PILOT STUDY

TO DETERMINE THE REDUCTION OF TIMBER DAMAGE

USING LIS PROCEDURES

Prepared for

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TABLE OF CONTENTS

TABLE OF TABLES

1.0 INTRODUCTION

Low impact seismic (LIS) line construction techniques are effective in reducing timber damages for certain stand types and density classes. What is not known is how much timber volume is lost during construction as compared to that of a conventional seismic line cut through the same stand types, considered as volume and volume/hectare. Actual LIS lines were compared to a simulated conventional seismic line of equal width (3.2-meters)[1]. A pilot project was initiated to compare timber volumes lost through the two seismic line construction methods using a remote sensing technique. This document summarizes the methods and results of the pilot project.

The objectives of the project are to:

1. Use pre and post disturbance aerial photographs to assess timber volume losses for LIS and traditional seismic line construction methods.
2. Collect additional ground data to better characterize the effect of LIS construction and to verify remote sensed information, including:

    - Line width measurements;
    - Tree damage due to line construction;
    - Push-out locations and dimensions;
    - Sample tree heights;
    - GPS LIS centre lines, push outs and sample trees; and
    - Understory estimates.

3. To determine if measurement tools being used are adequate and recommend changes if necessary.

1.1 Pilot Area

The pilot area was selected within Township 60, Range 12, west of the fifth meridian, sections 11,12,13, and 14 (Figure 1). This locale was selected for the following reasons:

- Seismic lines constructed using LIS technique within the last five years were in the area;
- 1:20,000 or larger scale aerial photograph coverage was available that had been taken prior to the LIS program and was no more then 10 years old;
- The LIS lines had to pass through target stand types; and
- The area was accessible for ground truthing.

[1] The project was initially intended to compare a simulated 5.5 m conventional line to an actual LIS line, however since TDA assessments account for line width directly, the project was adjusted to remove the area differences due to corridor width. Areas still vary between LIS and Traditional, but only as a function of the avoidance and line of sight objectives of the actual LIS.

2.0 METHODS

The process to determine how much volume has been removed during LIS and traditional seismic line construction used photo interpretation of pre and post disturbance aerial photographs using softcopy technology. Softcopy refers to a photogrammetric process where all work is done in the digital environment. Photo images are scanned and viewed with measurements made, on-screen, in 3-D stereo. The process allows for viewing images at very large scales limited by the original photo resolution and subsequent scanning rate.

2.1 Acquisition of Aerial Photographs

Pre-disturbance 1:15,000, black and white aerial photographs taken Aug 24, 1994 were found to be the most recent photographs available prior to LIS construction. New 1:10,000, black and white aerial photographs were acquired for post disturbance interpretation July 14, 2003 using the highest quality film and camera readily available.

2.2 Softcopy Preparation

Diapositives of the photographs were scanned at 15 microns (1700 dots per inch) and controlled using Alberta government ground control coordinates. Image and image model files were produced for input into a softcopy DiAp Viewer system. Reference files of the existing AVI and base map layer were produced for use as overlays registered to the scanned images. The system was then ready for 3-D stereo, on-screen viewing and measurement.

2.3 Selection of Candidate LIS Lines

The objective of LIS (also referred to as the 'path of least resistance') is to create a narrow, continuously meandering line. This reduces the line of sight to less than 200 meters, avoids larger trees (meandering avoidance), and leads the soil and ground generally undisturbed. The line width can range from 1.0 to 4.5 meters, and be a hand-cut or mechanically cut line.

Two field trips to the pilot area were made by various members of the LIS TDA Working Group Committee to determine line selection and other parameters to be measured. The line segments selected were examined by SRD and confirmed to be LIS. Line selection was based on previous committee meetings that defined several conditions or parameters as follows;

1. "A" density stands do not offer any significant opportunity for low-impact seismic operations because it is felt that traditional seismic line construction techniques in A density stands already approximate LIS techniques.

2. “D” density stands also offer little opportunity for LIS as the density of the trees is too high for operators to implement proactive avoidance.
3. “B” and “C” density stands offer the best opportunity for LIS operations.
4. The selection of specific line segments was intended to sample B and C density polygons.

Final line selection is shown in Figure 1.

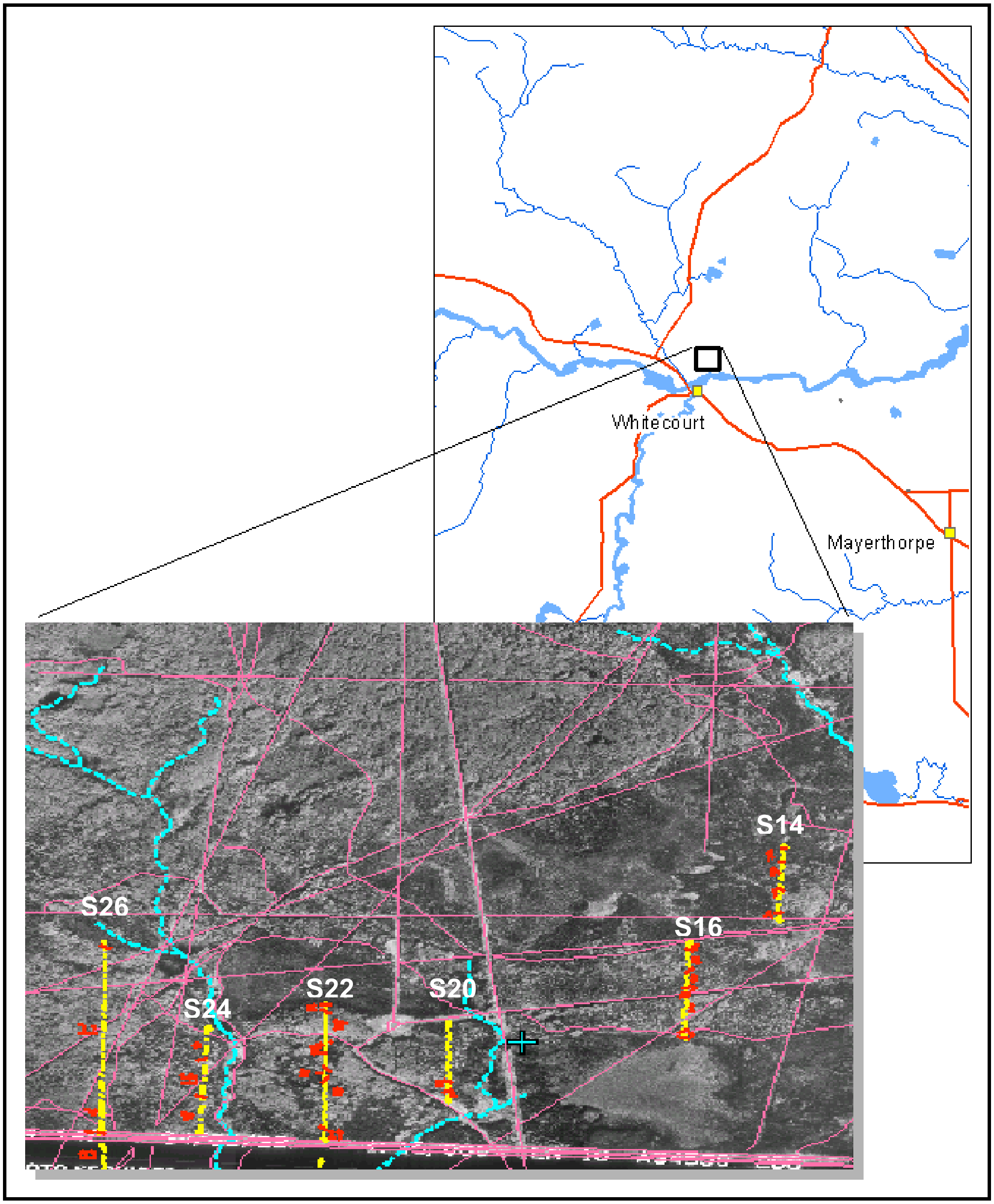

Figure 1. Location of pilot area and sample seismic lines (yellow)

2.4 Field Measurement

LIS lines were ground-truthed over a two-day field program. Parameters measured included:

- GPS of centrelines;
- LIS width recorded at start, end, and every 100m station, measured from edges of ground disturbance;
- GPS and dimensions of pushouts;
- Stem damage (5 cm^2 or greater) as a result of LIS construction, recorded as number of merchantable trees per every fifty meters;
- Stem count of downed merchantable trees (15/10) removed to produce the LIS line by species and diameter class;
- Sample height measurement of dominant and co dominant trees to provide reference heights and species for photo interpreters; and
- Presence of understory regeneration (less than merchantable limits), species and stems per hectare estimates.

The sample height trees were chosen to represent the stand types intercepted by the LIS lines. A minimum of one tree was usually measured at the start and every fifty meter station, if warranted. The location of each sample tree was also recorded by GPS.

3.0 PHOTO INTERPRETATION

The photo interpretation process involved all work done within the softcopy system. The GPS centre lines were registered to the new photos, then existing LIS and simulated conventional seismic line corridors were delineated. These corridors were then registered to the pre disturbance photos to determine what trees had been removed during LIS construction and what additional trees would have been removed if a conventional 3.2-meter line had been constructed. The process involved an overlay of lines on photos, inventory of merchantable trees and calculating volumes.

3.1 Overlay Seismic Lines on Digital Photos

The GPS centre line of the LIS lines were corrected and registered to the digital photos using control points. Connecting the centre point of each end point of each LIS seismic line with a straight line simulated the centre line of the conventional 3.2-meter seismic line.

The LIS seismic line corridors were then drawn based on measured field widths; an example of interpretation of the actual line is shown on the 1:10,000 photos (Figure 2). The traditional seismic line corridors were drawn using the centre line of the LIS line as an anchor and using a 3.2-meter width(Figure 3).

Each corridor was then registered to the pre-disturbance 1:15,000 photos ready for interpretation and measurement of trees that fell within the seismic corridor.

3.2 List All Trees from Photos

This process involved the estimation of species and heights for all merchantable trees for both the LIS and the simulated traditional seismic lines. The AVI forest coverage was also registered to the pre-disturbance photo so that all listed trees could be assigned to the AVI polygon number where they occurred. Each tree was assigned a:

- Seismic line identification number;
- Polygon number;
- Species code;
- Height to nearest meter; and
- An understory or overstory.

All merchantable trees that were observed were recorded. Merchantable trees were defined as having a 15cm stump (at 30cm stump height) and were at least 15 meters in height.

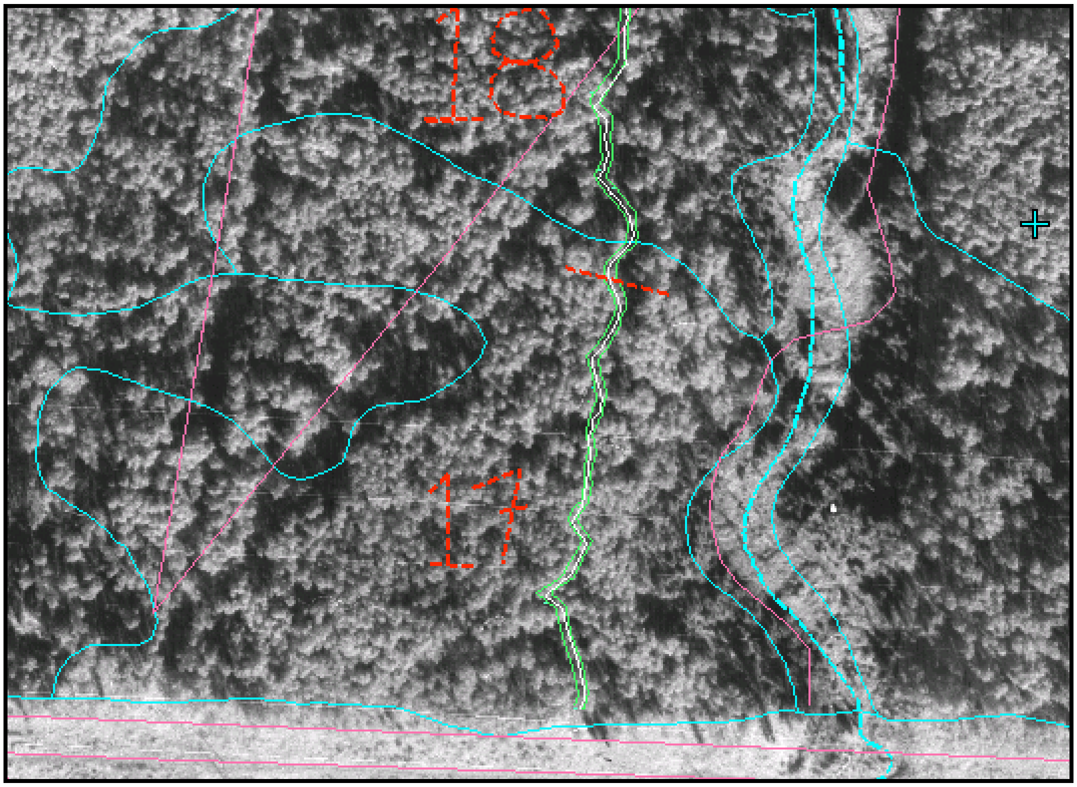

Figure 2. Mapped position (green lines) of low impact seismic line S24 superimposed onto 1:10,000 scale photograph (enlarged).

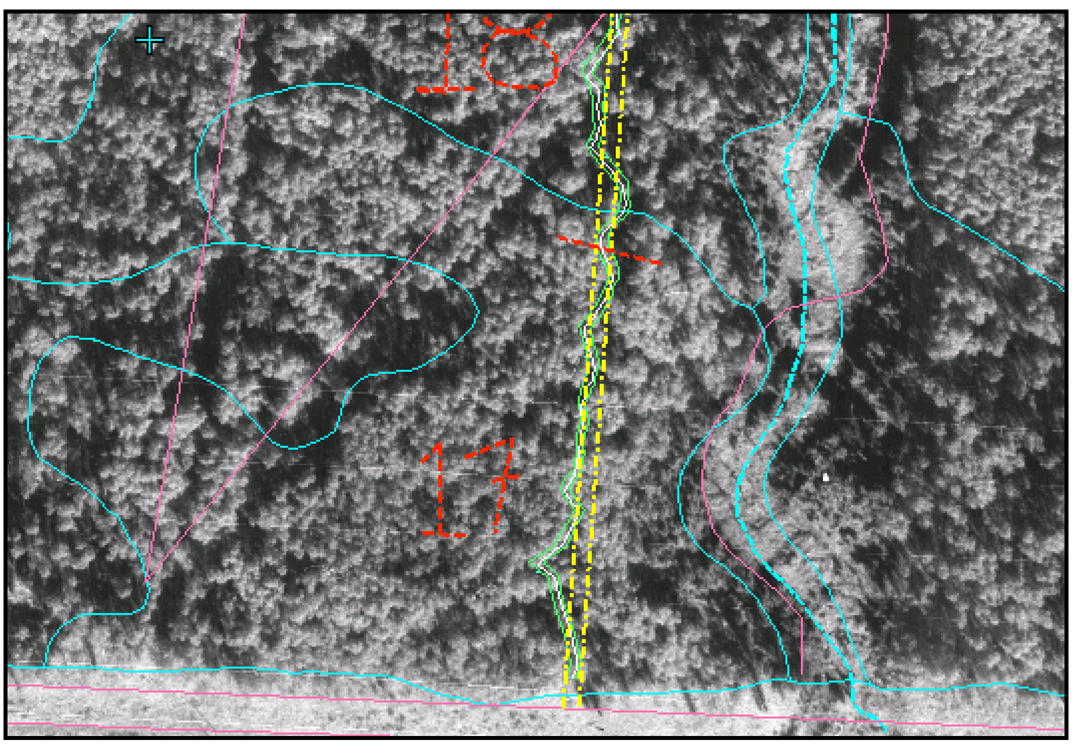

Figure 3. Mapped position of traditional seismic line (yellow) in relation to the actual LIS position of S24 superimposed onto 1:10,000 scale photograph (enlarged).

3.3 Calculate Volumes LIS versus Conventional Seismic

Total volumes estimated to have been removed by each seismic line construction technique are calculated using the tree list data. The difference between methods is expressed as a volume and a percent.

The tree volumes were calculated using the estimated heights from each individual tree and using standard forestry taper equations developed by Sustainable Resource division. Although diameter is an important variable for accurately calculating volumes, it was not available for this analysis; the assumption that diameter varies directly with height is made for volume calculations. Although the resulting volumes may be imprecise, all volumes are calculated similarly and therefore any biases will be evenly applied; relative percent differences should indicate useful trends.

4.0 RESULTS

4.1 Tree Count and Field Data

Table 1 summarizes data for each line segment recorded during the field and interpretation programs[2]. Of interest are the percentage numbers shown in the coniferous column of the 'Total Trees Ground LIS' section. These indicate the percentage of trees that were less than 20 cm in diameter and therefore more likely an understory merchantable tree. Very few understory merchantable trees were visible on the pre-disturbance photographs due to scale and photo quality. Table 2 summarizes each seismic line by area disturbed (not including pushouts which occupied a negligible area) for LIS and conventional methods. LIS area is calculated using two methods; by total length with an average width and by 100m segments with recorded field width. The difference in length between LIS and traditional lines ranged from 1.3 percent to 17.3 percent. The average was 4.5 percent.

4.2 Analysis

Low impact seismic construction is assumed to result in a lower volume per hectare removal, because of tree avoidance techniques practiced by operators. This assumption underlies the sample design and protocols for this pilot study. It is assumed, in other words, that there is not a direct correspondence between area disturbed and volume removed. For this reason this pilot study had to account for the actual trees removed under the two types of construction, instead of focusing on simple summaries of area disturbed.

The experimental unit for the study was selected portions of LIS lines. The selection was based on those portions of lines which were completely composed of AVI polygons of B or C crown closure. A and D crown closure were to have been excluded, as the terms of reference for the pilot study identified these as having the following attributes:

1. In A density stands avoidance techniques are nearly perfect, and little to no merchantable tree volume is removed.
2. In D density stands there is too high a density for avoidance techniques to reduce the volume/ha under LIS. The straight ratio of area between traditional and LIS is sufficient for these stands.

[2] Sample tree data, which were only used as reference heights for the photo interpreter, and the understory data which will be discussed in Section 5.0, are not shown in Table 1.

Table 1 Summary of Field and Photo Interpretation Measurement

Line Segment	Length (m)	Pushouts #	Damaged Trees Per 50 m	Total Trees Ground LIS (1)			Total Trees Softcopy LIS			Total Trees Traditional (3.2m)		
				Deciduous	Coniferous	Total	Deciduous	Coniferous	Total	Deciduous	Coniferous	Total
S26 North	1082	0	2.0	219 35%	6	225	204	5	209	160	10	170
S26 South	250	0	0.6	4	13 38%	17	4	11	15	5	17	22
S24 North	620	1	0.5	27	41 63%	68	29	23	52	44	23	67
S22 North	800	1	1.1	54	71 68%	125	57	52	109	95	32	127
S22 South	300	0	1.0	18	27 63%	45	13	12	25	19	17	36
S20 South	436	2	3.0	47	85 80%	132	55	29	84	56	25	81
S16 North	300	0	1.6	10	66 68%	76	13	42	55	26	40	66
S16 South	236	0	0.4	25	9 67%	34	19	6	25	42	5	47
S14 North	423	0	1.4	43	51 74%	94	44	37	81	50	30	80

*(1) percent values indicate amount of trees with dbh of less than 17.5 cm

Table 2 Total Area by Seismic Line for LIS and Traditional Methods (1)

Seismic Line	Length (m)	Ave Width (m)	Total Area LIS		Total Area Trad.(3.2m)	
			By Segment	Total Average	Length (m)	Area (ha)
S22 North	800	3.3	0.265	0.264	760	0.243
S22 South	300	2.8	0.084	0.084	248	0.079
S26 North	1082	3.5	0.374	0.379	1058	0.339
S26 South	250	3.0	0.076	0.075	219	0.070
S24 North	620	3.0	0.19	0.186	610	0.195
S14 North	423	3.1	0.133	0.131	408	0.131
S16 North	300	3.1	0.092	0.093	279	0.089
S16 South	236	2.8	0.066	0.066	230	0.074
S20 South	436	3.3	0.141	0.144	428	0.137

1) LIS area is calculated 2 ways, by 100m segments, and by total length with average width.

However because of an error in the map production, which was the basis for the sample line selection, the sampled lines included considerable area of A and D crown closure, contrary to the project terms of reference. Because of this, the overall rollup results are weighted to crown closure according to Table 3.

Table 3. Percent line length by Crown Closure

Crown Closure	Percent
A	22.9
B	15.0
C	21.0
D	41.1

A pair of overall summaries, combining all lines together, is shown in Tables 4 and 5, below. These summaries combine all crown closures and stand types.

Table 4. Overall LIS vs. Traditional summary at 15/10 utilization

Variable	LIS	Traditional	Percent change – Trad. to LIS
Number of trees	514	574	-10
Average tree size, M3/tree	.316	.367	-14
Volume M3	162.6	210.9	-23
Volume/ha M3	114.4	155.5	-26
Area ha	1.421	1.357	+5

Table 5. Overall LIS vs. Traditional summary at 0/0 utilization

Variable	LIS	Traditional	Percent change – Trad. to LIS
Number of trees	652	701	-7
Average tree size, M3/tree	.300	.330	-9
Volume M3	195.4	231.4	-16
Volume/ha M3	137.5	170.5	-19
Area ha	1.421	1.357	+5

A number of points may be summarized from the above tables;

- the merchantable volume removed using LIS is 23% less than from a traditional line of equal width
- this volume reduction is in spite of a marginally greater area disturbed using LIS (5% increase in area disturbed using LIS)
- the total volume/ha removal is 19% less using LIS, this difference is 26% considering merchantable volume.
- this reduction in volume/ha is related to the reduction in the average tree size removed, which declines by 14% using LIS
- making the comparison of 0/0 utilization shrinks all of these differences, which would be expected since the gains are assumed to come primarily from avoidance of larger trees

The remainder of the analysis will only present the 15/10 results. There was full analysis conducted on 0/0 utilization, however it mirrored the above finding, that the differences in tree size and volume/ha are reduced by considering all trees.

Since all crown closures were sampled, it was decided to conduct an analysis relating crown closure class to these variables. The crown closure values in Table 6 come from only those lines that had less than 5% in other crown classes. This restriction is necessary because the experimental unit is the entire sampled line portion. There can be no division of lines into components because the simulated traditional line was overlaid, with common start and finish points, on the selected LIS line portion. This means that the area comparisons must be taken within sampled lines as a whole, and ‘by polygon’ comparisons cannot be drawn.

Approximately 55% of the total line length from the complete pilot study was included in the density class summary presented in Table 6. The D density stands were aspen stands, and the A density stands were aspen-spruce. Because the data used in Table 6 is only a subset of the total data there is no direct comparison possible between Tables 4 and 5 with Table 6.

Table 6 By crown closure LIS vs. traditional summary at 15/10 utilization

Variable	A			B			C			D		
	LIS	Trad	Pct[2]	LIS	Trad	Pct	LIS	Trad	Pct	LIS	Trad	Pct
Number of trees	20	26	-23	10	13	-23	40	57	-30	213	202	+5
Tree size, M3/tree	.40	.67	-40	.60	.58	+3	.40	.45	-11	.25	.34	-26
Volume M3	8.0	17.4	-54	6.0	7.5	-20	15.9	25.4	-37	54.0	68.8	-22
Volume/ha M3	95.2	220.3	-57	79.3	107.1	-26	83.6	130.3	-36	122.9	166.6	-26
Area ha	.084	.079	+6	.076	.070	+9	.19	.195	-3	.44	.413	+7

[2] Pct =percent change from Traditional to LIS

With the exception of mean tree size, no statistical comparisons were possible because the true number of experimental units is the number of complete line portions. Since there was no replication, no statistics are possible. This was identified as the likely outcome of this pilot project, and if definitive statistical findings are required then a number of areas and a number of lines within these areas will require sampling.

A within density class statistical comparison was run on mean tree size. At the 5% confidence level, using t-tests, the differences are significant between LIS and traditional for A and D density, but not for B or C.

A number of points may be summarized from Table 6.

- the greatest reduction in tree size and volume/ha removal occurs in A density stands. This is predictable and is probably because as the stand density decreases, the opportunities to avoid larger trees increases.
- Contrary to expectations both A and D density stands in this sample showed benefits from LIS techniques. Smaller trees were removed, on average, and the volume/ha was lower, using LIS versus traditional.
- D density stands had the smallest average tree, as would be expected, but still had a significant reduction in tree size removed using LIS.

5.0 DISCUSSION

5.1 Aerial Photography

A key element of any remote sensing project is image resolution. Resolution must be sharp enough to capture the required detail, at a certain scale, to assess, measure, or monitor target attributes. Results of the LIS project are based on using pre-disturbance images that were less than optimum. The pilot area location only had existing aerial photo coverage at 1:15,000 scale from 1994. The photos were taken with an RC-10 camera with a resolution of 45-55 line pairs per millimetre (lpm). In contrast, the newer RC-30 camera has a resolution of over 90 lpm. The result is that the pre-disturbance photos were not sharp and lacked sufficient detail to discern smaller tree crowns or trees within shadows. The post-disturbance 1:10,000 aerial photos had very good resolution and the larger scale would have improved tree count and measurement.

5.2 Field Assessment

A field measurement program is necessary for LIS timber measurement to be successful. It is necessary to first verify that seismic lines are LIS as stated on the map. Minimum requirements include GPS of the LIS centre line, periodic seismic line width measurement, and sample tree data collection. The GPS centreline and LIS widths permit accurate mapping of the LIS corridor within a digital mapping and interpretation system. The sample tree data are used as reference points by the photo interpreter for species identification and stand height estimates.

5.3 Conifer Understory

Conifer understory trees (1 meter to 15 meters) were not visible under the overstory canopy using either the 1:15,000 or 1:10,000 photo scale. Several polygons were identified in the field with having significant conifer understory that could not be photo interpreted. A solution to this would be to acquire photographs when the deciduous overstory trees are in leaf-off condition. Conifer understory within conifer stands cannot be identified.

6.0 SUMMARY AND RECOMMENDATIONS

1. The limited study area and lack of replication from this pilot do not provide definitive quantitative results. Further research is required and the results identified in this study should not be used for operational purposes for reduction in timber damage assessment.
2. As a result of this pilot study, we recommend the following changes and or additions to the methodology.

   - The 1:15,000 photography used to derive the pre-disturbance tree lists was marginal for this purpose, and could only be used because the ground derived tree list was available as a check. The 1:10,000 photography obtained specifically for this pilot was adequate to good. It is strongly recommended that if this project is extended beyond the pilot stage, that 1:10,000 photography be obtained prior to LIS programs being run. Care would be required to ensure that no operator could know that their LIS program might be sampled.
   - Obtain proper replication of stand types and densities across the province, from lines assessed to be eligible for LIS according to regulatory criteria.
   - Traditional lines be simulated using the actual line width measured on the LIS line segment.

3. This pilot study shows that properly conducted LIS techniques provide a reduction in timber damage/harvest. Volume/ha and average tree size are lower using LIS.
4. The benefit extends to both A and D density crown closures, contrary to expectations. It should be noted, however, that the pilot study was only done in one area and had no replication. An extension of the program to ensure different stand types and areas were sampled using replication might show different results. Furthermore, the D density crown closure stands sampled were of good height, which is not the provincial norm for these types of stands.
5. A density stands provide the greatest benefit from applying LIS. The remaining density classes of B to D had similar LIS benefits which were not definitively different. Field observations suggest that avoidance is dependent on the size of the trees (merchantability) within C and D density stands. For example a 23-meter C density stand is a good candidate for avoidance where as a 17 meter C density stand might not be.