SNT Engineering Ltd.

Box 861
Nelson, BC
V1L 6A5
info@snteng.ca
www.snteng.ca

May 24, 2013

Brian Chow P.Eng.
Ministry of Forest, Lands and Natural Resources
3rd Floor-1520 Blanshard Street
Victoria BC V8W 9C3

Re: Road Load Rating Project-Original Date: March 30, 2012; Revised May 2013

SNT Engineering Ltd was retained in 2011-12 by Engineering Branch of the Ministry OF Forests, Lands and Natural Resource Operations, to review and move forward the previously initiated Road Load Rating Project and complete it to the stage that the values recommended are technically defensible and can be presented to stake holders for advice and discussion.

In May 2013 SNT was retained further to include values for the L60 Design Vehicle.

The goal of the project is to provide maximum weights (Posted Limits) for axle groups and Gross Vehicle Weights (GVW) for traffic on individual forest roads based on the load capacity of the bridges on that road i.e. "load rate the road". The Design Vehicle load capacities investigated were BCL625; BCFS L45, L60, L75, L100, L150 and L165; and as well, new proposed design configurations, Light Off Highway (LOH) and Heavy Off Highway (HOH). It is intended that the results would be used to derive Bridge Limit Postings for use at forest road entry points. The purpose of this information is for use by individual operators to assess their individual loads of their specific trucks or by owners of a fleet of vehicles to operate within an acceptable level of safety on any specific road.

Initially SNT was to investigate all the Logging Truck loadings plus a concentrated Short Truck and Tracked Vehicle. After some preliminary investigations and discussions it was decided that SNT would investigate only the Short Truck and Tracked Vehicle. The Posted Limits for the Logging Truck traffic would be delivered by Darrel Gagnon, P.Eng. of Buckland & Taylor Ltd as a logical extension of a body of work that he had done previously for the Ministry. In the previous work Mr. Gagnon performed a sophisticated analysis on extensive logging truck population data collected and presented in the reports: "Design Vehicle Configuration Analysis and CSA-S6-00 Implication Evaluation- Phase I, Phase II and Phase III" in 2002 to 2004. Those values are presented in Buckland & Taylor Ltd's separate report attached in the Appendix 1. As a result of this change in responsibilities, SNT Engineering Ltd role was liaison and coordination of this portion of the work.

This report is broken down into 2 major sections:

I. Methodology and results of SNT Engineering Ltd's work on the Short Truck and Tracked Vehicle.
II. Discussion of all results by Buckland & Taylor Ltd and SNT Engineering Ltd in the context of the initial assignment.

I. SHORT TRUCK AND TRACKED VEHICLE

DISCUSSION

The short trucks are expected to be "straight trucks" as discussed in the British Columbia Commercial Transport Act. That is, trucks with a single steering axle and a single set of drive axles. This would include some single truck logging trucks, fuel trucks, gravel trucks, and rock trucks. It would also capture graders, rubber tired loaders, and skidders amoungst others. The tracked vehicle would likely be logging road construction/ maintenance equipment such as excavators and crawler tractors or logging equipment such as yarders and log processors.

Other than the single truck logging trucks or fuel trucks, the vehicles in the "Short Truck" category are not scaled and thus there is little knowledge or control of the loads running over the individual bridges. Short of doing vehicle population studies, the load factors tables in Canadian Highway Bridge Design Code CAN/ CSA S6-06(CHBDC) don't capture this type of traffic. The loading effects of tracked vehicles is even poorer understood. Further increasing the complexity is the unknown and uncontrollable behaviour of machine operators while crossing the bridges in tracked vehicles. We know of no codes, population data or guidelines on the loading of tracked vehicles walking directly on logging bridges. Thus all loading criteria for the Short Truck and Tracked Vehicles are assumptions based on Engineering Judgment. **It is required that the Ministry of Forests, Lands and Natural Resource Operations review, understand, accept or adjust as required these loading assumptions of the Short Truck and Tracked Vehicle.**

METHODOLOGY

This work was done by broad scale screening of resistances based on the factored Live Load of the Design Vehicle versus the factored Live Loads of the Short Truck and the Tracked Vehicle. This was done for all Design Vehicles (L45, BCL625, L75 etc.). The force effects considered were Live Load moment and shear.

The factored Live Load force effects of a specific Design Vehicle were compared to the factored Live Load force effects generated by a specific Short Truck . If the force effects of the Design Vehicle were greater than the force effects of the Short Truck, the bridges would be assumed to be operating within an acceptable level of safety. Because the Dead Load for the Load is the same Dead Load for the Resistance, it can be "cancelled out" and is not required in the assessment.

The actual mechanics involved a trial and error process:

1. assigning a weight for the Short Truck
2. calculating the factored force effects based on the assigned weights
3. comparing those to that of the Design Vehicle and then adjusting the assigned weights until their factored force effects were close to those of the Design Vehicle

This was done for spans from 4 m to 36 m at 3 m increments and for all Design Vehicles. A similar exercise was done for the Tracked Vehicle.

Bridge Resistance Assumptions

- It was assumed that the existing bridges were designed to just accommodate the factored Live and Dead Loads of the Design Vehicle under Ultimate Limit States. Dead loads were not taken into account.
- It was assumed that all structures have been designed and constructed to meet the design code of the time; have been inspected, maintained and load rated as per Ministry policy.
- Structures that have a load rating of less than 100% of the Design Vehicle would **not** be captured and will have to be assessed individually.
- Structures that have been designated a load rating using the reduced load factors listed in CHBDC Section 14 are **not** captured in this screening exercise and would have to be assessed individually. E.g. A BCL625 bridge that has been evaluated and designated to L75 status by using the reduced load factors of CHBDC Section 14 would be not captured. Further discussion of this issue can be found in bullets "9" and "10" in "Comments for Discussion and/or Decision" of Section II of this report.
- The resistance factor of the above exercise is based on the factored live loads of the above Design Vehicles. Forest Bridges have been designed over the years under a progression of versions of CSA S6 codes and some version's methodologies vary from the previous and there is no one "official" live load factor that can be used for all the structures. However, based on earlier works by others doing similar exercises for the Ministry it is commonly agreed that a live load factor of 1.6 is appropriate for this type of work.
- Being a broad scale screening the actual structural designs of the bridges were not needed in this exercise.

Load Assumptions

Short Truck

- Axle spacing and loading was that of a Level 3 Evaluation truck in CHBDC Section 14. The values worked out to 0.166W for the steering axle and .417W for the tandem driving axles. The axle spacing for up to and including L75 was that shown in Section 14. The distance was 3.6 m between the steering axle and the first driver. Between the first driver and the second, 1.2 m was used.
- For the LOH and heavier logging trucks the distance between the two drivers was extended to 1.68 m to match the tandems of the design vehicles. Leaving the short truck tandem spacing at 1.2 m would have severely penalized the values generated for the very short spans. For this exercise the total length of the short truck was not changed and thus the spacing between the driver axle and the first driver was shortened to 3.12 m

- NP traffic
- Beta=3.75
- A single live load factor of 1.6 was used for all spans. Unlike the "Alternative Loading" in CHBDC Section 14 no special live load factor was used for short spans. Being a straight truck as opposed to tractor-trailer configuration, the chance of an operator having the correct GVW yet having a gross "overload" in one of the axles groups is much less than with a tractor-trailer configuration. As well, the Section 14 CHBDC truck has been calibrated to use the Live Load factors that don't require special attention to "Short Spans. This was assumed to apply to populations of off highway Short Trucks
- Distribution factor (D.F.) and Dynamic Load Allowance (D.L.A) were the same as the Design Vehicles

Tracked Vehicle

- The force effects of the tracked vehicle are an evenly distributed load 4m long.
- The Distribution factor of the load is 0.55.
- Live load factor is 2.0
- Although very different in nature it was assumed that the Dynamic Load Allowance (D.L.A.) was the same numerical value as the Design vehicle
- The tracked vehicle is walking down the centre of the bridge
- The tracked vehicle is on the bridge for the sole purpose of crossing the structure expediently as possible.

RESULTS

1. The results are tabulated in Table 1 on the following page. Values from previous work done by the Ministry and some weights of vehicles that commonly use Forest Bridges have been included as well.
2. The asterisked comments are presented to give the reader a sense of the magnitude of change that would result should there be a change of assumptions.
3. The values of the Short Truck seem a little low compared to what is practiced in the field. Reducing the Beta to 3.25 would increase them by about 9%..
4. The Tracked Vehicle values seem quite low compared to what is practised in the field. Lowering the live load factor to 1.6 would likely increase the Maximum GVW for the Tracked Vehicle by 25%.

Note: a broad discussion of the above results in context of the entire assignment is continued in Section II of this report.

Table 1

Summary of Maximum GVW for Short Trucks and Tracked Vehicles

	Short Truck			Tracked vehicles		
Design Loading	Max GVW (Tonnes) SNT Engineering*	Max GVW (Tonnes) Previous work	Max GVW of common vehicles (Tonnes)	Max GVW (Tonnes) SNT Engineering**	Max GVW (Tonnes) Previous work	Max GVW of common vehicles (Tonnes)
L45	25.5	25.8	Hwy Legal Tandem Gravel Truck 26.1	25	25.1	
BCL625	33.2	33.9		33	33.0	
L60	28	n.a.		27.5	n.a.	
L75	35.8	35.8		35	34.9	Cat 235 Excavator 38.2
LOH	46.4	44.8	Cat 725 Articulated Rock Truck 45.8	44	44	
L100	46.9	40.2		44	44	Hitachi EX 400 LC Excavator 45.6
HOH	71.4	61.9		67	67.2	
L150	69.9	n.a.	Volvo A30D Articulated Rock Truck 51	66	n.a.	Madill 122 Yarder 57.8
L165	89.8	77.7		85	85	Madill 144 Yarder 115

* If Beta is reduced from 3.75 to 3.25 for the Short Truck, Max GVW would likely increase by approx. 9%

** If Live Load factor for the Tracked Vehicle is reduced from 2.0 to 1.6 values would likely increase by 25%.

n.a.- There was no previous work done.

II DISCUSSION OF ALL RESULTS

Table 2
Recommended Posted Limits
Of
Various Forest Road Industrial Traffic Types

Max G.V.W., Single Axle, Tandem Axle & Tridem Axle by Buckland & Taylor Ltd
Max Short Truck and Tracked vehicle by SNT Engineering Ltd

Design Vehicle	Max. G.V.W. T.	Max. Single Axle T.	Max. Tandem Axle T.	Max. Tridem Axle T.	Max. Short Truck T.	Max. Tracked Vehicle T.
L45	43.5	8.5	16.1	17.7	25.5 (24.6)**	25
L60	58.1****	11.4****	21.5****	23.6****	28 (32.9)**	27.5
BCL 625	63.5***	9.1***	17***	24***	33.2 (26.1)**	33
L75	72.6	14.3	26.9	29.6	35.8 (41.1)**	35
LOH	83.2	20.3	38.3	42.1	46.4 (58.6)**	44
L100	96.7	19	35.8	39.4	46.9 (54.8)**	44
HOH	129.4	31.5	59.5	n.a.*	71.4 (91)**	67
L150	145.2	28.5	53.7	n.a.*	69.9 (82.2)**	66
L165	159.6	31.3	59.1	n.a.*	89.8 (90.4)**	85

*Maximum Tridem axle values were not provided for HOH, L150 & L165 as we are of the belief that there are no trucks with Tridem axles those traffic categories

**Bracketed figures are the sum of the single axle and tandem axle maximum for the logging traffic for comparison the Short truck Values.

*** As per the BC Commercial Transport Act

**** Derived using the methodology stated in B&T report

DIFFERENCE OF METHODOLOGY BETWEEN LOGGING TRUCK AND SHORT TRUCK & TRACKED VEHICLE

The Logging Traffic values were derived by taking large amounts of various real logging truck population data; calculating the force effects on a significant number of trucks; doing statistical analysis on the results and deriving truck loading characteristics for the various populations. These characteristics were then applied to the various Design Vehicles.

There is no population data for Short truck or Tracked Vehicles. The Short Truck and Tracked Vehicles were dealt with by assuming a specific loading arrangement to conservatively represent the populations. This representative model was then analysed and adjusted by total weight until the force effects approach the force effects of the various design vehicles.

GENERAL

All of the values in Table 2 assume that the bridges in place were correctly designed and constructed to the appropriate design code at the time and have been regularly inspected, maintained and load rated as per Ministry Policy. Only the force effects resistances of the superstructures components of the bridges were considered. There was no consideration of other design criteria such as substructure resistance, alignment, geometry etc.

The Posted Limits listed in Table 2 will penalize a few of the more efficient Logging Traffic axle configurations such that they could be assigned slightly higher values than those listed , resulting in a higher total GVW yet not exceeding the resistances of the Design Vehicle. This is due the nature of the assignment. The exercise captures a variety of truck configurations. To distill all the configurations down to 4 Maximums Posted Limits for each Design Vehicle will result in values not be absolutely optimum for every truck.

With more refined assumptions for any one vehicle the Posted Limits for that particular vehicle can be increased.

BENEFITS OF THE POSTED LIMITS

1. The posted limits add a much needed degree of clarity and safety to operators. Currently there is a lot of misunderstanding of bridge capacities by the Forest Sector. Typically the only Posted Limit referred to is the Max GVW of the Design Vehicle. There is a wide misconception that any particular bridge (long or short) can carry the entire max GVW. E.g. L75 implies that any L75 bridge can carry 75 tons total. This is not the case for the most bridges under about 24 m in length. Disturbingly, a large percentage of the bridges on Forest Roads are under 24 m and are subject to overloading based on this misconception
2. The Posted Limits provide for higher loads than previously allowed.
3. The Posted Limits should be helpful to BCTS bidders to determine what size of equipment and trucks would be appropriate for any particular sale.

4. The Logging Traffic Posted Limits should help facilitate the introduction of the new design models (LOH & HOH). The Posted Limits will make it easier for operators to determine what design model will capture their fleets.

COMMENTS FOR DISCUSSION AND/OR DECISION

1) The values for the maximum GVWs and axle weights for L45 traffic are problematic. Posting the above values would necessitate drivers to carry partial loads. It is very unlikely that they will carry partial loads. Either they will ignore the rating or not haul at all. With a closer analysis it is expected that L45 bridges should be able to pass "Highway" traffic. The analysis could be done in one of two ways:

   a. Do a Section 14 Evaluation on L45 designed bridge superstructures that have not already been evaluated. This may not be as daunting as it sounds. Some Forest Regions have already done this. Their experience shows that almost all bridges evaluated meet CL625 traffic requirements and thus can be kept in service for "Highway Traffic". The analysis for the remaining bridges that have not been evaluated could be done with the new evaluation program that the Ministry has recently acquired. As this approach requires utilization of the actual bridge superstructure design/fabrication drawings, it has the advantage of gaining extra capacity by accounting for any extra girder section over and above what is required to carry the original Design Vehicle. As well, hopefully it should deliver a load rating of CL 625 or more which is the CHBDC Design Load and thus capture a wide range of trucks.
   b. Alternately do a broad screening of L45 bridges similar to the approach that was taken for the Short Truck. The difference being that rather than checking the force effects of one representative vehicle over a variety of spans, the force effects of each type of logging truck that operates on "highway loading" forest roads would have to be investigated individually. The exercise would employ CHBDC Section 14 Evaluation methodologies. Every allowable truck configuration would have to be treated as a design vehicle and evaluated. The BC Commercial Transport Act provides legislated dimensions, axle spacings and axle loads for all trucks that haul on public roads (which by extension should apply to "highway loading" forest roads). CHBDC allows that a reduced Reliability Index (Beta) can be used when evaluating existing structures. CHBDC Section 14 calculations for the vast majority of L45 bridge styles yield an allowable Beta of 3.25. As well consideration should be given to categorizing the traffic as PA (Permit-Annual) rather than NP (Normal traffic). Population studies of BC logging traffic point to the populations behaving like PA traffic rather than NP Traffic. Even though the GVWs of the actual logging trucks are greater than Design Vehicle L45 (41 T), employing Beta = 3.25 and PA traffic load factors would reduce the calculated force effects of the individual trucks such that they may fall under the calculated force effects of the L45 and thus could be rationalized as operating safely. Different from "a" above this methodology would only capture the specific truck styles looked at rather than the whole truck population category of CL625.

2) The Ministry must consider how the above information can be effectively communicated to the operators. Signs are an obvious choice. However, consideration should be given that Table 2 Recommended Posted Limits be included in appropriate Ministry Permits. For example Road Use Permit, Cutting Permit and Construction Contracts and BCTS Bidding Information.

3) The above posted Limits would make a very good foundation for an updated Bridge Loading Rating Policy by the Ministry. Essentially it could use the above values as default bridge load rating postings but could allow operators to increase their loading for specific truck styles providing they meet certain requirements. These requirements could be obtaining a Section 14 Evaluation of their vehicles and the bridges they are going to cross and committing to monitor the loads for compliance. It would be helpful for the Ministry to clarify some of the assumptions of the load rating that it is comfortable with in the evaluation process rather than leave it to the judgement of the individual Engineers on the ground. This would ensure results with more consistent levels of safety.

4) Posted signs seem very appropriate to communicate information to Logging Trucks however consideration should be given to the cost effectiveness of the same for The Short Truck and Tracked Vehicle. The Short Truck and Tracked vehicle make up a very small percentage of the traffic on logging bridges. Many bridges may not see any Tracked Vehicle traffic. The more information on sign, the more it costs to buy and maintain. Perhaps Short trucks and Tracked Vehicle information could be better communicated through documents mentioned in "2" above.

5) Consideration should be given as to whether the Short Truck Posted Limits could be captured by summing Max Single Axle and Max Tandem Axle Posted Limits for Logging Traffic. The Short Truck column in Table 2 shows the calculated value of the Short Truck versus the Single Axle and Tandem Axle numbers added together. It can be seen that there is some divergence of the two numbers, particularly at the heavy loading, but it is expected that with a closer look at the assumptions on the Short Truck, maximum GVWs could rationalized up to close to that of the sum of the Single Axle and Tandem Axle combined.

6) If it is decided that the Short Truck maximums can be captured with the sum of the Single Axle and Tandem Axle of the Logging Traffic and that the Tracked Vehicle maximums could be captured in permit documentation such as cutting permits, road permits etc., the posted sign could be very similar to that used by MOT. That is Max GVW; Max Single Axle; Max Tandem Axle and Max Tridem Axle.

7) Even though maximum GVW and the maximum axle groupings weights provide operators enough detail to assess the loading; and the fact it is the convention for truck regulations on Public Roads, past experience suggests that operators focus primarily on the Max GVW and very little consideration is given to the axle grouping weights. To get practitioners to consider the axle grouping weights likely some sort of public education would be helpful. Perhaps an article in a trucking magazine.

8) Structures that have been rated with Load Ratings below 100% of the road Design Vehicle (i.e. down loaded structures) are not captured by the above screenings. They will have to be delineated out, analysed individually and have their own posting.

9) As mentioned in the Discussion for the Short Truck and Tracked Vehicles, structures with Load Ratings based on the reduced Live Load factors of CHBDC Section 14 Evaluation are not captured in the above analyses. Situations that may result in this are:

   a. Structures that were initially undersized for the traffic but through Evaluation had their Load rating increased e.g. A BCL625 bridge being increased to L75
   b. Similar to the above for structures that have been damaged or deteriorated
   c. Material Types under which the later codes have changed the load calculation methodology from when they were designed. E.g. shear loading in Glulam and Timber

   These structures will not fit into the broad screening approaches undertaken in this report and will have to be looked at individually. They may require a lesser posting than that for the whole road. Structures designated with a Live Load Capacity Factor (LLCF) of less than 1.0 (and thus already down loaded) will stand out. However many of the evaluated structures will have a LLCF of greater than 1.0 and are listed in the documentation and databases as meeting the loading requirements of the road They will not be so easy to find. It is believed that these would make up a small percentage of the Ministry Inventory. A large portion would be the L45s that have been uprated to "highway" capacity and are discussed in bullet "1" above.

10) Similar to the bullet "9" above, the load rating of all of the glulam bridges should be reviewed. Under new requirements of CHBDC the shear loading is calculated differently that was done in past codes and may yield higher than was calculated in the original design. If this occurs the reduced live load factors of CHBDC Section 14 may be required to provide a LLCF greater than 1.0. If this is the case the Posted Limits recommended in this report would not be applicable to those bridges. At this point in time the number of glulams in the Ministry inventory is fairly small and reviewing all of them is not expected to be too large a task.

11) This work should be reviewed at regular intervals. Say every 5 years

RECOMMENDATIONS FOR FURTHER WORK

The previous section has many recommendations most of which are to further the Road Load Rating Project. This section is limited to recommendations that are needed to complete the initial assignment of the providing Posted Limit Maximums.

1. A literature search should be done refine the loading assumptions of the tracked vehicle.
2. Review the shear loadings of Glulam Bridges.
3. We do not expect that there are categories structure material types that this screening does not capture other than shear in glulam. To be prudent it would advisable to obtain advice from a Structural Engineer experienced in forest bridge design on this matter.
4. Delineate out the structures that had have their load ratings uprated using the reduced load factors of CHBDC Section 14.

We trust that this report addresses your requirements and thank you for the interesting assignment. Please contact the undersigned at (250)374-6804 (email: garymc.eng@shaw.ca) if you have any questions or comments.

Yours Truly

SNT Engineering Ltd May 24, 2013

Gary McClelland, P.Eng.

cc Les Thiessen P.Eng.

Enclosures

APPENDIX 1
BUCKLAND & TAYLOR LTD REPORT
LOGGING TRAFFIC TARGET VEHICLES

BUCKLAND
& TAYLOR LTD.
a COWI company

101-788 Harbourside Drive, North Vancouver, BC, Canada V7P 3R7
E-mail: mainoffice@b-t.com Tel: (604) 986-1222
Web: www.b-t.com Fax: (604) 986-1302

Our Reference: 1579-mof-001-l-dpg

Our File: 1579
By Email

2012 April 09

Ministry of Forests, Lands and Natural Resource Operations
PO Box 9510 Stn prov Govt
3rd Flr - 1520 Blanshard Street
Victoria, BC V8W 9C3

Attention: Mr. Brian Chow, P.Eng., Chief Engineer

Dear Sirs,

Re: Logging Traffic Target Vehicles

At the request of the Ministry of Forests (MOF), Buckland & Taylor Ltd. (B&T) has developed the following recommendations for the load posting of forestry bridges.

Background

B&T has previously assessed logging traffic data provided by the MOF for various truck populations and based on this data, developed design vehicles for off-highway forestry bridges that are consistent for use with the provisions of the CAN/CSA-S6 bridge design standard. The results of this work are described in the following B&T reports previously provided to the MOF:

1. Design Vehicle Configuration Analysis and CSA-S6-00 Implication Evaluation, 2003 January 04.
2. Design Vehicle Configuration Analysis and CSA-S6-00 Implication Evaluation Phase II, 2003 June 27.
3. Design Vehicle Configuration Analysis and CSA-S6-00 Implication Evaluation Phase III, 2004 October 08.

To date, the design vehicles developed by B&T have not yet been implemented by the MOF.

The MOF is assessing the need to implement bridge load limit postings on the various MOF routes. Neither the L-Series of design vehicles currently employed by the MOF or the design vehicle configurations developed by B&T are intended to represent bridge load limit postings. Consequently, the MOF requested that B&T develop the following guidelines for bridge load limit postings based on the results of the above studies:

- Target Vehicle maximum GVWs, maximum single axle loads, maximum tandem axle group loads and maximum tridem axle group loads for MOF design vehicles including the L45, L75, L100, L165/150, Light-Off-Highway (LOH) and the Heavy-Off-Highway (HOH).
- Target vehicle Gross Vehicle Weight (GVW) and axle load limits shall be provided for both design levels ($\beta = 3.75$) and evaluation levels ($\beta = 3.25$).

- Review the L75 records assuming that Okanagan Falls Interior Off-Highway and Menzies Bay Off-Highway data reflect traffic operating under "Best Practices" and, if appropriate, provide advice on how to proceed with site specific posting limits.
- Provide guidelines for an "Alternative Design" vehicle if a truck population has characteristics that are substantially different from the general population.

Development of Target GVWs and Axle Limit Postings

The MOF L-Series design vehicles were developed for general application with the provisions of CAN/CSA-S6-88, while the LOH and HOH vehicles were developed for application with the provisions of CAN/CSA-S6-00 (including any revisions to date). However, these design vehicles were not intended to define load limits for either Gross Vehicle Weights (GVW) or axle group loadings. Therefore, development of a rationale for establishing load limits corresponding to each design vehicle is required.

Although the individual weights of the overall population of loaded highway trucks can vary widely, the mean weight of the loaded truck population is typically about 10% to 15% below the posted load limits. This represents the general level of adherence of the truck population to the posted limits with typical load limit enforcement measures being in place. For highway traffic the appropriate levels of design safety are obtained with a live load factor of 1.7 being applied to the CL-625 design vehicle. Note that while the CL-625 design vehicle GVW is equal to the legal highway load limit, the design vehicle axle loadings significantly exceed the legal axle load limits.

Off-highway forestry vehicles differ from highway trucks is two ways; the first being that forestry routes/bridges do not typically have posted load limits and the second is that the weight variations of forestry vehicles tend to be somewhat less than those for general highway traffic. The LOH and HOH design vehicles were derived from the survey weights of forestry vehicles to be applicable with a design live load factor of 1.7 to be consistent with the provisions of S6-00. However, since forestry traffic is less variable than highway traffic, the design live load factor could have been decreased to 1.5 with a corresponding increase in the weights of the design vehicles. Therefore, the GVW legal load limit for bridges designed for the LOH and HOH loadings could be increased by a ratio of the live load factors (1.7/1.5) = 1.133 over the design vehicle GVWs. The L-Series of design vehicles were applied with a live load factor of 1.6 and therefore, the GVW legal load limits for these bridges would be (1.6/1.5) = 1.067 over the design vehicle GVWs.

The previous assessment of forestry vehicles showed that axle group weights were significantly more variable than GVWs and that the design tandem axle group weight had to be increased by about 25% to be applicable with the same design live load factor as for GVW. Such increases were incorporated into the LOH and HOH design vehicle tandem axles but not on the L-Series design vehicles. Therefore, the legal limit for tandem axle groups requires that the heavy axle group on the design vehicles be reduced by a ratio of 0.8 to account for the higher variability of the axle loadings but then increased by the same ratios applied to the design vehicle GVWs. This results in the legal limit for a tandem axle group being 46% of the legal GVW for LOH and HOH design vehicles and 37% of the legal GVW for the L-Series design vehicles. Tridem axle groups spread the loading better than tandem axle groups depending on the span length being loaded. On a 6 m span tridems can be about 15% heavier than tandems and produce that same force effects. However, on 15 m spans the improvement reduces to being only 5% heavier. Since most bridge spans over 10 m in length are not governed by more than one axle groups, it is recommended that the limit for tridem axle group loading be set at 10% higher than the tandem loading. Single axle loadings do not typically govern over tandem axle groups but it is recommended that the single axle loading be set a 53% for the tandem loading.

A summary of the suggested posted load limits for bridges designed for each design vehicle (β=3.75) are provided in the following table. Note that GVW values should be rounded to the nearest tonne and Axle Loads to the nearest 0.5 tonne.

Bridge Design Vehicle	GVW Load Limit (tonnes)	Single Axle Load Limit (tonnes)	Tandem Axle Load Limit (tonnes)	Tridem Axle Load Limit (tonnes)
LOH	83.2	20.3	38.3	42.1
HOH	129.4	31.5	59.5	NA
L75	72.6	14.3	26.9	29.6
L100	96.7	19.0	35.8	39.4
L150	145.2	28.5	53.7	NA
L165	159.6	31.3	59.1	NA
L45*	43.5	8.5	16.1	17.7
BCL-625**	63.5	9.1	17	24

* Data for forestry truck populations using L45 bridges was not present in the previously referenced studies. Therefore, the variability of the L45 population was assumed to be relatively similar to that for the L75 to L165 populations.

** As per BC Commercial Transport Act.

The above load limits are based on a bridge being appropriately designed, constructed and maintained to carry the indicated design loading. Any known reductions in the expected capacities whether due to design, construction or deteriorations need to be appropriately addressed in the posted load limits.

Many of the logging trucks in a population are expected to be heavier than the design vehicle weights. However, if the number of logging trucks with weights exceeding the weights of the design vehicles are maintained within the following limits, the expected level of safety can be considered to be achieved for the LOH, HOH and L-Series vehicles:

- Less than 2.5% of the logging trucks should have weights (GVW) that exceed the weight of the design vehicle by more than 19%.
- Less than 0.15% of the logging trucks should have weights that exceed the weight of the design vehicle by more than 27.5%.
- No logging trucks should have weights that exceed the weight of the design vehicle by more than 36%.

If these limits are consistently being exceeded, consideration should be given to reducing truck weights, strengthening the bridge(s) as required or conducting a more detailed assessment of the logging truck population using the bridge.

Evaluation Load Limits

The above bridge load limits apply to design conditions where the reliability index, β, is 3.75. Under bridge evaluation conditions the target reliability index can be reduced based on the expected structural behaviour of the bridge and the implementation of a regular bridge inspection program. We understand that for forestry bridges a reliability index of 3.25 is typically considered appropriate for bridge evaluation. Reducing the reliability index from 3.75 to 3.25 would result in a 9% increase in the above load limits in cases where all the loading on a component is live load. The increase in load limits would be somewhat higher when dead load produces a significant component of the total loading.

If the original bridge design exceeded the design requirements, even higher evaluation load limits may be possible.

Best Practices Operations

The available data for the Okanagan Falls Off-Highway and Menzies Bay Off-Highway was reviewed to determine if site specific loadings for forestry bridges could be beneficial.

For both of these locations only limited data had been obtained during the initial study, 2003 January, with a 26 truck sample for Okanagan Falls and a 40 truck sample for Menzies Bay. No weigh scale data for these locations was obtained during Phase II of the study.

Although the available data is considered to be insufficient to form the bases for alternative load limits, the data indicates the following:

- The Okanagan Falls population provides a lower mean value but a somewhat higher coefficient of variation on GVWs. This suggests that slightly more beneficial load limits could be possible if these results are representative of the long-term behaviour.
- The Menzies Bay population provides a lower mean value and a lower coefficient of variation on GVWs. This suggests that a more significant benefit could be appropriate for the load limits if these results are representative of the long-term behaviour.

Extensive weight scale data over an extended period of time would be required to justify significant modifications to the load limits on the bridges servicing these locations.

Guidelines for an Alternative Design Vehicle

If a forestry truck population has characteristics that differ substantially from those used in the derivation of the LOH and HOH design vehicles, use of alternative design or evaluation vehicle models may be appropriate. Although the derivation of alternative design vehicles can be a complex procedure, the following simplified approach provides appropriate if somewhat conservative results. The procedure is as follows:

1. Collect GVW data from forestry trucks transiting the route being evaluated. Minimally, the data sample should include at least 60 trucks obtained under all operating conditions over a period of at least a year. Greater amounts of truck weight data are preferred and the data sample should exclude empty or partially loaded vehicles.
2. The Coefficient of Variation (population standard deviation divided by the mean) of the data sample shall be 0.075 or less.

3. The mean value of the population represents the design or evaluation vehicle GVW. The posted GVW load limit for the route shall be 1.1 times the population mean.

Closing

Please contact us if you have any questions or comments.

Yours truly,

BUCKLAND & TAYLOR LTD.

Darrel Gagnon, P.Eng.