Extension Note

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Forest access road widths in the Lakes Timber Supply Area

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Abstract

Roads are a significant feature in the forest landscape and represent a considerable reduction in the area of forest land that can be used for timber production. The mean widths of three types of roads (mainline, operational, and in-block) in the Lakes Timber Supply Area were determined. A stratified two-stage sampling approach was taken to estimate the mean width of each type of road. The first stage was road selection and the second stage was points along the road. The target sample size was 60 roads of each type and 10 points on each road; however, the number of roads sampled was less than the target of 60. The average estimated road widths were 27.3 m (mainline), 19.0 m (operational), and 8.4 m (in-block) and were comparable to the assumed widths of 30 m, 18 m, and 10 m, respectively. The estimated average widths of the mainline and operational roads were not significantly different from the assumed widths; the average estimated width of the in-block roads was significantly different from the assumed width. The area occupied by the three types of roads in the timber supply area was 1796 ha (mainline), 10 043 ha (operational), and 2159 ha (in-block). Road width data will lead to reduced uncertainty in allowable annual cut determinations.

KEYWORDS: *in-block; Lakes Timber Supply Area; mainline; Nadina; operational; road width; timber supply review.*

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Introduction

The purpose of this project was to provide data on the width of the three different types of forest access roads, and to assess the assumed road widths for the Lakes Timber Supply Area.

The Lakes Timber Supply Area (TSA) contains three different types of forest access roads: mainline, operational, and in-block roads (B.C. Ministry of Forests and Range 2010a). A mainline road is a main artery that provides access to a given geographic area for timber extraction purposes (Figure 1). These roads are often used year-round and are intended to carry a large volume of traffic, including heavy loads (e.g., off-highway logging trucks). An operational road typically branches off a mainline and leads to one or more cutblocks (Figure 2). An operational road may be used year-round and may be connected to other operational roads. An in-block road is sometimes referred to as a spur. In-block roads are wholly contained within a cutblock and are not expected to continue outside the cutblock in the future (Figure 3). These roads are used mostly to transport equipment into and out of a cutblock and to transport harvested timber to an operational road or a mainline.

FIGURE 1. Photo of a mainline road (junction of the Augier and Grizzly Forest Service roads).

Resource roads, which include forest access roads, are a significant part of the forest landscape. There are approximately 450 000 km of resource roads in British Columbia (D. Barker, pers. comm., November 2009). This is over 10 times the amount of provincial road in the province, which is just under 42 000 km (B.C. Ministry of Transportation 2003). The land occupied by roads represents a semi-permanent reduction in the area that can be used for timber production.

In the Lakes TSA, road widths are assumed to be 30 m, 18 m, and 10 m for mainline, operational, and in-block roads, respectively. The total road width includes the widths of the following road components: running surface, ditches, soil disturbance (e.g., pull-outs and gravel pits), and clearings (B.C. Ministry of Forests and Range 2009). The purpose of this project was to provide data on the width of the three different types of forest access roads, and to assess the assumed road widths for the Lakes TSA.

FIGURE 2. Photo of an operational road (Marlin Road, Taltapin Lake area).

FIGURE 3. Photo of in-block road (off the Endako Forest Service Road in the Taman Creek area).

Data

The population for this project consisted of all mainline, operational, and in-block roads in the Lakes TSA as obtained from the Nadina Road data set, which includes all roads within the timber harvesting land base as of approximately 2007. The sampling stratum was formed by placing the roads into one of the three categories. Samples within each stratum were collected using stratified two-stage sampling (Scheaffer et al. 1995). The first stage of the sample was road selection. The target sample size was 60 roads from each category. These roads were randomly selected with the Hawth's Sampling Tools (*http://www.spatialecology.com/index.php*), where each road had an equal probability of being selected. The second stage of the sample consisted of choosing 10 points along each selected road; each point was randomly chosen by multiplying the road length by a random number between 0 and 1, rounded to the nearest metre. This second stage was assumed to behave like a simple random sample of 10 points from among a frame of size M, where M is the length of the road in metres.

Road width field sampling protocols were developed to ensure that data were collected consistently among the surveyors. Seven measurements were taken at each sample point: the running surface width, the width of the ditch on both sides of the road, the soil disturbance width on both sides of the road, and the clearing width to the edge of the forest on both sides of the road. The total width of the road is the sum of the seven measurements. The components of the road were measured as follows.

- Running surface (the area of the road that carries the traffic): the hard, compact surface between the ditches, side slope, or berms, including the shoulders up to the point where they slope off into the ditch.
- Ditches: the width at the top of the ditch.
- Clearings: from the outside of the ditch, or the edge of the running surface if there is no ditch, to the tree-line or berm. The tree-line is the mature forest, live or dead, beyond the natural regeneration established after the disturbance.
- Soil disturbance: the compacted ground such as landings, pullouts, gravel pits, etc. to the tree-line.

The data were collected by the Nadina Forest District staff of the B.C. Ministry of Forests and Range in the course of their normal work. Time constraints, access, and weather (snow) prevented the full complement of roads from being sampled. There were only 47 mainline roads in the TSA, of which 40 were sampled. There were 2686 operational roads (49 sampled) and 4630 in-block roads (44 sampled).

A Geographic Positioning System was used to locate sample points on longer roads. A 50 m measuring tape was used to locate the sample points on shorter roads. All width measurements were taken to the nearest 0.1 m. The data were entered into an electronic spreadsheet for analysis.

Estimation

The simple random sampling ratio estimator of the population mean for two-stage stratified sampling was used within each stratum because the length of all the roads in the TSA was not known, only the length of those sampled. We calculated the mean and the variance of the mean for the width of the running surface, the total width of the ditches, the total width of the clearings, and the total road width. For each road type, the estimated mean road width (either by road component or total width), $\hat{\mu}_w$, is (equation 9.7 in Scheaffer et al. 1995):

$$\hat{\mu}_w = \frac{\sum_{i=1}^{n} M_i \bar{y}_i}{\sum_{i=1}^{n} M_i} \qquad [1]$$

where: n = number of roads selected for sampling,
M_i = length (metres) of road i,
$\bar{y}_i = \frac{\sum_{j=1}^{m_i} y_{ij}}{m_i}$, an estimate of the average width (metres) of road i,
m_i = number of sample points measured on road i (= 10 for all roads), and
y_{ij} = width (metres) of road i at sample point j.

The variance of the estimated mean road width, $\hat{V}(\hat{\mu}_w)$, is (equation 9.8 in Scheaffer et al. 1995):

$$\hat{V}(\hat{\mu}_w)=\left(\frac{N-n}{N}\right)\left(\frac{1}{n\bar{M}^2}\right)s_w^2+\frac{1}{nN\bar{M}^2}\sum_{i=1}^{n}M_i^2\left(\frac{M_i-m_i}{M_i}\right)\left(\frac{s_i^2}{m_i}\right) \qquad [2]$$

where: N = number of roads in the TSA,
$\bar{M} = \frac{\sum_{i=1}^{n} M_i}{n}$, the average road length (metres) of the sampled roads,
$s_w^2 = \frac{\sum_{i=1}^{n}(M_i\bar{y}_i - \hat{\mu}_w M_i)^2}{n-1}$, the between-road variance, equation 9.9 in Scheaffer et al. 1995,
$s_i^2 = \frac{\sum_{j=1}^{m_i}(y_{ij}-\bar{y}_i)^2}{m_i-1}$, the within-road variance, equation 9.10 in Scheaffer et al. 1995,
and all other variables are as previously defined.

The mean road width and its variance were used to calculate other statistics that indicate the precision of the estimate of the mean. These statistics are the standard error expressed as a percent of the mean ($SEPM_w$):

$$SEPM_w = 100\% \times \frac{\sqrt{\hat{V}(\hat{\mu}_w)}}{\hat{\mu}_w} \quad [3]$$

and the lower and upper bounds on the 95% confidence interval:

$$\hat{\mu}_w \pm t_{n-1,\,0.025}\sqrt{\hat{V}(\hat{\mu}_w)} \quad [4]$$

where: $t_{n-1,\,0.025}$ = upper 0.025 point of the t distribution with $n-1$ degrees of freedom and all other variables are as previously defined.

The mean road length and its 95% confidence interval were also calculated by road type using the simple random sampling without replacement formulae. Note that the finite population correction factor was used in all variance calculations for the mainline roads since most of these roads were sampled. The estimated road area and its 95% confidence interval were calculated using the formula for the mean and variance of the product of two independent random variables, x (i.e., estimated total road length) and y (i.e., estimated average road width) (Blumenfeld 2001):

$$\hat{\mu}_{x\times y} = \hat{\mu}_x \times \hat{\mu}_y \quad [5]$$

$$Var(x \times y) = Var(x) \times Var(y) + Var(x) \times \hat{\mu}_y^2 + Var(y) \times \hat{\mu}_x^2 \,. \quad [6]$$

Results

The mainline roads were the most difficult to measure. Some were wide with lots of compacted areas that did not clearly fit into any of the categories. Sometimes it was hard to discern whether a ditch existed or if it was a fill with natural drainage that had formed over time. Clearings were also hard to delineate. In some situations, there would be a natural opening in the clearing, and it was difficult to discern where the road-building disturbance ended and the natural opening began as both would have an alder (*Alnus* spp.)/willow (*Salix* spp.) complex. It was also hard to identify clearings when there was a strip of natural pine (*Pinus* spp.) ingress in the clearing with a plantation of the same age behind it.

Operational roads were more straightforward to measure. Some roads were built to an in-block road specification whereas others accessed multiple blocks and had easily distinguishable components. An operational road that travelled through a plantation would be measured to the planted tree-line. Some roads had ditches running the full length on both sides of the road, sometimes only on one side, and some roads had partial ditches that disappeared.

In-block roads were the easiest to measure as they usually consisted of just a running surface. In most cases, the measurement was taken to the plantation edges. In some cases, the measurements were taken to the berm of up-rooted stumps, debris, and rock where no trees were planted, and were recorded as either clearing or soil disturbance.

There was some subjectivity by the surveyors in identifying the individual components of the roads; however, the total width was accurate. The mean road widths for the mainline, operational, and in-block roads were 27.3 m, 19.0 m, and 8.4 m, respectively. This compares well to the assumed values of 30 m for mainlines, 18 m for operational roads, and 10 m for in-block roads. Table 1 contains the complete results of the road width analysis for the three different types of roads.

The widths of the running surfaces were quite uniform, as evidenced by the low standard errors as a percent of the mean, and the narrow confidence intervals for the running surface width of the different road types. The running surface of the in-block roads was just less than 2 m narrower on average than the running surface on mainline roads, with operational roads about mid-way between these types of roads.

The average ditch width was 1 m less on the mainline roads than on the operational roads. However, the ditch width on the mainline roads was much more consistent than on operational roads as evidenced by the smaller standard error as a percent of the mean. Part of the reason for the consistency of ditch width on mainline roads is that 72.5% of the sample points on these roads had a ditch, whereas only 60% of the sample points on operational roads had a ditch. Where no ditch existed, it was given a width of 0 m. The small average width and the large standard error as a percent of the mean for the in-block ditches are largely a result of only 15.9% of the sample points having a ditch.

This study estimates the total length of roads in the TSA by road type, and consequently the area occupied by roads. The average road lengths and 95% confidence intervals for the mainline, operational, and in-block roads were 13.992 ±2.077 km, 1.968 ±0.832 km, and 0.555 ±0.110 km, respectively. Multiplying these lengths by the number of roads of each type in the TSA gave total road lengths of 658 ±98 km (47 mainline roads), 5286 ±2235 km (2686 operational roads), and

TABLE 1. Estimated road width parameters for the different road components and road types

Road type	Average width (m)	Variance of average	$SEPM_w$ (%)[a]	95% confidence interval	
				Lower	Upper
Mainline					
Total	27.3	1.95	5.1	24.5	30.1
Ditch	3.4	0.06	7.3	2.9	3.9
Clearing	15.8	1.77	8.4	13.1	18.5
Running surface	6.3	0.03	2.7	6.0	6.7
Operational					
Total	19.0	0.67	4.3	17.4	20.7
Ditch	4.4	0.71	19.1	2.7	6.1
Clearing	8.3	0.63	9.6	6.7	9.9
Running surface	5.2	0.04	3.8	4.8	5.6
In-block					
Total	8.4	0.48	8.2	7.0	9.8
Ditch	0.4	0.01	28.8	0.2	0.7
Clearing	2.1	0.22	22.5	1.2	3.1
Running surface	4.5	0.01	2.7	4.3	4.8

[a] $SEPM_w$ = Standard error as a percent of the mean.

2570 ± 509 km (4630 in-block roads). The length of mainline road was relatively small, while the bulk of road length was for operational roads. To convert road length to area, the total road length was multiplied by the average road width. This yielded 1796 ±325 ha, 10 043 ±4348 ha, and 2159 ±558 ha of estimated area occupied by mainline, operational, and in-block roads, respectively, and a total area of 13 998 ±5231 ha. The same calculations using the assumed road widths were 1974 ha, 9515 ha, and 2570 ha for mainline, operational, and in-block roads, respectively, with a total area of 14 059 ha, which is very close to the area when using mean estimated road width.

Discussion and recommendations

The assumed widths for the mainline (30 m) and operational (18 m) roads compare well to the estimated widths of 27.3 m and 19.0 m, respectively. The assumed widths are 2.7 m wider and 1.0 m narrower than the estimated average widths for the mainline and operational roads, respectively, and are within the 95% confidence intervals for the estimated widths. The estimated width (8.4 m) of the in-block roads is about 1.6 m narrower than the assumed width (10 m), which is a statistically significant difference. Since statistical significance depends on sample size (and other factors), significant differences can likely be detected by simply increasing the sample size. Therefore, the practical implications of the differences between the assumed and estimated road widths are more important than statistical significance. For example, the estimated road width for the operational roads is close to the assumed width. However, this translates into large differences in area occupied by operational roads (discussed below), because there are a large number of operational roads.

The clearing widths were widest on the mainline roads, followed by the operational roads, with the in-block roads having a very small average clearing width. The clearings on both sides of the road provide better visibility, especially on curves. Therefore, the mainline and operational roads may need wider clearings than in-block roads. Clearings also accommodate decked timber, pull-outs, landings, gravel pits, etc. The mainline sample points with the largest widths were those at road junctions and landings. These points contributed to the large variance associated with the average mainline clearing width and increased the average total width.

The Ministry of Forests and Range periodically determines the amount of timber volume that is available for harvesting (B.C. Ministry of Forests and Range 2010b). This process is called a Timber Supply Review and one of its main purposes is to provide information to the Chief Forester for setting the allowable annual cut (AAC). Areas where timber harvesting will not occur are excluded from the timber harvesting land base, and hence do not contribute to the timber supply. This includes the area occupied by roads (B.C. Ministry of Forests and Range 2010b). Consequently, the assumptions used for road widths will affect the timber supply and the AAC. Although the road width estimates of this study are similar to the assumed widths, our method will reduce uncertainty in an AAC determination. Since the methodology is generally applicable, the study can be replicated to further improve information about timber supply in other management units in the province.

For those who may want to do a similar study in their management unit, we recommend the following.

- Obtaining a good inventory of the roads. Given the low number of mainline roads, we likely over-sampled these roads. As well, some of the roads that were supposed to be sampled were barge-access only; however, the barge was not available at the time of the sampling. A better road inventory may have allowed us to identify this problem and find alternative means of sampling these roads.
- Planning the field work for good weather and assigning adequate resources to the data collection. Local forest fires took away some of the resources from our sampling and early snowfalls made sampling difficult later in the year.
- Taking an independent sample of road length if you are interested in the total area of the roads. We did not sample enough roads for road length, as evidenced by the large confidence interval widths for the average road lengths. A prior estimate of road length could be used to determine the sample size. Alternatively, and preferably, obtain a census of the road lengths from a GIS where the roads are accurately mapped.

Although the road width estimates of this study are similar to the assumed widths, our method will reduce uncertainty in an allowable annual cut determination.

- Sampling more than 10 points along mainline roads if there are small numbers of them. The within-road variance was small compared to the between-road variance for the operational and in-block roads. This is largely due to the large number of roads in these classes. Therefore, sampling 10 points along these roads is adequate.

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Test Your Knowledge . . .

Forest access road widths in the Lakes Timber Supply Area

How well can you recall some of the main messages in the preceding Extension Note? Test your knowledge by answering the following questions. Answers are at the bottom of the page.

1. What are the three common types of forest roads?
   A) Mainline, operational, and in-block
   B) Highways, gravel roads, dirt roads
   C) Public, private, and trails

2. What type of sampling is appropriate to obtain average widths of the three types of roads?
   A) Stratified two-stage sampling
   B) Representative sampling
   C) Simple random sampling

3. What are the approximate average road widths for the three different types of roads in the Nadina Forest District?
   A) Mainline – 30 m, Operational – 20 m, In-block – 10 m
   B) Mainline – 20 m, Operational – 10 m, In-block – 5 m
   C) Mainline – 50 m, Operational – 40 m, In-block – 20 m

ANSWERS

1. A 2. A 3. A