (%):	1.46	1.56
Elevation (Mean):	854	857
Geology (primary):	Sedimentary	Sedimentary
Harvested Area (%):	50.33	52.98
Dominant Forest Cover:	Pine	Pine



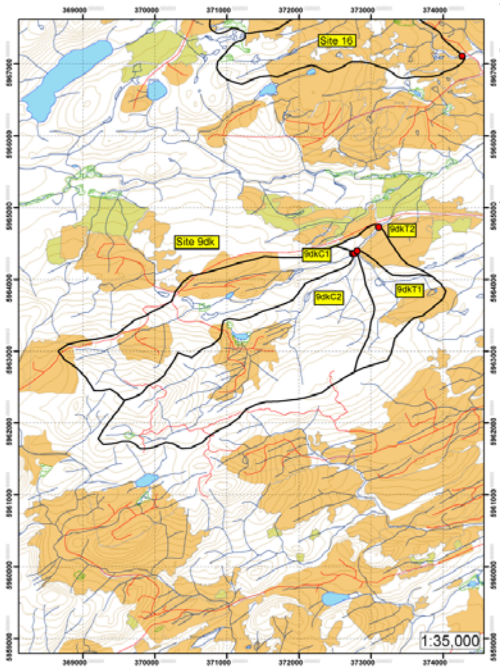
Site 9



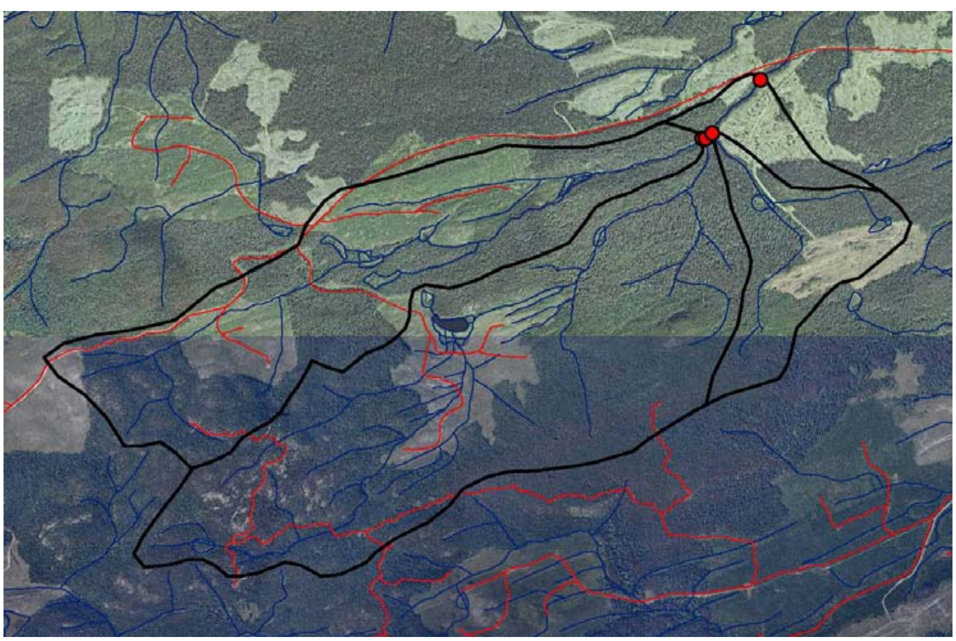


	9C	9T
Watershed Area (km2):	2.72	2.82
Aspect:	W	W
BEC Zone:	SBS dw2	SBS dw2
Treatment Condition:	Red Attack	Red Attack
Source water:	Swamp	Swamp
Drainage Density (km/km^2):	1.61	1.67
Road Density (km/km^2):	2.42	2.39
Standing Water Area (%):	0.01	0.01
Wetland Area (%):	2.97	2.88
Elevation (Mean):	960	958
Geology (primary):	Volcanic	Volcanic
Harvested Area (%):	31.63	30.97
Dominant Forest Cover:	Pine	Pine

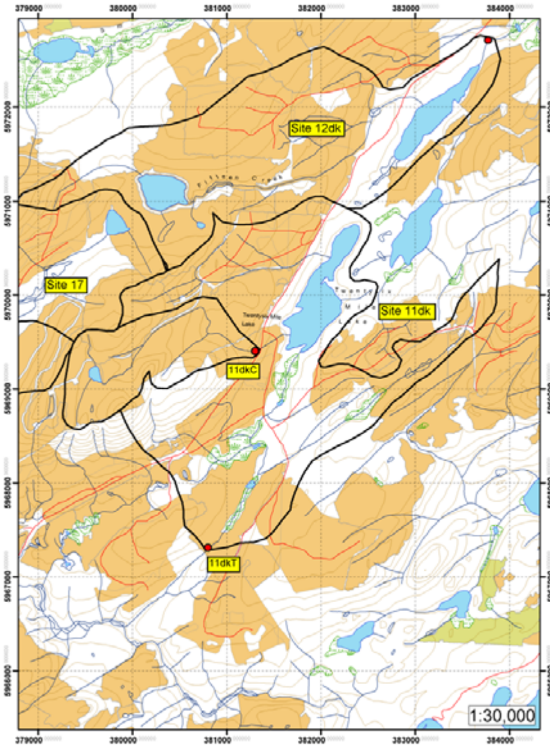
Site 9dk



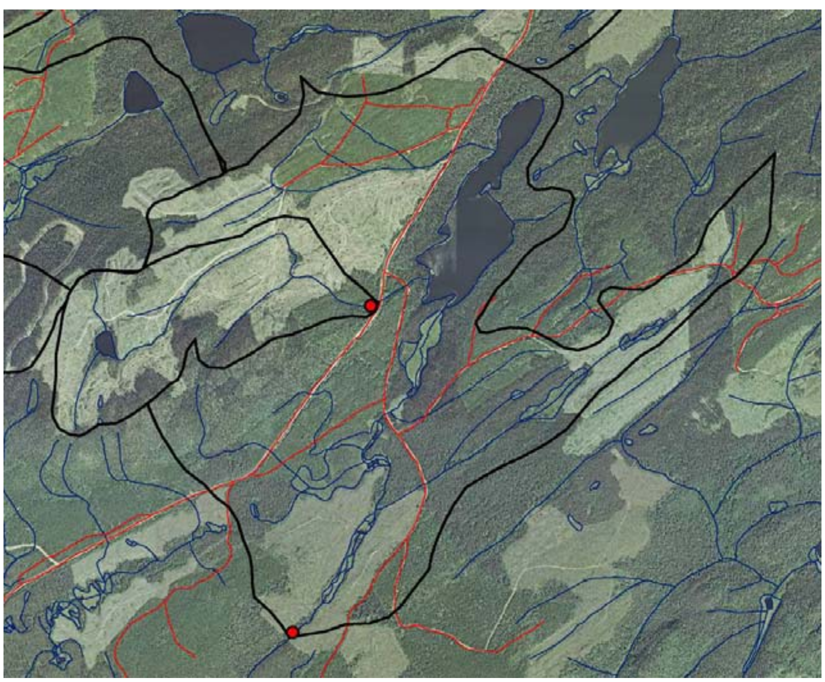
	9dkC1	9dkT1	9dkC2	9dkT2
Watershed Area (km^2)	2.90	0.92	4.45	8.60
Aspect	NE	NE	NE	NE
BEC Zone	SBS mc2	SBS mc2	SBS mc2	SBS dk
Treatment Condition	Red Attack	Red Attack	Red Attack	Red Attack
Source water	Headwater	Headwater	Headwater	Headwater
Drainage Density (km/km^2)	3.92	3.79	4.18	3.96
Road Density (km/km^2)	1.85	NA	1.27	1.28
Standing Water Area (%)	0.21	0.09	0.29	0.23
Wetland Area (%)	0.38	0	0.79	0.54
Elevation (Mean)	1190	1124	1201	1190
Geology (primary)	Volcanic	Volcanic	Volcanic	Volcanic
Upstream Harvested Area (%)	33.70	28.74	13.37	23.66
Dominant Forest Cover	Pine	Pine	Pine	Pine



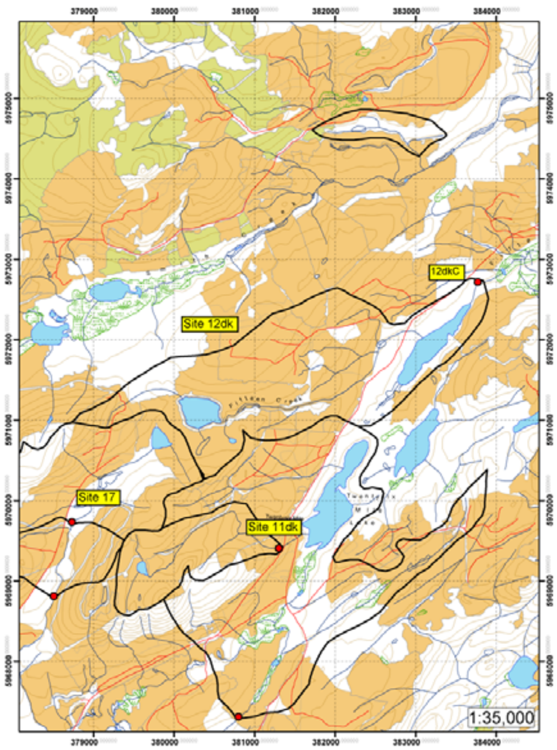
Site 11dk



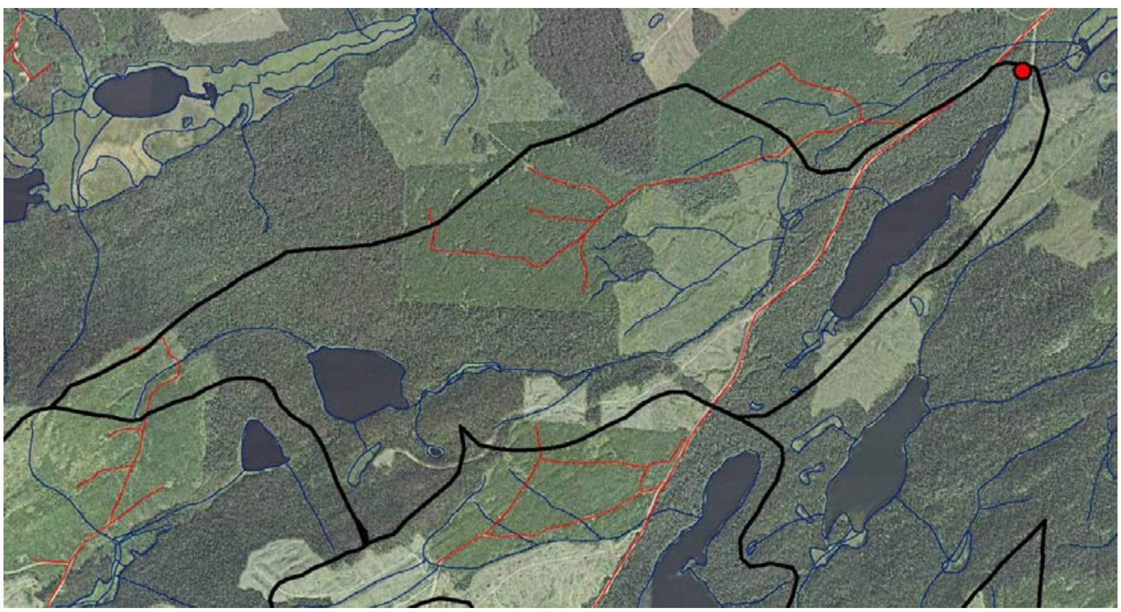
	11dkC	11dkT
Watershed Area (km^2):	1.50	8.14
Aspect:	SW	SW
BEC Zone:	SBS mc2	SBS dk
Treatment Condition:	Red Attack	Red Attack
Source water:	Lake	Lake/Swamp
Drainage Density (km/km^2):	3.41	3.32
Road Density (km/km^2):	NA	1.63
Standing Water Area (%):	0.67	4.96
Wetland Area (%):	0	3.19
Elevation (Mean):	1102	1016
Geology (primary):	Intrusive	Intrusive
Harvested Area (%):	91.27	61.71
Dominant Forest Cover:	Pine	Pine



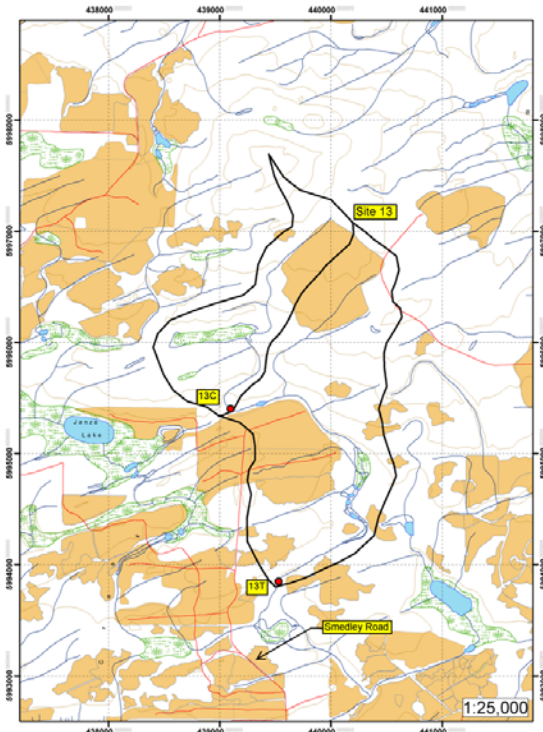
Site 12dk

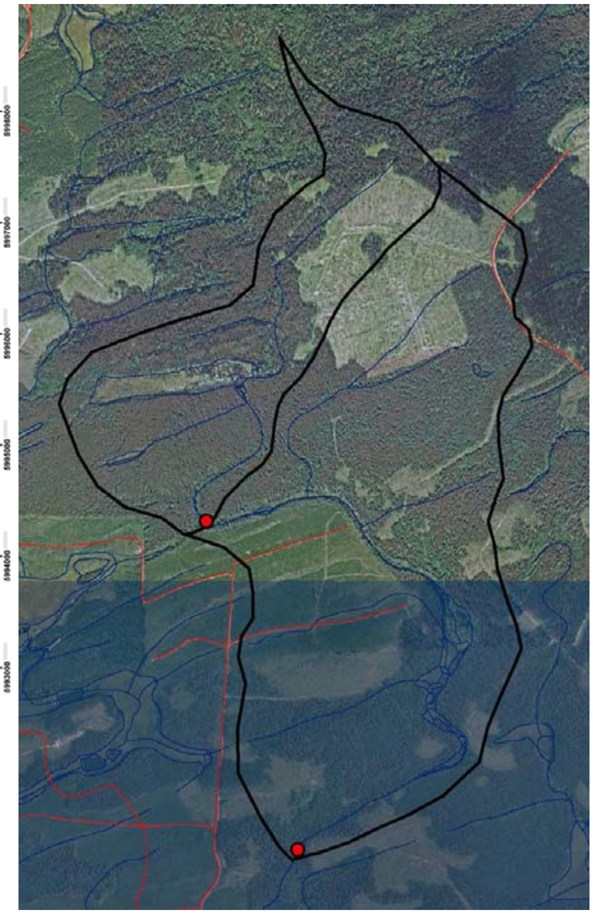


	12dkC
Watershed Area (km^2):	5.40
Aspect:	NE
BEC Zone:	SBS dk
Treatment Condition:	Red Attack
Source water:	Lake
Drainage Density (km/km^2):	3.2
Road Density (km/km^2):	1.18
Standing Water Area (%):	6.89
Wetland Area (%):	0
Elevation (Mean):	1049
Geology (primary):	Intrusive
Harvested Area (%):	68.23
Dominant Forest Cover:	Pine



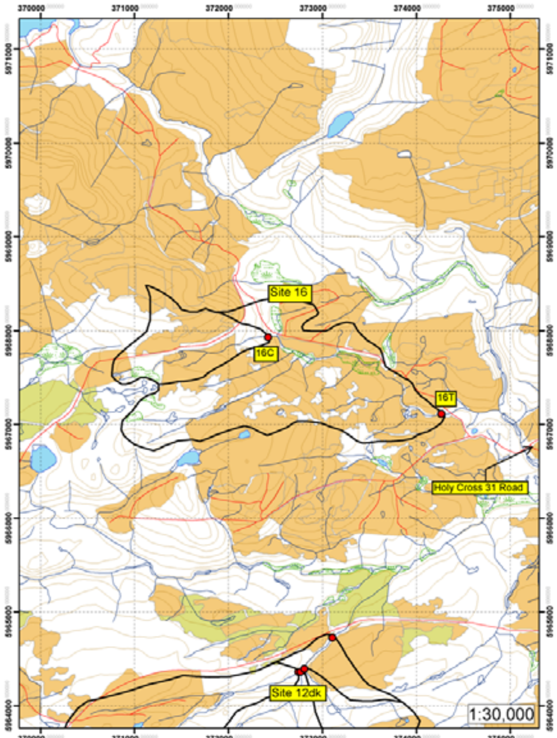
Site 13



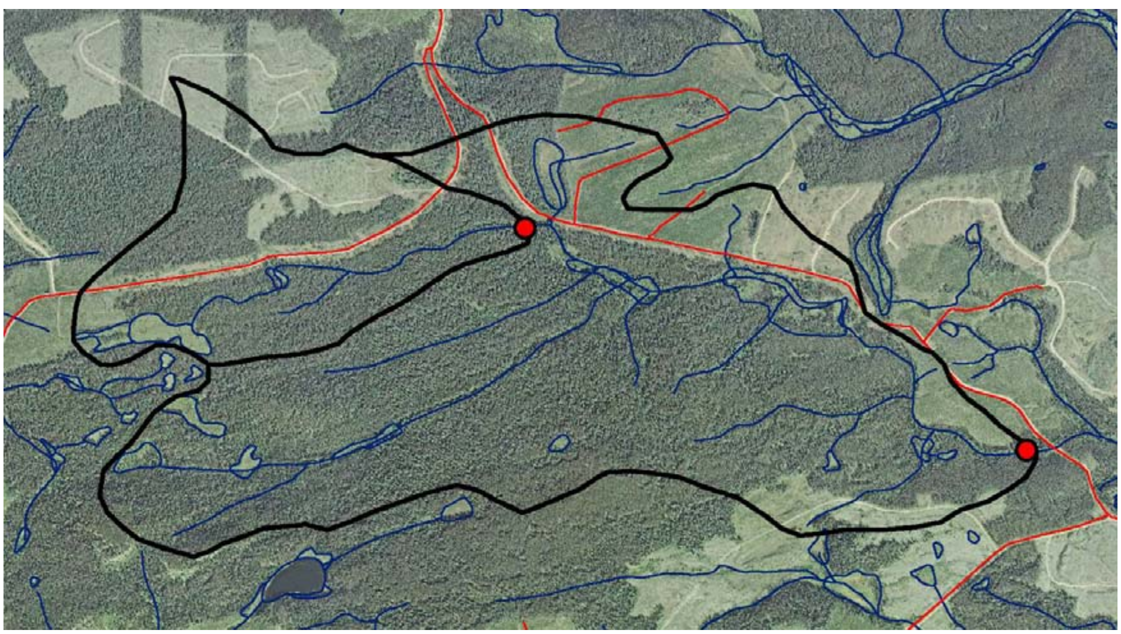


	13C	13T
Watershed Area (km^2):	1.41	4.57
Aspect:	S	S
BEC Zone:	SBS dw3	SBS dw3
Treatment Condition:	Red Attack	Red Attack
Source water:	Swamp	Swamp
Drainage Density (km/km^2):	2.44	3.19
Road Density (km/km^2):	0	0.42
Standing Water Area (%):	0	0.2
Wetland Area (%):	4.88	2.1
Elevation (Mean):	884	858
Geology (primary):	Sedimentary	Sedimentary
Harvested Area (%):	16.18	30.34
Dominant Forest Cover:	Other than Pine/Spruce	Other than Pine/Spruce

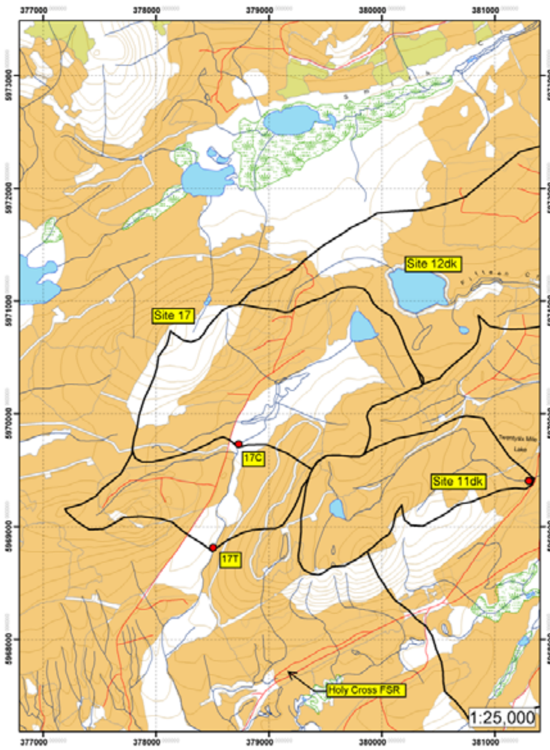
Site 16



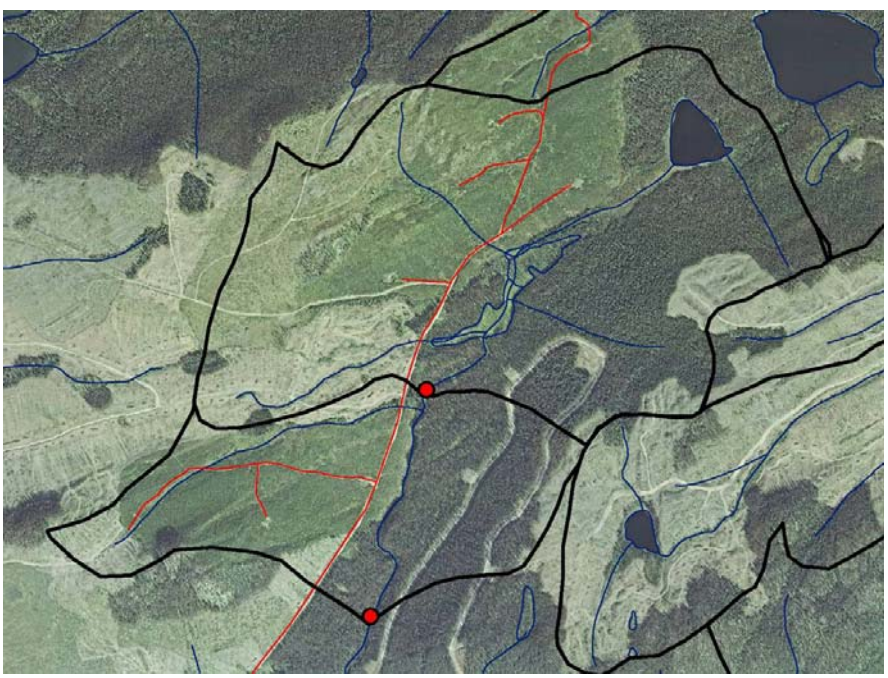
	16C	16T
Watershed Area (km^2):	0.92	3.81
Aspect:	E	E
BEC Zone:	SBS mc2	SBS dk
Treatment Condition:	Grey	Grey
Source water:	Headwater	Swamp
Drainage Density (km/km^2):	2.78	3.64
Road Density (km/km^2):	1.55	1.09
Standing Water Area (%):	0	0
Wetland Area (%):	2.62	3.75
Elevation (Mean):	1144	1086
Geology (primary):	Volcanic	Volcanic
Harvested Area (%):	63.06	65.6
Dominant Forest Cover:	Pine	Pine



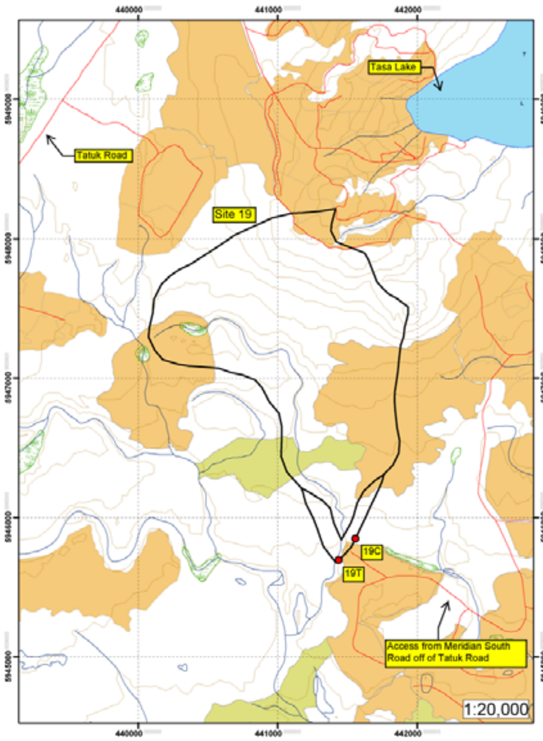
Site 17

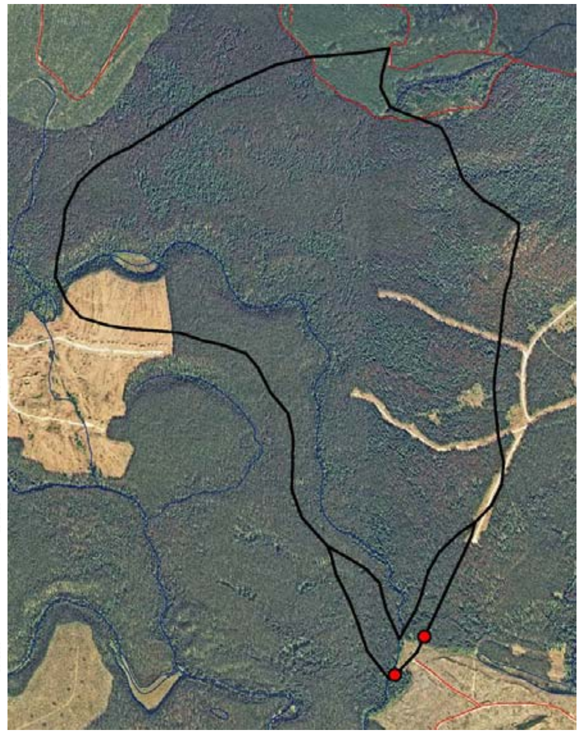


	17C	17T
Watershed Area (km^2):	2.72	3.95
Aspect:	SW	SW
BEC Zone:	SBS mc2	SBS mc2
Treatment Condition:	Grey	Grey
Source water:	Lake	Lake
Drainage Density (km/km^2):	2.77	2.54
Road Density (km/km^2):	0.88	1.18
Standing Water Area (%):	1.58	1.09
Wetland Area (%):	0	0
Elevation (Mean):	1108	1104
Geology (primary):	Intrusive	Intrusive
Harvested Area (%):	63.45	69.11
Dominant Forest Cover:	Pine	Pine



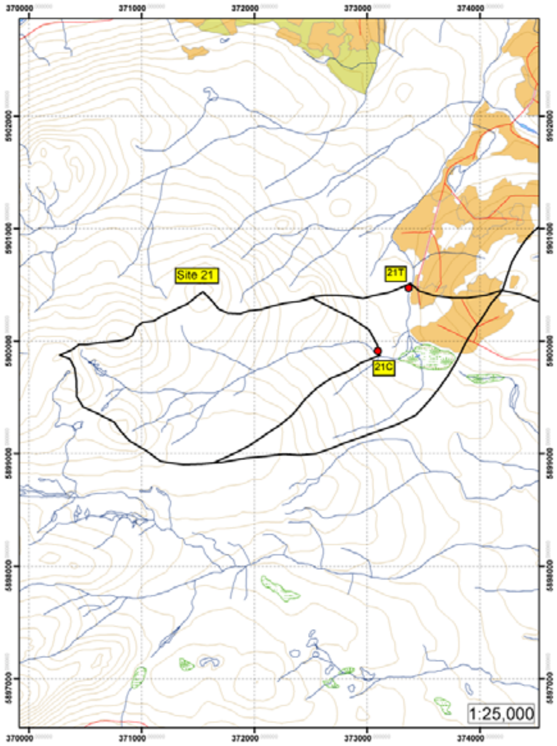
Site 19



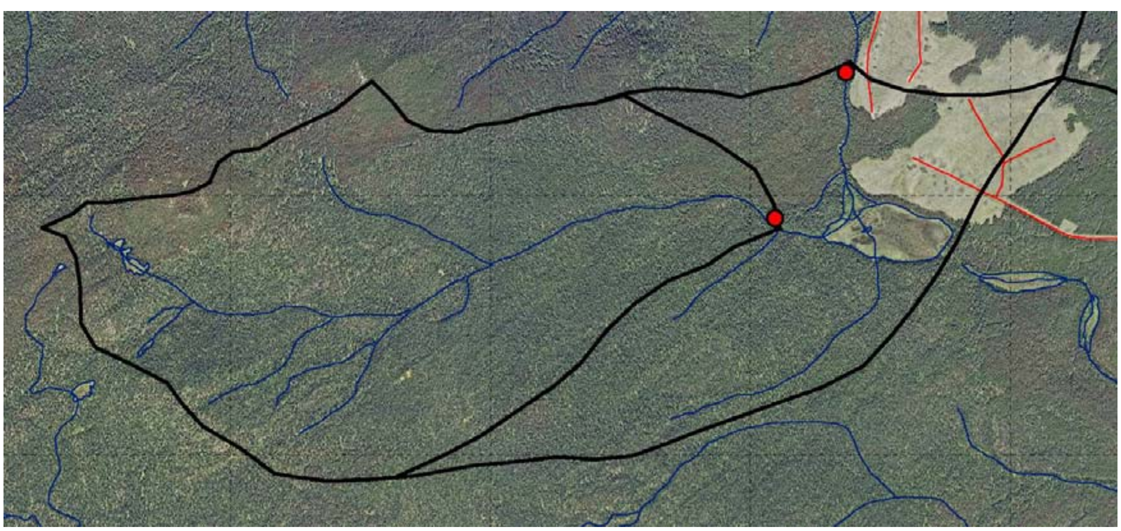


	19C	19T
Watershed Area (km^2):	2.36	2.46
Aspect:	S	S
BEC Zone:	SBS mc2	SBS mc2
Treatment Condition:	Red Attack	Red Attack
Source water:	Swamp	Swamp
Drainage Density (km/km^2):	1.16	1.18
Road Density (km/km^2):	0.24	0.23
Standing Water Area (%):	0	0
Wetland Area (%):	0.55	0.53
Elevation (Mean):	1153	1149
Geology (primary):	Intrusive	Intrusive
Harvested Area (%):	25.73	25.13
Dominant Forest Cover:	Pine	Pine

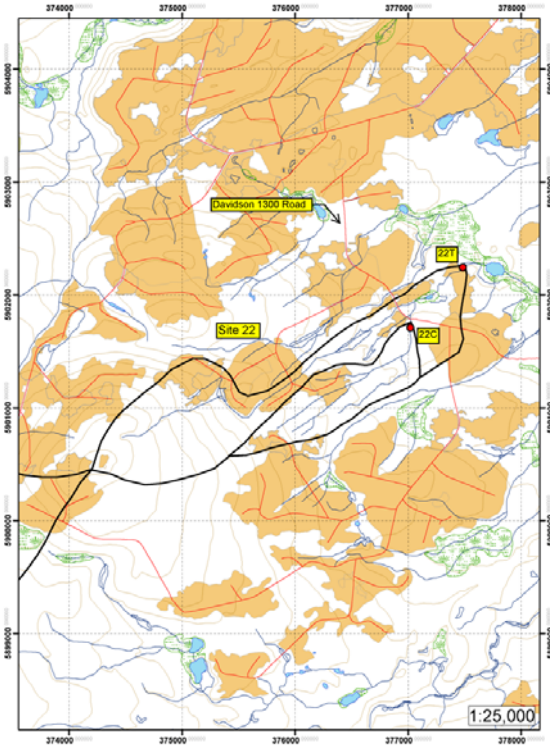
Site 21



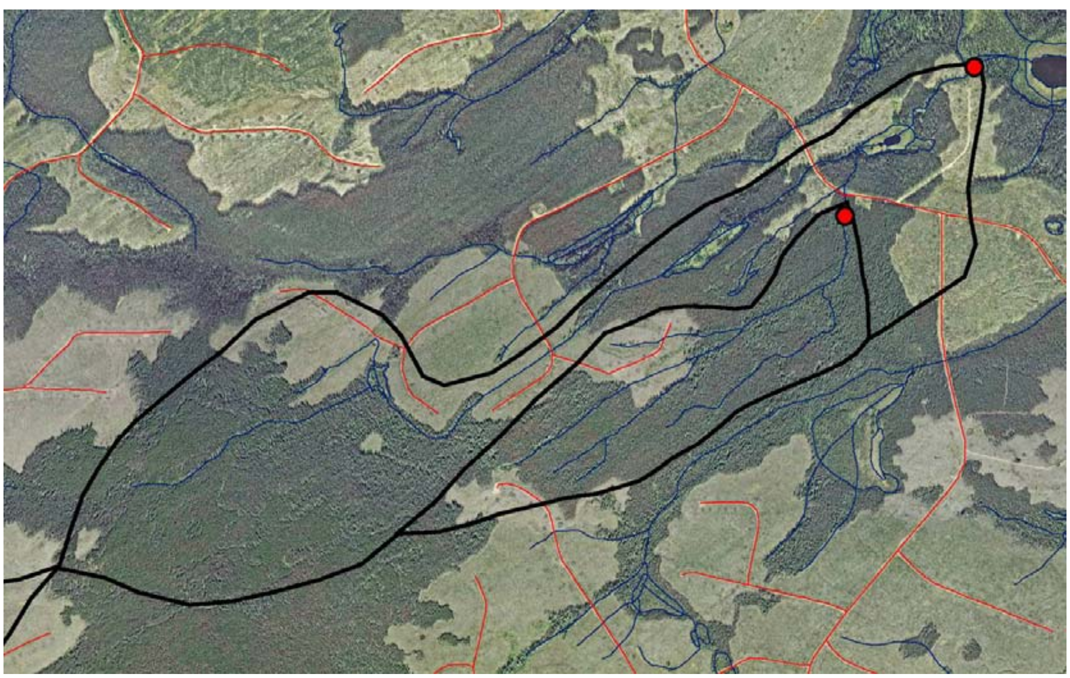
	21C	21T
Watershed Area (km^2):	2.58	4.05
Aspect:	E	N-NE
BEC Zone:	ESSF mv1	ESSF mv1
Treatment Condition:	Grey	Grey
Source water:	Headwater	Headwater/Swamp
Drainage Density (km/km^2):	2.69	2.54
Road Density (km/km^2):	0	0.17
Standing Water Area (%):	0	0.01
Wetland Area (%):	0	1.83
Elevation (Mean):	1477	1431
Geology (primary):	Volcanic	Volcanic
Harvested Area (%):	5.04	5.26
Dominant Forest Cover:	Pine	Pine



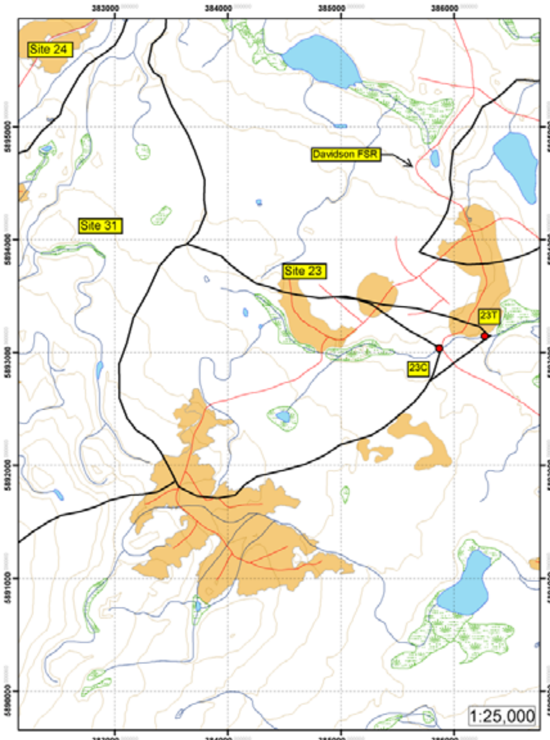
Site 22



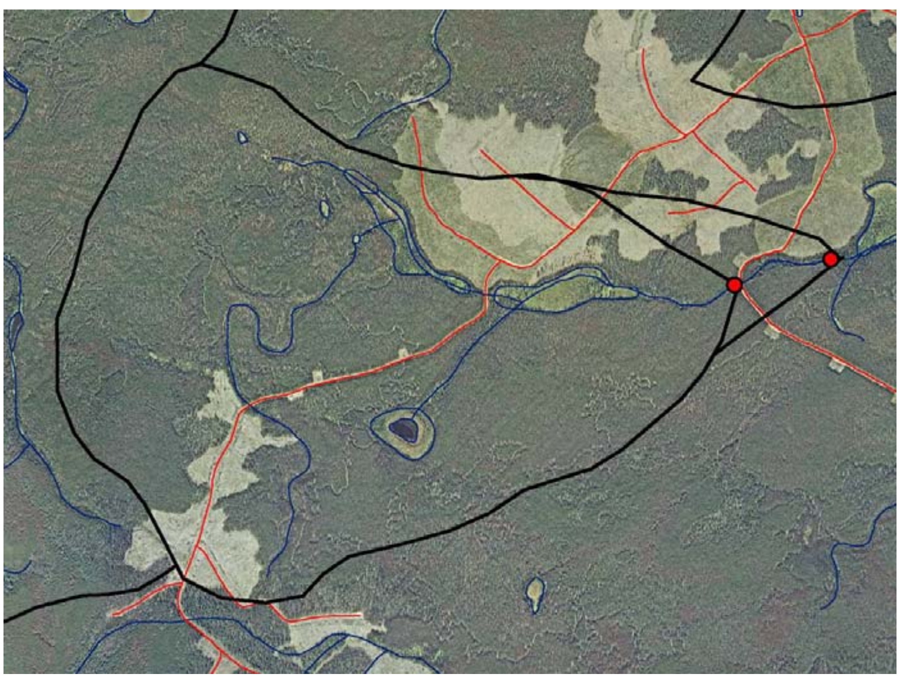
	22C	22T
Watershed Area (km^2):	0.68	2.47
Aspect:	NE	NE
BEC Zone:	SBS mc3	SBS mc3
Treatment Condition:	Grey	Grey
Source water:	Headwater	Headwater/Swamp
Drainage Density (km/km^2):	5.82	4.32
Road Density (km/km^2):	0.91	1.12
Standing Water Area (%):	0	0.05
Wetland Area (%):	0	0.49
Elevation (Mean):	1189	1230
Geology (primary):	Volcanic	Volcanic
Harvested Area (%):	19.28	24.63
Dominant Forest Cover:	Pine	Pine



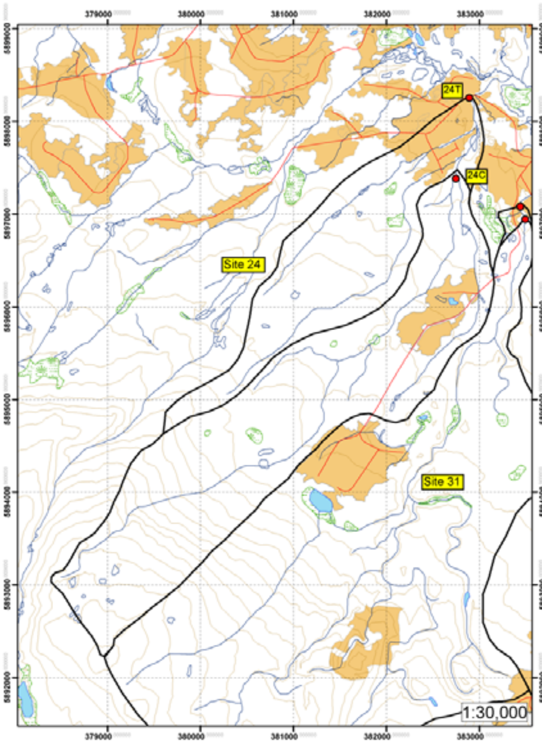
Site 23

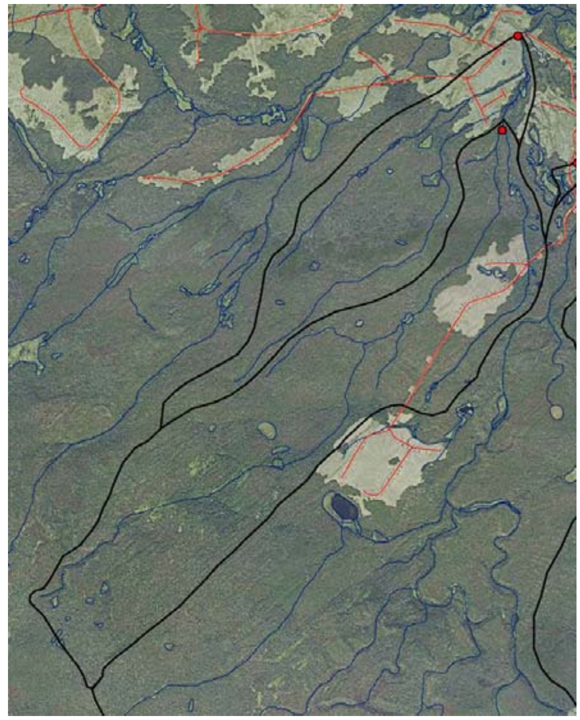


	23C	23T
Watershed Area (km^2):	4.01	4.25
Aspect:	E	E
BEC Zone:	SBS mc3	SBS mc3
Treatment Condition:	Grey	Grey
Source water:	Swamp	Swamp
Drainage Density (km/km^2):	1.41	1.44
Road Density (km/km^2):	0.96	1.08
Standing Water Area (%):	0.27	0.26
Wetland Area (%):	3.69	3.48
Elevation (Mean):	1226	1224
Geology (primary):	Unknown	Unknown
Harvested Area (%):	11.15	11.58
Dominant Forest Cover:	Pine	Pine



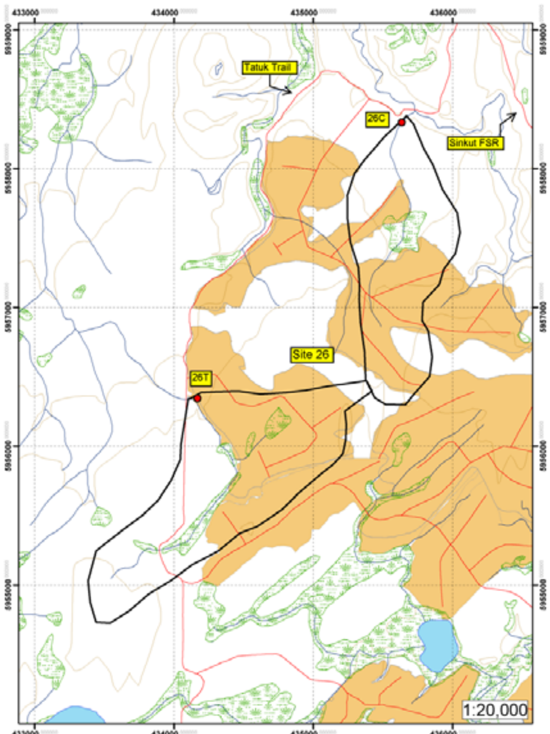
Site 24

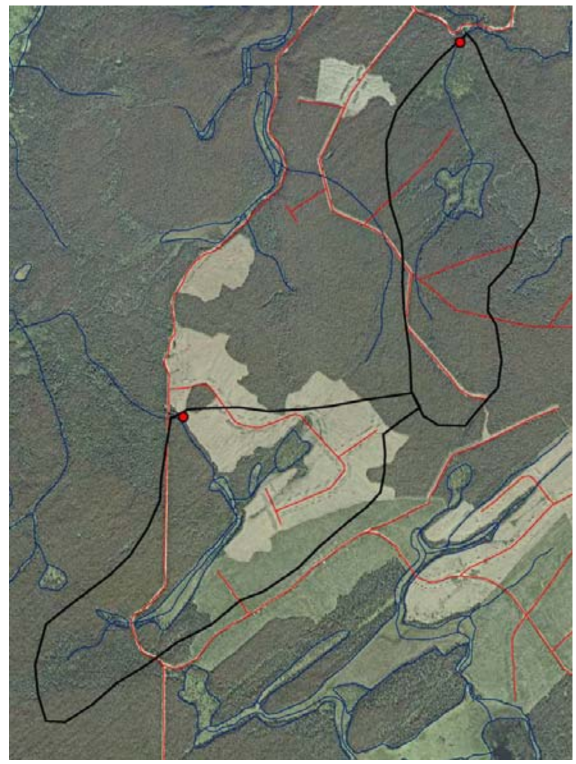




	24C	24T
Watershed Area (km^2):	6.66	9.94
Aspect:	N-NE	N-NE
BEC Zone:	SBS mc3	SBS mc3
Treatment Condition:	Grey	Grey
Source water:	Headwater	Headwater
Drainage Density (km/km^2):	2.5	2.74
Road Density (km/km^2):	0.36	0.39
Standing Water Area (%):	0.07	0.05
Wetland Area (%):	0.51	0.6
Elevation (Mean):	1300	1268
Geology (primary):	Unknown	Unknown
Harvested Area (%):	5.63	7.77
Dominant Forest Cover:	Pine	Pine

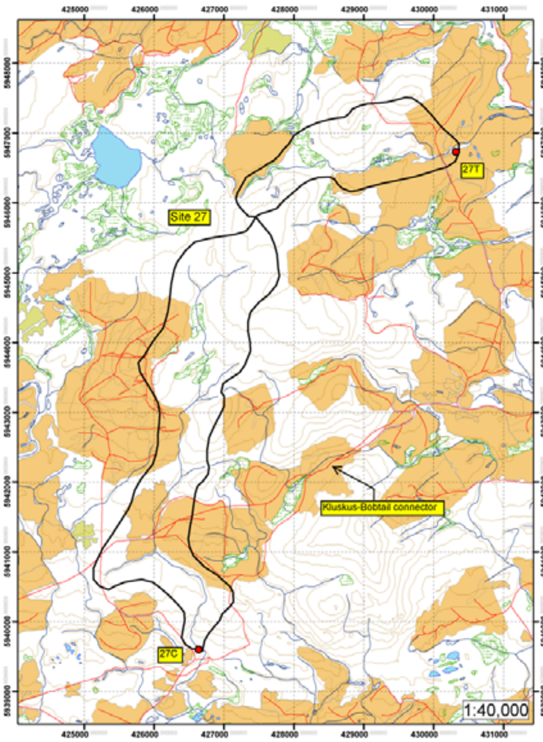
Site 26





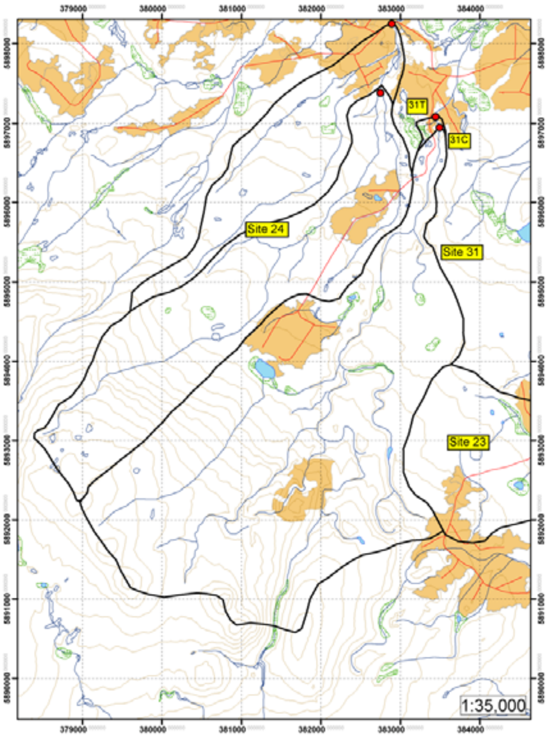
	26C	26T
Watershed Area (km^2):	1.08	1.49
Aspect:	N	N
BEC Zone:	SBS mc2	SBS mc2
Treatment Condition:	Grey	Grey
Source water:	Swamp	Swamp
Drainage Density (km/km^2):	1.58	1.36
Road Density (km/km^2):	2.31	2.16
Standing Water Area (%):	0	0
Wetland Area (%):	5.38	6.69
Elevation (Mean):	1131	1153
Geology (primary):	Metamorphic	Metamorphic
Harvested Area (%):	46.47	50.60
Dominant Forest Cover:	Pine	Pine

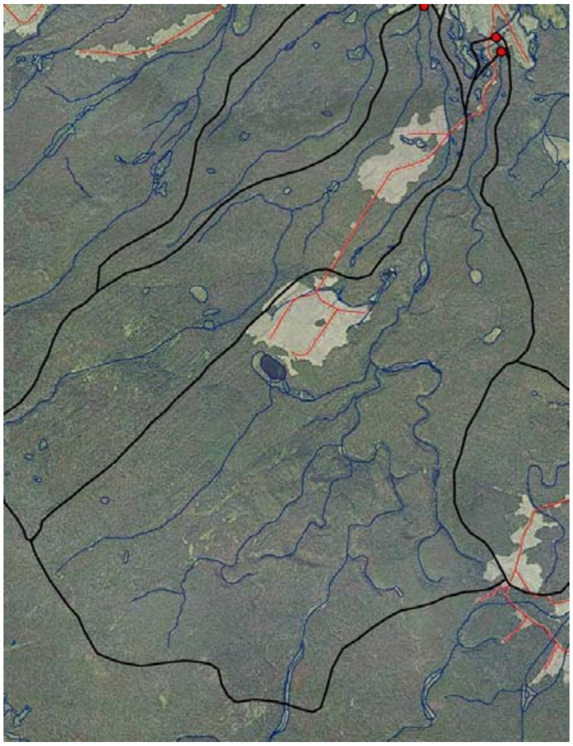
Site 27



	27C	27T
Watershed Area (km^2):	6.41	2.72
Aspect:	S	E
BEC Zone:	SBS mc2	ESSF mv1
Treatment Condition:	Grey	Grey
Source water:	Swamp	Swamp
Drainage Density (km/km^2):	1.60	2.39
Road Density (km/km^2):	1.22	0.66
Standing Water Area (%):	0	0
Wetland Area (%):	2.61	6.64
Elevation (Mean):	1242	1311
Geology (primary):	Intrusive	Intrusive
Harvested Area (%):	24.21	27.62
Dominant Forest Cover:	Spruce	Spruce

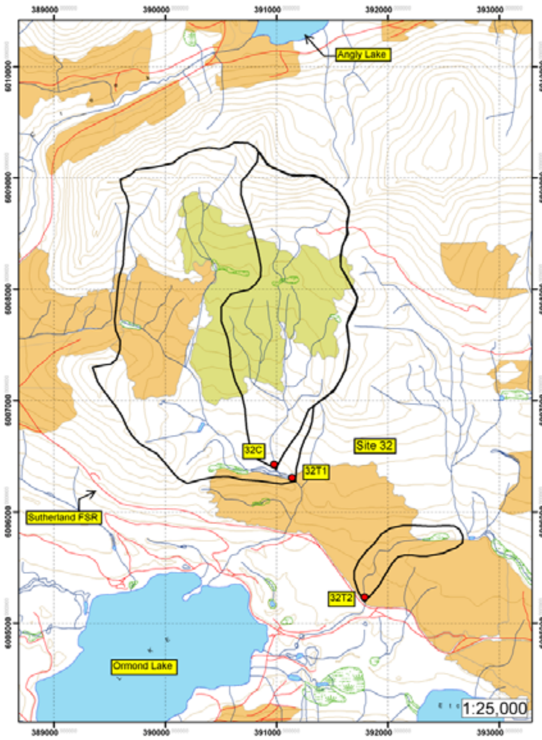
Site 31

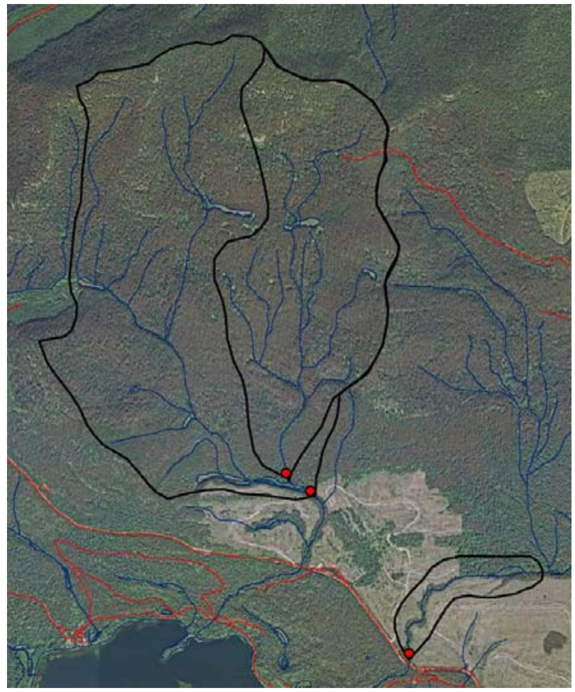




	31C	31T
Watershed Area (km^2):	13.72	13.79
Aspect:	N-NE	N-NE
BEC Zone:	SBS mc3	SBS mc3
Treatment Condition:	Grey	Grey
Source water:	Headwater	Headwater
Drainage Density (km/km^2):	2.11	2.14
Road Density (km/km^2):	0.21	0.22
Standing Water Area (%):	0.36	0.36
Wetland Area (%):	1.25	1.29
Elevation (Mean):	1334	1333
Geology (primary):	Volcanic	Volcanic
Harvested Area (%):	7.1	7.23
Dominant Forest Cover:	Pine	Pine

Site 32





	32C	32T1	32T2
Watershed Area (km^2):	2.16	5.41	0.28
Aspect:	S	S	SW
BEC Zone:	SBS mc2	SBS mc2	SBS dw3
Treatment Condition:	Grey	Grey	Grey
Source water:	Headwater	Headwater	Headwater
Drainage Density (km/km^2):	3.75	3.59	3.60
Road Density (km/km^2):	0.14	0.06	0
Standing Water Area (%):	0	0.04	0
Wetland Area (%):	0.56	0.89	3.16
Elevation (Mean):	1117	1106	894
Geology (primary):	Volcanic	Volcanic	Volcanic
Harvested Area (%):	0	18.43	80.68
Dominant Forest Cover:	Pine	Pine	Pine