BUREAU OF SUGAR EXPERIMENT STATIONS

QUEENSLAND, AUSTRALIA

FINAL REPORT - SRDC PROJECT BS190S

UPGRADING LOAD AND SPEED LIMITS FOR CANE TRANSPORT VEHICLES

by

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SD01004

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SUMMARY

Each year about 40 million tonnes of sugarcane is transported to our mills. All of this cane must be transported, for some component of its journey, by a sugarcane haulout with in-field transport ability.

This project has produced to most complete ‘snapshot’ of the range of equipment currently used for road transportation of sugarcane in Queensland. The haulout survey was a mammoth undertaking and relied on the cooperation of staff from Queensland Transport, BSES, Queensland Caneharvesters', CANEGROWERS, mill transport and most importantly, the sugarcane harvesting contractors. This detailed examination of the haulage vehicles involved weighing, dimension measurement and the recording of tyre specifications, etc. The survey database is unique within the sugar industry and has been used by legislators, haulout manufacturers and tyre manufacturers to produce more efficient, safer and legally conforming haulout vehicles. Haulout owners and operators involved in the survey have had an assessment and recommendations given for safe and legal operation of current vehicles.

The allowable operating speed of sugarcane haulouts has increased from 40 kmh^{-1} to 50 kmh^{-1} for current equipment. Speeds of greater than 50 kmh^{-1} are now allowable, if appropriate Australian Design Rules are satisfied and appropriately rated tyres fitted. The survey highlighted the importance of the tyre loading concession to the Queensland sugar industry and also the poor understanding implications of this tool by many haulout manufacturers and operators. The load concession for low pressure, high flotation tyres has been retained but the method of assessment has been greatly simplified. Many anomalies within the previous load assessment system have been corrected and tyres such as radial earthmover tyres are now eligible for load concessions, if operated at the correct inflation pressures. The importance of tyre inflation pressure to optimise tyre performance and maximise tyre life was also illustrated from the survey results.

The survey data also highlighted the potential benefits that could be obtained through the use of efficient load sharing hitches and the use of lower tare weight materials in the construction of future sugarcane haulouts.

The researchers also determined that tyre surface temperature was a useful measure of tyre operating condition. The use of non-contact, infrared temperature measurement appears to be appropriate for vehicles such as sugarcane haulouts. This is a low cost method of monitoring tyre operation and can indicated inappropriate operation such as under-inflation of tyres. The infrared sensors are a valuable research tool that could become an option for fitment to commercial haulouts. The haulout trip profiles have been useful to illustrate the operation of current haulouts to industry representatives. The measuring and logging equipment development within this project will be used on haulouts and harvesters during future research projects.

At the time of compiling this report, not all vehicle guidelines were completed and the information disseminated but these tasks were progressing as quickly as possible. The use of agricultural vehicle operating guidelines will enable all parties to clearly understand their requirements when designing, manufacturing and operating sugarcane haulouts.

Whilst difficult to quantify, this project has greatly increased the awareness by manufacturers, owners and operators of requirements for safe operation of their sugar cane haulage vehicles. After receiving their survey results, many co-operators were eager to obtain more information on how to correct identified deficiencies within their haulage machinery. This project has also helped create the environment that will enable development of safe and efficient sugarcane haulouts that conform to all appropriate guidelines.

1.0 BACKGROUND

This project evolved from BS174S *'Developing a Framework for Advancing Road Transportation of Sugarcane'*. As the title suggests the initial project set the framework for the implementation of this project. Significant potential for change had been identified during this project.

Following an initial project meeting between Queensland Transport (QT), Bureau of Sugar Experiment Station (BSES) staff and Sugar Research and Development Corporation (SRDC) representatives, it was agreed to amend the original project aims to incorporate a field survey of haulout equipment used within the sugar industry. It was obvious that the types of haulage vehicles used in the Queensland sugar industry and their variations have never been documented. Even those closely associated with the sugarcane haulage sector could not claim to have a full knowledge of the types of haulouts used. A sound knowledge of the range of current haulage vehicles was considered an essential first step in the process of improving haulage machinery and practices.

This survey was the first of its kind within the sugarcane industry. The survey data has been of use to QT, BSES and other researchers, industry organisations (harvest and transport), haulout owners and operators, haulout manufacturers and tyre and component manufacturers.

2.0 OBJECTIVES

The primary objective of this project was to reduce costs associated with the haulout of cane by facilitating the continued development of haulout equipment, appropriate to the needs of the industry.

This was achieved by:

- Progressing the draft proposal developed in BS174S to form the basis of future legislation.
- Developing speed and load ratings for low-pressure agricultural tyres which are appropriate for cane haulout equipment
- Developing new loading concession, recognising the low pavement stresses of low-pressure agricultural and special purpose tyres, as recommended in BS174S.

This project considered sugarcane haulage as part of the cane production system and recommendations must benefit the total industry not just the transport component. All facets of the project were undertaken in association with representatives from Queensland Transport, CANEGROWERS, Queensland Caneharvesters', haulout manufacturers and tyre manufacturers.

3.0 SUGAR INDUSTRY HAULOUT SURVEY

The survey of haulout equipment used in Queensland was essential to ensure that any proposed changes to legislation would be compatible with the current legislation and suit the future haulout needs of the industry. A review of sugarcane haulout research showed that a survey of this magnitude had never been attempted within the industry. The survey data would also be used to provide a measure of the efficiency of the current haulout vehicles. Billeted sugarcane haulout equipment had evolved from single 3 tonne roll-on roll-off trailers drawn by standard farm tractors to dedicated self-propelled units often carrying in excess of 14 tonnes of cane. The current range of sugarcane haulout vehicles is the result of many evolutionary changes, some of which were not appropriate for the industry. Criteria for the survey were determined through discussions with all relevant parties. Circulars were sent out to both cane growers and cane harvesters informing them of the intended survey. Most industries that haul material on public roads are very sensitive to the presence of QT personnel, particularly when these personnel are conducting weighings of contractors vehicles. Clear communication between interested parties with respect to the aims of the survey was critical if the required vehicles were to be made available by the harvesting contractors. BSES and QT personnel commenced the survey on 5 August 1997 and concluded on 26 September 1997.

The survey involved detailed weighing and dimensional measurement of a selected sample (135) of cane haulout vehicles from Rocky Point to Mossman. The resources of QT were an essential component of the survey as they provided the vehicle weighing equipment and qualified operators. Many of the measurement recorded were based on QT pro formas for other vehicles. The survey vehicles were selected to determine the variation of haulage vehicles used in the sugarcane industry. Some vehicle duplication was inevitable but the survey aimed to quantify the range of equipment used to haul sugarcane. The organising of the survey was quite daunting, as the data collection phase required significant travel and coordination with harvesting operators. A key criteria stipulated by Queensland Transport representatives was that all vehicle weighing must occur at the siding or point of transfer from the in-field haulout to the next transport stage. This ensured that should a weighed vehicle exceed current allowable axle loadings, the vehicle could be unloaded without any need for additional travel on public roads. Any operation outside current Queensland Transport guidelines would be reported immediately to the vehicle operator and, where possible, the vehicle owner. Prior to commencing the survey, Queensland Transport representatives assured the project team that haulout operators would be immediately made aware of non-conforming vehicles but infringement notices would not be issued. This point was conveyed to all co-operators and helped to ensure their support.

Circulars sent out to both cane growers and cane harvesters informing them of the timing and the intentions of the survey. The first vehicle weighing was conducted on 5 August 1997 in the Bundaberg region to trial the survey process. The process required only minor fine-tuning and the survey team moved south to Childers. The southern area was completed at Rocky Point and the survey team recommenced at Mackay and moved north.

The surveyed vehicles comprised of the following categories and numbers:

- Tractor/trailer combination (94)
  - Roll-on/roll-off (13)
  - side tipper (38)
  - conveyor elevator (42)
  - slide-on/slide-off (1)
- Rigid self-propelled (15)
  - Side tipper (9)
  - Conveyor elevator (6)
- Articulated self-propelled (18)
  - Side tipper (4)
  - Conveyor elevator (11)
  - Roll-on/roll-off (3)
- Truck (8)
  - Side tipper (3)
  - Conveyor elevator (1)
  - Roll-on/roll-off (4)
- Harvester (1)

The harvester was a 1996 wheeled Austoft 7000 and this machine was included at the request of the Queensland Transport representatives. A braking test was conducted on the harvester by the QT staff. Measurements were also taken of a farmers spray boom during a visit to one property. The survey was a good opportunity to ensure QT staff are aware of the varied equipment used in the sugar industry and also enabled QT staff to explain points of non-conformity identified during the survey visits.

Each haulout was weighed while loaded and dimensional measurements were recorded. The tare weigh of the haulout was then measured prior to the haulout leaving the siding. After completion of the survey, data was entered into a computer database for analysis. The Microsoft program Access was used for the database and research team member, Rohan Geddes, acquired sufficient knowledge to design and set-up the database.

This database is a powerful tool for the sugar industry and the following data were recorded for each haulout:

Unit No
Mill Area
Date
Time Machine Stopped
Time Machine started
Trading Name
Owner/Agent
Address of Owner/Agent
Post Code
Home Phone
Work Phone
Other Phone
Mobile Phone
UHF Channel
Fax No.
Trailer Gross Axle 2.
Trailer Tare Axle 1.
Trailer Tare Axle 2.
Total Gross
Total Tare
Total Payload
Load Index
No. Tractor Axles
No. Trailer Axles
Tyre Pressure
Tractor Highest Rear Tyre Pressure
Tractor Lowest Rear Pressure
Trailer Highest Rear Tyre Pressure
Trailer Lowest Rear Tyre Pressure
Water in Tyres Y/N

Name & Description of Machine
Tyre Make
Tyre & Ply Dimensions
General Notes
Photo No. 1
Prime Mover Gross Axle 1.
Prime Mover Gross Axle 2.
Prime Mover Tare Axle 1.
Prime Mover Tare Axle 2.
Trailer Gross Axle 1.
Total Haul Distance
Cane Variety & Age
Average Billet Length
Cane type green/burnt
Vehicle Track Width
Vehicle Width
Vehicle Height
Vehicle Length
Additional Notes

To ensure positive identification of each vehicle and to assist in describing vehicle types, several photographs were taken of each vehicle.

When interpreting results from the survey, it is essential to realise that the intention of this survey was to quantify the range of equipment used to haul sugarcane in Queensland and therefore the data are not a statistically valid representation of the current Queensland haulout fleet. The survey is comprised of a purposely-biased sample and great care must be taken when attempting to extrapolate trends from the survey data.

Preliminary findings of the survey data were presented at Cane Harvester Association forums in early December 1997. An ASSCT paper was written on the same topic. A meeting was held on 7 January 1988 between BSES and Queensland Transport staff to exchange information and ideas. A date was set for a further meeting of BSES and Queensland Transport staff with representatives from the Canegrowers Association, Cane Harvesters Association', SRDC and ASMC to discuss the presentation of information to their respective members.

The survey had two main outputs:

- A measure, from a purposely–biased sample, of the compliance level of vehicles to current sugarcane transport regulations.
- The database showing the range of haulout machines used in the Queensland sugar industry.

3.1 Compliance with mass requirements

- Number of units weighed - **133**
- Number of units which comply with mass requirements - **43**
- Number of units which **did not** comply with mass requirements – **90**

NB: 136 vehicles were included in the survey though only 133 vehicles had full weight data sets.

Over two thirds of the surveyed vehicles did not comply with Queensland Transport legislation governing mass limits. However, as previously stated the survey comprised of a purposely-biased sample and hence the researchers emphasise that the data does NOT indicate that two-thirds of the Queensland commercial cane haulage fleet do not comply with mass limiting legislation. Mass was the greatest area of non-compliance and much of this can be explained by examining the history of cane haulout development. In the past, there has been a poor understanding of allowable loading of load concession and non-concession tyres, loads allowed on different axle configuration and limited enforcement of mass requirements by the various regulatory organisations. Many of the older haulout machines were either owner manufactured or significantly modified by the owner with little regard for the legal requirements. Several of the haulout vehicles had compliance plates fitted that did not accurately reflect how the machine should be loaded or operated.

TABLE 1
Mass compliance of different vehicle types

Vehicle	Comply	Non-comply	% Comply of type
Tractor/trailer	37	57	39
Articulated	3	16	16
Rigid body	1	11	8
Trucks	2	6	25
Total	43	90	32

(It is important to note that some vehicles were not grossly over-mass)

About one third of the vehicles were not fitted with loading concession tyres. Certain low pressure, high flotation tyres have been approved to carry increased loads as defined in the Queensland Transport Information Bulletin VSS.02.6/94 CANE BIN TRAILERS. When operated at the specified inflation pressures, these tyres have been shown to cause less pavement damage and hence allowable loading have been increased. Vehicles not fitted with these tyres are not effectively utilising the available carrying capacity of cane haulage vehicles. In several cases the low pressure, load concession tyres had been replaced with conventional earthmover tyres. The earthmover tyres are of heavier construction than agricultural tyres and due to excessive firmness of the tyre sidewalls are not eligible for the loading concession. These haulout owners had spent additional money on tyres that had actually lowered their load carrying ability. Reinstating the vehicle to the manufacturer’s original configuration was the preferred option in many cases.

Of those vehicles that did not comply with the mass requirements, over half were fitted with concession tyres yet still exceeded the mass limits. Re-distributing the mass more appropriately over the vehicle axles would have rectified the problem in most cases.

Discussions with haulout manufacturers, owners and operators indicated that there was a poor understanding of tyre loadings and the implications of using load concession tyres. BSES and QT staff have addressed this issue and will continue to do so. Several of the changes to allowable tyre loading that have resulted since the survey would reclassify a few vehicles as conforming.

3.2 Compliance with dimensional requirements

- Number of units surveyed - **135**
- Number of units which comply with dimension requirements - **47**
- Number of units which **do not** comply with dimension requirements **– 88**

Examining the different vehicle combinations revealed that trucks followed by tractor/trailer units were the vehicles of greatest compliance (see Table 2).

TABLE 2
Dimension compliance of different vehicle types

Vehicle	Comply	Non-comply	% Comply
Tractor/trailer	67	27	71
Articulated	8	12	40
Rigid body	5	8	38
Trucks	8	0	100
Total	88	47	65

The areas of non-compliance were:

- Length 10
- Width 42
- Height 0
- Rear overhang 9
- Drawbar 2

(Some vehicles had more than one area of non-compliance.)

Due to the awareness campaign associated with this and the previous project (BSS170), all post 1998 haulage vehicles must comply with dimension limits. From the survey findings, width was the main area of non-compliance. Width is considered a critical dimension for on road use and permits may be issued on pre-1998 vehicles but this would be on the basis of individual assessment.

3.3 Loading efficiency (Load Index)

The researchers have developed a simple load index to help quantify the efficiency of the surveyed haulout vehicles as load carrying machines. This load index was defined as vehicle payload divided by gross vehicle mass. An efficient haulage vehicle would have a load index of 0.5 or greater whilst an inefficient haulage vehicles would present figures of around the 0.2 (see Table 3).

In most cases, the older vehicles had lower load indexes than new vehicles. This implies the newer vehicles feature better, more efficient designs. There were, unfortunately, some exceptions to this statement but these were normally contractor or grower designed vehicle.

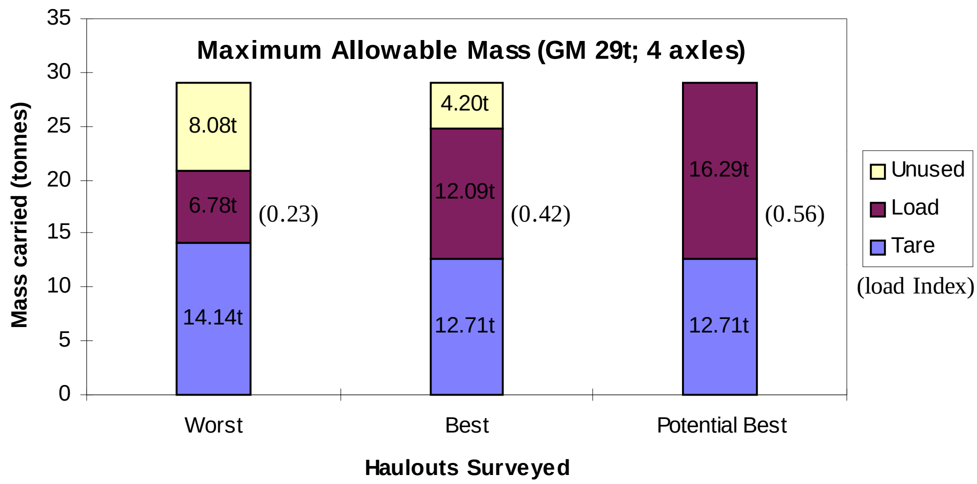

Figure 1 - Tractor/Trailer haulouts showing load distribution

In Figures 1, 2 and 3 data from the survey has been used to highlight one area of potential gain for cane haulage vehicles. Load index in these figures is based on the allowable gross vehicle mass. For the three categories, the 'worst' load carrying classification was based on the average of the 10% of vehicles with the lowest load index and the best vehicles were the average of the 10% with the highest load index. This analysis assumes loads can be equally shared between all axles and maximum allowable axle loadings are permitted (see Geddes *et al.*, 1998).

As previously stated, tractor/trailer units were the first types of billeted sugarcane haulage vehicles and are also a system that has undergone significant refinement. This vehicle class normally has up to 4 axles and a maximum allowable mass of about 29 t (see Figure 1). The worst tractor/trailer classification had a load index of 0.23 or had a tare weight of about 14 t for a load of less than 7 t. This vehicle has about 8 t (29 – 14 – 7) of its allowable load carrying capacity unutilised. The best tractor/trailer units from the survey carried a load almost equal to their tare weight. The potential best unit is assumed to have the same tare weight as the best measured but carried a greater load through improved load distribution onto all axles. The potential best vehicle had a load index of 0.56, which is considered quite achievable.

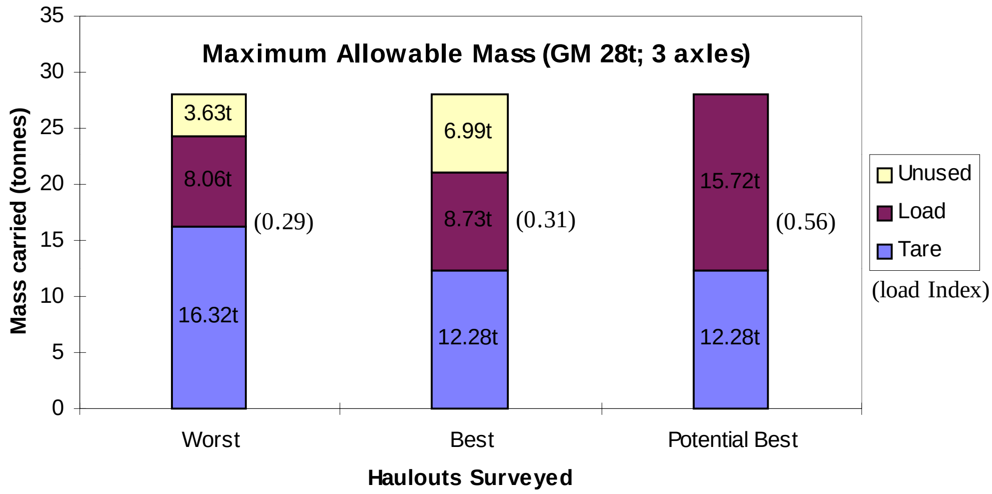

Figure 2 - Rigid self-propelled haulouts showing load distribution

The rigid self-propelled haulouts are generally of older designs and often owner-built. This is shown by the very small difference between worst and best load indices (0.29–0.31). These units also have high tare weights for the load carried. Good mechanical design could lift the load index of this vehicle type to greater than 0.5 but the role of this vehicle appears to be limited within the current transport system.

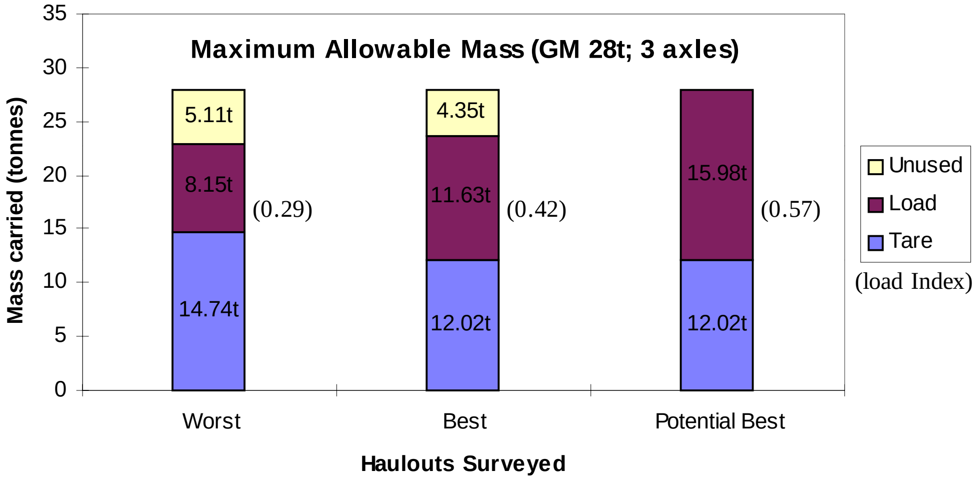

Figure 3 - Articulated self-propelled haulouts showing load distribution

Articulated self-propelled haulouts are units of 2-3 axles and with a permanently attached, single axle prime mover. These vehicles are normally only two-wheel drive configuration and the front axle is the drive axle. Earlier versions used converted farm tractors with the front axle removed but several dedicated prime movers are now available. It is interesting to note that in most cases different manufacturers produce the prime mover and the trailed haulout bin. The current 'best' units are quite refined as indicated by a load index of 0.42. Several manufacturers of this machinery have made significant reductions in tare weight through design improvements. There is still considerable potential to increase the load index to greater than 0.5.

TABLE 3
Haulage vehicle comparison table

Vehicle	Range of Load/Gross Mass Ratios
Tractor/trailer	0.23 – 0.42
Rigid	0.29 – 0.31
Articulated	0.29 – 0.42
Industry Comparison	Average Load/Gross Mass Ratio
Construction tipper	0.55
Semi-trailer	0.62
Grain chaser bin	0.57

The ranking of current (old and new) sugarcane haulage equipment relative to other industries is shown in Table 3. The road-based semi-trailer has the highest load index, as it is a basic load-carrying platform without a loading/unloading mechanism. Mechanisms for unload add to the vehicle tare weight but the grain and construction industries indicate tare weight reductions are possible.

The use of low tare weight materials and improved structural design could further increase achievable load index. Experience in other industries has shown an increasing use of finite element analysis of completed machine designs prior to manufacture. Weight reductions in the range of 10–25% are often achieved through this process (Gordon Baillie, *pers comm* 2000). An indication of the level of over-design of some sugarcane haulouts is illustrated by the age of some vehicles still in use. Haulage vehicles aged between 15–20 years and greater are not uncommon. The economic design life for an efficient sugarcane haulage vehicle was discussed with several participants at the ISSCT Harvest and Transport Workshop, July 2000, in South Africa. A figure of 7–10 years of serviceable life was considered acceptable. This figure was based on the experiences of several manufacturers who believed the cumulative additional load carried by a low tare vehicle would more than justify replacement after this period of time. An economic evaluation based on Australian industry parameters would be of great interest and value to the industry.

Concepts such as a portable transloader at the siding could also be worthy of consideration for future transport systems. The use of a transloader would enable the design of the haulout vehicle to be simplified, as part of the unloading function would no longer be required to be present on the haulout. Reducing the tare mass of the vehicle would result in an increase of the mass available for load carrying.

3.4 Weight transfer – from front axle to rear axle

Most trailers exert a vertical force onto the coupling point of the prime mover. As this point is often rearward of the back axle, additional weight is transferred from the front axle of the prime mover to the rear axle. This is the ‘lightened front end’ sensation experienced by many operators when hauling heavy loads on a trailer. In the worst situations, additional mass in the form of water in the front tyres or cast iron masses attached to the front of the tractor is used to ensure safe operation. The addition of mass permanently attached to the tractor or dead load is in conflict with maximising the load carrying capability of a haulage vehicle.

A correctly designed weight transfer linkage will enable the transferred load from the trailer to be applied proportionally to both the front and rear axles of the prime mover. Under this configuration, all axles would carry appropriate loads without exceeding allowable axle load limits.

Of the 93 tractor/trailer combination vehicles, about 70% (64 vehicles) had negative weight transfer as the mass on the front axle reduced after the vehicle was loaded. Two vehicles had the same front axle mass after loading with cane and 27 vehicles had additional mass transferred to the front axle. A total of 50 tractor/trailer units utilised weight transfer couplings but only about half (24) of the systems actually transferred weight to the front axle. Most of the weight transfer couplings kept the load on the front axle constant or exhibited a very slight (less than 0.2 t transfer of load onto the front axle. All of the weight transfer couplings were of quite heavy construction and some designs trended to become unstable when the vehicle undertakes right angle turns.

3.5 Tyre inflation pressure

Tyre inflation pressure is often overlooked as a major factor to optimise tyre performance and life. A pneumatic tyre is flexible, rubber carcass that is filled with a compressed gas, normally air. It is the air contained within the tyre that carries the majority of the load. When a load is placed on the tyre, it will deflect. A certain amount of deflection (about 22%) is essential for safe operation of an agricultural tyre. As the load on the tyre increases, the tyre inflation pressure must be increased to keep the tyre deflection constant. Excessive tyre deflection or operation at reduced inflation pressures can result in:

- overheating of the tyre sidewall leading to premature tyre failure,
- excessive tyre wear and
- poor vehicle stability.

Tyre operation when over-inflated (excessive inflation pressure) can cause:

- rough ride causing fatigue to vehicle components
- reduced vehicle flotation as tyre contact patch or footprint is smaller than specified.

The tyre pressure is one variable that the vehicle operator can control and hence significantly influence both the performance and the life expectance of the tyres. Tyre pressures varied considerably between tyres on the same axle and between axles of a large percentage of haulouts surveyed. Discussions with Mr Ian Broughton of South Pacific Tyres (formerly Dunlop & Olympic Tyres) indicated that the maximum acceptable variation of inflation pressure was 14 kPa (2 psi) for low pressure, high flotation agricultural tyres. Of the haulout prime movers, 34% or 43 of the 128 vehicle with a complete data set had tyre pressure variations outside this accepted industry allowance for a low-pressure agricultural tyre.

The trailers surveyed were equipped with both load concession low pressure, high flotation tyres and industrial (earthmover type) tyres that have a reduced load rating. The trailers were divided into groups with and without load concession tyres. A larger inflation pressure variation of 44 kPa (6 psi) was applied to the non-load concession tyres. Of the 120 vehicles (with complete data for the prime mover and trailer) 53% or 64 machines had tyre inflation pressure variations outside the maximum allowable range.

The duty cycle of a sugarcane haulout is such that the tyre will operate under various different combinations of load and speed. The most extreme case is with the tyre fully loaded and operating at high road speeds. Axle loadings may equal the maximum allowable loading for the tyre and speeds up to 40 kmh^{-1}. However speeds of 50 kmh^{-1} or greater could require the use of reduced loadings. As tyre pressure cannot be altered ‘on the move’ on current vehicles, a tyre should be operated at the appropriate pressure for the maximum load carried, not for the average load carried. All agricultural tyres must be operated within the load and inflation pressure limitation defined by the Tyre and Rim Association of Australia. Because of the low and high loading cycle, haulout tyres operate within the special operating conditions of this document. The sugar industry is somewhat limited by the QT definition of the load concession tyres. Load concession tyres cannot be inflated to pressures greater than 2.6 bar (260 kPa or 38 psi). Trials have shown that operation of these tyres at inflation pressures greater than 2.6 bar can result in increased pavement damage. The life of many larger high flotation, low pressure tyres would potentially increased if they were operated at pressures greater than 2.6 bar but operation at these pressures will result in these tyres not being eligible for the load concessions.

Most tyre manufacturers recommend that tyre inflation pressures should be checked weekly or definitely at intervals not greater than fortnightly intervals. The tyre manufacturer or distributor should be consulted if the required inflation pressure is not known.

The survey showed that a good quality tyre pressure gauge is an essential accessory for each sugarcane haulout vehicle. Regular checking will ensure leaking tyres are quickly identified and repair undertaken. While little data is available from the sugarcane transport industry, information from the road freight sector and the agricultural tractor industry has shown that under-inflation of tyres is the greatest cause of premature tyre failure. A tyre maintenance is always cheaper than the purchase of a new tyre.

3.6 Survey reports

A detailed report was produced for each vehicle surveyed and mailed to the respective owner or operator. This report was a summary of the data collected in the survey (see Figure 4). The layout of the report was designed to assist the owner to easily understand the information presented and the conclusions derived by the researchers. The use of a photograph and symbols for the wheels/axles both personalised the report and aided in the understanding.

Date of Survey:	01-Sep-97
Unit No:	53
Owner/Agent:	
Name and Description of Machine:	BSM 12t Double Side Tipper with Chamberlain 4480 Tractor

Tare Axle Mass (t):	1.70	4.69	3.68	3.85
Gross Axle Mass (t):	1.80	6.08	9.30	9.61
Allowable Gross Axle Mass (t):	2.40	8.00	10.00	10.00

Tyre /Ply Dimensions (front axle to rear axle): 11.00-16x 8PR, 24.5-32x 10PR, 2x 23.1-26x 12PR

Tyre Pressure (psi; anti clockwise tractor/artic 1st- near side):

Total Tare Mass (t):	13.92	**Payload (t):**	12.87
Total Measured Gross Mass (t):	26.79	**Payload / Gross Ratio:**	
Maximum Allowable Gross Mass (t):	30.40	12.87 / 26.79 = 0.48	

Total No. Machines Surveyed:	136	**Average Gross Mass of Category (t):**	24.31
No. In This Category:	56	**Average Payload of Category (t):**	10.07
Average Tare Mass of Category (t):	14.23	**Average Payload / Gross Ratio:**	0.41

Comments:

As a result of this haulout survey, regulations governing areas of vehicle dimensions and allowable mass are currently under review. Some concession tyre allowable loads may be increased. These changes will not be completed in time to cover the 1988 crushing season. Contact Queensland Transport and tyre companies before undertaking modifications. Allowable gross axle mass on front and rear tractor axles were calculated using tyre specifications only. These figures should be checked against tractor manufacturers allowable limits. The mass of this haulout is 3.61 t below the maximum allowable gross mass for this configuration. All of the axles are below the allowable mass for the tyres used. This haulout exhibited positive weight transfer as the weight on the front axle increased when the bin was loaded. The hitch is effectively transferring the trailer weight to both axles of the tractor. The payload to gross ratio is a measure of how efficiently the vehicle carries the load. This vehicle had a ratio of 0.48 which is above the average for this category, 0.41. The survey results indicate that future haulouts will have payload to gross mass ratios of 0.5 or better.

Monday, 26 March 2001

Figure 4 – Sample Survey Report

In cases where the surveyed machine failed to conform to current Queensland Transport regulations, a detailed explanation was supplied with the report. Some non-conformity could be rectified by minor actions such as redistribution of the load but others required major alteration of vehicle dimensions or the use of alternate tyre tyres and sizes. The response from the recipients of the reports was, in most cases, positive. Several haulout owners contacted the researchers for additional explanation of their survey result and for assistance on how to modify current equipment.

Duplicates of these reports were also mailed to the manufacturer of each brand of haulout. The researchers were aware of the commercial sensitivity of this type of data and had assured manufacturers that data specific to their machines would not be made public or supplied to other manufacturers. Whilst this may has slightly limited the usefulness of survey data, the cooperation of some haulout manufacturers was conditional on this commitment.

Generalised trends from the survey were published in the CANEGROWERS and Caneharvesters magazines respectively. The complete survey data set, on CD format, was provided to Queensland Transport, CANEGROWERS and Queensland Caneharvesters.

3.7 Outcomes from the sugarcane haulout survey

The sugarcane haulout survey highlighted many areas of vehicle design and operation requiring clarification and/or modification. These ranged from an awareness program of haulout manufacturers and operators of the advantages of load concession, low pressure, high flotation tyres to inconsistencies with how current regulations applied to the various classifications of haulout vehicles.

Mr Ross Berry, Senior Project Officer (Vehicle Operations), was part of the survey team and undertook to investigate solutions to some of the problems identified by the survey. He produced a list of allowable axle loadings for many of the different tyres encountered and proposed several changes to remove anomalies that had developed over time.

Vehicle mass loads as specified in the current bulletin (5VSO/94) will be upgrades with the speed increase to 50 kmh^{-1} and proposed changes include:

tractor/trailer units

- steer axle allowable limit of 10 t
- drive axle allowable limit of 10 t
- trailing tandem axle group allowable limit of 20t but must be fitted with ADR38 brakes (ADR is the abbreviation for Australian Design Rules)
- trailing single axle allowable load limit of 11 t

rigid or articulated units

- steer/front axle allowable limit of 10 t
- trailing tandem axle group allowable limit of 20t but must be fitted with ADR38 brakes (ADR is the abbreviation for Australian Design Rules)
- trailing single axle allowable load limit of 11 t

rigid truck with load concession tyres

- steer/front axle allowable limit of 7 t
- twin steer axle allowable limit of 16 t (load share) and 10 t (non-load share)
- tandem drive group allowable limit of 20 t.

With the increase in operating speed and allowable mass, certain construction standards will now apply. Theses include:

- Brakes – for operation in excess of 50 kmh^{-1} or 20 t GTM, air bakes to ADR38 will be mandatory
- Lights – all vehicles to comply with traffic regulations including clearance lights
- Couplings – ADR 62/01 will apply to couplings for haulage units operated at greater than 50 kmh^{-1}. Current approved couplings can be used for speeds under 50 kmh^{-1}.
- Steering – back up steering system is required for hydraulic systems operating at greater than 50 kmh^{-1} if the unit cannot be easily steered after engine or system failure (the current SAE standard will be used, if possible)
- Hydrostatic and powershift transmissions – a failsafe back up brake to be fitted and neutral lockout for starting be used.

Performance guidelines are to be developed for agricultural vehicles as part of the implementation of National Regulations. The use of performance guidelines will also standardise the current permit conditions.

The series of industry meetings to explain the outcomes of the survey were used as a platform to increase awareness of the advantages of using load concession, low pressure, and high flotation tyres. Items identified from the survey for updating included:

- Increasing the allowable loads on all wheel drive vehicles
- Investigate the allowable loads for radial earthmoving tyres when operated at low pressure
- Include new tyres in the listing.

This awareness program was obviously successful as it was followed by a significant increase in requests from tyre manufacturers, tyre dealers, haulout manufacturers and operators of the allowable loads for tyres not included in the current listing of load concession tyres.

The previous system required a QT officer to undertake calculations for each tyre size. With the increased usage of radial tractor tyres, the availability of some radial earthmover type tyres and imported specialist flotation tyres, this task had the potential to become a significant workload for the staff member. Any inquiries with respect to non-standard tyre had to be referred to the QT officer further increasing the workload.

The tyre load concessions for low pressure, high flotation tyres are a valuable asset of the sugarcane transport industry and retaining this concession was essential. A better way of assessing tyres to determine their allowable load rating was required. Mr Ross Rieschieck, an engineer with the Vehicle Standards Section of Queensland Transport, developed a sugar industry tyre selection chart that would enable tyre manufacturers and tyre users to determine the allowable loads for any haulage tyre (see Figure 5). This chart relates tyre inflation pressure to the allowable load carried by that tyre for operation on

Queensland public roads. The graph determines the maximum allowable load a tyre may carry for a given inflation pressure and ASSUMES THIS LOAD IS WITHIN THE TYRE MANUFACTURERS ALLOWABLE LOADING. Many tyres are not capable of carry the maximum allowable load at the specified inflation pressure and the majority of those that can, have speed limitations imposed by the tyre manufacturer. This method of determining allowable tyre loadings effectively removed the decision of tyre suitability from QT and placed it in the hands of the tyre manufacturer and finally the tyre user. Tyre manufacturers have assisted in explaining this concept to manufacturers and owners. The industry is always striving to improve haulout performance but researchers with tyre manufacturer representatives have explained that the concept of a high speed and low inflation pressure tyre is a contradiction to current tyre construction techniques.

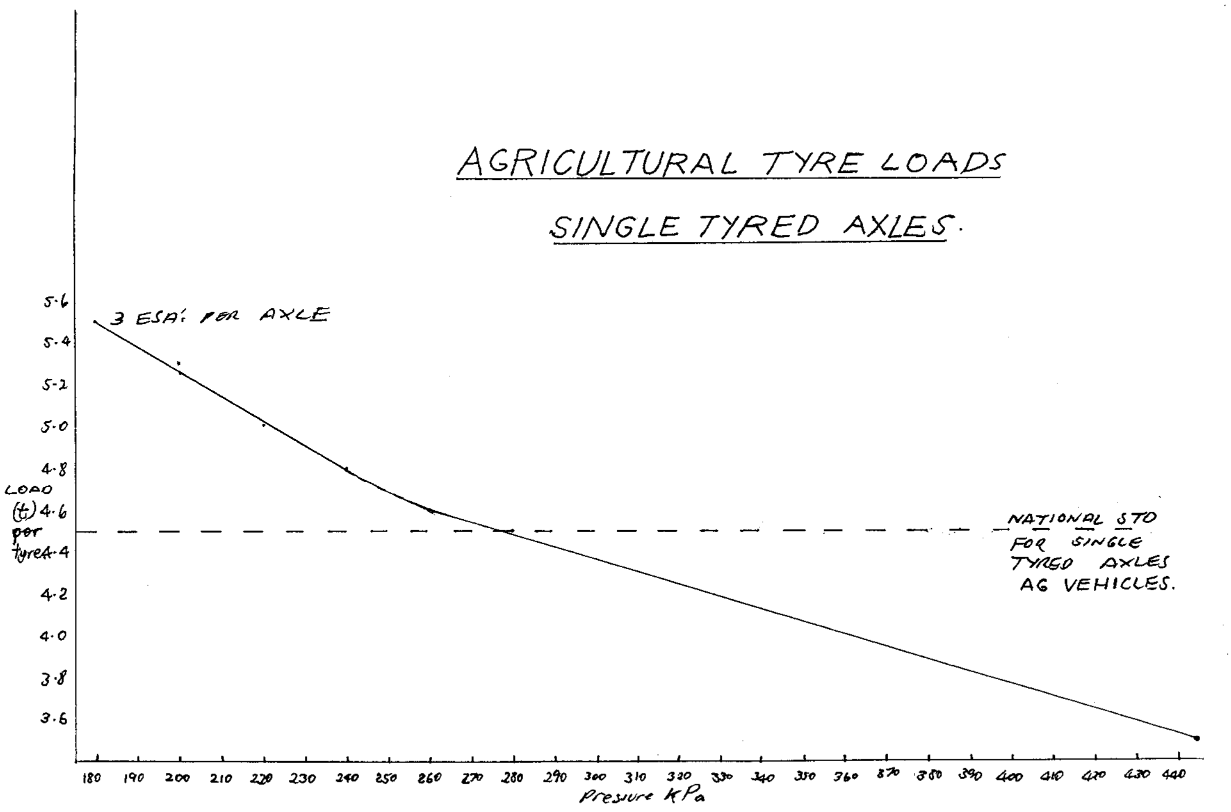

Figure 5 - Draft version of sugar industry agricultural tyre load selection graph (source: Queensland Transport)

For example, a tyre inflated to 240 kPa has a maximum allowable loading of 4.8 t per tyre. The tyre manufacturer MUST approve the particular tyre for use at this loading, pressure and, of course, operating speed. The table effectively defines the maximum loading allowable for any inflation pressure and relies on the tyre manufacturer to determine where his tyre can operate within the load and inflation pressure constraints. The table is a convenient method of determining the allowable loading for any tyre used in sugarcane transport and retains all previous tyre load concessions.

The sugar industry load concessions is illustrated graphically as the triangular area to the left of the intersection between the solid and dashed lines. The industry is allowed axle loadings up to 3 ESA (Equivalent Standard Axles) at an inflation pressure of 180 kPa. This equated to a maximum axle loading of 11 t and is a significant increase above the

National Standard for Agricultural Vehicles of 9 t. As tyre inflation pressure is increased, the cushioning ability of the tyre is reduced and the potential to cause pavement damage increases. Therefore allowable tyre loads reduce with increasing tyre inflation pressure. The agricultural tyre selection chart is not speed specific but speed is a critical criterion for the tyre load/inflation recommendations from tyre manufacturers. When enforcing this improved allowable tyre loading system, legislators must be aware that the measurement of both tyre load AND tyre inflation pressure are essential to determine conformity to vehicle guidelines (refer Figure 5). Through this tyre load selection graph, this project has further highlighted the importance of tyre inflation pressure for safe tyre operation.

Tyre manufacturers have responded with appropriate load/inflation tables for 40 kmh^{-1} and 50 kmh^{-1} operating speeds (see Appendix 1).

QT staff proposed a program for implementation of these changes. The initial program is listed in Appendix 2 but due to other legislation being given a higher priority, this program could not be adhered to. Several attempts were made to reinstate the implementation program. Unfortunately this was also a period of several staff changes within the Brisbane head office of Queensland Transport. Mr Ross Berry left Queensland Transport and much of his workload was redistributed to other staff members. Mr Ross Rieschieck is currently seconded to the Main Roads Department. Both of these staff changes further slowed the implementation of the performance guidelines. Several performance guidelines were gazetted on the March 30, 2001. As of mid-April 2001, these guidelines had not been published but could be viewed on the QT website (www. transport.qld.gov on the heavy vehicle page).

Changes to the vehicle performance guidelines will be an oncoming process but the major step of establishing acceptable vehicle performance guidelines has been achieved.

4.0 TYRE TEMPERATURE TRIALS

This section of the project examined methods of quantifying the work done by tyres during normal haulout duty cycles. This data would assist tyre manufacturers and suppliers to determine how the allowable loads for current haulout tyres must be altered when the allowable haulout speed increased from 40 kmh^{-1} to 50 kmh^{-1}. This 25% increase in allowable operating speed of the current design of haulout is a significant workrate gain for the sugarcane transport sector. A 25% increase in operating speed is also a significant increase in work (tyre flexing) done by the tyre particularly if the 2.6 bar inflation pressure limitation is not to be exceeded. A number of vehicles currently available have the engine power and the appropriate gearing to operate within this speed range.

Tyre temperature is a reliable measure of the work done by a pneumatic tyre. If tyre temperature remains below design limits, tyre life is maximised and, in some cases, tyre operating speeds and/or tyre loads could be increased. It is very important to note that increasing either speed or load will increase the work done by the tyre. In most cases, an increase in tyre operating speed would require a reduction in the allowable load carried by that tyre. The tyre load/inflation tables from the Tyre and Rim Association Manual clearly illustrates this relationship.

Variations in haulout tyre temperatures under current operating conditions were measured and recorded. Haulout vehicles with longer haul distances were used in the trials. A sufficient number of operating parameters were recorded to enable trip profiles to be developed for each haulout. Using these trip profiles, it was be possible to study the performance of the haulout vehicles.

4.1 Trial methodology

Sugarcane haulout vehicles for the trial were selected on the following criteria:

- conformed with Queensland Transport mass and dimension specifications,
- of recent manufacture and commercially available,
- have the ability to operate at speeds in excess of 40 kmh^{-1},
- be fitted with load concession tyres (low pressure high flotation tyres).

The aims of the tests and the test equipment to be installed were explained to the owners and/or operators of the selected haulouts. The test equipment comprised of a data logger and transducers to measure ground speed, tyre temperature, ambient air temperature and bin status (full/empty). Fitting the test equipment to a haulout took 1 - 3 hours depending on the layout of the machine. In several cases, two visits were required, as it was necessary to fabricate suitable mounting brackets. After fitting and testing of the equipment, the haulout was returned to normal operation. Test data were downloaded daily using a laptop computer. The retrieved data was briefly examined to ensure all transducers were functioning and the data was representative of the normal operation of this vehicle. A brief period of the haulouts daily operation was manually recorded as a check of the electronically logged data. Recording of vehicle operations was continued until sufficient representative data had been recorded. The test equipment was then removed and fitted to another haulout.

4.2 Transducers used

All transducers and the data logger were bench tested by the BSES researcher prior to fitting onto haulouts. A commercial radar unit (DICKY-john DjRVS II) was used for speed measurement. The logger was configured to record the output from the radar unit as a frequency. The radar unit was initially placed at the rear of the haulout. In later tests, the unit was mounted on the front ‘pushbar’ of the tractor as it was:

- simple to attach
- closer to the data logger and
- visible to the drivers of the haulout vehicles.

An infrared temperature sensor (THERMALERT® CI™ 3A) was used to measure the temperature of the tyre carcass. This non-contact method of temperature measurement was quick to fit, reasonable robust and of acceptable accuracy for field use. The temperature sensor was mounted to record the maximum temperature of a haulout tyre. Based on information provided by technicians of Dunlop Olympic, the sensor measured the temperature at the interface between the tyre and rim. This is the region of maximum temperature during tyre usage. The sensing zone of the infrared sensor is conical in shape and the area of temperature measurement increases as the sensor is moved further from the target. Measurement accuracy decreases with distance from the tyre. The sensor was mounted approximately 50 mm from the tyre resulting in a circular sensing area with a diameter of about 10 mm. Minor problems occurred with the infrared sensor during the tests and a replacement unit was always carried.

A thermocouple was used to measure the ambient air temperature. A simple, lever operated switch indicated whether the bin was empty or not. The mechanism was positioned on the bottom of the bin so that cane billets pushed against the lever and activated the switch. When the bin was empty, the switch was open circuit.

Sensor wires suffered physical damage several times during the trials. These problems were quickly identified and often the data collection period was extended to ensure sufficient data was collected. The researcher quickly determined the preferred way of routing the transducer cables to minimise the risk of damage.

4.3 Results

A total of seven haulout units were tested, in Bundaberg, Ingham, Atherton and Mackay. Vehicles tested were:

- 12 tonne double side tipper and FWA tractor
- 12 tonne single elevator tipper and FWA tractor
- 10 tonne articulated side tipper
- 12 tonne dual elevator tipper and FWA tractor (three off)
- 7 tonne high lift side tipper and 4WD tractor.

The results shown are from a haulout in the Bundaberg district. This unit was a tractor/trailer combination and comprised of an LG Engineering 12t side tipper drawn by a Case IH FWA 8910 tractor. The trailer tyres were 18.4-26 (12ply rated) and the inflation pressure was 262 kPa (38 psi) per tyre. The rear axle loads were approximately 7.7 t per axle. The average cycle distance (from harvester to siding and return to harvester) was 20.5 km. The corresponding average cycle time was 55 minutes. The highest speed achieved by this haulout was 47 kmh^{-1}.

The heat sensor was fitted to the left-hand, rear trailer tyre. The maximum recorded tyre temperature was 51°C (average temperature 47.8°C). This maximum temperature was measured at the rail siding after a loaded trip (road speed of 40 kmh^{-1} or greater) from the paddock. This tyre temperature was a 29°C rise above ambient temperature. Tyre temperatures of 80°C or greater can result in significantly reduce tyre life or even tyre failure. Figure 6 is a graphical representation of part of the daily operation of this haulout. The periods of high speed road travel, filling in the field and waiting can be clearly seen from the graph.

Information on these trials was reported in October/November issue of *The Caneharvester* magazine.

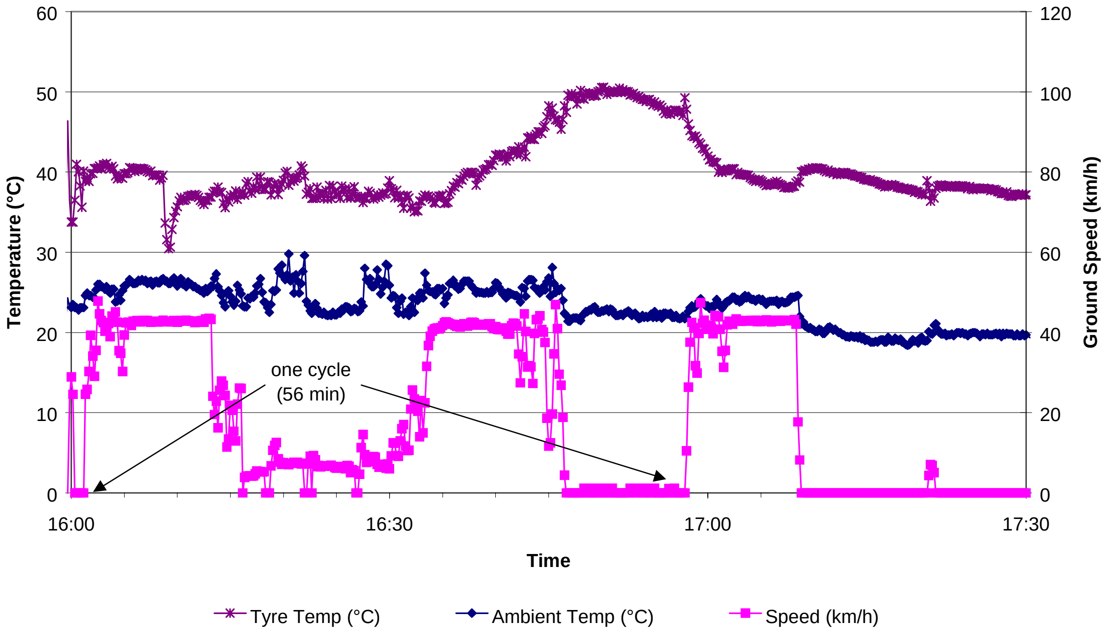

Figure 6 - Graphical representation of one duty cycle

In hindsight, about three vehicles trials would have been adequate, as the tyre temperature data from the five trials was very similar. The test program did provide valuable data on the trip profiles, similar to Figure 6, for various types of sugarcane haulage vehicle operating in different cane growing regions. This data is essential to validate and update tools such as the harvest and transport costing model.

5.0 TEMPERATURE SENSOR COMPARISON

Summarised information from all tyre temperature trials, conducted during the 1998 sugarcane harvest, was supplied to staff from Dunlop Olympic Tyres and Queensland Transport. Dunlop Olympic Tyres representatives use a special temperature probe, which is pushed into the tyre bead, to measure internal tyre temperature. This probe is a highly accurate measure of tyre temperature but cannot be used while a vehicle is moving. Both tyre temperature measuring systems have a role but the correlation between external and internal temperature for high flotation agriculture had not been investigated

5.1 Trial 1

On the 30 March 1999, tests were conducted to compare the performance of the infrared sensor (IRS) (THERMALERT® CI™ used in previous trials and a temperature probe supplied by Dunlop Olympic Tyres. The temperature probe (TP) must be manually inserted into the casing of a stationary tyre. The tests were conducted using a sugarcane haulout supplied by Bundaberg harvesting contractor, Mr Brian Cantrell. The trial was undertaken by Ian Broughton (Dunlop Olympic), Rohan Geddes (BSES), Win Chappell (BSES) and Robert Da Paoli (haulout driver and employee of Cantrell Harvesting).

5.1.1 Methodology

The trial attempted to simulate the normal duty cycle of a sugarcane haulout. The vehicle comprised of a 12 tonne dual conveyor elevating Carta bin articulated to a Cantrell prime mover. The load consisted of large bags (approximately 1 tonne capacity) of sand with a total mass of 8.9 tonnes. The tyre inflation pressures were altered so the front drive tyres were at 235 kPa (34 psi) and the trailer tyres were at 250 kPa (36 psi). The infrared temperature sensor (IRTS) was installed on the left-hand front trailer tyre bead near the rim. The front driven tyres were 24.5-32 (12 ply rated) and trailer tyres were 23.1-26 (14 ply). The IRTS, radar unit and ambient temperature probe were connected to a data logger. The manual temperature probe (TP) was used when the vehicle was stationary, before and after each simulation run. Times of manual probe measurements were also recorded. The test program comprised of:

- Three 4.2 km runs at 30 kmh^{-1} empty,
- Three 8.4 km runs at 30 kmh^{-1} empty,
- Three 4.2 km runs at 50 kmh^{-1} empty,
- Two 8.4 km runs at 50 kmh^{-1} empty,
- Two 4.2 km runs at 30 kmh^{-1} loaded,
- Two 8.4 km runs at 30 kmh^{-1} loaded,
- Two 4.2 km runs at 50 kmh^{-1} loaded,
- Three 8.4 km runs at 50 kmh^{-1} loaded.

To ensure that the IRTS was operating satisfactorily, manual readings of the tyre surface were regularly taken using a digital thermometer.

5.1.2 Discussion and observations

During the test program, several minor electrical problems occurred. However, within each test runs at least one full data cycle was recorded. The periodic measurements taken with the digital thermometer indicated the IRTS to be a very accurate, non-contact method of measuring tyre surface temperature as temperature variations were less than 0.5°C.

The testing program was designed to simulate increasing work levels for the tyres. The data showed a continual rise in the internal tyre temperature over the test period, as measured by the IRTS probe (Figures 7 and 8).

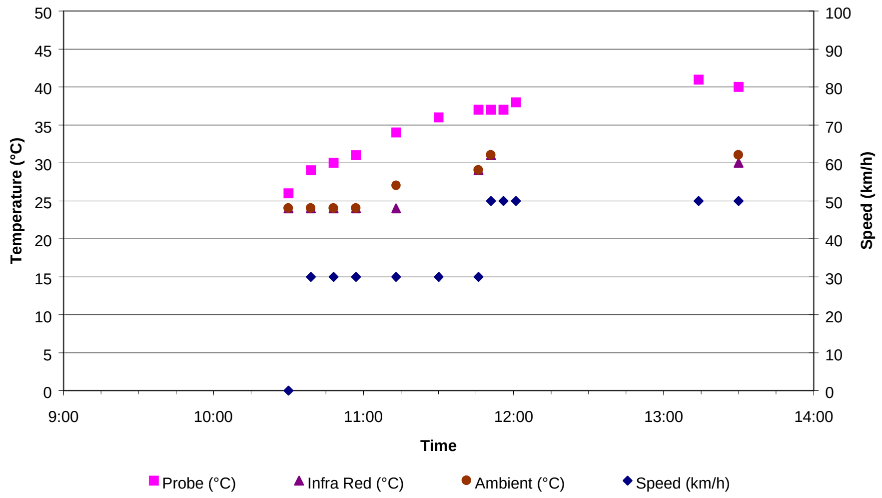

Figure 7 - Haulout Unloaded Cycle

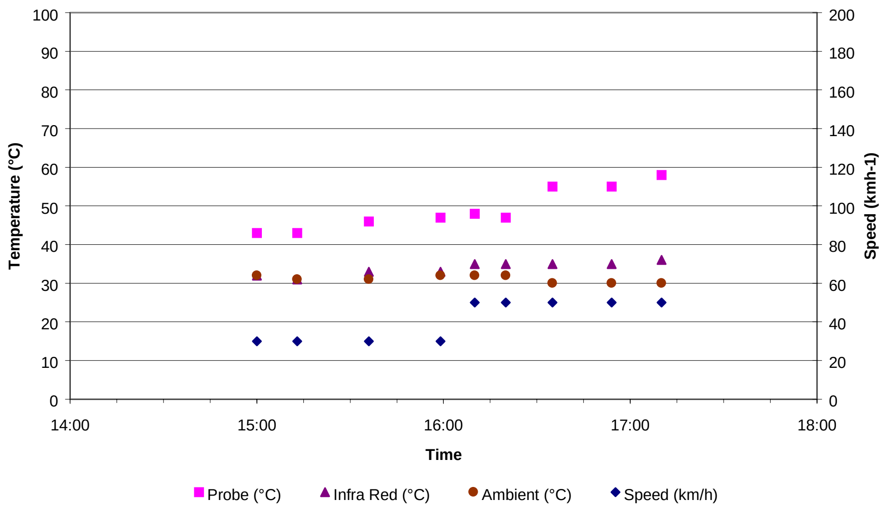

Figure 8 - Haulout Loaded Cycle

There was no significant rise, above ambient, of the tyre surface temperature when the haulout was operated in the unloaded condition (Figure 7). Tyre surface temperature was initially 24°C and increased to 30°C. The internal tyre temperature increased to 40°C, a 10°C temperature rise. The total temperature rise was quite small and due to the limited work (low levels of tyre flexing) performed by the tyre and the fact that the tyres were theoretically over-inflated when in the unloaded state. Both internal and external tyre temperatures rose with each subsequent test run. This was expected as the tyre increasingly performed more work as the distance and operating speeds increased with each test run.

The external tyre temperature, measured with the infrared sensor, did not show a significant rise above ambient temperature until the haulout was loaded and performing the first run at 50 kmh^{-1} (Figure 8). After this run, the tyre surface temperature can be seen to diverge from the ambient temperature. At the end of the test runs, the change in tyre surface temperature was very low when compared to the change in internal tyre bead temperature.

The responses of the IRS and TP appear to diverge with time and hence increasing work loadings of the tyre. In this test, tyre surface temperature showed only a small temperature rise (6°C) while the tyre internal temperature has recorded a larger temperature rise (15°C). Based on this initial trial result, external tyre temperature as a reliable predictor of tyre work is questionable and further investigation over a greater number of loading cycles may result in tyre surface temperature producing a more reliable indicator of tyre bead condition. Literature reviewed has shown the use of IRS and similar technology to measure the temperature of highly stressed tyres on racing cars. Automotive tyres are of lighter construction than the high flotation tyre used on sugarcane haulouts. The thick bead and sidewall together with the large mass of agricultural tyres may contribute to the differences between tyre internal bead temperature and tyre surface temperature.

5.2 Trial two

As the temperature test equipment has been developed and tested with some success, additional trials were conducted on haulout during the 1999 cane harvest comparing a tyre of light construction (18.4-24) to the common ‘heavier’ tyres such as the 23.1-26 or 24.5-32. The initial trial was not conclusion as to whether tyre surface temperature was a useful predictor of tyre work and tyre current operating condition.

The researchers could not determine a satisfactory method of static simulation of tyre temperature fluctuations so again a road-based trial was again undertaken. Two commercial haulout vehicles were used.

5.2.1 Methodology

Data were collected on haulout tyre temperature using:

- two measuring instruments and
- two sugarcane haulout vehicles operating under normal conditions.

The infrared temperature sensor (THERMALERT® CI™ 3A) was used to monitor the forward right hand trailer tyre on each vehicle. A DICKY-john DjRVS II Radar Velocity Sensor was used measure groundspeed. Ambient air temperature was measured and recorded using an internal temperature transducer in the datalogger and an external thermocouple (see Figures 9 and 10).

A 12 tonne dual conveyor elevated Carta haulout articulated to a Cantrell prime mover (Figures 11 and 12) and a 12 tonne LG Engineering trailer pulled by a John Deere 7810 tractor (Figure 13 and 14) were used in this trial. Both units were field loaded with cane billets to within the manufacturers recommended capacity. The haulout tyres monitored were a tyre of ‘heavy’ construction, 23.1–26 16PR and a ‘lighter’ tyre, 18.4-24 12PR.

Figure 9 - Datataker 500 – data storage unit

Figure 10 - Radar and infrared temperature sensor

The datalogger recorded ambient temperature, surface tyre temperature and groundspeed at 10 second intervals. When practical (machine was stationary), the Dunlop Olympic temperature probe was inserted into the tyre bead as close as possible to the measuring point of the IRTS. The internal temperature and time of measurement were recorded for later comparison and evaluation with the surface temperature readings.

Figure 11 - Cantrell prime mover with 12t Carta bin

Figure 12 - Tyre pressure and axle tare of articulated unit

Figure 13 - John Deere 7810 with 12t LG Engineering trailed bin

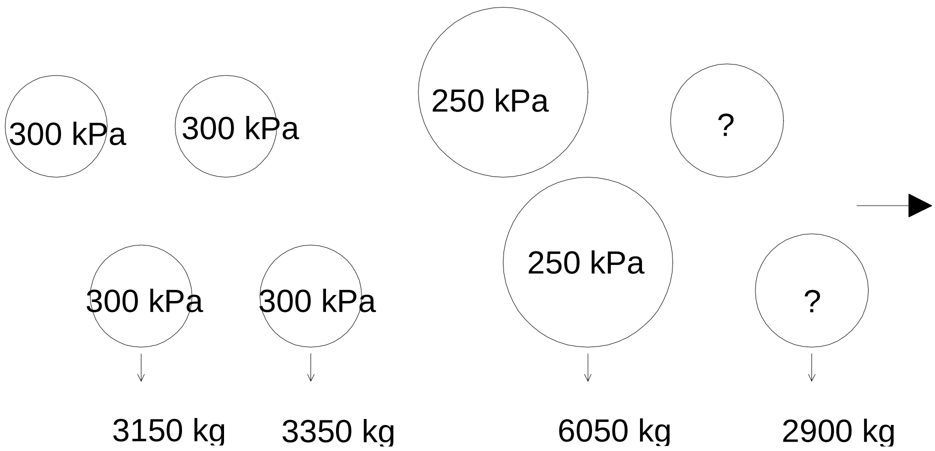

Figure 14 - Tyre pressure and axle tare of tractor/trailer unit

5.2.2 Results and discussion

Plots of surface temperature verses internal temperature are shown for both the 18.4-26 12PR and 23.1-26 16PR tyres in Figure 15. Statistical analysis of the two data sets showed the derived regression curves to be significantly different. The slopes were not to be significantly different, but the intercepts were. It is suspected that there may be a different relationship (equation) for each size and ply rating of tyre. This result indicates that there is a linear relationship between tyre surface temperature and tyre internal temperature. The monitoring of tyre surface temperature, therefore, could be used to safeguard tyre use.

The LG Engineering haulout did not have a suspension system and used a simple walking beam, load sharing system. These tyres would not only to carry the load but would also deflect to absorb impacts and bumps. This additional tyre deflection together with the lighter construction tyres could contribute to the higher internal temperatures. There was not a significant difference between the external and internal temperatures of both tyres. However, that the differences in surface temperature rise above ambient temperature of the two tyres is different, see Figure16 and Figure 17. The larger 23.1-26 tyre either produced heat at a lower rate or was able to dissipate heat at a higher rate than the lighter 18.4-26 tyre. The larger surface area of the 23.1-26 tyre may be a contributing factor. Conversely however, the larger tyre has a higher ply rating and greater wall thickness and this could tend to retain internal heat.

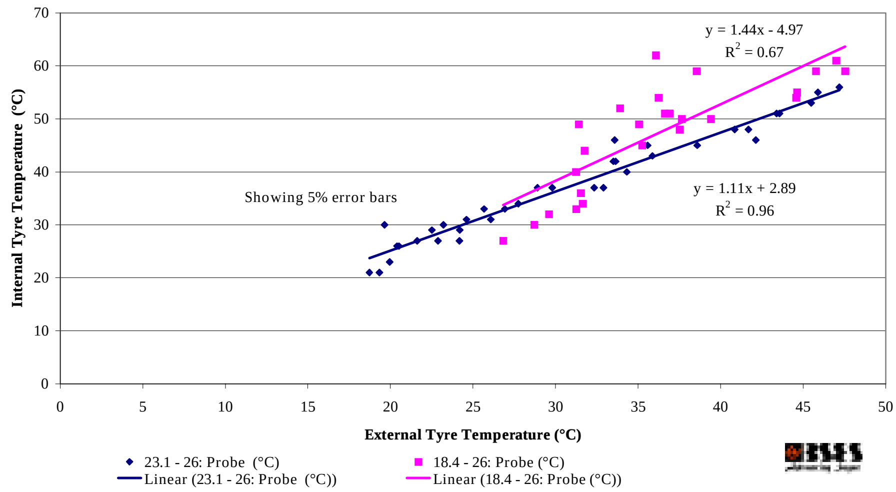

Figure 15 - Relationship of internal to external tyre temperature

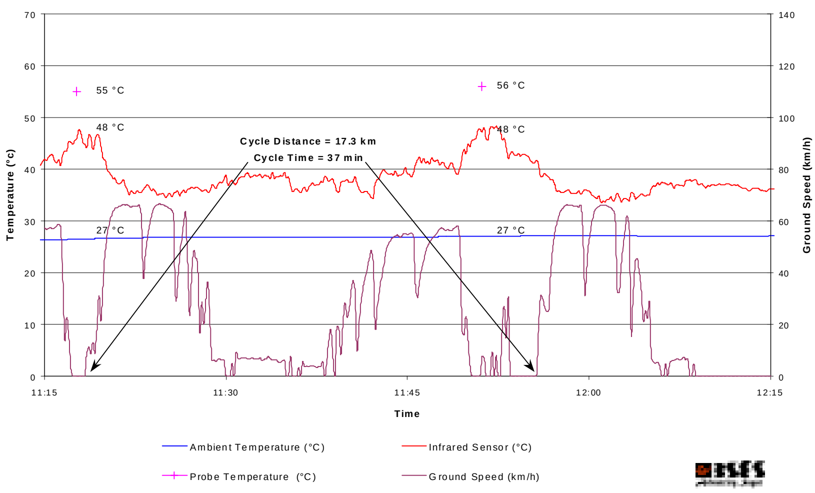

Figure 16 – Trip profile showing one complete duty cycle of the articulated unit

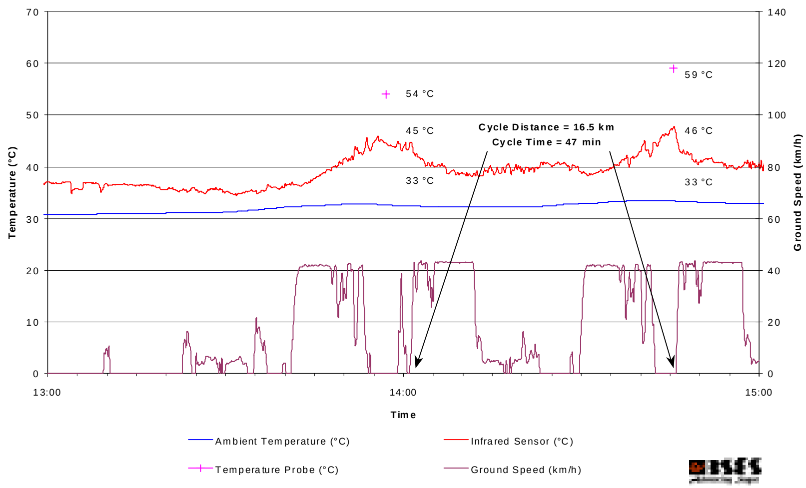

Figure 17 – Trip profile showing one complete duty cycle of tractor/trailer unit

The results clearly show the effect of the thermal mass of the tyre as the tyres take a significant period of high-speed travel before an increase in external tyre temperature can be measured. The cooling effect of a moving tyre is also obvious as when the vehicle stopped, especially when stopping to unload after high speed and loaded travel, the thermal energy within the tyre is dissipated through the tyre sidewalls and a significant increase in tyre temperature is measured. With both tyres, the maximum tyre temperatures (48°C and 46°C respectively) were measured after the tyre had been at rest for several minutes.

The haulout trip profiles were again very interesting and valuable additions to our haulout knowledge. The trial clearly indicated the 2 classes of machinery that are evolving in the sugarcane transport sector. The articulated unit was an example of a modern higher speed unit. This machine exceeded 50 kmh^{-1} when loaded and 60 kmh^{-1} when unloaded (see Figure 16). The tractor/trailer unit has a lower maximum operating speed due to the use of a tractor-based transmission. The operating speeds are just in excess of 40 kmh^{-1} for both loaded and unloaded cases (see Figure 17). The effects of hills and physical road impediments can be easily seen as the vehicle operating speeds are reduced when these constraints are encountered. The trip profile is repeated in reverse as the machine returns to the field from the siding and encounter these constraints. The repeatability of the haulout operators driving pattern is very high as illustrated on the trip profiles. The unloaded return trip speeds between 11.15 and 11.30 compare favourably unloaded return trip between about 11.55 and 12.07 on Figure 16. The shape of the speed verse time curve is determined by the physical constraints (hills, bends, etc) that prevent the operator from maintaining a constant speed during the journey.

The infrared temperature sensor was shown to be a simple, inexpensive and accurate method of measuring tyre surface temperature. The convenience of operation is somewhat limited by the relationship between internal and external tyre temperature. Because there appears to be a unique relationship (of internal temperature to external temperature) for each tyre size, the usefulness of the infrared temperature sensor as a research tool for tyre temperature measurement is somewhat diminished. The infrared temperature sensor may be useful to monitor all vehicle tyres to ensure tyre inflation pressures are maintained and axle loadings are not altered excessively. The sensor did prove to be as useful a tool but in its present form is not sufficiently robust for commercial use.

6.0 INFORMATION DISSEMINATION

During all phases of this project, significant effort was made to ensure all parties were informed of intended events and progress to date. The researchers have not attempted to document the number of meetings attended but all major canegrowing regions had at least one meeting to discuss project results. The project funded the hire of a mini-bus to transport representatives of QT, BSES, Canegrowers and Caneharvesters from Cairns to Mackay for a series of meetings at all major centres.

A presentation to the CANEGROWERS Executive by Ross Berry and Brian Robotham ensured both central and regional representatives of this organisation were aware of project progress.

7.0 PUBLICATIONS ARISING FROM THE PROJECT

Geddes, R, Robotham, B G, Berry, R and Rieschieck R**.** (1998). A comparative analysis of vehicles used for road transportation of sugarcane. Proc. Aust. Soc. Sugar Cane Technol., 20: 17-21

***Articles in the Australian Canegrower Magazine*:**

February 1998 page 5.Photograph of haulout survey working group
February 1998 page 17. Transport study could yield savings
April 1998 page 9. Haulout meetings set

Articles in The Caneharvester Magazine:

December 1997 page 5. Haulout load carrying efficiency
February 1998 page 16. Transport regulation review group meets
April 1998 page 5. Cane transport information meetings
June/July 1998 page 11 Haulout survey summary
August/ September 1998 page 14. Proposed tyre loads
October/November 1998 page 15. Determination of tyre limits on agriculture vehicles
October/November 1998 page 27. Haulout research
December/ January 1998/99 page 33. Weigh and see
February/March 1999 page 17. Are you purchasing haulout equipment?

8.0 ACKNOWLEDGMENTS

This project and, in particular, the transport survey, was good example of various organisations working together for the common benefit of the sugar industry. The authors thank:

- Queensland Transport staff especially those involved in the survey – Mr Ross Berry, Ross Rieschieck, Wayne Bryan, John Beasley and other inspectors
- John Powell and members of the Queensland Caneharvesters Association
- Pam Poggi and the regional staff and members of CANEGROWERS
- Mill transport staff
- Canegrowers who allowed us access to machinery

- Harvesting contractors and haulout operators
- Haulout manufacturers who assisted in the survey and supplied technical information
- Ian Broughton of South Pacific Tyres (formerly Dunlop and Olympic Tyres) and other tyre suppliers.

The funding from the Sugar Research and Development Corporation (SRDC) and the Bureau of Sugar Experiment Stations (BSES) was essential and is gratefully acknowledged.

9.0 REFERENCES

Anon. 1994. Information Bulletin. Queensland Transport. VSS.02.6/94.

The Tyre and Rim Association Australian. 1999 Standards Manual

APPENDIX 1

PROPOSED TYRE LOADS, TILLAGE & HAULOUT (SUGAR INDUSTRY ONLY)

	Normal Farming Practices			Cyclic Operation Haulout Equipment (high load variation up to 40 kmh)						Queensland Transport Current allowable Axle Loads Haulout Equipment	
	Tillage High sustained Torque			Driven No sustained High Torque			Free Rolling Trailer			Driven	Non-driven
Size Ply Rating	Max load kgs	Inflation pressure psi	Inflation pressure kpa	Max load kgs	Inflation pressure psi	Inflation pressure kpa	Max load kgs	Inflation pressure psi	Inflation pressure kpa	kgs	kgs
18.4-26 12pr	2,650	34	220	3,180	38	260	4,050	38	260	6,000	8,000
23.1-30 10pr	3,150	22	140	3,780	26	180	5,130	26	180	7,000	9,400
23.1-26 12pr	3,450	26	180	4,140	33	220	5,560	33	220	7,600	10,000
23.1-26 14pr	3,650	29	200	4,500	34	240	6,050	34	240	9,000	10,000
23.1-34 10pr	3,350	22	140	4,020	26	180	5,395	26	180	7,400	10,000
24.5-32 12pr	4,000	26	180	5,120	32	210	5,680	32	210	10,240	11,000
24.5-32 14pr	4,375	29	200	5,500	34	240	6,220	34	240	11,000	11,000
(Ground Hog) 22.5-26 12pr	-	-	-	-	-	-	5,725	34	240	-	9,000
30.5-32 10pr	3,875	18	120	4,650	26	180	5,560	26	180	8,600	11,000
30.5-32 12pr	4,250	22	140	5,165	29	200	6,050	29	200	9,600	11,200

** For speeds up to 50 kmh on Haulout Equipment - please contact manufacturer for loadings.

PROPOSED TYRE LOADS, TILLAGE & HAULOUT (SUGAR INDUSTRY ONLY)

	Normal Farming Practices (40 kmh)			Cyclic Operation Haulout Equipment (high load variation up to 50 kmh)						Queensland Transport Current allowable Axle Loads Haulout Equipment	
	Tillage High sustained Torque			Driven No sustained High Torque			Free Rolling Trailer			Driven	Non-driven
Size Ply Rating	Max load kgs	Inflation pressure		Max load kgs	Inflation pressure		Max load kgs	Inflation pressure		kgs	kgs
		psi	kpa		psi	kpa		psi	kpa		
18.4-26 12pr	2,650	34	220	2,865	38	260	3,580	38	260	6,000	8,000
23.1-30 10pr	3,150	22	140	3,400	26	180	4,250	26	180	7,000	9,400
23.1-26 12pr	3,450	26	180	3,725	33	220	4,660	33	220	7,600	10,000
23.1-26 14pr	3,650	29	200	3,940	34	240	4,925	34	240	9,000	10,000
23.1-34 10pr	3,350	22	140	3,620	26	180	4,525	26	180	7,400	10,000
24.5-32 12pr	4,000	26	180	4,320	30	210	5,400	30	210	10,240	11,000
24.5-32 14pr	4,375	29	200	4,675	34	210	5,845	34	240	11,000	11,000
(Ground Hog) 22.5-26 12pr	-	-	-	-	-	-	5,300	34	240	-	9,000
30.5-32 10pr	3,875	18	120	4,185	26	180	5,230	26	180	8,600	11,000
30.5-32 12pr	4,250	22	140	4,590	29	200	5,735	29	200	9,600	11,200

APPENDIX 2

IMPLEMENTATION OF SPECIAL PURPOSE VEHICLES PERFORMANCE GUIDELINES

1. Firm up on format
   include core info in all Performance Guidelines } by 15 December 1997
   document approach }
2. Create draft guideline (including check with NRTC on currency of OSOM) by 31 January 1998.
3. Circulate to regions (QT, QPS) for comment by 28 February 1998.
4. Revise guideline incorporating comments by 31 March 1998.
5. Circulate to industry and QT and QPS and regions again for final - seek comment on training needs - comment by 30 April 1998.
6. Finalise draft by 15 May 1998.
7. Finalise copy for printing by 15 June 1998.
   (commence discussions with communication strategy on guideline implementation by 1 February 1998)
8. Finalise training package by 15 June 1998.
9. Implement training by 15 July 1998.
10. Implement guideline by 15 September 1998.
11. Implement public education by 15 September 1998.

IMPLEMENT LOAD CARRYING VEHICLES FOR INDIVISIBLE ARTICLES PERFORMANCE GUIDELINES

1. Firm up on format - include core information in all performance guidelines - document approach.
2. Create draft guidelines by 31 January 1998.
3. Commence discussion with communication strategy on guideline implementation by 1 February 1998.
4. Circulate to regions, QT and QPS for comment by 28 February 1998.
5. Revise guidelines incorporating comments by 31 March 1998.
6. Circulate to industry, QT and QPS and regions, for final comment by 30 April 1998 (seek comments on training needs and methods).
7. Finalise draft by 15 May 1998.
8. Finalise copy for printing by 15 June 1998.
9. Finalise training package by 15 July 1998.
10. Implement training by 15 September 1998.
11. Implement guideline by 15 September 1998.
12. Implement public education by 15 September 1998.

IMPLEMENT AGRICULTURAL MACHINERY PERFORMANCE GUIDELINES

1. Firm up on format - include core information in all performance guidelines - document approach.
2. Create draft guideline by 31 January 1998.
3. Commence discussion with communication strategy on guideline implementation by 1 February 1998.

4. Circulate to regions, QT and QPS for comment by 28 February 1998.
5. Revise guidelines incorporating comments by 31 March 1998.
6. Circulate to industry, QT, QPS and regions, for final comment by 30 April 1998 (seek comments on training needs and methods).
7. Finalise draft by 15 May 1998.
8. Finalise copy for printing by 15 June 1998.
9. Finalise training package by 15 July 1998.
10. Implement training by 15 September 1998.
11. Implement guideline by 15 September 1998.
12. Implement public education by 15 September 1998.

IMPLEMENT GUIDE ON PERMIT TRAVEL

1. Finalise format by 15 December 1997.
2. Analyse NRTC document for need to include additional information by 31 January 1998.
3. Editing of NRTC document following ID of changes/additions (may need to borrow from QPS) by February 1998.
4. Circulate for comment to stakeholders by 31 March 1998.
5. Incorporate comments by 30 April 1998.
6. Finalise text for printing by 15 May 1998.
7. Text returned from printer by 15 June 1998.
8. Develop training by 15 July 1998.
9. Training completed by 15 September 1998.
10. Implement guide with other documents by 15 September 1998.

REVISE IMPLEMENT CONSTRUCTION STANDARDS

1. Finalise format by 15 December 1997.
2. Create revised construction standards document by 28 February 1998.
3. Circulate to stakeholders (DUM) for comment back by 31 March 1998.
4. Revise document incorporating comments by 30 April 1998.
5. Prepare for catalogue of SPV's by 15 May 1998 - include hard copy and electronic (lotus notes).
6. Organise industry support for HVRAS assessment of above by 15 June 1998.
7. Finalise copy for printing by 15 May 1998.
8. Copy of construction standards returned from printer by 15 June 1998.
9. Finalise text of hard copy and electronic versions of catalogue by 15 July 1998.
10. Electronic versions installed and hard copies of standards and catalogue by 15 August 1998.
11. Develop training package by 15 August 1998.
12. Implement training during 15 August 1998 to 15 September 1998.
13. Implementation by 15 September 1998.