Extending Hauling Operations on Thawing Roads by Using Road-Friendly Technologies

Colin Blair
Colin Blair, P.Eng. Researcher. Forest Engineering Research Institute of Canada. 2601 East Mall. Vancouver, B.C. V6T 1Z4, cwblair@shaw.ca, ph: (604) 228-1555, fax: (604) 228-0999

ABSTRACT - In the springs of 2000, the Forest Engineering Research Institute of Canada (FERIC) undertook a series of studies to investigate the potential of using a combination of technologies to extend log hauling operations during the traditional spring break-up period. During spring break-up, thin pavement roads are weakened, resulting in the application of government-imposed load restrictions to prevent road damage from heavy haul traffic. These load restrictions typically result in the suspension of log hauling operations for a period of six to ten weeks. The undertaken studies examined the use of Central Tire Inflation (CTI) systems in combination with a variety of axle arrangements on log trucks to minimize road damage while hauling full loads during the traditional load restriction period.

Keywords: Load restrictions, Thawing roads, Log hauling roads, Logging trucks, Central tire inflation systems.

INTRODUCTION

In many regions of North America, load restrictions are imposed on thawing, secondary roads to mitigate damage from heavy haul traffic and can last from six to ten weeks. Several methods described by Kestler et al (2000) including regional frost probes, historical dates and pavement deflection testing are used to impose and remove load restrictions. These load restricted secondary roads often form a bottleneck in log transportation operations as primary roads are not restricted and higher elevation forest roads are still frozen. As a result, the log haul is usually suspended because it is not economically viable to operate at reduced loads.

Previous work (Bradley 1997) indicates that optimized tire pressures have the potential to alleviate damage to thawing thin pavement roads. For example, fully loaded logging trucks operating at lower speeds can safely reduce tire pressures to increase the tire contact area, or footprint, which reduces the horizontal and vertical strains applied to the road structure. Central Tire Inflation (CTI) systems provide a convenient means for truck drivers to monitor and adjust tire pressures. As well, multi-axle groupings that have lower individual axle loads compared to single axle groups can reduce the strains in the road structure. Both of these technologies are considered to be road-friendly and may provide opportunities to operate fully-loaded trucks during a substantial portion of the traditional load restriction period.

The strength of a road structure is highest during the winter when it is frozen, however, the strength drops quickly as it thaws (Figure 1). Load restrictions are usually imposed at the start of spring thaw when the road strength begins to decrease. This weakening is due to the water from the melting frost becoming trapped in the road bed. As thawing continues, the water starts to drain from the road bed and the strength recovers into the summer. Once the road has recovered to an acceptable level of strength, the load restrictions are removed and trucks are allowed to resume hauling at full axle weights.

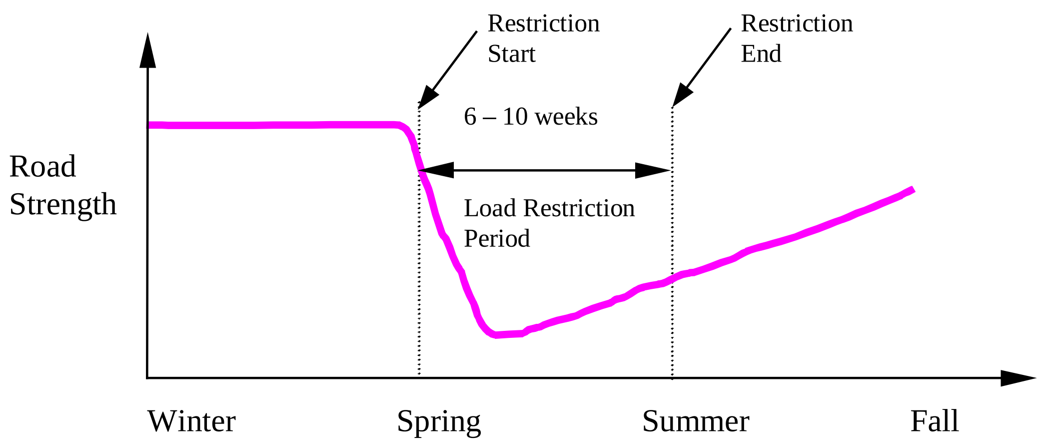

Figure 1: Seasonal fluctuations of road strength

The actual thaw period may be less than one week whereas the strength loss can last five weeks or longer. As trucks equipped with road-friendly technologies impart less strain on a road compared to conventional trucks, they may be able to resume hauling earlier than the traditional end of the load restriction period. Benefits from a longer haul season can include reduced truck hourly ownership costs, reduced carrying charges for log yard inventory, end-product quality improvements from a fresher wood supply and more flexible harvesting and hauling operations. Concerns that arise included regulatory issues associated with the risks to the infrastructure and costs of monitoring the road and haul fleet for compliance.

During February and March 2000, the Forest Engineering Research Institute of Canada (FERIC) undertook a field trial to evaluate the potential to extend the log haul season by using road-friendly technologies. The trial took place near Kelowna, B.C. with the cooperation of Riverside Forest Products Ltd. and the B.C. Ministry of Transportation.

OBJECTIVE

The objective of this study was to investigate the potential to resume hauling during the latter portion of the spring load restriction period by using road-friendly technologies.

METHODOLOGY

Philpott Road near Kelowna, B.C. was selected as the test road for this study because it is a secondary, thin pavement road that has historically been a log haul bottleneck for Riverside Forest Products Ltd. The road was instrumented with a frost probe containing twelve temperature sensors and three moisture sensors connected to a datalogger (Figure 2). The datalogger was also connected to a telephone line for remote monitoring of the thaw and recovery period. Road core samples were taken to determine the road structure.

Figure 2: Gathering data from the Philpott Road datalogger

Examining a typical road cross-section with an imposed wheel load reveals two critical strains: the horizontal tensile stain at the bottom of the asphalt layer and the vertical compressive strain at the bottom of the base course (Figure 3). The horizontal tensile strain relates to fatigue failure of the road while the vertical compressive strain relates to rutting failure of the road. Many computer programs, including ELSYM-5[1], have been developed to calculate the stresses, strains and displacements in a road structure caused by imposed wheel loads. ELSYM-5 describes the road structure in layers including each layers' Modulus of Elasticity and thickness, while the wheel load is described by its load, ground pressure, and footprint.

In the B.C.truck regulations, there are three available axle configurations: tridem axle groups allowed 8000 kg per axle; tandem axle groups allowed 8500 kg per axle; and single axles allowed 9100 kg (Figure 4). It is evident that the lower axle loads of the tridem group make it the more road-friendly axle configuration. Central Tire Inflation systems can be used to optimize tire pressures and improve the overall road-friendliness of the log truck configuration. Travelling at lower speeds (e.g. 30 – 60 km/h) which is typical of secondary roads provides more opportunity to reduce the tire pressure for a given load. Operating with optimized tire pressures[2] has been shown to decrease fatigue damage (NCHRP 1997) compared to operating at normal highway tire pressure[3]. ELSYM-5 was used to compare each axle group with full load, 90% load, normal highway tire pressure and optimized tire pressure to determine the most road-friendly combination.

The B.C. Ministry of Transportation has historically used a maximum expected deflection[4] of 1.25 mm to indicate the end of the load restriction period. Using the road core samples to

---

1 ELSYM-5 is a computer procedure that uses elastic layer theory to calculate the stresses, strains and displacements in a pavement system that was developed for the US Department of Transportation and Federal Highway Administration.

2 Optimized tire pressure as recommended by the Tire and Rim Association (1999) is dependent on vehicle load and travel speed. Can be as low as 172 kPa (25 psi).

3 Normal highway tire pressure is typically 690 kPa (100 psi)

4 Maximum expected deflection is the mean plus two standard deviations of a set of Benkelman beam tests.

describe the road structure, ELSYM-5 was used to determine the road strength at this maximum expected deflection. Once the road strength was known, the strains imposed by each of the axle group load/tire pressure combinations were calculated. The maximum calculated strain was then used as the maximum allowable strain. ELSYM-5 was then used to determine at what road strength each axle group load/tire pressure combination causes the maximum allowable strain. This becomes the road strength when a log truck with this axle group load/tire pressure combination can resume hauling after spring break-up. Benkelman beam5 measurements were used to monitor the road strength during the trial. The log trucks resumed hauling once the predicted road strength for the maximum allowable strain for the particular axle group load/tire pressure combination was achieved. Based on work by Mahoney et al. (1994), it was assumed that the road would fail through fatigue cracking rather than rutting. Therefore, the amount of horizontal tensile strain imposed by a given combination formed the basis of its road-friendliness ranking.

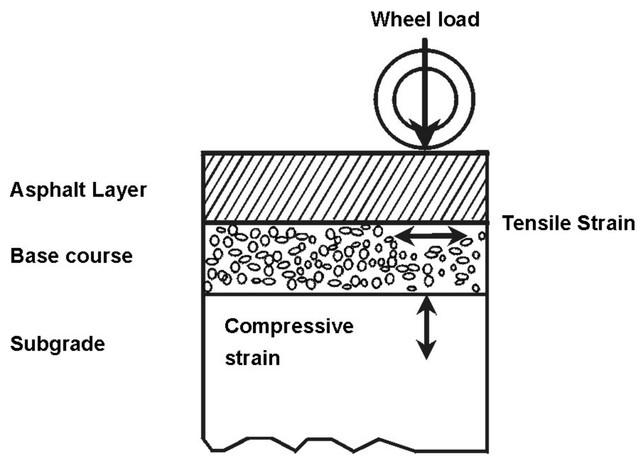

Figure 3: Typical road cross-section.

Monitoring methods acceptable to the B.C. Ministry of Transportation were needed to ensure that operating road-friendly configurations before the end of the load restriction period would not cause unacceptable damage to the road. The first method was to use surface distress surveys (Aderichin 1994), to monitor the surface condition before, during and after the trial. Five representative sections 50 m in length were observed for signs of surface distress, including pavement cracking, lifting and pothole development. If areas outside of the survey sections were noticed to be breaking up, they were added to the survey sections. As well, the rutting rate of the road was assessed using before and after measurements of the road cross-section profile from three 25 m sections. FERIC personnel were on-site to monitor the road strength and surface condition. In addition, they verified the tire pressures and axle loads on the log trucks for conformance to the test parameters (Figure 5.)

ELSYM-5 was used to determine that the road strength corresponding to a 1.25 mm maximum expected deflection for Philpott Road was 55.2 MPa (8000 psi). Using this road strength, the horizontal strains were calculated for each axle group load/tire pressure combination (Figure 6). The horizontal tensile strain for a single axle with normal highway tire pressure loaded to a typical load restriction of 75% is included in the chart for comparison purposes. The single axle

5 Benkelman beam is a device used to measure the road surface deflection rebound due to a standard axle load which can then be related to road strength.

with normal highway tire pressure and 100% load causes the highest strain (1.37×10^{-3} mm/mm) whereas the tridem axle with optimized tire pressure and 90% load causes the lowest strain (0.28×10^{-3} mm/mm). It can be seen that reducing the tire pressure has a greater affect on the tensile strain than reducing the load. It should be noted that a fully-loaded axle group with optimized tire pressure causes less strain than the same partially-loaded axle group with normal highway tire pressure. The strains will vary depending on the thickness and strength of the various layers in the road structure.

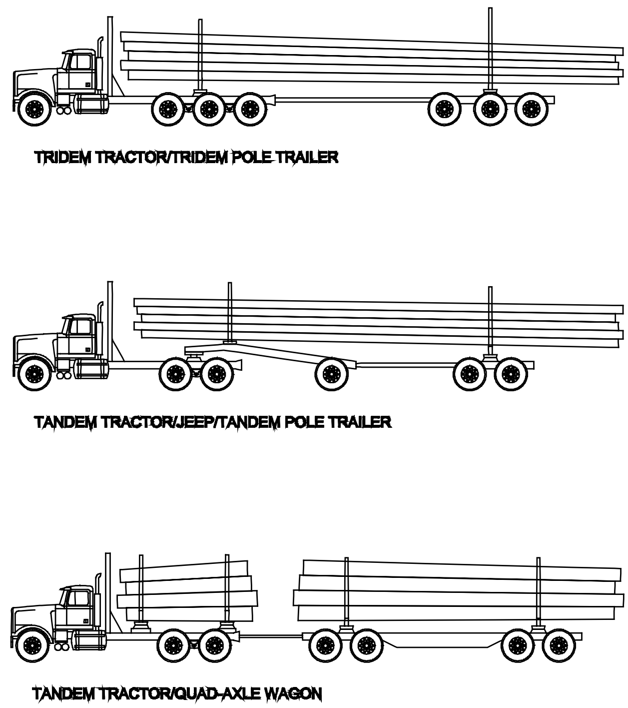

Figure 4: Examples of B.C. log truck configurations.

Figure 5. FERIC personnel monitoring log truck conformance.

RESULTS AND DISCUSSION

Past B.C. Ministry of Transportation experience in this region indicated that spring thaw begins when the temperature in the top 450 mm of the roadway rises above –1°C. Accordingly, 70%

load restrictions were initiated on Philpott Road on February 25, 2000. The road had sufficiently recovered to allow 100% legal axle loads full all truck configurations with normal highway tire pressures by April 7 and then the restrictions were completely lifted for overload-by-permit on May 9, 2000. FERIC personnel were on site to monitor the road during the trial of the road-friendly trucks from February 25 until March 30.

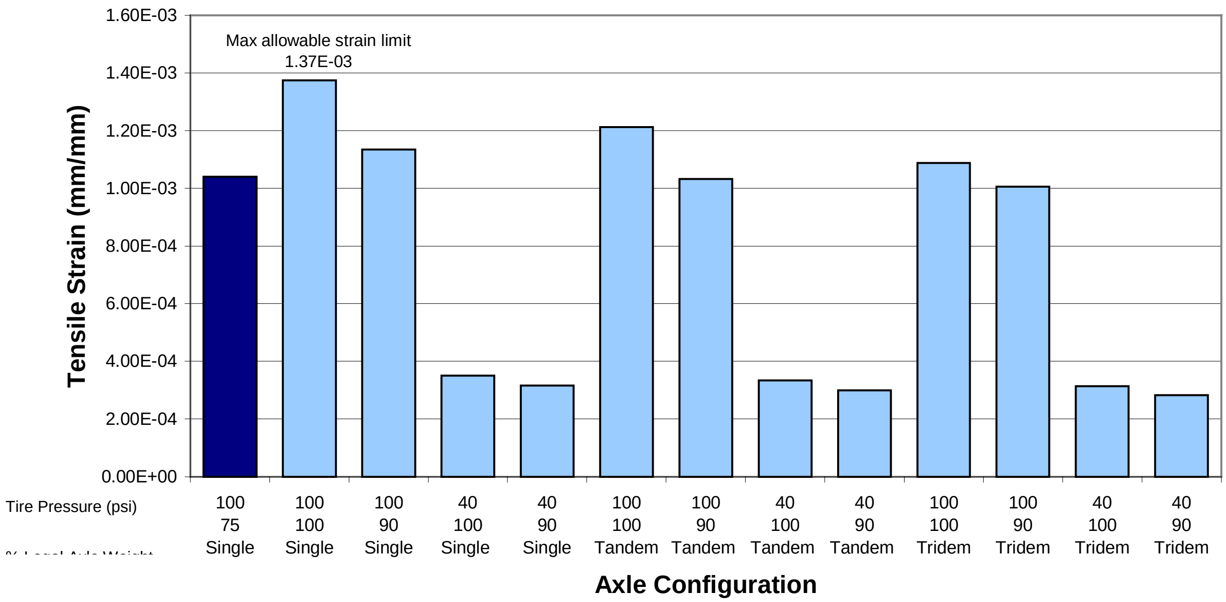

Figure 6: Predicted horizontal tensile strains for axle load/tire pressure combinations

The Benkelman beam data was regularly gathered and then the maximum expected rebound[6] was calculated for each data set (Figure 7). During the early portion of the trial, Philpott Road was saturated resulting in a weak road structure and in some sections the dual tires of the Benkelman beam truck would leave an imprint in the road surface. The measured rebounds increased to a maximum of 3.5 mm on March 5, 2000 and then recovered to a rebound of 1.52 mm on March 25, 2000. The maximum expected rebounds for both post-trial Benkelman beam measurements were 1.48 mm and 1.51 mm in May and June respectively. The Benkelman beam data from November 1999 had a maximum expected rebound of 0.90 mm. The summer deflection of about 1.50 mm was slightly greater than one and half times the fall deflection while the maximum spring deflection was almost four times greater than the fall deflection.

The tridem tractor/tridem pole trailer with optimized tire pressure and 90% load was first to resume hauling on March 13, followed by the tandem configuration, 90% load, and optimized tire pressure on March 20. By March 23, the road strength had recovered sufficiently to allow the tridem configuration with 100% load and optimized tire pressure to haul. The tandem configuration at 100% load and optimized tire pressure was allowed to haul after March 28.

---

6 Maximum expected rebound is the mean plus two standard deviations calculated from a set of Benkelman beam test data.

Figure 8 shows the road strength and the corresponding point when the various configurations resumed hauling. By the end of the trial, the road had not recovered sufficiently to allow the normal highway tire pressure configurations to resume hauling. On March 27, the tridem configurations were shut down as long logs were no longer available, and by April 3 the tandem configurations were shut down because the higher elevation forest roads had started to thaw.

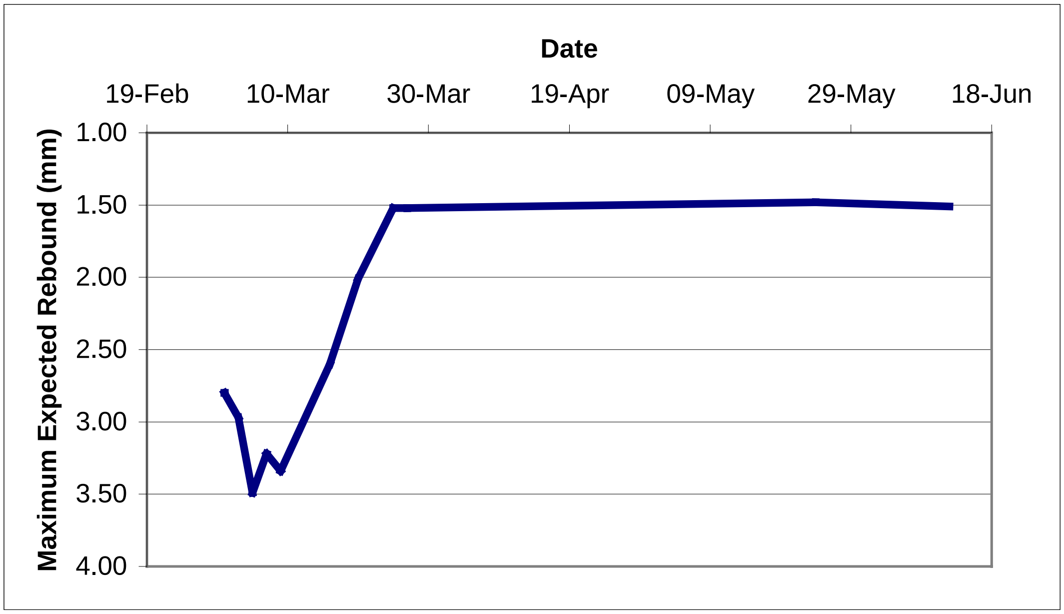

Figure 7. Maximum expected rebound results from Benkelman beam tests.

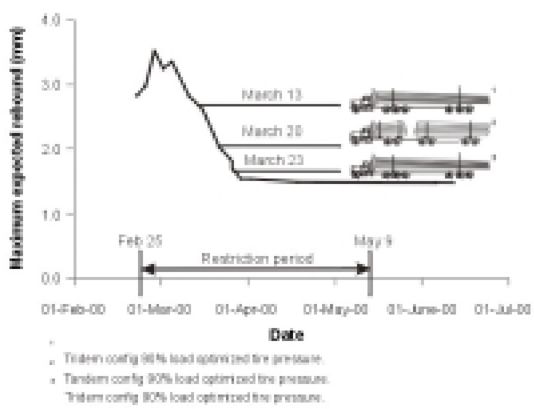

Figure 8: Log truck haul resumption and road strength

In total, over 150 loads were hauled across the test road prior to the end of the traditional load restriction period, and an additional twenty-two haul days were realized through the use of road-friendly technologies. These 22 additional hauling days were based on the number of days between the start of hauling (March 13) and when the bush roads were shut down (April 3). An additional four haul days could have been achieved before the 70% load restriction was lifted to 100% (April 7) had the bush roads not been shut down. It should be recognized that the most road-friendly configuration (tridem groups) was able to haul an additional week before the next most road-friendly configuration (tandem groups) resumed hauling. Unfortunately, no configurations with single axle groups were available at the time of the trial.

At the end of the trial, there were no significant changes in the surface distress survey sections due to trafficking during the load restriction period. The sections were surveyed (Figure 9) three times: once pre-trial (March 7/8, 2000), once at the end of the trial (March 28, 2000) and once post-trial (May 23, 2000). One or two new potholes appeared per survey section and some of the potholes increased in size. As well, no changes in the post-trial surface distress conditions occurred between March and May. The condition of the post trial road was considered to be no worse than a typical year when hauling had been suspended7 for the load restriction period.

The second method used to monitor the road condition was rutting measurements. Performing an Analysis of Variance of the before and after profiles showed that there was no change in the profiles within a 95% confidence interval. The three rutting test sections showed no visible change in road profile during the trial. In addition, no visible change in rutting was noted in other sections of the road.

Figure 9: Measuring crack length in a surface distress survey

The economics for a mill requiring 320 000 m^3 of logs annually with 160 haul days and a fleet of sixteen CTI-equipped log trucks were examined using the Foothills Transportation Model (Blair 1999); the projected haul cost would be approximately \$9.20/m^3. Increasing the number of hauling days for the entire fleet by twenty-two reduces the haul cost by about \$0.60/m^3 or \$192 000 per year. The average cycle time for these scenarios was just over 3.5 hours. This cost saving is based on achieving an average of twenty-two additional hauling days per year as a result of using this technology. It should be noted that this is only the haul cost saving and does not include any savings from reduced log yard inventory costs, more flexible harvesting operations or improvements in product quality from using greener wood. It is recognized that the number of days that the haul season can be extended is dependent on how quickly the road recovers and will vary from year to year. In addition to the economic benefits that may be

7 Personal communication. John Hallam, Area Manager (Kelowna Management Area), B.C. Ministry of Transportation and Highways. May 11, 2000.

achieved, the public may benefit from reduced heavy haul traffic density that could result from an extended haul season.

CONCLUSIONS

1. For this test road and the weather conditions encountered, the use of road-friendly technologies, particularly CTI, extended the log haul season by twenty-two days, allowing the resumption of hauling before the traditional end of the spring load restriction period. This log haul season extension was achieved without causing increased damage to the road.

2. Modelling the log trucks and the road in ELSYM-5 to rank the road-friendliness of log truck configurations was an acceptable method for determining the return to hauling because the road was not significantly damaged by hauling sooner after the spring break-up.

3. In this field trial, the potential haul cost saving for extending the haul season by 22 days was shown to be about $0.60/m^3 or $192 000 annually.

4. Both methods (surface distress surveys and rutting rate measurements) used to monitor the surface condition of the road showed no significant increase in damage.

RECOMMENDATIONS

Using road-friendly technologies to extend the haul season into the traditional load restriction period showed good potential to reduce log hauling costs and should therefore be pursued by the forest industry. Forest operators should work closely with their respective highway regulators to implement these findings. Based on the findings of the field trial, each road will need to be individually reviewed to optimize the haul season extension and then considered in combination with the road-friendliness of the log trucks in the haul fleet. It is recognized that a method for monitoring compliance with tire pressures and travel speeds to travel on load-restricted roads will be necessary. On-board truck monitoring systems equipped with global positioning systems are capable of fulfilling the requirements.

Further work is needed to identify relationships between the road strength and both the ambient temperature and soil moisture content. This research is recommended because such relationships could provide a simplified, cost effective method for predicting when the road has regained sufficient strength to allow the resumption of hauling.

ACKNOWLEDGEMENTS

The author would like to take this opportunity to thank the following for their invaluable assistance with this project: Allan Bradley (formerly of FERIC, now with Saskatchewan Highways) for his background work with CTI and helping to develop the methodology for the field trial; Dr. Tom Christison and Dr. Joe Mahoney for providing their expertise and guidance with developing the field trial methodology; Eric Amlin, Brian Bulley, Rob Jokai of FERIC for their assistance with the field trial; Bob Harrison, Mike Thomas and Dave Farrow of Riverside Forest Products Ltd.; Dick Weichel, Jim Mader and John Hallam of B.C. Ministry of Transportation and Highways; the drivers of Duncan Logging Contractors Ltd. and Darryl Hanet of Brookside Select Logging for their cooperation and participation in the field trial.

REFERENCES

1. Aderichin, A. 1994. Pavement surface condition rating manual. B.C. Ministry of Transportation and Highways Geotechnical and Material Engineering Branch. Victoria.

2. Blair, C.W. 1999. Log Transportation Cost Model. FERIC. Vancouver, B.C. Field Note: Loading and Trucking-67

3. Bradley, A.H. 1997. The effect of reduced tire inflation pressures on road damage: A literature review. FERIC. Vancouver, B.C. Special Report SR-123.

4. Kestler, M.A., Knight, T., Krat, A.S. 2000. Thaw weakening and load restriction practices on low volume roads. US Army Corps of Engineers Engineer research and Development Center. Hanover, New Hampshire. ERDC/CRREL TR-00-6.

5. Mahoney, J.P., Sweet, B.R., Copstead, R.L., Keller, R.R. 1994. The potential use of central tire inflation during load restriction periods. Society of Automotive Engineers (SAE), Warrendale, PA. SAE Paper 942245. SP-1061.

6. National Co-operative Highway Research Program. 1997. Pavement and Bridge Loading. Transportation Research Board. Washington DC

7. Tire and Rim Association Year Book. 1999. Tire and Rim Association Inc. Copley, Ohio.