TRAFFIC NOISE FROM UNINTERRUPTED TRAFFIC FLOWS

Transit New Zealand Research Report No. 28

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in association with
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Amendments to Report

Page 45, May 1994.
Appendix 3, May 1994.

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APPENDICES

EXECUTIVE SUMMARY

Reliable techniques have been used in a number of countries throughout the world for some years for the prediction of road traffic noise. As part of Transit New Zealand's ongoing research into traffic noise, Beca Carter Hollings & Ferner Ltd, in association with Hegley Acoustic Consultants Ltd, have completed a two-year project to produce a mathematical model capable of predicting the noise created by uninterrupted traffic flows.

A mathematical model produced by the United Kingdom Department of Transport (the CRTN or Calculation of Road Traffic Noise method) already exists and the first part of the project was to quantify its relevance to the New Zealand situation.

For New Zealand pavement and traffic characteristics it was discovered that the UK CRTN model could not predict to the required 2 dB(A) tolerance level. One hundred surveys were completed both in urban and rural areas with most being for a continuous 24-hour period. A wide variety of situations were surveyed which included: geographical location; traffic volume; vehicle speed; proportion of trucks; roadway gradient; road pavement surface type and where appropriate chipseal texture.

From this large range of variables for the mathematical model, a marked difference in noise production was found between identical traffic streams travelling on asphalt, friction course or chipseal pavement surfaces. Further to this, there was a difference between chipseals of different texture depths. Survey sites were then split into the three pavement surface types and each group was analysed separately. To quantify the texture of chipseals the TNZ T/3 (1981) Sand Circle test was performed at these sites.

The variable for the percentage of heavy vehicles used in the CRTN model did not adequately describe the heavy vehicle noise characteristics of the vehicle stream. A new variable was introduced, that of the ratio between medium heavy vehicles (i.e. 2 axle trucks) and large heavy vehicles (3 or more axles). This was measured using automatic vehicle classifiers for the entire survey period, with checks being made manually.

After computer statistical analysis of the survey data, it was decided to keep the form of the UK CRTN model but to add correction factors for heavy vehicle ratios and pavement types. These factors contained allowances for chipseal texture related to average speed and medium to large heavy vehicle ratio, related to the total percentage of trucks in the traffic stream.

This gave a mathematical model capable of predicting the L_{10} (the average maximum noise level) over the 18-hour period from 6am to midnight, to within 2 dB(A) of the measured L_{10} for over 95% of cases.

The 1-hour L_{10} value can be obtained by adding 13 dB(A) to the 18-hour modified CTRN formula.

The difference in traffic noise level between friction course and chipseal pavements on a rural highway could be expected to be around 6 dB(A), and with the new correction factors these differences can now be more accurately quantified.

By making use of these new refined vehicle noise prediction models, planners and engineers will be able to more accurately define noise control devices to abate vehicle noise and have a basis on which to estimate the environmental impacts of new roading projects or pavement seal changes.

ABSTRACT

The modification of the UK CRTN (Calculation of Road Traffic Noise) formulae for the prediction of traffic noise from uninterrupted traffic flows has been researched. The report details the methods used for data collection of noise and traffic relationships, shows the shortcomings of the CRTN model in the New Zealand situation, and shows how pavement type and chipseal texture as well as the ratio of medium to heavy trucks affect the level of traffic noise.

Full equations are provided that can predict the L_{10} traffic noise level from uninterrupted traffic flows to a tolerance of 2 dB(A) 95% of the time. The 1-hour L_{10} value can be obtained by adding 13 dB(A) to the 18-hour modified CRTN formula.

Details are provided on the effects of ground cover, facade reflection, and variance in noise-traffic relationships over a number of days. A guide to predicting traffic noise using the modified CRTN formulae is appended.

1. INTRODUCTION

1.1 Background

This report details the methods and results of Transit New Zealand project TN/3. The goal of the research project was to determine, with an overall accuracy of $\pm$ 2 dB(A) (at the 95% confidence level), a method of predicting traffic noise for New Zealand conditions based on the UK CRTN model (DOT 1988).

The CRTN (Calculation of Road Traffic Noise) model was produced by the Welsh Office of the Department of Transport in the United Kingdom in 1988. The 1988 CRTN model was based on a previous model produced by the United Kingdom Department of the Environment in 1975 (DoE 1975).

Modifications to the CRTN model to account for New Zealand traffic and pavement characteristics are the product of analysis of traffic noise and uninterrupted traffic flow relationships sampled at 100 sites throughout North Island. The modifications are based on two newly incorporated factors: road surface characteristics and the ratio of medium to large heavy vehicles.

It is assumed that people who use the formulae in this report to predict traffic noise levels are familiar with the CRTN (DOT 1988) method. Several sections in the CRTN (1988) report were not in the scope of this research report, and they need to be referred to when predicting traffic noise. A guide using the modified CRTN formula is in Appendix 1.

1.2 Definition and Interpretation

The procedures (DOT 1988) assume typical traffic noise propagation conditions which are consistent with moderately adverse wind velocities and directions. All noise levels are expressed in terms of the index L_{10} (1 Hr) dB(A) or L_{10} (18 Hr) dB(A). The value of L_{10} (1 Hr) dB(A) is the noise exceeded for just 10% of the time over the period of one hour. The L_{10} (18 Hr) dB(A) is the arithmetic average of the values of L_{10} hourly dB(A) for each of the eighteen one-hour periods between 0600 to 2400 hours. The source of traffic noise (the source line) is taken to be a line 0.5 metres above the carriageway level and 3.5 metres in from the nearside carriageway edge. Note that the edge of the carriageway is the edge of the area used by traffic and excludes hard shoulders and parking areas.

Section 3.5 details the limitations of the prediction model. Care should be taken when interpreting noise level predictions which are close to the noise levels expected from non-traffic sources; the formulae given in the report do not take account of extraneous noise sources. Site noise levels which are effected by noise, for example, from aircraft passing overhead, industrial plant, general background sources etc., will tend to be underestimated by the prediction method. In these circumstances it would be advisable for a noise survey to be done in accordance with NZS6801:1991 "Measurement of sound - methods of measuring noise" (NZSA 1991).

1.3 Glossary of Terms

Angle of view — The angle of road that can be seen from the observation point.

Attenuation effects — Effects which reduce the level of noise received as the distance from the source increases.

Carriageway — Paved area of roadway, including unpaved medians.

Chipseal texture — Texture of the pavement surface related to the volume of voids in the pavement surface. (It is measured using the sand circle test.)

CRTN model — Calculation of Road Traffic Noise formulae (documented in the report *"Calculation of Road Traffic Noise"*, published by the Welsh Office of the United Kingdom Department of Transport, 1988).

dB — Decibels (a measurement of noise: the decibel scale is logarithmic which makes the numbers more manageable).

dB(A)	Units of noise level (Units are measured by a sound level meter which contains a special circuit called an A-weighting filter. The filter attempts to measure noise frequencies likely to be heard by the human ear. This is almost universally used in assessing community noise.)
Facade	The outside wall of a structure.
Heavy vehicle (HV)	A vehicle with dual tyres on each rear axle.
Medium HV	A heavy vehicle with no more than two axles.
Large HV	A heavy vehicle with three or more axles (including trailer unit axles).
L_{10}	The sound level that is equalled or exceeded for 10% of the measurement period. (It can be described as the average maximum noise level and is a commonly used method of rating nuisance noise.)
Reflective ground cover	Ground with either paved or other hard cover, that has no vertical obstructions.
Road roughness	A measure of the unevenness of a pavement surface.
Road pavement surface type	Type of pavement material (e.g. chipseal, asphaltic concrete, or friction course) of uppermost layer of road pavement.
Roadway gradient	Longitudinal gradient of the road section.
Traffic volume	The number of vehicles passing a specified point on a road in a certain time period.

1.4 Variables in Formulae

Variable	Unit	Definition
Q	(veh)	18-hour flow (6am to midnight)
V	(km/h)	Average speed of vehicle traffic
P	(%)	Percentage of heavy vehicles in traffic stream
G	(%)	Average longitudinal gradient of road section
A	(degs)	Angle of view to roadway
D	(m)	Distance from reception point of noise to trafficked part of carriageway
H	(m)	Average height of propagation between the reception point of noise and the effective source position of noise above the intervening ground. (The effective source position is assumed to be 0.5m above the carriageway.)
h	(m)	Relative height between the reception point of noise and the carriageway.
F	none	A variable between 0 and 1 which accounts for attenuation effects caused by non-reflective ground cover. (Consult the table in paragraph 20.4 of the 1988 DOT CRTN method for explanation.)
r	fraction	Ratio of medium heavy vehicles to large heavy vehicles.
S	(mm)	The diameter of the sand circle obtained by the standard test procedure for measurement of texture by the sand circle method (TNZ T/3 (1981) specification).
C	none	Chipseal noise constant: equals 1 if the pavement type is a chipseal; equals 0 if pavement is other than a chipseal.
X	none	Friction course noise constant: equals 1 if the pavement type is a friction course; equals 0 if pavement is other than friction course.

2. NOISE AND TRAFFIC SURVEYS

2.1 Site Selection

The findings in this report are based on surveys of traffic noise and flow characteristics at 100 sites. Noise levels at 83 of these sites were monitored for at least one 24-hour period, two of those sites having seven days of continuous noise monitoring. The balance of the sites were monitored for a period of at least one hour and were used to accurately target areas of the model where it was felt that further refinement was necessary.

Sites were chosen in three main areas of the North Island: Auckland, Central North Island, and Wellington (Figure 1).

The 100 sites (listed in Appendix 3 and shown in Appendix 5) represent roads having a wide variety of traffic and carriageway characteristics. In particular an effort was made to give a range of:

- Geographic location
- Traffic volume (over 18 hours and over one hour)
- Proportion of heavy vehicles in traffic stream (over 18 hours and over one hour)
- Ratio of medium to large heavy vehicles (over 18 hours and over one hour)
- Vehicle speed
- Roadway gradient
- Road pavement surface type
- Chipseal texture

The spread of sites surveyed according to these characteristics are displayed graphically in Appendix 2.

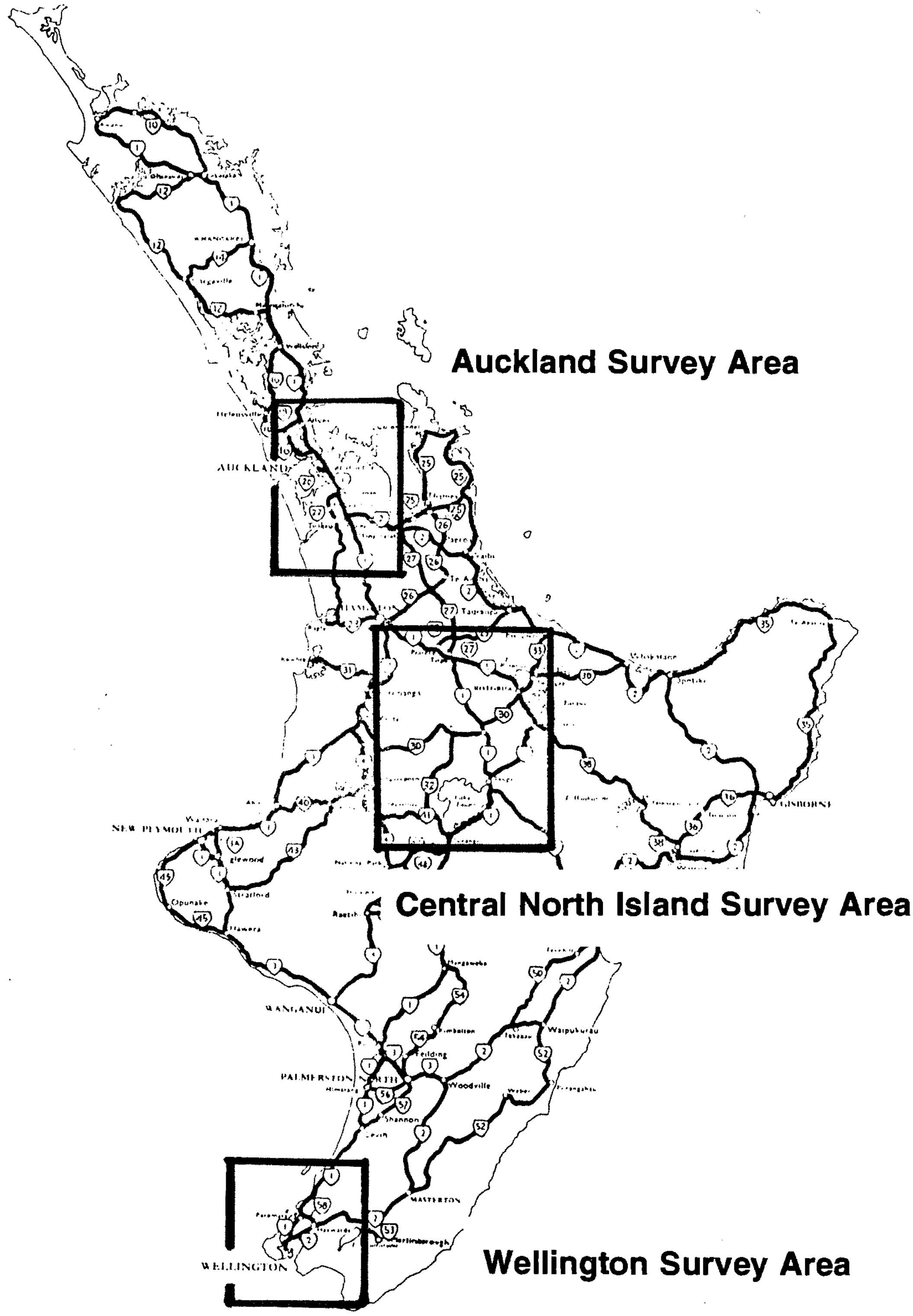

Figure 1. Location of the survey areas in which the 100 sites (listed in Appendix 3) were located. The locations of the sites are shown in Appendix 5.

2.2 Conduct of Traffic Noise Surveys

The traffic noise surveys have been conducted by using the following personnel and equipment:

Personnel	Associated Organisation	Equipment Used	Area Covered	Sites Surveyed
Michael Hart	NECAL Laboratories	B & K 4426 & 4427	Auckland	24
Philip Dickinson	Dept of Health	QUEST M28	Wellington	14
Bob Thorne	South Waikato District Council	QUEST M28	Central North Island	12
Matthew Ensor	Beca Carter Hollings & Ferner	QUEST M28	North Island	50

All noise level meters were calibrated before measurements were started at each site. This involved placing a calibrator, which produced a known frequency at a known noise level, over the microphone and checking the sound level showing on the meter. In the case of the (QUEST) M-28 meter, the machine automatically compensates for any adjustment that is required. All measurements were carried out in accordance with the New Zealand Standard NZS6801:1991 (SANZ 1991) which details methods for measuring noise.

The microphones were set up as close as possible to the carriageway with a minimum setback of 3.5 metres and an average setback of around 10 metres. This allowed unquantifiable effects such as ground cover to be ignored for the first part of the analysis. Generally the microphones were hidden, normally behind vegetation, from sight of passing pedestrians to give the equipment some security. A lot of care was taken to pick good sites for the microphone and they were not particularly common. The number of possible locations for one-hour surveys was greater as the equipment could be left in the open under watch of the manual vehicle surveyor.

The surveys were all undertaken in mainly dry and relatively calm conditions in the first half of both 1990 and 1991.

2.3 Conduct of Traffic and Roadway Surveys

At most of the sites, traffic surveys were undertaken simultaneously with the noise surveys. Automatic vehicle classifiers (GK5000) were used at most sites with normally one pair of tubes and classifier being placed in each of the two opposing directions of traffic. At six of the sites, results from Transit New Zealand's remote vehicle classifying system have been used.

At a further six sites, traffic patterns have been determined from Transit New Zealand axle counts supplemented by manual or automatic vehicle classification counts and manual speed surveys. At sites with multiple lanes and high traffic volumes (e.g. Auckland and Wellington Motorways), the use of the automatic vehicle classifiers was impractical. Traffic counting tubes were laid at least 30m down the road from the microphones so that the noise of vehicles crossing the tubes did not affect the L_{10} traffic noise measurements.

At most sites manual traffic volume and vehicle classification surveys were undertaken for a minimum of one hour. While providing a check on the performance of the automatic classifiers, these manual surveys also provide an accurate volume and classification count from which an assessment of the 1-hour CRTN model could also be made.

Vehicles were classified into the following three classes:

- Cars and other light vehicles

- Medium heavy vehicles, no more than two axles with dual tyres on each rear wheel

- Large heavy vehicles, three or more axles

Vehicle speeds in most cases were classified into three groups, an estimate of the mean being obtained by assuming that vehicle speeds followed a normal distribution, the variance being determined as a proportion of the mean. This method was validated by work conducted on speed distributions in New Zealand by the MOT.

At each site the roadway gradient was measured, using a thrust gauge attached to a long straight length of wood over a selection of places on the road. Surface texture was quantified on chipseal using a sand circle test that was made on a typical section of pavement traversed by vehicle tyres. Surface types were classified as:

- chipseal
- asphalt, or
- friction course

The BCHF* Road Roughness vehicle was used to measure the roughness of the surveyed sites in all three survey areas to determine any relationships between the NAASRA** roughness count (Duffill Watts & King 1988) and traffic noise.

2.4 Data Storage

All data were entered into a computer spreadsheet so that trends could be seen and mathematical analysis could be done more easily. These spreadsheets are in Lotus 1-2-3 version 2.4 and are held by Transit New Zealand (Research & Development Section).

* Beca Carter Hollings & Ferner

** National Association of Australian State Road Authorities

3. ANALYSIS OF SURVEY DATA

3.1 Evaluation of UK CRTN Noise Prediction Model

The first stage of the analysis was to assess the adequacy of the unmodified UK CRTN model under New Zealand conditions. The necessary data were entered into a computer spreadsheet which contained the CRTN prediction formulae, and the performance of the model was evaluated.

3.1.1 Model Input Requirements

The CRTN model was used to predict the expected L_{10} noise level for 18-hour and 1-hour periods at each site. The following traffic and roadway characteristics were determined for each site and entered into the computer spreadsheet CRTN model:

- Traffic volume
- Traffic speed
- Percentage of heavy vehicles
- Distance of measurement point to nearside carriageway
- Angle of view
- Gradient
- Height of measurement

3.1.2 Ground Cover and Other Attenuation Effects

The CRTN model contains a formula to correct for ground cover effects. The level of correction to be applied is related to the percentage of ground, between the noise source and the observer, that is absorbent. At most sites this correction was not appropriate because ground cover was reflective. At a small number of sites some ground cover attenuation effects could have been expected but every effort was made to minimise these effects by placing the noise reception point as close as possible to the carriageway with a minimum set back of 3.5 metres. At three sites corrections had to be employed as noise levels at the reception point were affected by the presence of low walls.

3.1.3 Traffic Flow Recording

The vehicle classifiers used did not classify vehicles as accurately as anticipated. In particular, in high traffic flows they often confused cars travelling close behind each other, and cars following medium trucks, with heavy trucks. Fortunately the manual classification counts conducted as checks enabled the outputs of the machines to be calibrated to obtain reasonably accurate classifications for 24-hour periods. As well the manual counts enabled the 1-hour CRTN model to be evaluated for accurate classifications.

3.1.4 Unmodified UK CRTN Prediction Model

Figures 2 and 3 display summaries of the measured and the CRTN-predicted noise levels at the 100 sites for 18-hour periods (0600-2400 hours) and for 1-hour periods. Summaries of each site are provided in Appendix 3.

It is evident from Figures 2 and 3 that an unmodified UK CRTN model does not predict actual L_{10}(18 Hr) and L_{10}(1 Hr) noise levels under New Zealand conditions with the required accuracy. However patterns were found to exist in the differences, with the ratio of medium to heavy trucks and the road surface type and texture both having apparently significant effects. These patterns are displayed in Figures 4 and 5.

3.2 Formulation of a Modified UK CRTN Noise Prediction Model

A regression analysis was performed on the differences between the L_{10}(18 Hr) measured and predicted noise levels using the following independent variables:

- log (s/v) (chipseal surfaces only) — s - sand circle reading (mm); v - mean speed (km/h)
- log (P/r) — P - percentage of trucks; r - ratio of medium:heavy trucks

This exercise produced three formulae which provide a modification of the CRTN L_{10}(18 Hr) model for New Zealand conditions.

These formulae are:

Chipseal :	1.66 - 5.57 log (s/v) + 1.65 log (P/r)
Asphalt :	-2.63 + 1.65 log (P/r)
Friction course:	-6.03 + 1.65 log (P/r)

Figure 6 displays a graph of the measured versus predicted noise levels (using these modifications) for L_{10}(18 Hr) values using the modified UK Department of Transport noise prediction model.

The relationship between the L_{10}(18 Hr) value and the L_{10}(1 Hr) value is generally constant. The 1-hour value can be obtained from the 18-hour CRTN formula, with pavement surface type corrections as well, by adding a further 13 dB(A).

Figure 7 displays a graph of the measured versus predicted noise levels (using modifications) for L_{10}(1 Hr) values. All the measured and predicted noise levels (L_{10}(18 Hr) and L_{10}(1 Hr)) at each site are shown in Appendix 3.

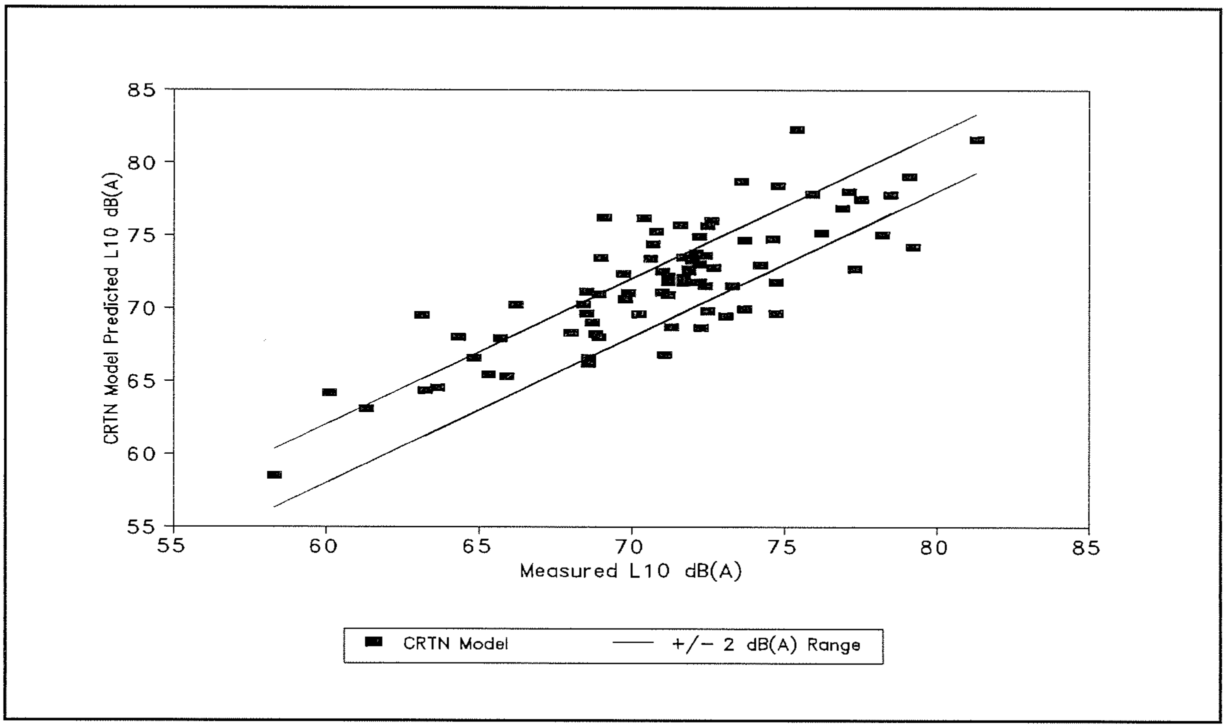

Figure 2. Measured noise vs UK CRTN predicted noise, L_{10}(18 Hr).

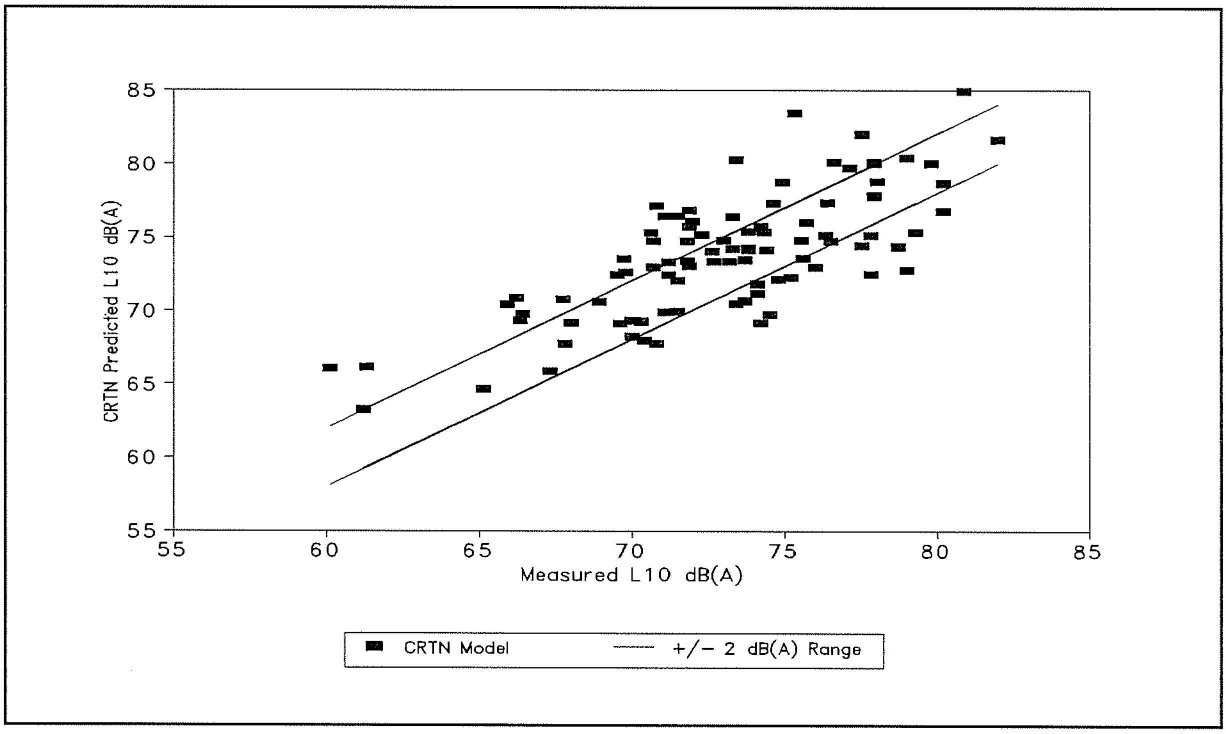

Figure 3. Measured noise vs UK CRTN predicted noise, L_{10}(1 Hr).

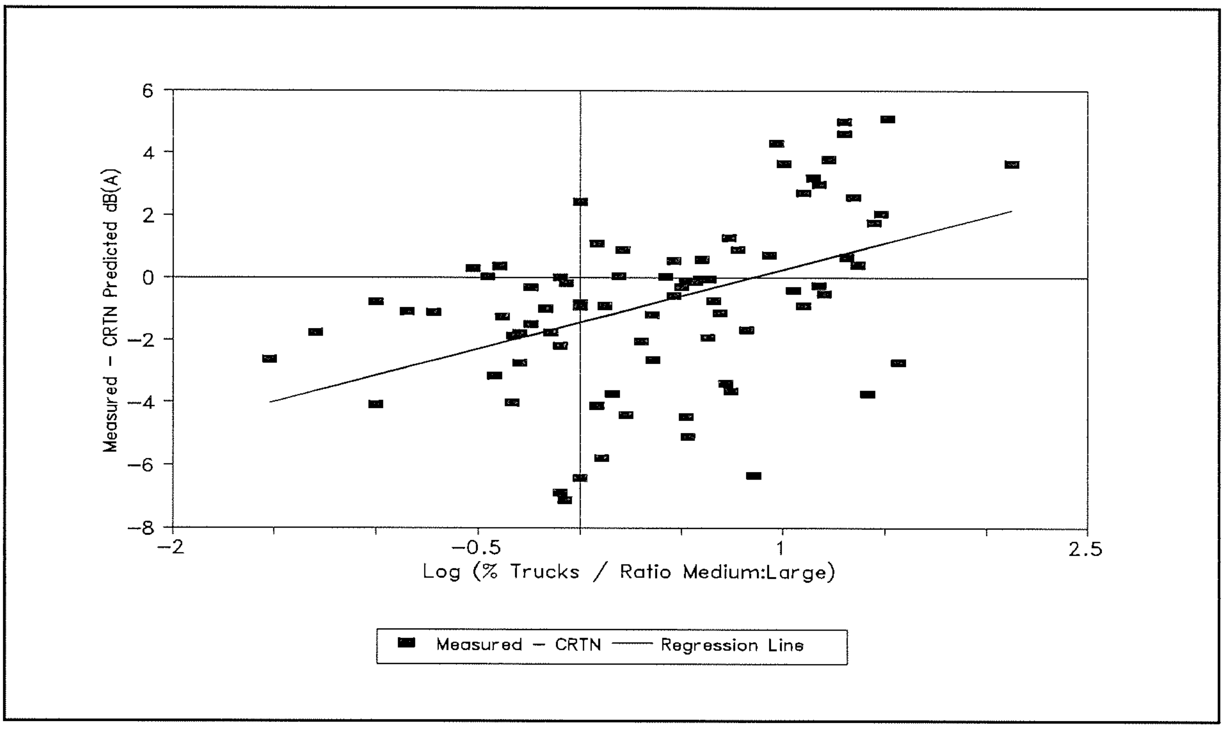

Figure 4. Variation between measured and predicted UK CRTN L_{10}(18 Hr) noise levels with percentage of trucks and ratio of medium to large heavy vehicles.

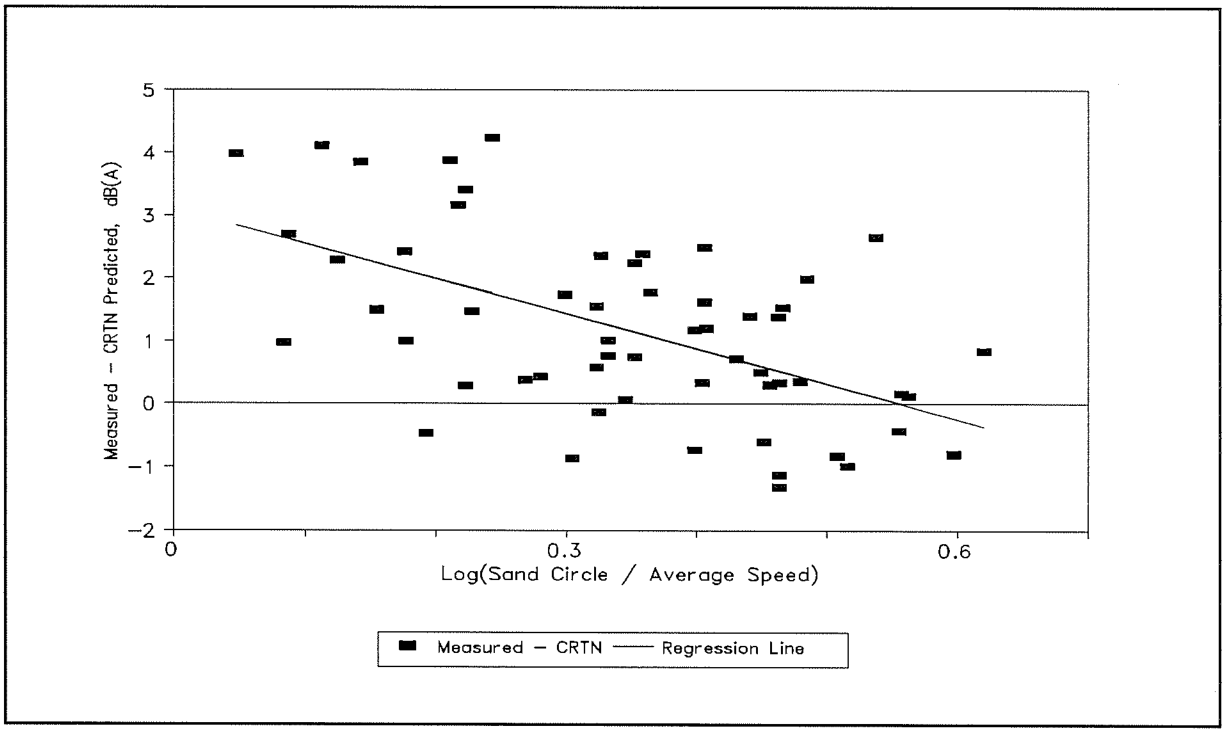

Figure 5. Variation between measured and predicted UK CRTN L_{10}(18 Hr) noise levels with road surface texture (sand circle/average speed).

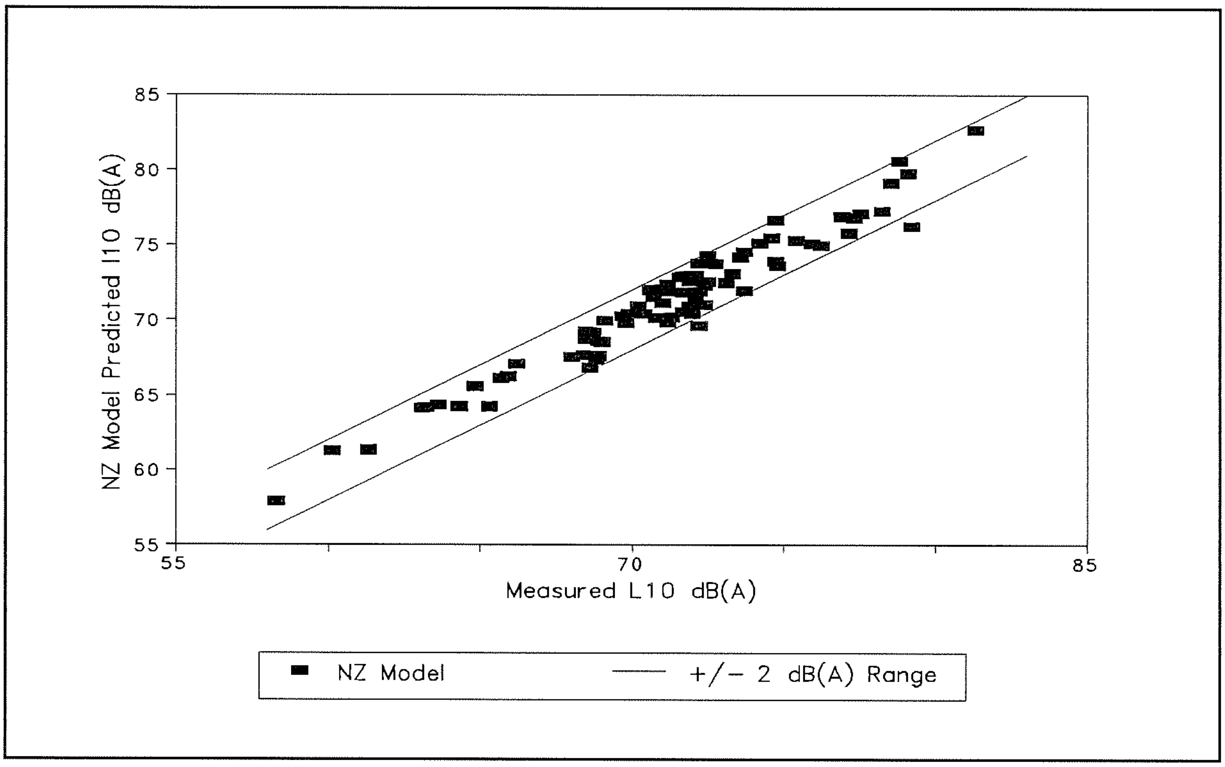

Figure 6. Measured L_{10}(18 Hr) vs predicted L_{10}(18 Hr) modified UK CRTN noise prediction model.

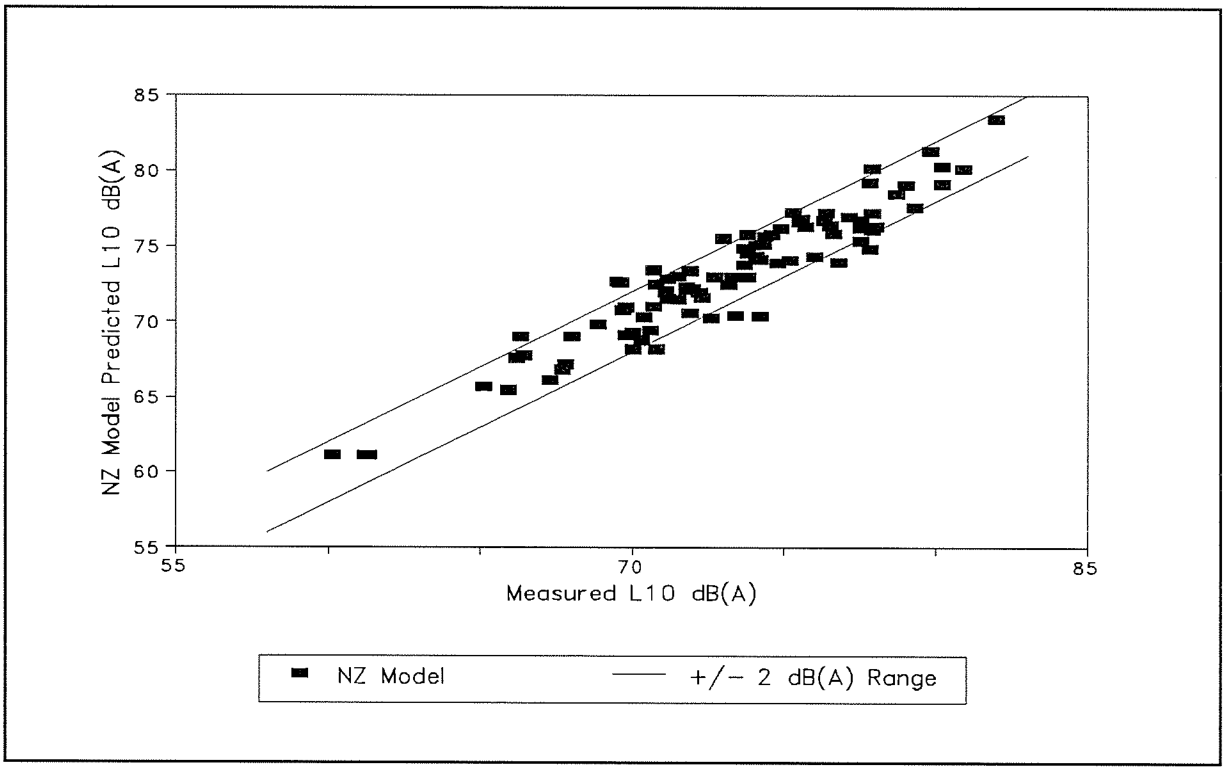

Figure 7. Measured L_{10}(1 Hr) vs predicted L_{10}(1 Hr) modified UK CRTN noise prediction model.

Figures 8 and 9 display the corrections required for the UK CRTN L_{10}(18 Hr) model to adapt it to New Zealand conditions.

The final equation for predicting L_{10}(18 Hr) noise from uninterrupted traffic flows is shown below (see Section 1.4 or Appendix 1 for explanation of variables in UK CRTN formulae):

$$26.5+10\,Log(Q)+33\,Log\left(V+40+\left(\frac{500}{V}\right)\right)+10\,Log\left(1+\frac{5P}{V}\right)-68.8+0.3\,G$$

$$+10\times Log\left(\frac{A}{180}\right)-10\times Log\left(\frac{\sqrt{((D+3.5)^2+(h-0.5)^2)}}{13.5}\right)+F\times 5.2\times Log\left(\frac{6H-1.5}{D+3.5}\right)$$

$$+\ 1.65\ Log\ \frac{P}{r}\ +\ 5.57\ C\left(0.77\ -\ Log\ \frac{S}{V}\right)\ -\ 3.4\ X$$

This equation only applies for:

$$0.75\ \leq\ H\ <\ \frac{d+5}{6}$$

If the following conditions apply, replace the ground cover correction term with the appropriate term:

for $H < 0.75$ *use*: $F \times 5.2 \times Log\left(\frac{3}{d+3.5}\right)$

for $H \geq \frac{d+5}{6}$ *use*: 0

3.3 Performance of the Modified UK CRTN Noise Prediction Model

The modified Noise Prediction Model can result in substantial variations from the UK CRTN model depending on the road surface and vehicle characteristics. Table 1 (p.25) displays some typical hourly predicted L_{10} (1 Hr) noise levels for a basic flow rate of 500 veh/h (vehicles per hour), a distance of 10 metres from the carriageway, an angle of view of 180 degrees, a gradient of 0%, and a receiver height of 1.2 metres.

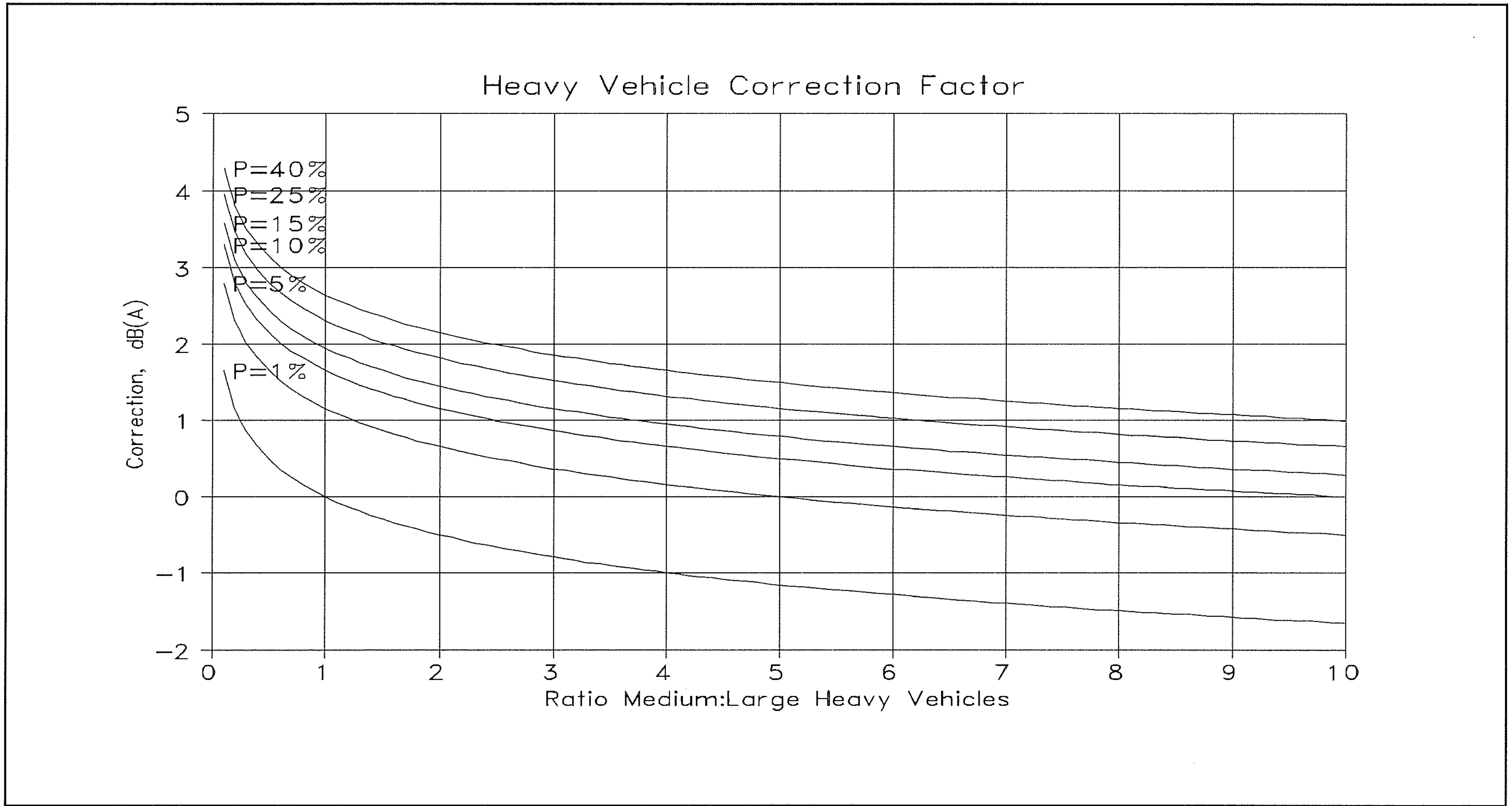

Figure 8. Corrections to UK CRTN model for different ratios (r) of medium to large heavy vehicles for six percentages of heavy vehicles (P = 1%, 5%, 10%, 15%, 25%, 40%).

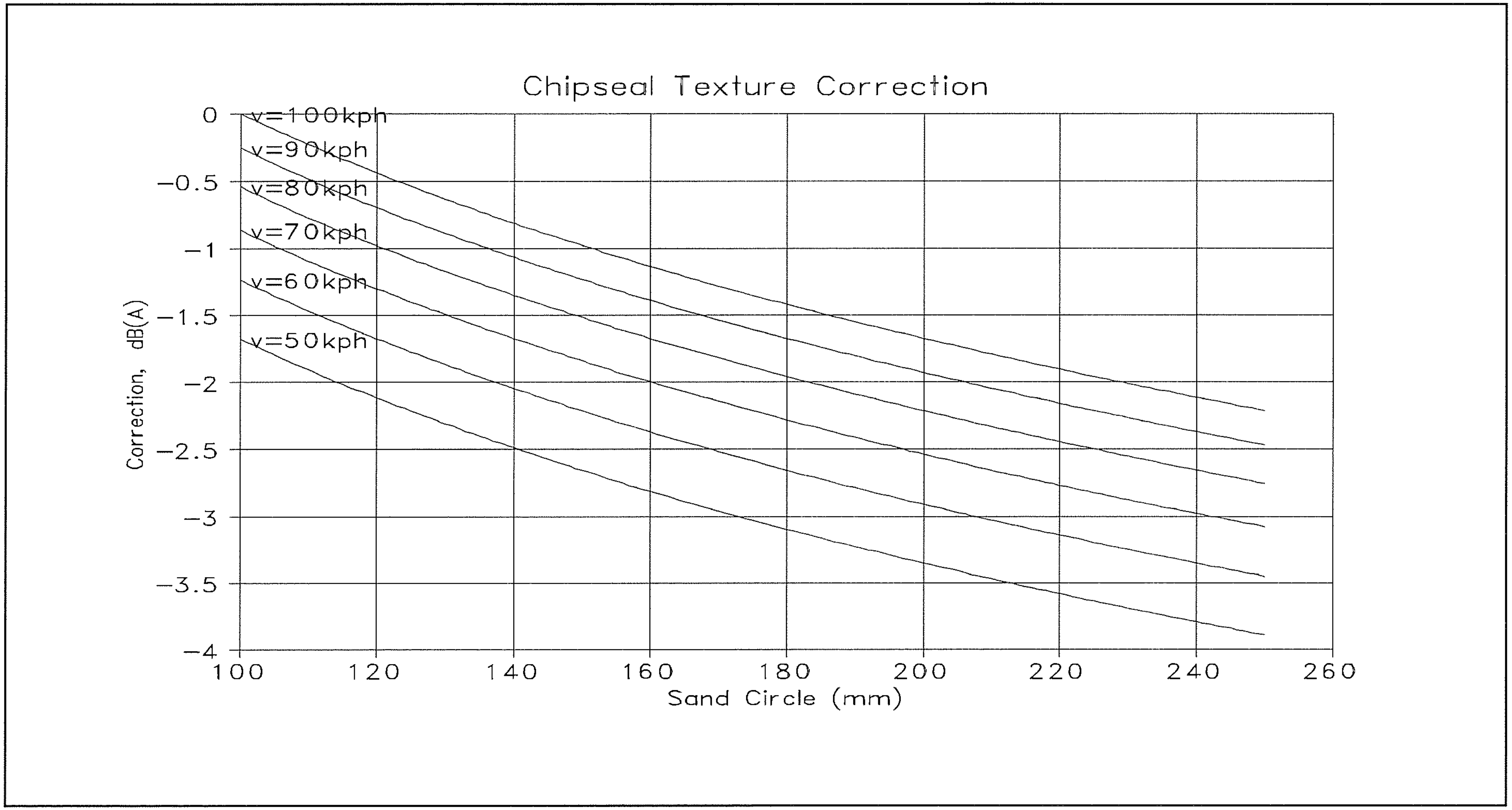

Figure 9. Corrections to UK CRTN predicted L_{10}(18 Hr) for different sand circle readings (mm) at six speeds (v = 50, 60, 70, 80, 90, 100 km/h).

Table 1. Comparison of UK CRTN and New Zealand-modified model predictions of L_{10}(1 Hr) under typical conditions.

	Road Surface	% Heavy	Medium : Large	Sand Circle	Mean Speed	CRTN Model	NZ Model	Difference
Urban (suburban)	Chip	5	8	150	60	69.0	68.1	-0.9
	Asphalt	5	8	NA	60	69.0	66.0	-3.0
	Friction	5	8	NA	60	69.0	62.6	-6.4
Urban (Industrial)	Chip	20	1	150	60	71.8	73.4	+1.6
	Asphalt	20	1	NA	60	71.8	71.3	-0.5
	Friction	20	1	NA	60	71.8	67.9	-3.9
Rural	Chip	5	1.5	130	97	72.4	74.2	+1.8
	Asphalt	5	1.5	NA	97	72.4	70.6	-1.8
	Friction	5	1.5	NA	97	72.4	67.2	-5.2
Rural (Trunk)	Chip	14	0.5	130	97	73.8	74.8	+1.0
	Asphalt	14	0.5	NA	97	73.8	71.2	-2.6
	Friction	14	0.5	NA	97	73.8	67.8	-6.0

The modified L_{10}(18 Hr) model predicted all but five 18-hour sites to within $\pm$ 2 dB(A) of tolerance. At one site, SH1 at Huntly, South Auckland (site 169, Appendices 3, 5), significant platooning occurred but other reasons could have been heavy trucks using their engine brakes, and the difficulty in calculating the distance between the microphone and the traffic stream because slower vehicles would pull over onto the road shoulder. The Oak Tree Avenue site (site 4, Appendices 3, 5) had traffic flows below the critical level for accurate prediction (see Section 3.5.1). At the other three sites (sites 2, 8, 210, Appendices 3, 5), a number of different factors could possibly have caused the predicted value to fall outside the $\pm$ 2 dB(A).

Overall the modifications to the UK CRTN model are consistent with what may have been expected. Generally chipseal contributes 2.5 to 4.0 dB(A) extra traffic noise compared with asphalt, and this effect becomes greater with increasing speed. Friction course appears to be significantly quieter than asphalt by a factor of around 3.4 dB(A). Thus sealing a higher speed road (with average speed greater than 80 km/h) with friction course instead of chipseal could be expected to reduce L_{10} levels by around 6 dB(A).

3.4 Considerations in the Production of L_{10}(18 Hour) Model

3.4.1 Determining the 18-Hour Period

It was considered whether the 18-hour period from 6am to midnight should be shortened because relatively low traffic flows are experienced on some New Zealand roads after 10pm. To analyse this problem daily flow profile data from a representative sample of sites were combined. Because traffic noise levels are related to the Log_{10} of traffic flow, these flow profiles were also adjusted to a logarithmic scale.

Flow profiles from typical residential distributors and arterials were considered for comparison and, as expected, roads with different functions had different 24-hour traffic characteristics.

As can be seen in Figure 10, traffic levels remain significant until near midnight, and build up sufficiently in the hour ending 7am. For this reason it is recommended that the 18-hour time period of 6am to midnight be retained, as during the course of the investigation 18-hour time periods have been used without any problems. However, should a night-time noise evaluation be carried out, then this should be done separately from the 18-hour model.

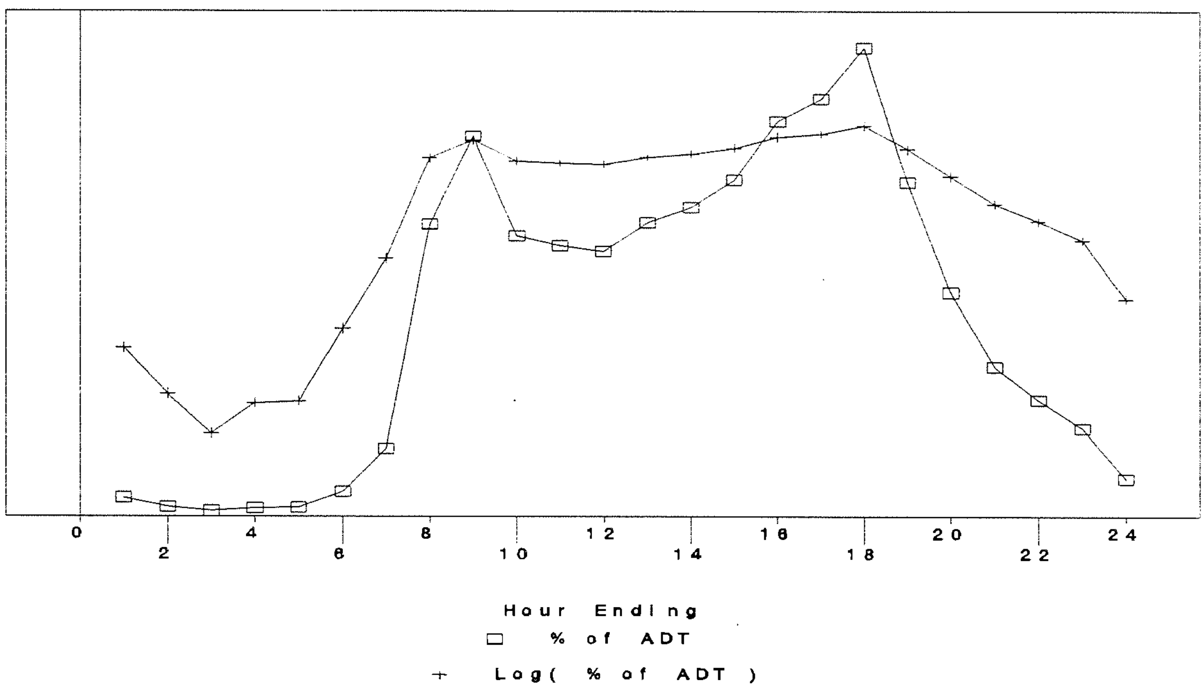

Figure 10. All-day flow profile from selected arterial and principal roads.

3.4.2 Average Speed

One of the input factors in the UK CRTN model is the average speed of traffic. In New Zealand however, the 85th percentile speed is more often used. Therefore this value was investigated to determine if it was more relevant to the model than the average speed. But it was noted that higher speed traffic was not necessarily the critical traffic component in the L_{10} noise value. Generally heavy vehicles and motorcycles produce the higher levels of noise and these vehicle types were not over-represented in the higher speed traffic recorded at the sites during the survey.

The average speed value then seems to suffice for the formulae quoted in this report and this maintains compatibility with the CRTN formulae.

If the CRTN model was to be converted to accept the 85th percentile speed as an input, in place of the average speed, then this could be done in two ways:

- Calculation or measurement of 85th percentile speed at sites surveyed in this project followed by a re-calibration of the CRTN model.

- Insert a mathematical conversion into the CRTN formulae which assumes that there is a relationship between average speed and the standard deviation of those speeds.

Speed data for most of the sites were "binned" into three speed ranges as appropriate. The ranges were chosen to allow calculation of the average speed. Accurate estimates of the 85th percentile speed would not be possible for these surveyed sites from data already collected.

In producing a mathematical conversion formulae from mean to 85th percentile speed, it would be reasonable to assume a normal distribution for speeds. Previous unpublished studies by the MOT indicated only minor positive skewness. The following relationship applies:

$$\text{85th Percentile Speed} \approx \text{Average Speed} + 1.04 \times \text{Standard Deviation}$$

It would be reasonable to assume that the ratio of the standard deviation to the mean (the coefficient of variation) remains constant across a range of speeds. While this would simplify calculations, the associated inherently larger uncertainties in the estimate of the 85th percentile (as opposed to the mean) speed remain. Thus an estimation of the 85th percentile speed of traffic from its average speed would result in a figure which would be an estimate from an estimate.

For this reason the recommendation is that, if 85th percentile speed values need to be used, research be done to re-measure speeds at project sites where insufficient data were available for the 85th percentile speed, and then either recalibrating the speed terms in the model or if possible producing a small conversion formula.

3.4.3 Relationship with Road Roughness

The relationship between road roughness (NAASRA Roughness Test) and traffic noise was also investigated. At approximately 30 sites the BCHF NAASRA-calibrated roughness vehicle was used to acquire road roughness values. These data are contained in a spreadsheet held by Transit New Zealand (Research & Development Section).

These values were then analysed in a linear regression model. A linear regression using the inbuilt function of the Lotus 1-2-3 spreadsheet (version 2.2) was performed on the residual difference between the New Zealand CRTN formula and the measured noise level, compared to the NAASRA roughness count. Logarithms and polynomials containing the NAASRA roughness count were also analysed. However, no direct relationship could be found (as R^2 ranged from 0.03 to 0.05).

This lack of relationship corresponds with observations made at the roadside. Although changes in frequency of vehicle noise caused by jolting of vehicles over rougher roads may occur, it is generally short duration noise and has little effect on the measured sound levels. There would therefore seem no reason to include road roughness in the noise model.

3.4.4 Differences in Sound Level Meters

The sound level meters that were used employ slightly different sampling methods. The Bruel & Kjeer (B & K) 4426 & 4427 machines sample about 10 times a second and at the end of each hour take the noise level achieved for 10% of the time. The Quest M-28 machine samples 16 times a second and takes the average of these samples every ten seconds. The L_{10} value is then taken as the ten-second average exceeded for 10% of the time. This difference in sampling has been shown to have negligible effect on higher volume roads (ADT > 10,000 veh/d) because of the almost constant noise generated. However, on lower volume roads (ADT < 5,000 veh/d), the difference may become more marked.

A comparative test was carried out between Quest M-28 and Quest 2800 machines. The two machines were placed side by side on the verge of a low volume rural road and the results compared. Both machines recorded the same L_{10} value over the whole of each measurement period but, using the top 10% of ten-second averages on the M-28 for 1 hour of the period, gave results that were some 1.5 dB(A) lower. This led to some doubt as to the accuracy of the M-28 machine so all 18-hour results were analysed using a regression model to predict any difference between the B & K and M-28 machines. No difference was found (R^2=0.06). The log of the volume was then used to emphasise the lower flow sites but again this produced no difference between the machines.

The conclusion is that, at the majority of sites for 18-hour values, the differences in the sampling methods are unimportant. For individual hourly readings, however, the variance may become larger. This is reflected in the increased difficulty in getting the 1 hour sites to within the ±2 dB(A) tolerance. Sites where M-28 18-hour surveys were carried out on low volume roads (e.g. Acacia Bay Road, Taupo, site 131, Appendices 3, 5) still remained well within the ±2 dB(A) tolerance for 18 hours.

3.4.5 Average of 1-Hour Formulae Predictions vs 18-Hour Formulae

The 18-hour L_{10} value could be estimated by predicting in turn each hour's L_{10} and taking the average of these values. This project identified this as an unnecessary process as the 18-hour formula estimates the L_{10} with the desired accuracy for a large variety of traffic characteristics. If the hourly results are averaged over 18 hours it can also be expected that the 18-hour formula will give more realistic (if not very similar) results.

3.5 Limitations to Use of Modified UK CRTN Model

3.5.1 Critical Traffic Flows

As the hourly flow decreases on a particular road, a certain critical flow is reached, below which the model fails to estimate the measured L_{10} accurately for at least two reasons.

First, the L_{10} value relies on the fact that for 10% of the time, a noise level higher than the background level will be achieved. At flow levels of 40 veh/h, this is not the case. Second, at these very low flows, the hourly L_{10} value is vulnerable to high background noise levels as well as to very noisy vehicles. Either of these factors can alter the values significantly between hourly measurements even if there is no change in flow or traffic characteristics.

An analysis of vehicle flows and L_{10} measurements was carried out to theoretically predict the flow level required to produce a critical L_{10} level and the critical hourly flow of around 40 vehicles was determined as follows:

- An assumption made was that each vehicle produced a noise level greater than the background noise for an interval of 10 seconds. This was also the time period over which the M-28 noise level machine integrated individual noise samples. An hour therefore gives 360 ten-second intervals. Taking 10% of this gives 36 intervals. Using the above assumption, 36 intervals would have to contain traffic noise greater than the background noise before traffic either controls or contributes to the L_{10} value.

- Given that some platooning of traffic will occur (more so on roads with grades and limited passing opportunities), more than one vehicle will pass in some 10-second intervals. A platooning factor of 10% was estimated. This platooning factor will vary with the number of passing opportunities on the road section.

- So assuming that, of the 36 vehicles, another four vehicles will be included in the same interval, a likely minimum hourly flow required for traffic noise to dominate is 40 veh/h.

It must be emphasised that this critical hourly flow will vary with background noise levels, the level of platooning, and also that a low traffic flow of 40 veh/h means that the traffic will control the L_{10} level only if background noise levels are insignificant. Thus for hourly model calculations, to ensure that traffic noise does control the L_{10} level, it would be prudent to set the minimum hourly flow at a figure higher than 40 veh/h. To maintain compatibility with the UK CRTN recommendations, a figure of 50 veh/h is recommended.

For likely minimum 18-hour traffic flows, a daily flow profile was built up by assimilating all the daily flow profiles from low volume sites surveyed (volume < 2000 vehicles per day (veh/d)). Using an iterative technique of inserting 18-hour totals into the flow profile, an 18-hour total was obtained that gave hourly flows greater than the 40 veh/h critical value found above. An 18-hour flow of around 1300 vehicles was found to give the critical result. For this reason it is recommended that the modified UK CRTN model is not used to predict traffic noise for roads carrying less than 1300 veh/d.

This is, coincidentally, reinforced by two sites which were surveyed. Sartors Avenue (1323 veh/18 hr, site 3, Appendices 3, 5) could be predicted within the 2 dB(A) tolerance while Oak Tree Avenue (1180 veh/18 hr, site 4, Appendices 3, 5) could not.

The modified UK CRTN model will predict high by an unacceptable margin if flows less than these critical values (50 veh/h; 1300 veh/h) occur.

The UK CRTN (1988) method uses additional correction formulae for roads carrying less than 4000 veh/d. No reason has been found to use these additional formulae for the New Zealand model.

3.5.2 Maximum Heavy Vehicle Ratio

In some cases, because of the nature of the road, the number of heavy vehicles in the traffic stream will be very small. In these cases the difference between one or two trucks can cause large changes in the medium:large heavy vehicle ratio, and a maximum value of 10 has been set for this ratio.

3.5.3 Sand Circle

The sand circle value for any particular chipseal surface will vary with increasing time as the stones become more flush with the bitumen.

If the average texture depth is known but not the sand circle, the following correction formula can be used:

$$S = \sqrt{\frac{57300}{T}}$$

S = Sand circle (mm)
T = Average texture depth

3.5.4 Steep Gradients

To obtain noise level predictions on road sections with gradients greater than 7%, with set back of less than 50 metres, the distance of the noise reception point from the road must be measured as the distance to the closest vehicle track on the uphill side of the carriageway. The noise levels received, say, 5 metres back from traffic on each side of the road will differ significantly, especially on carriageways with greater widths (e.g. median-separated dual carriageways). This effect will decrease as the distance from the road increases.

3.5.5 Prediction of Traffic Noise from Dual Carriageways

Dual carriageways separated by a median of at least 5 metres width will have two separate noise source distances. Where the required set back distance is less than 50 metres, a separate prediction should be done for each carriageway and then combined. The effective source distance should be taken as the distance to the nearest trafficked area on the far carriageway. Where the far carriageway is separated by a solid median barrier, then a low wall correction should be made for the traffic noise prediction for that carriageway.

Note that a logarithmic addition should be performed as written below:

$$L_{10_{(1,2,\ldots n)}} = 10 \times Log\,(10^{\frac{L_{10_{(1)}}}{10}} + 10^{\frac{L_{10_{(2)}}}{10}} + \ldots\ldots + 10^{\frac{L_{10_{(n)}}}{10}})$$

4. FURTHER SURVEY ANALYSIS

4.1 Multiple Day Surveys

At two sites (No. 113, 114, Appendices 3, 5) in the Wellington area, noise measurements were continued over several days. Tables 2 and 3 show the results of these surveys.

Table 2. Noise measurements at Paekakariki site (No. 113) for four days.

Traffic Volume (18 hour)	Calculated L_{10} dB(A)	Measured L_{10} dB(A)
19 338 vehicles	75.7	76.0
17 306 vehicles	75.2	74.5
16 666 vehicles	75.1	73.7
21 042 vehicles	76.1	74.0

Table 3. Noise measurements at Papakowhai site (No. 114) for seven days.

Traffic Volume (18 Hour)	Calculated L_{10} dB(A)	Measured L_{10} dB(A)
23 000 vehicles	67.0	66.4
24 200 vehicles	67.2	65.9
24 300 vehicles	67.3	65.4
24 800 vehicles	67.3	64.9
24 800 vehicles	67.3	67.0
25 800 vehicles	67.5	66.0
25 100 vehicles	67.4	67.8

In general the calculated values and the measured values remain close. This stability is expected as the two sites had fairly high 18-hour flows. The lower the flow the more unstable the readings could be expected because of the increased effect of the odd noisy vehicle and for reasons described in Section 3.5.1.

While small fluctuations were recorded between most daily L_{10} readings, on several days the noise level differed significantly at one site (i.e. 2nd, 3rd and 4th day at Papakowhai). These significant fluctuations coincided with changed weather patterns on those days and indicates the effects of wind disturbance on observed traffic noise when measured 100 metres from the source.

4.2 Ground Cover Correction

The UK CRTN model contains a formula for calculating the effects of ground cover on the observed noise levels that are set back more than 4m from the traffic stream. However, the ground cover correction formula was used only a few times in the course of the survey programme because at most sites ground cover was reflective. The ground cover effect was found to be more relevant where noise levels are to be estimated at a point relatively remote from the roadside (say >30m).

An idea of the ground cover effects over a variety of ground cover conditions was obtained, in particular, from surveys done beside the Auckland Northern Motorway (site 141), Hobsonville Road (site 145) in West Auckland, and the Wellington Motorway near Porirua (site 113).

These surveys used two identical synchronised noise level meters recording simultaneously at different distances from the road. An exception to this arrangement was the survey carried out on a grassed area beside the Auckland Northern motorway just south of the Northcote Road interchange. At this site the traffic noise level was constant enough to require only one meter that was positioned at various distances from the carriageway. Data from these surveys are held by Transit New Zealand (R&D Section).

By analysing the difference in noise propagation that occurred over various distances and various ground conditions, the effects of ground cover could be estimated.

The CRTN (DOT 1988) model differs from the earlier 1975 UK Department of Environment model in that it now contains factors for areas where only part of the ground cover from the carriageway to the observation point is absorbent.

The current research showed that, in most cases where a grassed area was between the carriageway and the reception point, the ground correction in the 1975 formula overestimated the attenuation effect. Therefore Table 20.4 in the 1988 CRTN report should be followed.

The moisture content of the ground between the road and the reception point had a marked effect on the attenuation effect. Whereas hard dry ground with mown grass has basically no attenuation effect, this same ground when water-saturated may have an attenuation effect closer to the CRTN ground cover correction.

In conclusion, during the long dry periods (summer: November-March) which occur in New Zealand's climate, the CRTN ground cover correction factor would seem to overestimate the ground attenuation effect, while in the wet periods (winter: May-September) it would seem to more accurately estimate the attenuation.

Surveys over several days at the same site in both dry and saturated ground conditions would be advantageous to better quantify these seasonal effects.

4.3 Facade Reflection

The UK CRTN Model refers to facade reflection both from a point behind the reception point, and from the opposite side of the road.

4.3.1 Facade Effect - Behind Reception Point

The CRTN model recommends a correction of +2.5 dB(A) for the calculation of noise at one metre from a facade. Measurements made in front of typical New Zealand house facades confirm that this correction factor is applicable.

Surveys were carried out in Dominion Road and Vincent Street (Auckland) where measurements were taken in front of the building facade. (These data are held by Transit New Zealand, R&D Section.) Allowing for the accuracy and sampling method of the meter used, and for other possible minor effects, the facade effect was estimated as being close to 2.5 dB(A).

A standard +2.5 dB(A) correction is recommended to account for facade effects. This is in line with the CRTN report recommendations.

4.3.2 Facade Effect - Reflection from Opposite Side of Roadway

Many of the sites that were surveyed in this project were in predominantly urban areas where house or building facades were present but set well off the road. Evidence did not suggest that in these cases reflections from facades on the opposite side of the road had any effect on the level of noise received at the reception point.

5. CONCLUSIONS

This survey has produced a modified CRTN noise prediction formula for the 18-hour L_{10} noise level. These modifications ensure that the noise level estimate is within $\pm$ 2dB(A) of the actual figure for at least 95% of the time.

The 18-hour formula predicts with sufficient accuracy to render the 1-hour formula to a secondary role. The 1-hour L_{10} value can be obtained from the 18-hour modified CRTN formula by adding 13 dB(A). The L_{10} level of traffic noise may vary over different hours of identical traffic flow characteristics because of individual noisy vehicles. The 1-hour formula may provide a prediction of the theoretical or expected L_{10} level although this may not agree with individual field observations. For this reason, the 18-hour model should be preferred as a more accurate description of traffic noise level characteristics.

6. REFERENCES

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APPENDICES

APPENDIX 1. GUIDE TO PREDICTING TRAFFIC NOISE FROM UNINTERRUPTED TRAFFIC FLOWS

A1.1 Introduction

Traffic noise can be a significant factor when planning future development. Tyre noise, engine noise and other vehicle noises combine to create noise levels which can now be estimated using the UK CRTN model for uninterrupted traffic flows, and modified for New Zealand conditions. This model is applicable to free-flowing traffic situations only. Where vehicles are decelerating or accelerating near an intersection, then an interrupted flow noise prediction model should be used.

A1.2 UK CRTN Variables

The modified UK CRTN model uses the following variables:

Q 18-Hr Traffic Volume: Traffic volume for the section of road between the hours of 6am to midnight (in number of vehicles).

D Distance: Distance from the reception point of noise to the nearest trafficked part of the carriageway. (Distance for roads with wide shoulders not used by traffic includes the width of the effective shoulder. On steep gradients (>7%), distance should be the distance to the nearest uphill vehicle track in the case that the downhill vehicle track is closer.)

G Gradient: Average longitudinal road gradient of the section of road. (Where the road gradient oscillates at the section in question, an average value of the absolute gradient of the section is acceptable to use in the model. For example, for a brow of a hill with +1% and -1% grade, a G value of 1 would be entered into the formula.)

A Angle of View: Value (in degrees) of the angle of view of the section of roadway. (The angle of view takes into account noise barriers such as buildings, walls, and other obstructions. A clear view of the roadway would have an angle of view of 180 degrees.)

H Average Height of Propagation: Average height (m) of propagation between the reception point of noise and the effective source position of noise above the intervening ground. (The effective source position is assumed to be 0.5m above the carriageway.)

h Height: Relative height (m) between the reception point of noise and the carriageway.

V Average Speed: Average speed (km/h) of vehicle traffic over the road section being surveyed. (Note that this is not necessarily the posted speed.)

F Ground Cover: A variable between 0 and 1 which accounts for attenuation effects caused by non-reflective ground cover. (Consult Table 20.4 in the DOT 1988 CRTN report.)

S Sand Circle: Diameter (mm) of the sand circle obtained using the standard test procedure for measurement of texture by the Sand Circle test (TNZ T/3 1981) (see Appendix 4). (Method used for chipseals only. Where possible these tests should be carried out. Several tests should be done, each on a separate representative portion of seal. If testing is impractical then estimates can be made using Table A1.1. The value of the sand circle will change with age of the chipseal pavement as the stones become more flush with the seal.)

Table A1.1. Estimate of sand circle readings for chipseals.

Description of Chipseal	**Sand Circle Range (mm)**	**Value for Formulae (mm)**
Coarse chip, no sign of flushing	110 - 130	120
Medium chip, no sign of flushing	130 - 200	165
Fine chip, no sign of flushing	200 - 250	225
Chips close to being flush with bitumen	250 - 290	270
Bitumen covers chips, unsatisfactory pavement	290 ->	300

P Percentage Heavy Vehicles: Percentage of heavy vehicles in the traffic stream. (A heavy vehicle is defined as any vehicle with dual rear tyres or super-singles and includes buses.)

r Ratio of Medium to Large Heavy Vehicles: Ratio obtained from the number of medium heavy vehicles divided by the number of large heavy vehicles.

A medium heavy vehicle is defined in this case as any vehicle with dual rear tyres or super-singles and a total of no more than two axles. A large heavy vehicle can be defined as any vehicle with dual rear tyres or super-singles and more than two axles. Where surveys can not be practically carried out, Table A1.2 can be referred to for an estimate. For situations where the **r** ratio is greater than 10, the value 10 should be entered into the formula.

Table A1.2. Estimate of medium : large heavy vehicle ratio.

Description of Road Environment	**Estimated Ratio, r**
Urban (Suburban)	8
Urban (Industrial)	1.5
Urban (Arterial)	3
Urban (Limited Access)	2
Rural (General)	1.5
Rural (Trunk)	0.5

C Chipseal noise constant: Constant: equals 1 if the pavement is a chipseal; equals 0 if pavement is other than a chipseal.

X Friction course noise constant: Constant: equals 1 if the pavement is a friction course; equals 0 if pavement is other than friction course.

Both **C** and **X** equal 0 if pavement is asphaltic concrete.

A1.3 Limitations of Model

The critical traffic flow required to control the L_{10} noise level will vary with the level of platooning and will also depend on whether the background noise levels are significant. The modified model should be used only for roads carrying at least 1,300 vehicles per day or, for an hourly L_{10} prediction, 50 vehicles should pass in the hour.

A1.4 Modified UK CRTN Formulae

$$L_{10}(18\text{ Hr})\text{ Noise Level, dB(A)} =$$

$$26.5 + 10\,Log(Q) + 33\,Log\left(V + 40 + (\frac{500}{V})\right) + 10\,Log\left(1 + \frac{5P}{V}\right) - 68.8 + 0.3G$$

$$+ 10\,Log\left(\frac{A}{180}\right) - 10\,Log\left(\frac{\sqrt{((D+3.5)^2+(h-0.5)^2)}}{13.5}\right) + F \times 5.2\,Log\left(\frac{6H-1.5}{D+3.5}\right)$$

$$+1.65\ Log\ \frac{P}{r}\ +\ 5.57 \times C\left(\ 0.77 - Log\ \frac{S}{V}\right)\ -\ 3.4 \times X$$

This equation only applies for:

$$0.75 \leq H < \frac{d+5}{6}$$

If the following conditions apply, replace the ground cover correction term with the appropriate term:

for $H < 0.75$ *use*: $F \times 5.2 \times Log\left(\frac{3}{d+3.5}\right)$

for $H \geq \frac{d+5}{6}$ *use*: 0

A correction of +2.5 dB(A) should be used if a point 1m in front of a facade is being considered.

The model estimates L_{10}(18 Hr) values to an expected accuracy of ±2 dB(A). In most cases when accurate variables are used then the accuracy could be expected to be better than this.

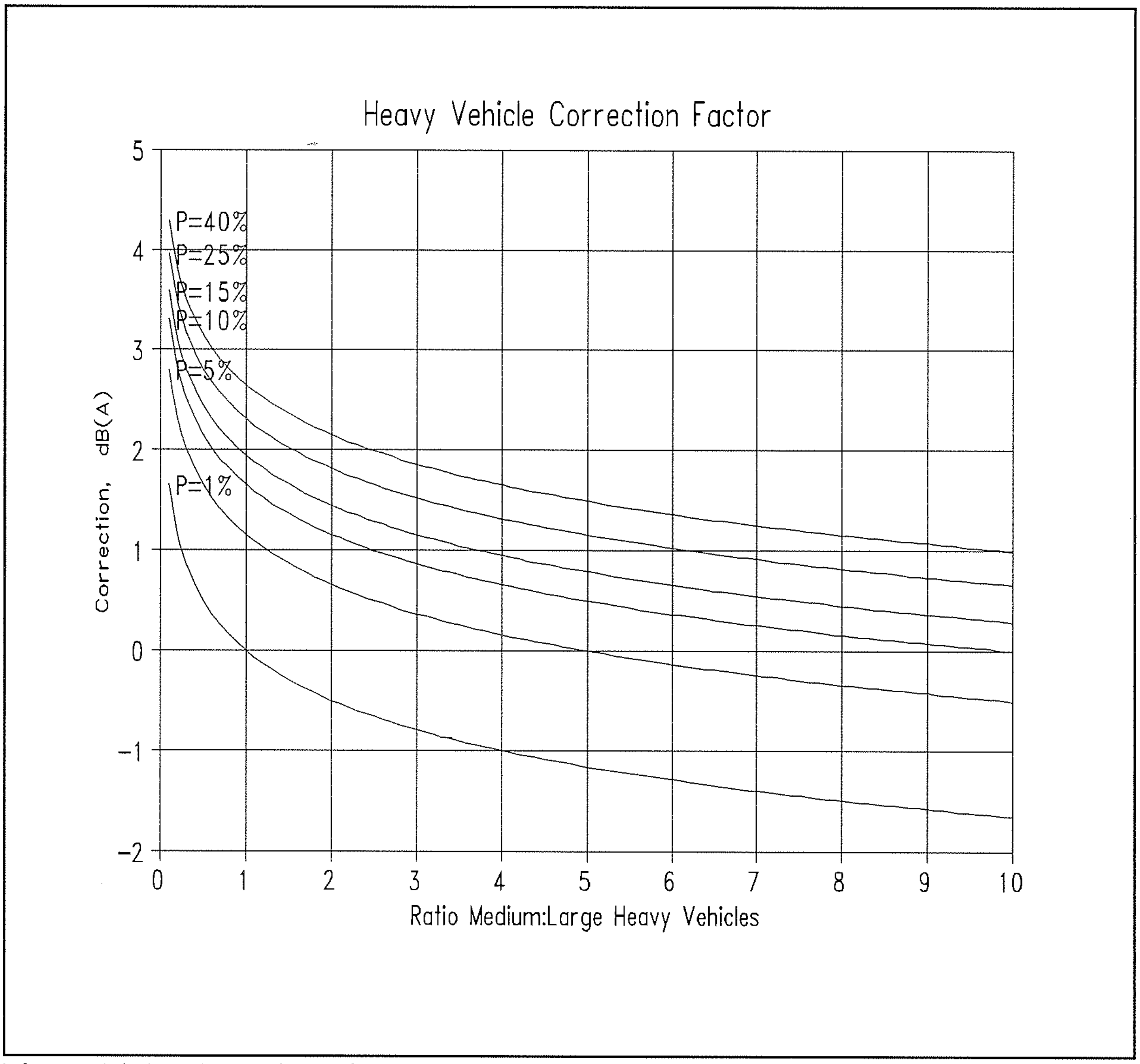


Figure A1.1. Corrections for ratios of medium to large heavy vehicles for six given percentages (P) of heavy vehicles.

$(= +1.65 \text{ Log } (^{P}/_{r}))$

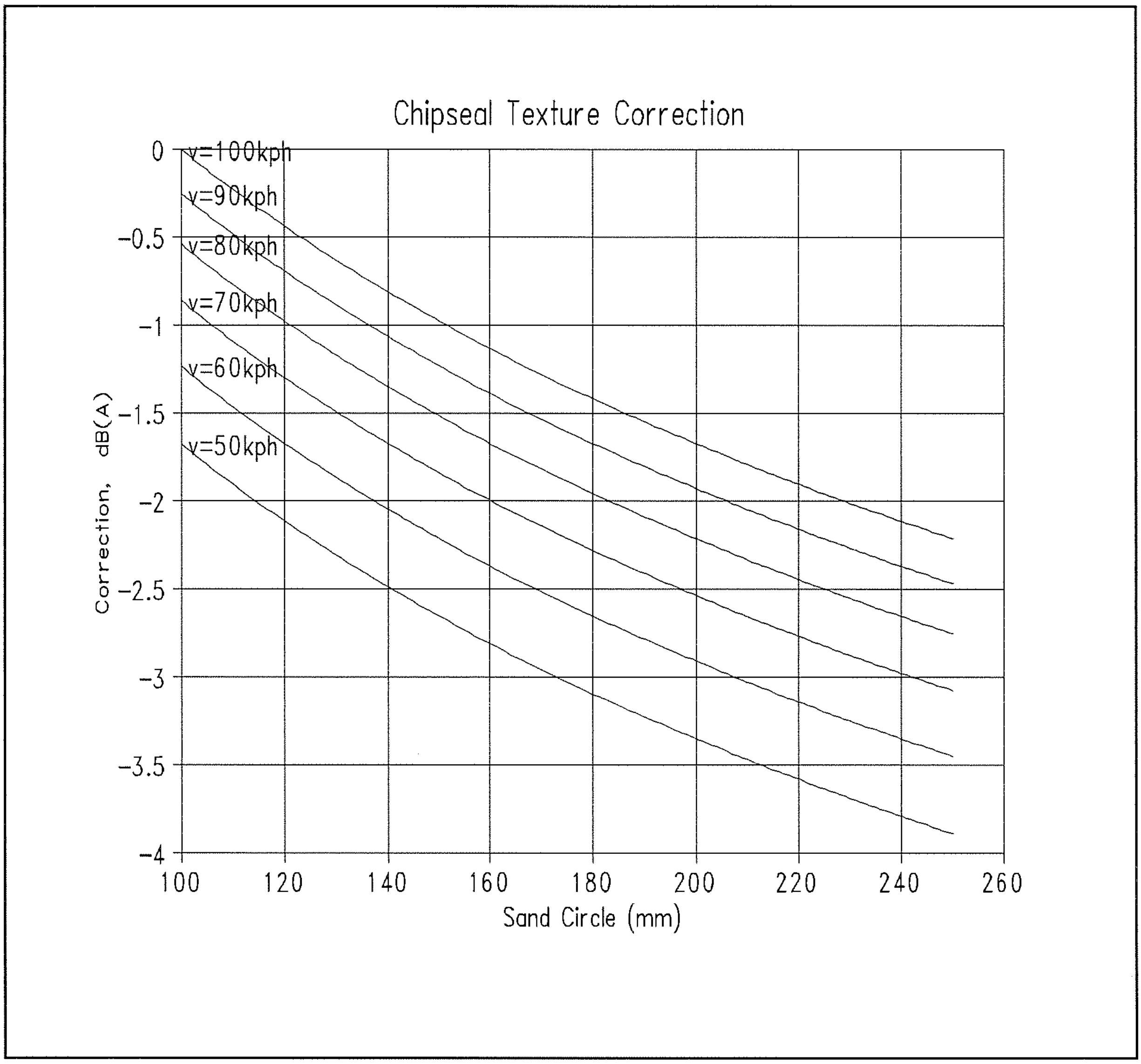


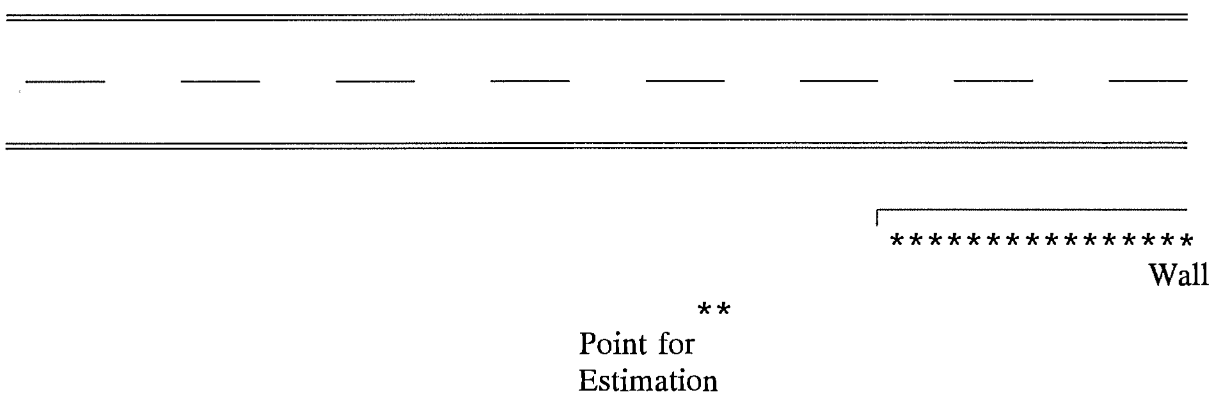
Figure A1.2. Corrections for sand circle readings (mm) for six given average speeds (v = km/h).

(= -5.57 Log ($^{S}/_{V}$))

A1.5 Example Problem

A road section carries **9000** veh/18 Hr. It has a constant gradient of **8.5%** and a **chipseal** pavement. The speed limit is posted at 50km/h but the average speed of traffic was measured at **53 km/h. 8%** of the traffic flow are heavy vehicles and the ratio is 10 to 1 **(=10)** for medium to large heavy vehicles. The average sand circle reading of the seal is **150mm.** The L_{10}(18 Hr) level is to be estimated at a point **19m back from the nearest vehicle track.** At this point, the view of the road is estimated to only be **150 degrees** as a wall obscures view down the road to the right. The ground surface is level between the point where the estimation is to be made and the road, so a default value of **1.2m** is used for the height variables.

Figure of road section:



Values of variables:
Calculations:

Q= 9000 veh
D= 19 m
G= 8.5 %
A= 150 degrees
H= 1.2 m
h= 1.2 m
V= 53 km/h
F= 0 (no ground cover effect)
S= 150 mm
P= 8 %
r= 10 (10:1)
C= 1
X= 0

Erratum: page substituted, May 1994

Inserting the variables into the modified UK CRTN formula gives:

$L_{10}(18\,Hour),\ dB(A)\ =$

$$26.5+10\,Log(9000)+33\,Log\left(53+40+(\frac{500}{53})\right)+10\,Log\left(1+\frac{5\times8}{53}\right)-68.8+0.3\times8.5$$

$$+10\,Log\left(\frac{150}{180}\right)-10\,Log\left(\frac{\sqrt{((19+3.5)^2+(1.2-0.5)^2)}}{13.5}\right)+\ 0\times5.2\,Log\left(\frac{6\times1.2-1.5}{19+3.5}\right)$$

$$+1.65\ Log\left(\frac{8}{10}\right)+5.57\times1\times\left(0.77-Log\left(\frac{150}{53}\right)\right)-0$$

$$=\quad 26.5+39.54+33\,Log(102.43)+10\,Log(1.75)-68.8+2.55$$

$$+(-0.79)-10\,Log\left(\frac{\sqrt{(506.74)}}{13.5}\right)+0-0.16+5.57\times0.32-0$$

$$=\quad 26.5+39.54+66.4+2.43-68.8+2.55$$

$$-0.79-2.22-0.16+1.78$$

$$=\quad 67.2\ dB(A)\ \ (67\ dB(A))$$

APPENDIX 2. SPREAD OF SURVEY SITES OVER RANGES OF TRAFFIC AND CARRIAGEWAY CHARACTERISTICS

(listed on p.13)

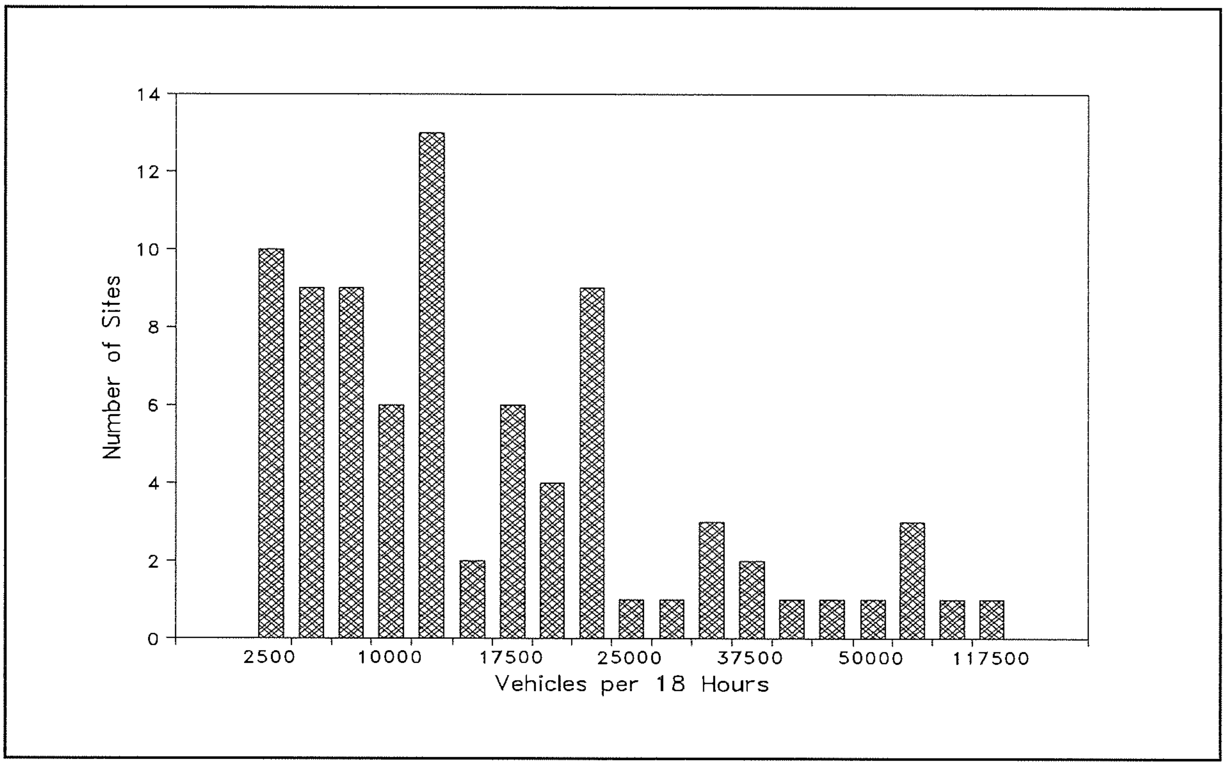


Figure A2.1. Traffic volume over 0600 - 2400 hours (per 18 hours).

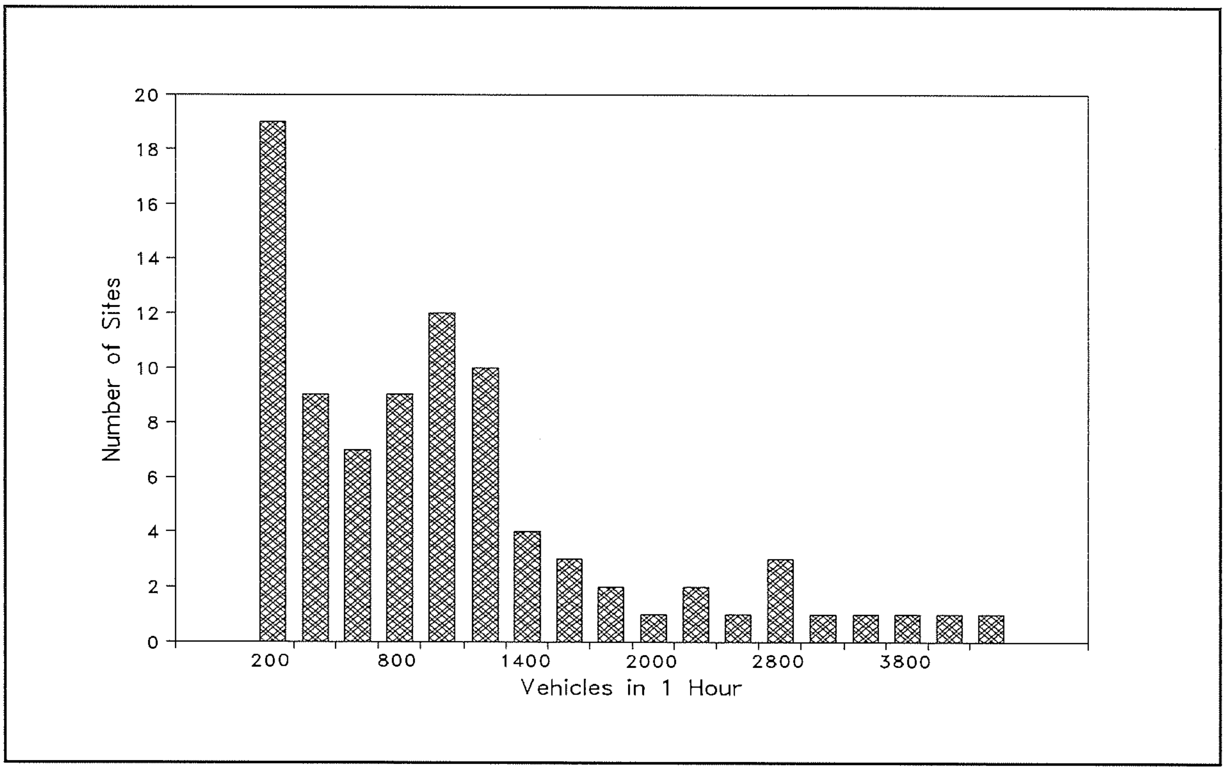


Figure A2.2. Traffic volumes of 1 hour surveys.

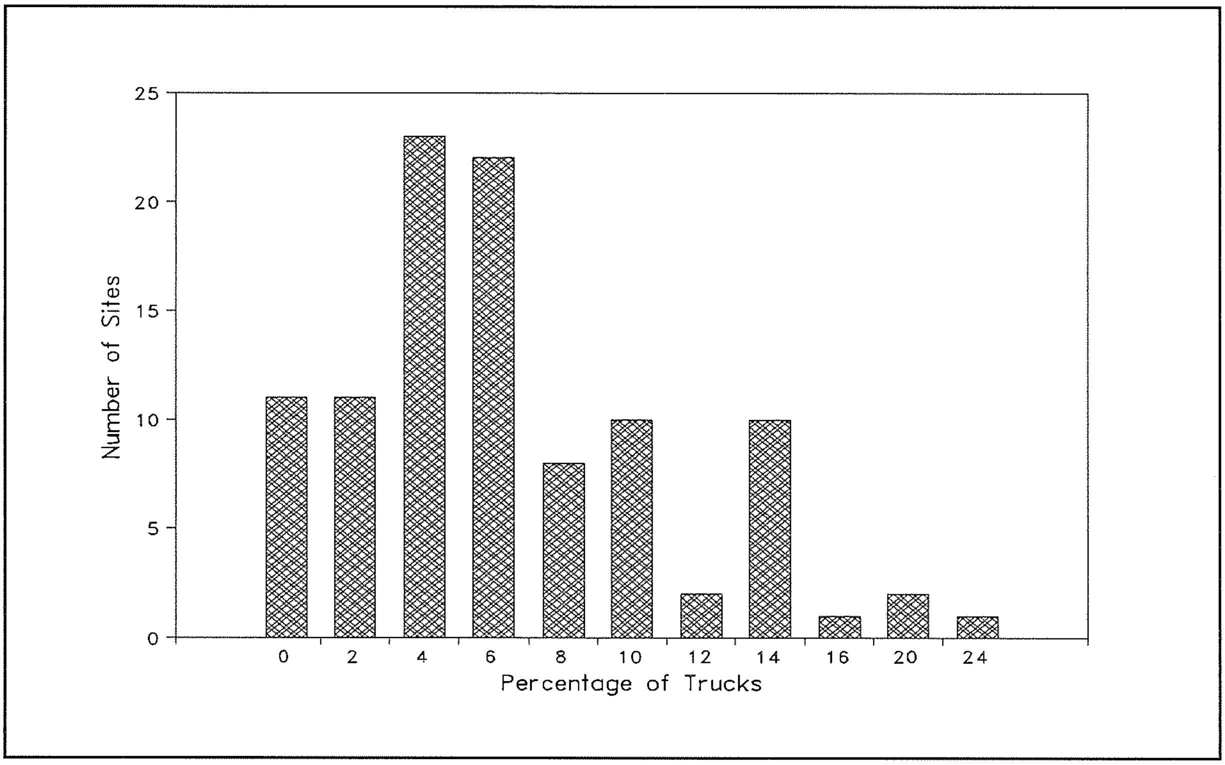


Figure A2.3. Proportion of heavy vehicles (over 18 hours).

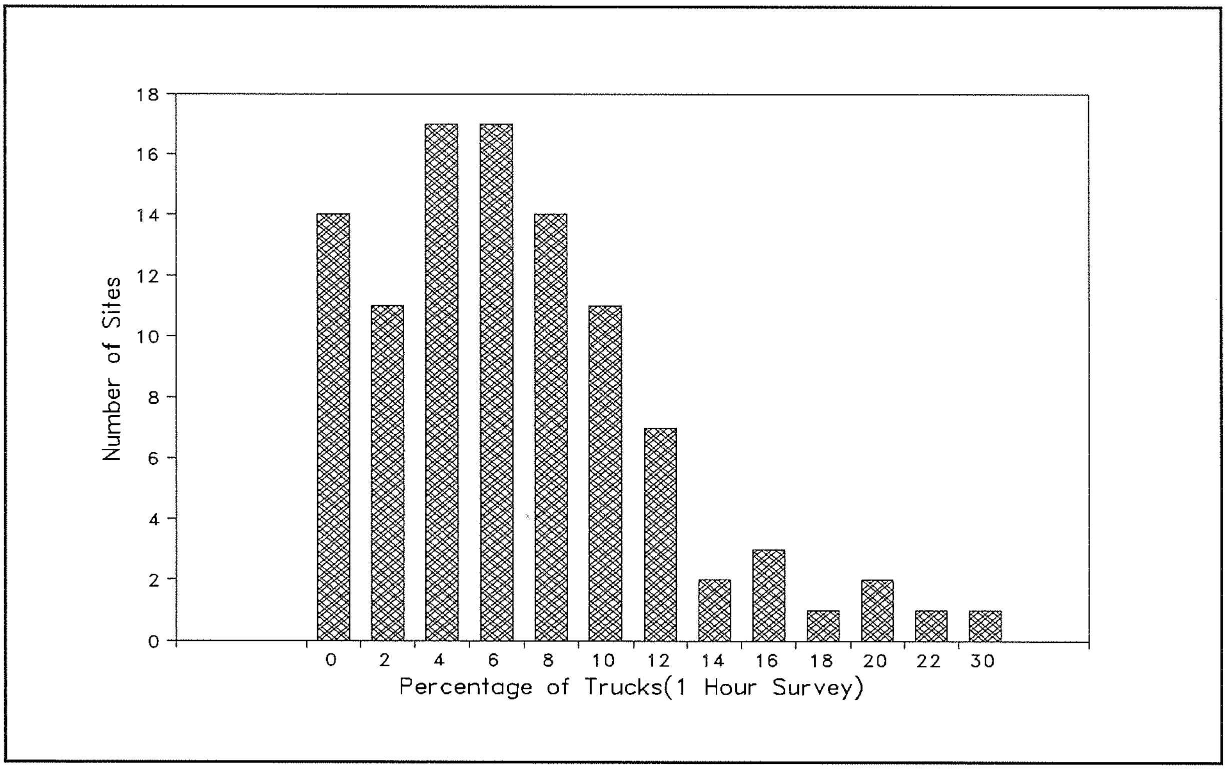


Figure A2.4. Proportion of heavy vehicles (over 1 hour).

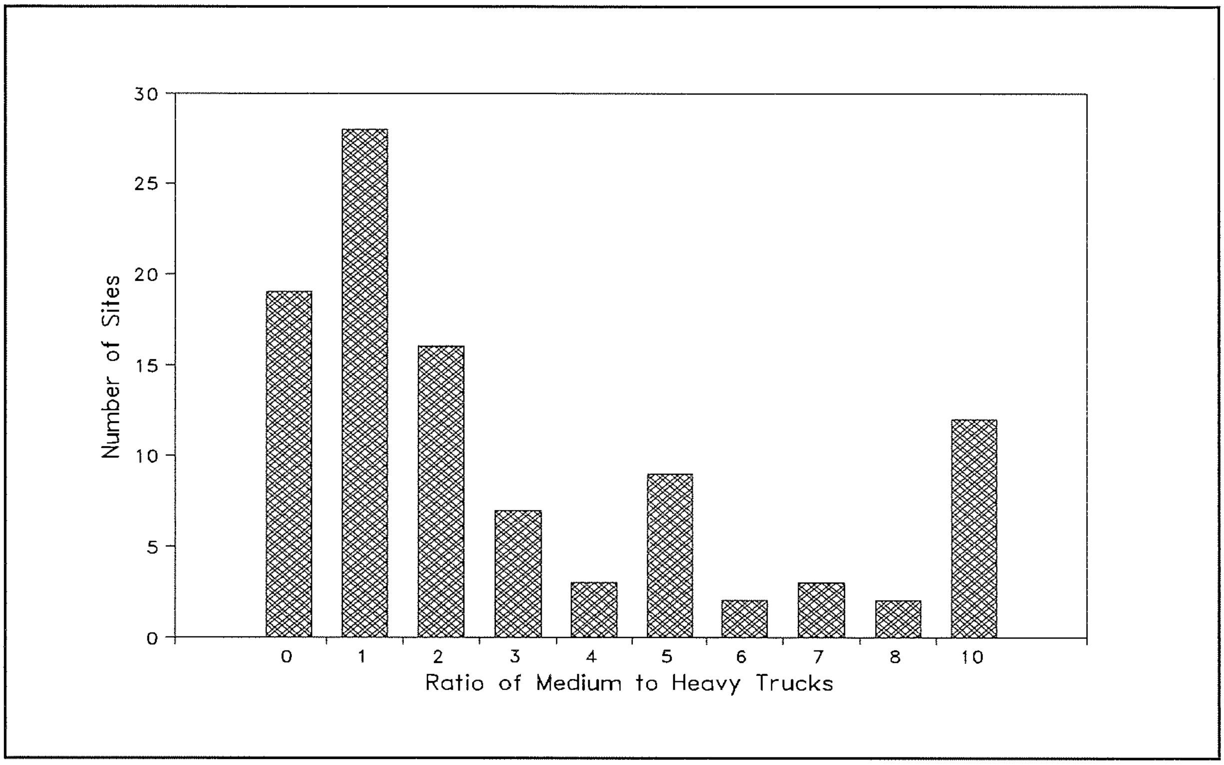


Figure A2.5. Ratio medium:large heavy vehicles (over 18 hours).

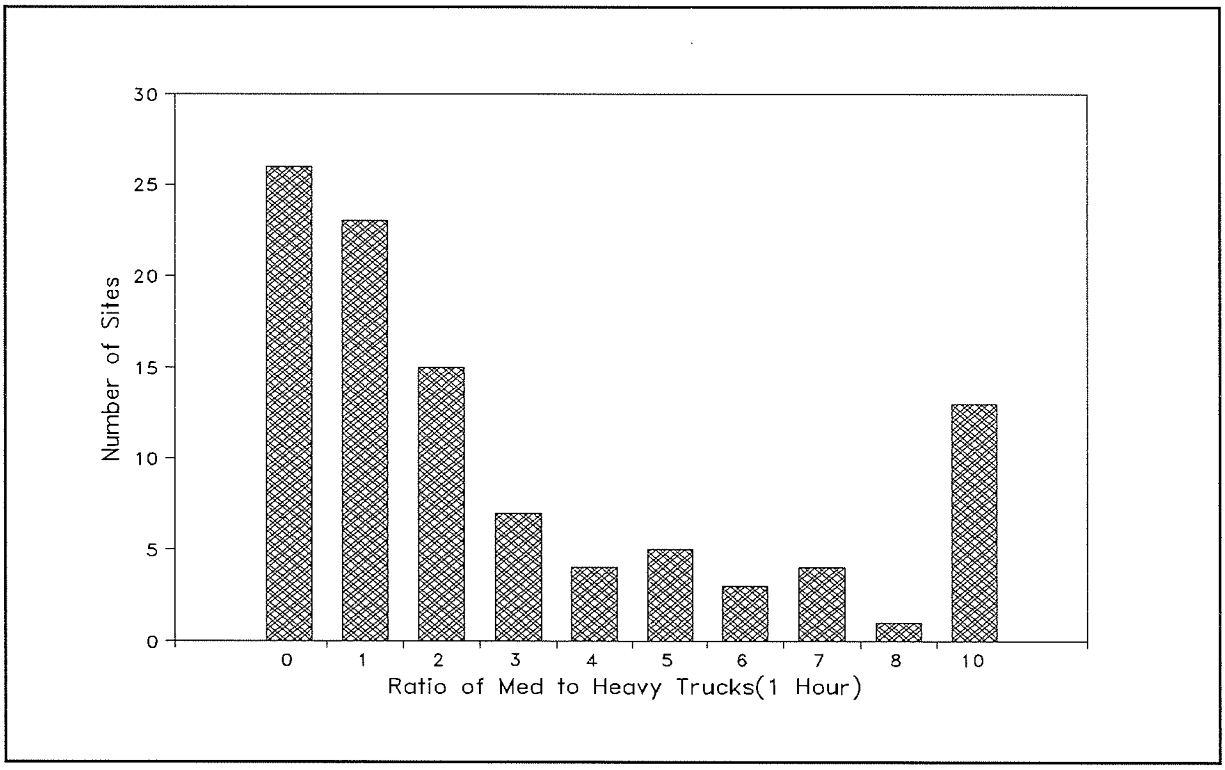


Figure A2.6. Ratio medium:large heavy vehicles (over 1 hour).

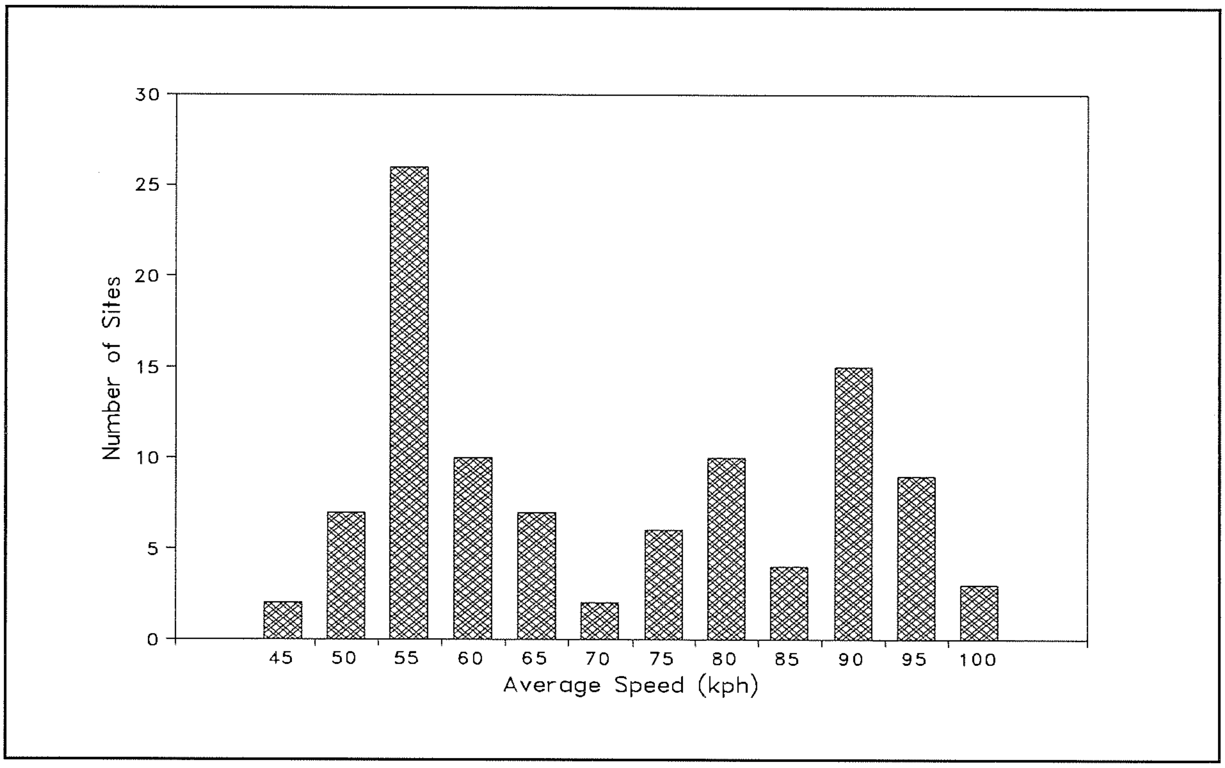


Figure A2.7. Average vehicle speed at each survey site.

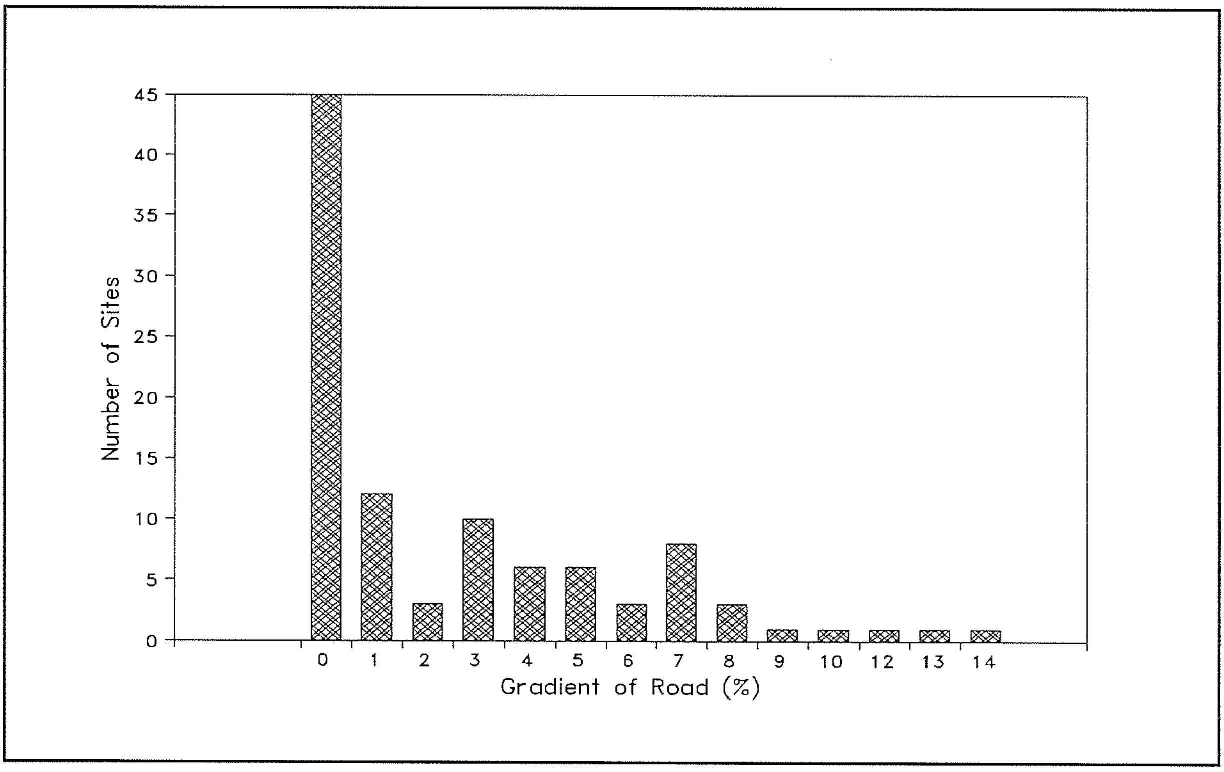


Figure A2.8. Roadway gradient at each survey site.

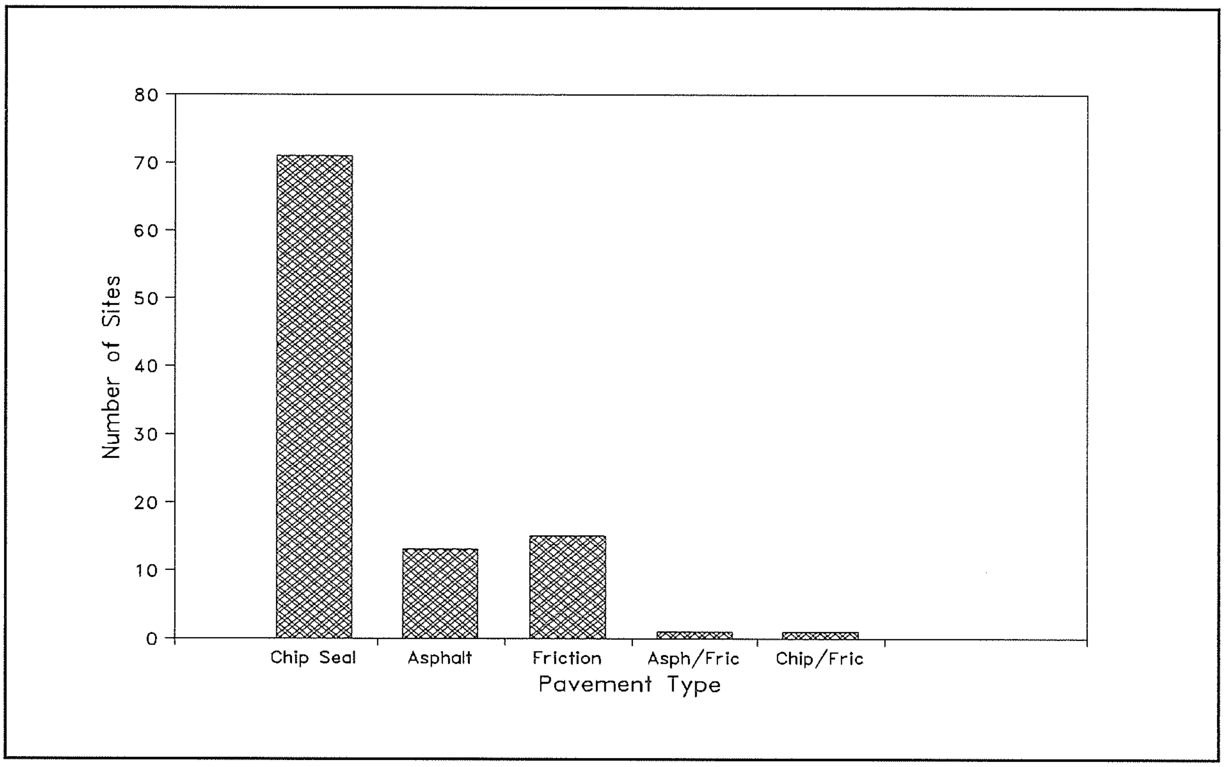


Figure A2.9. Road pavement surface type at each survey site.

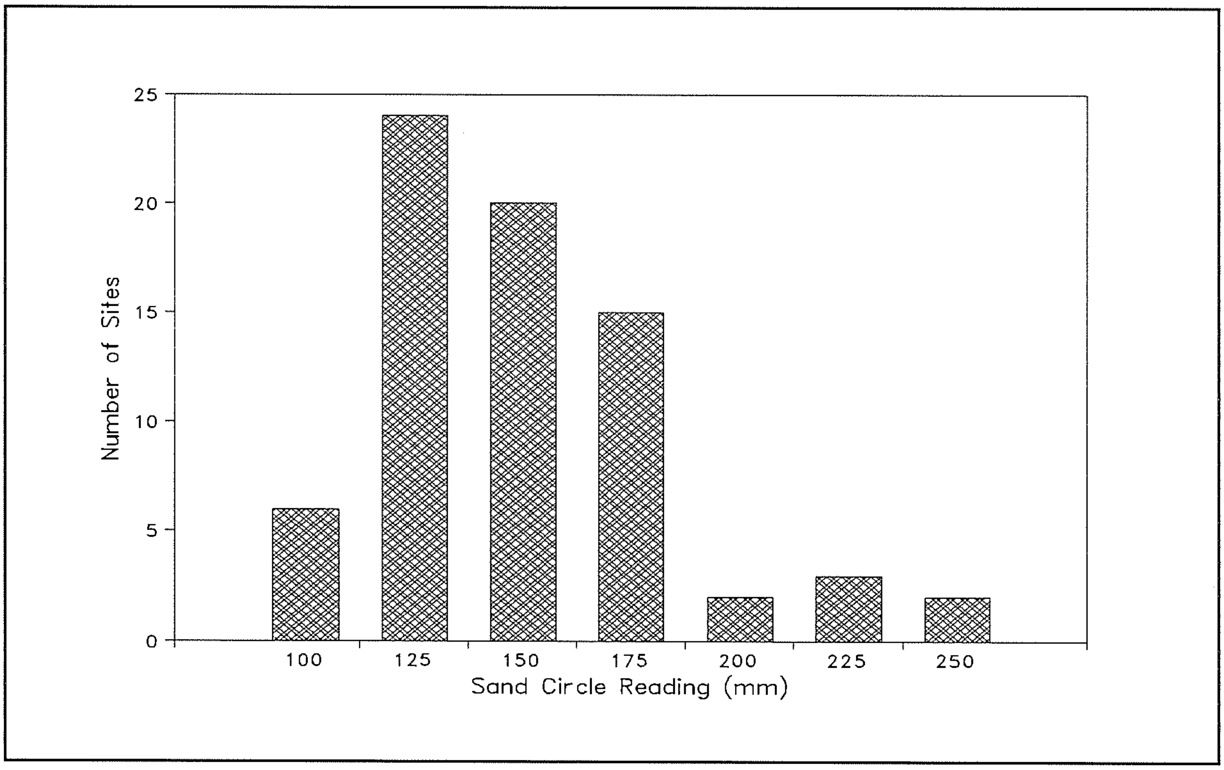


Figure A2.10. Chipseal texture at each survey site.

APPENDIX 3. DATA OBTAINED AT 18-HOUR AND 1-HOUR CHIPSEAL AND ASPHALT/FRICTION COURSE SITES

18 Hour Chipseal Sites

Site Name	Site No.	NZ Region	Machine Type	Date	Road Surface	Sand Circle (mm)	Aver. Speed (kph)	Road Gradient (%)	Percent Heavy (%)	Ratio Med: Large	Angle view (deg)	Set Back (m)	Mic. Height (m)	Ground Cover	Volume [18hr] (vehs)	Predicted L10 CRTN Model [18h] dB(A)	Measured L10 [18h] dB(A)	NZ Model [18h] dB(A)	Diff NZ v Meas dB(A)	Site Status
SH1 Albany South	1	A	B & K	22/1/90	Chip Seal	150	81	1.7	7.8	2.0	180	14.0	3.5	0	15,805	72.8	72.7	73.9	-1.2	Ok
Bush Road (WEPB)	2	A	B & K	22/1/90	Chip Seal	135	67	0.0	14.7	3.0	180	12.0	1.2	1.0	3,757	64.3	63.2	65.5	-2.3	No Good
East Coast Road	5	A	B & K	01/3/90	Chip Seal	165	65	1.7	2.5	1.9	180	17.0	1.2	+	24,000	64.5	63.6	64.1	-0.5	Ok
Beach Road	6	A	B & K	07/3/90	Chip Seal	190	52	6.1	2.7	5.8	180	9.0	1.2	0.5	14,043	70.3	68.4	68.2	0.2	Ok
SH18 Coatesville	7	A	B & K	06/3/90	Chip Seal	200	69	0.9	1.1	1.3	100	25.0	1.2	0	3,328	58.5	58.3	57.4	0.9	Ok
Oteha Valley Road	8	A	B & K	13/3/90	Chip Seal	265	77	3.5	2.6	8.8	180	4.0	1.2	0	5,378	70.9	71.2	68.7	2.5	No Good
Deep Creek Road	9	A	B & K	01/3/90	Chip Seal	120	57	14.9	1.9	10.0	180	7.0	1.2	0	5,872	71.0	69.9	69.7	0.2	Ok
Upper Harbour Drive	10	A	B & K	25/1/90	Chip Seal	210	78	7.9	2.0	3.0	135	7.0	1.2	1	13,947	72.2	71.2	71.2	0.0	Ok
Albany Hill	12	A	B & K	01/6/90	Chip Seal	140	83	7.0	6.5	1.2	180	13.0	1.2	1	18,713	72.9	74.2	74.6	-0.4	Ok
Vincent Street	14	A	B & K	26/1/90	Chip Seal	150	53	8.7	8.0	10.0	140	19.0	1.2	0	8,952	67.9	65.7	66.9	-1.2	Ok
O'Rorke Road	16	A	B & K	06/3/90	Chip Seal	145	58	1.7	16.9	1.5	180	9.0	1.2	0	10,307	72.1	71.7	73.3	-1.6	Ok
Church Street	17	A	B & K	26/1/90	Chip Seal	160	55	0.0	10.8	2.9	180	21.0	1.2	1	14,039	65.4	65.3	65.5	-0.2	Ok
Neilson Street	19	A	B & K	07/3/90	Chip Seal	160	55	0.9	24.0	1.5	180	16.0	1.2	0	13,070	71.7	71.2	72.9	-1.7	Ok
Mt Albert Road	20	A	B & K	03/3/90	Chip Seal	180	59	0.0	4.0	2.5	180	8.0	1.2	+	23,500	68.0	68.9	67.3	1.6	Ok
Southern M'way Ramarama	24	A	B & K	15/3/90	Chip Seal	115	103	0.9	13.0	0.4	180	Dual	1.2	0	16,740	69.6	74.7	73.6	1.1	Ok
Haywards Hill	102	W	M-28	03/3/90	Chip Seal	155	70	8.7	7.0	2.4	150	6.5	1.2	0	8,046	72.5	71.9	73.0	-1.1	Ok
Judgeford	103	W	M-28	05/2/90	Chip Seal	225	88	1.7	7.0	2.4	180	12.5	1.2	1	7,776	68.3	68.8	68.4	0.4	Ok
Titahi Bay	104	W	M-28	05/2/90	Chip Seal	190	65	0.0	2.5	4.4	180	16.5	1.2	0	13,356	68.3	68.0	67.0	1.0	Ok
Wainuiomata	109	W	M-28	12/2/90	Chip Seal	250	60	0.0	3.0	7.3	180	6.0	1.2	0	21,500	73.3	72.0	70.8	1.2	Ok
Khandallah	110	W	M-28	11/4/90	Chip Seal	160	58	5.2	0.3	10.0	180	5.5	1.2	0	11,178	71.1	68.5	67.7	0.8	Ok
Wilton	111	W	M-28	15/2/90	Chip Seal	125	54	7.9	0.9	6.0	180	4.0	1.2	0	5,771	69.6	68.5	67.8	0.7	Ok
Moorefield	112	W	M-28	13/3/90	Chip Seal	125	59	7.0	1.0	10.0	180	9.0	2.0	0	11,221	70.6	69.8	68.7	1.1	Ok
Papakowhai	113	W	M-28	21/2/90	Chip Seal	140	93	0.0	6.0	1.5	130	105.0	1.2	0	23,000	65.3	65.9	67.0	-1.1	Ok
Paekakariki	114	W	M-28	16/2/90	Chip Seal	160	84	0.0	5.0	1.5	180	8.0	1.2	0	19,254	74.7	74.6	75.7	-1.1	Ok
Maungaiti Hill	201	C	M-28	16/2/90	Chip Seal	180	80	3.5	14.0	0.5	180	5.5	3.0	0	4,491	71.5	73.3	73.7	-0.4	Ok
Atiamuri South	202	C	M-28	19/2/90	Chip Seal	125	103	0.0	15.0	0.5	180	15.0	1.2	0	2,319	66.6	68.6	70.3	-1.7	Ok
Wairakei	203	C	M-28	20/2/90	Chip Seal	185	93	3.5	11.0	0.5	180	15.0	2.0	1	5,450	68.7	71.3	71.0	0.3	Ok
Tahorakuri Forest	204	C	M-28	21/2/90	Chip Seal	135	104	0.0	6.5	0.7	180	5.5	1.2	0	1,538	66.8	71.1	69.5	1.6	Ok
Waitoka	206	C	M-28	23/2/90	Chip Seal	160	96	0.0	10.2	1.0	180	8.0	1.2	0	3,059	68.6	72.3	70.8	1.5	Ok
Napier Highway	207	C	M-28	27/2/90	Chip Seal	140	98	1.7	20.0	0.2	180	5.5	3.0	0	1,927	69.4	73.1	73.9	-0.8	Ok
Hallets Bay	208	C	M-28	27/2/90	Chip Seal	150	91	1.7	15.0	0.9	180	5.5	1.2	0	2,682	69.9	73.7	72.4	1.3	Ok
Hinemaia Hill	209	C	M-28	27/2/90	Chip Seal	135	90	8.0	15.0	1.0	180	5.5	1.2	0	2,682	71.7	74.7	74.4	0.3	Ok
Putaruru South	210	C	M-28	28/2/90	Chip Seal	145	93	0.9	14.0	0.6	180	10.0	1.2	0	6,494	71.8	72.2	74.7	-2.5	No Good
Karapiro	211	C	M-28	28/2/90	Chip Seal	115	94	1.7	14.0	1.0	180	5.5	1.2	0	8,471	75.0	78.2	78.1	0.1	Ok
Ngongotaha	212	C	M-28	28/2/90	Chip Seal	190	90	3.5	14.4	0.7	180	10.0	1.2	0	3,382	69.5	70.2	71.6	-1.4	Ok
Ngaio Gorge	122	W	M-28	18/2/91	Chip Seal	190	48	7.0	5.0	10.0	180	2.5	1.2	0	9,710	73.4	70.6	71.2	-0.6	Ok
Ruahine Road (Victoria Tunnel)	125	W	M-28	20/2/91	Chip Seal	135	60	5.2	3.5	10.0	180	2.5	1.2	0	24,341	77.5	77.5	76.4	1.1	Ok
Acacia Bay Road	131	C	M-28	23/2/91	Chip Seal	135	83	0.9	1.0	1.0	180	6.5	1.2	0	2,757	66.2	68.6	66.7	1.9	Ok
Spa Road	132	C	M-28	23/2/91	Chip Seal	180	50	5.2	1.5	3.0	180	9.5	1.2	0	6,250	66.6	64.8	64.6	0.2	Ok
Lake Terrace	133	C	M-28	24/2/91	Chip Seal	180	56	0.0	7.5	0.5	180	9.0	1.2	1.0	13,200	69.0	68.7	69.8	-1.1	Ok
Northern M'way: Northcote Road	141	A	M-28	18/3/91	Chip Seal	150	90	3.5	7.0	2.2	180	Dual	1.2	0	62,250	81.6	81.3	82.9	-1.6	Ok
Pakuranga Highway	148	A	M-28	08/4/91	Chip Seal	180	64	4.4	4.0	4.0	180	6.0	1.2	0	41,000	78.0	77.1	77.2	-0.1	Ok
Waipuna Road	149	A	M-28	08/4/91	Chip Seal	135	63	4.4	6.0	2.3	180	4.0	1.2	0	37,500	79.1	79.1	79.6	-0.5	Ok
Pakuranga Road (Howick)	150	A	M-28	11/4/91	Chip Seal	180	55	3.5	3.0	8.0	180	7.5	1.2	0	38,000	75.7	72.5	73.7	-1.2	Ok
Lunn Avenue	152	A	M-28	23/4/91	Chip Seal	120	56	0.0	6.0	1.0	180	6.0	1.2	0	13,000	71.5	72.4	72.6	-0.2	Ok
St Johns Road	154	A	M-28	29/4/91	Chip Seal	140	55	2.6	4.0	5.0	180	7.0	1.2	0	14,500	71.7	71.7	70.9	0.8	Ok
Penrose Road	156	A	M-28	01/5/91	Chip Seal	190	53	0.0	10.0	2.2	180	8.0	1.2	0	17,500	72.6	71.9	72.3	-0.4	Ok
Gt South Road (Southdown)	157	A	M-28	01/5/91	Chip Seal	120	57	0.0	14.5	1.7	180	3.5	1.2	0	26,800	77.8	78.5	79.2	-0.7	Ok
Sylvia Park Road	158	A	M-28	02/5/91	Chip Seal	160	55	1.7	20.0	1.6	180	8.0	1.2	1.0	23,000	74.6	73.7	75.5	-1.8	Ok
Gt South Road (Greenlane)	159	A	M-28	02/5/91	Chip Seal	140	55	5.0	4.0	10.0	180	9.0	1.2	0	14,750	71.7	72.1	70.5	1.6	Ok
Campbell Road	163	A	M-28	06/5/91	Chip Seal	175	58	7.0	4.0	7.0	180	8.0	1.2	0	13,200	72.5	71.0	71.1	-0.1	Ok
New North Road	165	A	M-28	08/5/91	Chip Seal	130	57	0.0	6.0	5.0	180	4.5	1.2	0	24,700	75.1	76.2	74.9	1.3	Ok
Great North Road	167	A	M-28	09/5/91	Chip Seal	150	60	2.6	7.0	4.5	180	5.0	1.2	0	29,000	76.8	76.9	76.6	0.3	Ok
SH2 Bombay	168	A	M-28	13/5/91	Chip Seal	125	90	0.0	10.0	0.5	180	7.0	1.2	0	8,000	72.7	77.3	75.8	1.5	Ok
SH1 Huntly	169	A	M-28	13/5/91	Chip Seal	145	83	0.0	10.0	0.5	180	5.0	1.2	0	10,500	74.2	79.2	76.7	2.5	No Good
Waipa	170	C	M-28	22/1/91	Chip Seal	120	90	0.0	10.0	0.8	180	10.0	1.2	0	5,278	69.8	72.5	72.6	-0.1	Ok
Puhinui Road	171	A	M-28	21/5/90	Chip Seal	160	56	0.0	10.0	2.3	180	8.0	1.2	0	11,500	71.1	71.0	71.3	-0.3	Ok

+ Low wall correction used* Dual carriageway analysis used

Table A3.1.Data obtained at 18-hour chipseal sites.

Erratum: page substituted, May 1994

18 Hour Asphalt/Friction Course Sites

Site Name	Site No.	NZ Region	Machine Type	Date	Road Surface	Aver. Speed (kph)	Road Gradient (%)	Percent Heavy (%)	Ratio Med: Large	Angle view (deg)	Set Back (m)	Mic. Height (m)	Ground Cover	Volume [18hr] (vehs)	Predicted L10 CRTN Model [18h] dB(A)	Measured L10 [18h] dB(A)	NZ Model [18h] dB(A)	Difference NZ v Meas dB(A)	Site Status
Sartors Avenue	3	A	B & K	24/1/90	Asphalt	48	13.1	1.0	10.0	180	4.0	1.2	0	1,323	64.2	60.1	59.8	0.3	Ok
Oak Tree Avenue	4	A	B & K	24/1/90	Asphalt	56	12.2	0.5	10.0	180	6.0	1.2	0	1,180	63.1	61.3	58.2	3.1	No Good
Dairy Flat (SH1)	13	A	B & K	03/3/90	Friction	87	3.5	5.0	1.5	180	13.0	1.2	0	23,000	75.2	70.8	70.1	0.7	Ok
Grafton Road Onramps	15	A	B & K	07/3/90	Asphalt/Friction	68	5.2	6.0	0.9	180	5.5	1.2	0	11,300	73.8	72.1	72.5	-0.4	Ok
Queenstown Road	18	A	B & K	14/3/90	Friction	59	10.0	7.2	5.7	180	7.0	1.2	0	18,656	76.2	70.4	70.3	0.1	Ok
Balmoral Road	21	A	B & K	31/1/90	Friction	57	9.6	5.0	6.0	150	5.0	1.2	0	22,200	76.2	69.1	70.1	-1.0	Ok
SH1 Bombay	23	A	B & K	31/1/90	Friction	81	6.0	14.8	0.4	135	9.0	1.2	0	14,090	74.9	72.2	71.6	0.6	Ok
Dominion Road	22	A	B & K	20/2/90	Asphalt	55	4.3	3.0	10.0	180	5.0	1.2	0	20,986	74.4	69.1	67.5	1.6	Ok
Southern M'way Manurewa	25	A	B & K	05/3/90	Friction/Chip Seal	94	2.6	9.5	1.7	180	16.0	1.2	0.5	60,540	78.4	74.8	73.7	1.1	Ok
West Hutt Motorway	101	W	M-28	02/2/90	Asphalt	99	0.0	5.0	5.0	180	24.5	1.2	0	23,422	73.0	72.2	70.4	1.8	Ok
Main Road Tawa	105	W	M-28	07/3/90	Asphalt	54	0.0	5.0	2.5	170	5.7	4.0	0	13,864	71.0	68.9	68.8	0.1	Ok
Hutt Road	106	W	M-28	08/2/90	Asphalt	90	0.0	6.0	1.4	150	13.5	4.0	0	60,400	77.8	75.9	76.3	-0.4	Ok
Wellington Motorway	107	W	M-28	05/3/90	Asphalt	98	0.0	6.3	1.2	135	Dual	1.7	0	35,000	76.0	72.6	74.6	-2.0	Ok
Eastbourne	108	W	M-28	09/2/90	Asphalt	67	0.0	4.6	10.0	170	7.0	1.2	0	9,711	70.2	66.2	67.0	-0.8	Ok
SH1 Turangi Township	205	C	M-28	21/2/90	Friction	78	0.0	13.0	0.5	180	10.0	1.2	0	3,951	68.0	64.3	64.4	-0.1	Ok
Wellington Urban Motorway	127	W	M-28	21/2/91	Friction	95	1.7	4.0	5.0	180	3.0	1.2	0	46,290	82.3	75.4	76.1	-0.7	Ok
Southern M'way: Market Road	142	A	M-28	18/3/91	Friction	90	0.0	10.0	1.4	180	5.5	1.2	0	119,850	85.1	78.8	80.5	-1.7	Ok
Northwestern M'way: W. Springs	143	A	M-28	19/3/91	Friction	90	0.0	6.5	1.9	180	Dual	1.2	0	71,600	78.7	73.6	73.6	0.0	Ok
Hobsonville Road	145	A	M-28	21/3/91	Asphalt	65	0.0	4.5	2.0	180	3.5	1.2	0	14,000	73.6	72.4	71.6	0.8	Ok
Lagoon Drive	153	A	M-28	23/4/91	Asphalt	57	0.0	6.0	5.0	180	Dual	1.2	0	37,000	75.7	71.6	73.2	-1.6	Ok
Ellerslie-Panmure Highway	151	A	M-28	16/4/91	Friction	60	0.0	5.0	5.0	180	16.5	1.0	1	36,500	69.5	63.1	63.5	-0.4	Ok
College Road	155	A	M-28	29/4/91	Asphalt	50	3.5	8.0	3.5	180	4.0	1.2	0	9,800	72.3	69.7	70.3	-0.6	Ok
Pah Road	162	A	M-28	07/5/91	Asphalt	56	1.5	5.0	7.0	180	5.5	1.2	0	18,500	73.5	71.7	70.6	1.1	Ok
St Lukes Road	164	A	M-28	08/5/91	Friction	58	3.5	5.0	3.0	180	Dual	1.2	0	22,443	73.4	69.0	67.7	1.3	Ok
Rata Street	166	A	M-28	09/5/91	Asphalt	60	3.5	5.0	3.5	180	8.0	1.2	0	23,500	74.4	70.7	72.0	-1.3	Ok

\+ Low wall correction used * Dual carriageway analysis used

Table A3.2. Data obtained at 18-hour asphalt/friction course sites.

Erratum: page substituted, May 1994

1 Hour Chipseal Sites

Site Name	Site No.	NZ Region	Machine Type	Date	Road Surface	Sand Circle (mm)	Aver. Speed (kph)	Road Gradient (%)	Percent Heavy (%)	Ratio Med: Large	Angle view (deg)	Set Back (m)	Mic. Height (m)	Ground Cover	Volume [1hr] (vehs)	Predicted L10 CRTN Model [1h] dB(A)	Measured L10 [1h] dB(A)	NZ Model [1h] dB(A)	Difference NZ vs Meas dB(A)	Site Status
SH1 Albany South	1	A	B & K	22/1/90	Chip Seal	150	81	1.7	7.8	2.0	180	14.0	3.5	0	1,061	74.1	74.4	75.3	-0.9	Ok
Bush Road (WEPB)	2	A	B & K	22/1/90	Chip Seal	135	67	0.0	14.7	3.0	180	12.0	1.2	1	260	65.8	67.3	66.9	0.4	Ok
East Coast Road	5	A	B & K	01/3/90	Chip Seal	165	65	1.7	2.5	1.9	180	17.0	1.2	+	1,284	64.6	65.1	64.2	0.9	Ok
Beach Road	6	A	B & K	07/3/90	Chip Seal	190	52	6.1	2.7	5.8	180	9.0	1.2	0.5	1,170	72.6	69.8	70.5	-0.7	Ok
SH18 Coatesville	7	A	B & K	06/3/90	Chip Seal	200	69	0.9	1.1	1.3	180	25.0	1.2	0	271	63.2	61.2	62.2	-1.0	Ok
Oteha Valley Road	8	A	B & K	13/3/90	Chip Seal	265	77	3.5	5.0	8.0	180	3.5	1.2	0	376	73.3	73.2	71.6	1.6	Ok
Deep Creek Road	9	A	B & K	01/3/90	Chip Seal	120	57	14.9	1.9	10.0	180	7.0	1.2	0	392	72.4	69.5	71.0	-1.5	Ok
Upper Harbour Drive	10	A	B & K	25/1/90	Chip Seal	210	78	7.9	2.0	3.0	180	7.0	1.2	1	798	74.1	73.3	73.1	0.2	Ok
Albany Hill	12	A	B & K	01/6/90	Chip Seal	140	83	7.0	6.5	1.2	180	13.0	1.2	1	1,056	73.5	75.6	75.1	0.5	Ok
Vincent Street	14	A	B & K	26/1/90	Chip Seal	150	53	8.7	8.0	10.0	150	19.0	1.2	0	625	69.7	66.4	68.7	-2.3	No Good
O'Rorke Road	16	A	B & K	06/3/90	Chip Seal	145	58	1.7	16.9	1.5	180	9.0	1.2	0	935	74.8	75.5	75.9	-0.4	Ok
Church Street	17	A	B & K	26/1/90	Chip Seal	160	55	0.0	10.8	2.9	180	21.0	1.2	1	1,167	67.7	67.8	67.7	0.1	Ok
Neilson Street	19	A	B & K	07/3/90	Chip Seal	160	55	0.9	24.0	1.5	180	16.0	1.2	0	1,256	74.7	76.5	75.7	0.8	Ok
Mt Albert Road	20	A	B & K	03/3/90	Chip Seal	180	59	0.0	4.0	2.4	180	8.0	1.2	+	1,367	69.3	70.0	68.6	1.4	Ok
Southern M'way Ramarama	24	A	B & K	15/3/90	Chip Seal	115	103	0.9	13.0	0.4	180	Dual	1.2	0	1,179	75.1	77.8	79.0	-1.2	Ok
Haywards Hill	102	W	M-28	03/3/90	Chip Seal	155	70	8.7	9.8	2.4	180	6.5	1.2	0	477	74.7	71.8	75.4	-3.6	No Good
Judgeford	103	W	M-28	05/2/90	Chip Seal	225	88	1.7	7.0	2.4	180	12.5	1.2	1	477	69.2	70.3	69.4	0.9	Ok
Titahi Bay	104	W	M-28	05/2/90	Chip Seal	190	65	0.0	2.5	4.4	180	16.5	1.2	0	779	69.1	68.0	67.7	0.3	Ok
Wainuiomata	109	W	M-28	12/2/90	Chip Seal	250	60	0.0	3.0	7.3	180	6.0	1.2	0	2,154	76.4	73.3	73.9	-0.6	Ok
Khandallah	110	W	M-28	11/4/90	Chip Seal	160	58	5.2	0.3	10.0	180	5.5	1.2	0	824	72.9	70.7	69.6	1.1	Ok
Wilton	111	W	M-28	15/2/90	Chip Seal	125	54	7.9	1.7	6.0	180	4.0	1.2	0	458	72.0	71.5	70.7	0.8	Ok
Moorefield	112	W	M-28	13/3/90	Chip Seal	125	59	7.0	1.0	10.0	180	9.0	2	0	1,040	73.4	71.8	71.5	0.3	Ok
Paekakariki	114	W	M-28	16/2/90	Chip Seal	160	84	0.0	5.0	1.5	180	8.0	1.2	0	1,021	75.1	76.3	76.0	0.3	Ok
Maungaiti Hill	201	C	M-28	16/2/90	Chip Seal	180	80	3.5	14.0	0.5	180	5.5	3	0	251	72.1	74.8	74.2	0.6	Ok
Atiamuri South	202	C	M-28	19/2/90	Chip Seal	125	103	0.0	15.0	0.5	180	15.0	1.2	0	201	69.0	69.6	72.7	-3.1	No Good
Wairakei	203	C	M-28	20/2/90	Chip Seal	185	93	3.5	11.0	0.5	180	15.0	2	1	350	69.9	71.5	72.1	-0.6	Ok
Tahorakuri Forest	204	C	M-28	21/2/90	Chip Seal	135	104	0.0	6.5	0.7	180	5.5	1.2	0	153	69.9	71.1	72.5	-1.4	Ok
Waitoka	206	C	M-28	23/2/90	Chip Seal	160	96	0.0	10.2	1.0	180	8.0	1.2	0	235	70.6	73.7	72.7	1.0	Ok
Napier Highway	207	C	M-28	27/2/90	Chip Seal	140	98	1.7	35.0	0.2	180	5.5	3	0	136	72.4	77.8	77.1	0.7	Ok
Hallets Bay	208	C	M-28	27/2/90	Chip Seal	150	91	1.7	15.0	0.9	180	5.5	1.2	0	222	72.2	75.2	74.7	0.5	Ok
Hinemaia Hill	209	C	M-28	27/2/90	Chip Seal	135	90	8.0	15.0	1.0	180	5.5	1.2	0	244	74.4	77.5	77.0	0.5	Ok
Putaruru South	210	C	M-28	28/2/90	Chip Seal	145	93	0.9	14.0	0.6	180	10.0	1.2	0	317	71.8	74.1	74.6	-0.5	Ok
Karapiro	211	C	M-28	28/2/90	Chip Seal	115	94	1.7	14.0	1.0	180	5.5	1.2	0	446	75.3	79.3	78.4	0.9	Ok
Ngongotaha	212	C	M-28	28/2/90	Chip Seal	190	90	3.5	14.4	0.7	180	10.0	1.2	0	239	71.1	74.1	73.2	0.9	Ok
Ngaio Gorge	122	W	M-28	18/2/91	Chip Seal	190	48	7.0	5.0	15.0	180	2.5	1.2	0	380	72.4	71.2	69.9	1.3	Ok
Ruahine Road (Victoria Tunnel)	125	W	M-28	20/2/91	Chip Seal	135	60	5.2	3.5	10.0	180	2.5	1.2	0	2,331	80.4	79.0	79.3	-0.3	Ok
Acacia Bay Road	131	C	M-28	23/2/91	Chip Seal	135	83	0.9	1.0	1.0	180	6.5	1.2	0	215	68.2	70.0	68.7	1.3	Ok
Spa Road	132	C	M-28	23/2/91	Chip Seal	180	50	5.2	1.5	3.0	180	9.5	1.2	0	569	69.3	66.3	67.3	-1.0	Ok
Lake Terrace	133	C	M-28	24/2/91	Chip Seal	180	56	0.0	7.5	0.5	180	9.0	1.2	1	925	70.5	68.9	71.3	-2.4	No Good
Northern M'way: Northcote Road	141	A	M-28	18/3/91	Chip Seal	150	90	3.5	7.0	2.2	180	Dual	1.2	0	3,858	81.6	82.0	82.8	-0.8	Ok
Pakuranga Highway	148	A	M-28	08/4/91	Chip Seal	180	64	4.4	4.0	4.0	180	6.0	1.2	0	2,917	79.7	77.1	78.8	-1.7	Ok
Waipuna Road	149	A	M-28	08/4/91	Chip Seal	135	63	4.4	6.0	2.3	180	4.0	1.2	0	2,270	80.0	79.8	80.5	-0.7	Ok
Pakuranga Road (Howick)	150	A	M-28	11/4/91	Chip Seal	180	55	3.5	3.0	8.0	180	7.5	1.2	0	1,511	74.7	73.0	72.8	0.2	Ok
Lunn Avenue	152	A	M-28	23/4/91	Chip Seal	120	56	0.0	6.0	1.0	180	5.5	1.2	0	938	73.4	73.7	74.5	-0.8	Ok
St Johns Road	154	A	M-28	29/4/91	Chip Seal	140	55	2.6	4.0	5.0	180	7.0	1.2	0	963	73.0	71.9	72.2	-0.3	Ok
Penrose Road	156	A	M-28	01/5/91	Chip Seal	190	53	0.0	10.0	2.2	180	8.0	1.2	0	1,232	74.2	73.8	73.9	-0.1	Ok
Gt South Road (Southdown)	157	A	M-28	01/5/91	Chip Seal	120	57	0.0	14.5	1.7	180	3.5	1.2	0	1,609	78.7	80.2	80.0	0.2	Ok
Sylvia Park Road	158	A	M-28	02/5/91	Chip Seal	160	55	1.7	20.0	1.6	180	8.0	1.2	1	1,544	76.0	75.7	76.8	-1.1	Ok
Gt South Road (Greenlane)	159	A	M-28	02/5/91	Chip Seal	140	55	5.0	4.0	15.0	180	9.0	1.2	0	1,042	73.3	72.7	71.8	0.9	Ok
Campbell Road	163	A	M-28	06/5/91	Chip Seal	175	58	7.0	4.0	7.0	180	8.0	1.2	0	772	73.3	71.2	71.8	-0.6	Ok
New North Road	165	A	M-28	08/5/91	Chip Seal	130	57	0.0	6.0	5.0	180	4.5	1.2	0	2,241	77.8	77.9	77.6	0.3	Ok
Great North Road	167	A	M-28	09/5/91	Chip Seal	150	60	2.6	7.0	4.5	180	5.0	1.2	0	2,920	80.0	77.9	79.7	-1.8	Ok
SH2 Bombay	168	A	M-28	13/5/91	Chip Seal	125	90	0.0	11.0	0.4	180	7.0	1.2	0	556	74.4	78.7	77.6	1.1	Ok
SH1 Huntly	169	A	M-28	13/5/91	Chip Seal	145	83	0.0	10.0	0.5	180	5.0	1.2	0	925	76.8	80.2	79.2	1.0	Ok
East Coast Highway	300	A	M-28	16/4/91	Chip Seal	130	89	1.0	5.2	3.3	180	10.0	1.2	0	581	72.7	79.0	73.8	5.2	No Good
Mill Road West	301	A	M-28	22/6/91	Chip Seal	165	78	4.0	2.0	5.0	180	6.0	1.2	0	294	70.5	73.4	69.6	3.8	No Good
Mill Road East	302	A	M-28	22/6/91	Chip Seal	160	79	0.0	4.3	1.8	180	7.5	1.2	0	326	69.7	74.5	70.3	4.2	No Good
SH16 M'way Hobsonville	303	A	M-28	18/6/91	Chip Seal	180	91	4.0	7.3	2.1	180	9.0	1.2	0	1,122	77.4	76.4	78.2	-1.8	Ok
Whenuapai	304	A	M-28	19/6/91	Chip Seal	145	80	5.0	11.0	1.6	180	6.0	1.2	0	309	72.9	76.0	74.5	1.5	Ok
SH16 Bus Depot	305	A	M-28	21/6/91	Chip Seal	145	84	0.0	9.4	1.0	180	8.5	1.2	0	713	74.1	73.8	76.1	-2.3	No Good
SH18 (near SH16)	306	A	M-28	21/6/91	Chip Seal	180	76	0.0	6.4	2.7	180	6.0	1.2	0	172	67.7	70.8	67.9	2.9	No Good
SH16 Kumeu	307	A	M-28	21/6/91	Chip Seal	150	88	0.0	6.7	1.2	180	6.5	1.2	0	194	69.1	74.2	70.7	3.5	No Good
Muriwai	308	A	M-28	21/6/91	Chip Seal	125	73	4.5	4.9	15.0	180	5.5	1.2	0	144	67.9	70.4	67.5	2.9	No Good

\+ Low wall correction used   * Dual carriageway analysis used

Table A3.3. Data obtained at 1-hour chipseal sites.

Erratum: page substituted, May 1994

1 Hour Asphalt/Friction Course Sites

Site Name	Site No.	NZ Region	Machine Type	Date	Road Surface	Aver. Speed (kph)	Road Gradient (%)	Percent Heavy (%)	Ratio Med: Large	Angle view (deg)	Set Back (m)	Mic. Height (m)	Ground Cover	Volume [1hr] (vehs)	Predicted L10 CRTN Model [1h] dB(A)	Measured L10 [1h] dB(A)	NZ Model [1h] dB(A)	Difference NZ vs Meas dB(A)	Site Status
Sartors Avenue	3	A	B & K	24/1/90	Asphalt	48	13.1	1.0	10.0	180	4.0	1.2	0	99	66.0	60.1	61.8	-1.7	Ok
Oak Tree Avenue	4	A	B & K	24/1/90	Asphalt	56	12.2	0.0	0.0	180	6.0	1.2	0	122	66.1	61.3	63.5	-2.2	No Good
Dairy Flat (SH1)	13	A	B & K	03/3/90	Friction	87	3.5	5.0	1.5	180	13.0	1.2	0	1,354	76.0	72.0	70.9	1.1	Ok
Grafton Road Onramps	15	A	B & K	07/3/90	Asphalt/Friction	68	5.2	6.0	0.9	180	5.5	1.2	0	785	75.3	74.3	74.1	0.2	Ok
Queenstown Road	18	A	B & K	14/3/90	Friction	59	10.0	7.2	5.7	180	7.0	1.2	0	963	76.4	71.1	70.6	0.5	Ok
Balmoral Road	21	A	B & K	31/1/90	Friction	57	9.6	5.0	6.0	150	5.0	1.2	0	1,330	77.1	70.8	71.0	-0.2	Ok
Dominion Road	22	A	B & K	28/2/90	Asphalt	55	4.3	3.5	10.0	180	8.0	1.2	+	1,614	75.2	70.6	71.9	-1.3	Ok
SH1 Bombay	23	A	B & K	31/1/90	Friction	81	6.0	14.8	0.4	135	9.0	1.2	0	1,179	77.3	74.6	73.8	0.8	Ok
Southern M'way Manurewa	25	A	B & K	05/3/90	Friction/Chip Seal	94	2.6	9.5	1.7	180	16.0	1.2	0.5	3,490	80.1	76.6	75.3	1.3	Ok
West Hutt Motorway	101	W	M-28	02/2/90	Asphalt	99	0.0	5.0	5.0	180	24.5	1.2	0	1,439	74.0	72.6	71.4	1.2	Ok
Main Road Tawa	105	W	M-28	07/3/90	Asphalt	54	0.0	5.0	2.5	170	5.7	4.0	0	984	72.6	69.8	70.5	-0.7	Ok
Hutt Road	106	W	M-28	08/2/90	Asphalt	90	0.0	6.0	1.4	150	13.5	4.0	0	3,680	78.8	78.0	77.2	0.8	Ok
Wellington Motorway	107	W	M-28	05/3/90	Asphalt	98	0.0	6.3	1.2	135	Dual	1.7	0	1,330	74.7	70.7	73.3	-2.6	No Good
Eastbourne	108	W	M-28	09/2/90	Asphalt	67	0.0	4.6	10.0	170	7.0	1.2	0	530	70.7	67.7	67.5	0.2	Ok
SH1 Turangi Township	205	C	M-28	21/2/90	Friction	78	0.0	13.0	0.5	180	10.0	1.2	0	368	70.8	66.2	67.2	-1.0	Ok
Porirua Motorway	123	W	M-28	20/2/91	Friction	98	0.0	10.0	1.6	180	Dual	1.2	0	826	80.1	77.9	74.1	3.8	No Good
Wainuiomata Road	124	W	M-28	20/2/91	Friction	60	0.0	8.0	10.0	180	3.0	1.2	0	1,234	76.8	71.9	70.8	1.1	Ok
Western Hutt Motorway	126	W	M-28	22/2/91	Friction	99	0.0	8.2	1.9	180	Dual	1.2	0	1,362	81.9	77.5	76.9	0.6	Ok
Wellington Urban Motorway	127	W	M-28	21/2/91	Friction	95	1.7	4.0	5.0	180	3.0	1.2	0	2,938	83.4	75.3	77.3	-2.0	Ok
Southern M'way: Market Road	142	A	M-28	18/3/91	Friction	90	0.0	10.0	1.4	180	Dual	1.2	0	8,176	84.9	80.9	80.3	0.6	Ok
Northwestern M'way: W. Springs	143	A	M-28	19/3/91	Friction	90	0.0	6.5	1.9	180	Dual	1.2	0	4,418	78.7	74.9	73.6	1.3	Ok
Hobsonville Road	145	A	M-28	21/3/91	Asphalt	65	0.0	9.5	1.8	180	3.5	1.2	0	805	75.4	73.8	74.0	-0.2	Ok
Dairy Flat	146	A	M-28	21/3/91	Friction	95	1.0	8.5	1.5	180	14.5	1.2	0	1,070	75.7	71.9	70.9	1.0	Ok
Lagoon Drive	153	A	M-28	23/4/91	Asphalt	57	0.0	6.0	5.0	180	Dual	1.2	0	2,766	75.7	74.2	73.2	1.0	Ok
Ellerslie-Panmure Highway	151	A	M-28	16/4/91	Friction	60	0.0	6.0	5.0	180	16.5	1.0	0.9	1,920	70.4	65.9	64.5	1.4	Ok
College Road	155	A	M-28	29/4/91	Asphalt	50	3.5	8.0	3.5	180	4.0	1.2	0	621	73.5	69.7	71.5	-1.8	Ok
Pah Road	162	A	M-28	07/5/91	Asphalt	56	1.5	5.0	7.0	180	5.5	1.2	0	1,338	75.2	72.3	72.3	-0.0	Ok
St Lukes Road	164	A	M-28	08/5/91	Friction	58	3.5	5.0	3.0	180	Dual	1.2	0	1,427	80.2	73.4	74.6	-1.2	Ok
Rata Street	166	A	M-28	09/5/91	Asphalt	60	3.5	5.0	3.5	180	8.0	1.2	0	1,832	76.4	71.5	74.1	-2.6	No Good

+ Low wall correction used   * Dual carriageway analysis used

Table A3.4. Data obtained at 1-hour asphalt/friction course sites.

Erratum: page substituted, May 1994

APPENDIX 4. STANDARD TEST PROCEDURE FOR MEASUREMENT OF TEXTURE BY SAND CIRCLE METHOD (TNZ T/3 (1981) specification)

APPENDIX 4. STANDARD TEST PROCEDURE FOR MEASUREMENT OF TEXTURE BY SAND CIRCLE METHOD (TNZ T/3 (1981) specification)

A4.1 Scope

This test procedure covers the determination of the average texture depth of a paved surface using sand to give the volume of voids. The method is suitable for the measurement of surfaces with average texture depths greater than 0.45mm (less than 350mm sand circle diameter).

A4.2 Apparatus and Materials

- A ruler or tape graduated in millimetres at least 400mm in length.
- A soft brush or hand-broom.
- A straight-edge between 150 and 160mm in length.
- A sand-measuring cylinder 30 to 45mm in diameter having an internal volume of 45 $\pm$ 0.5ml. The top of the cylinder shall be machined flat to assist striking off.
- A quantity of clean dry sand with well rounded grains, 100% passing the 600μm and 100% retained on the 300μm BS 410 test sieves.

A4.3 Procedure

- Ensure that the area to be tested is dry and free from detritus. Brush any fine material from the surface.
- Fill the cylinder with sand and tap lightly until the sand ceases to compact. Top up the cylinder and carefully strike off the surface with the straight edge.
- Pour out the sand in a conical heap in the centre of the area to be tested (Figure A2.1). (In windy conditions the use of a tyre or screen to surround the sand is recommended.)
- Using the straight-edge, spread the sand into a circular patch so that the surface depressions are filled to the level of the tops of the stones (Figure A2.2). The tops of the larger stones should only just be visible through the sand layer.
- Measure the diameter of the patch twice, the direction of the second measure approximately at right angles to the first. Average the measurements to give D, the sand circle diameter.

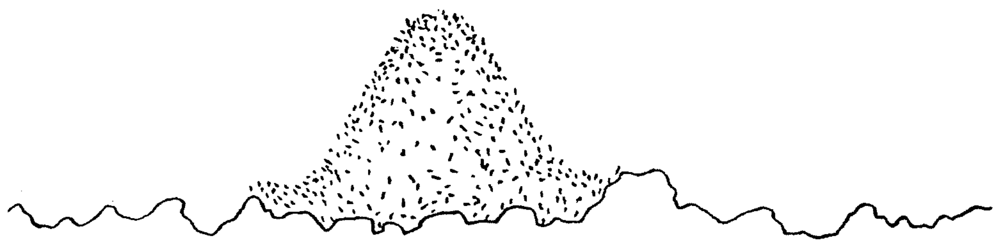


Figure A4.1. Sand poured onto pavement.

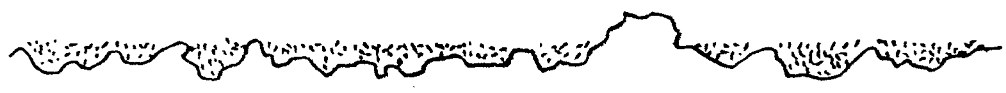


Figure A4.2. Sand spread evenly over pavement
(note how large irregularities in surface are ignored).

APPENDIX 5. LOCATIONS OF SURVEY SITES

AUCKLAND SURVEY AREA

INDEX OF SURVEY SITES

Chipseal Sites

1	SH1 Albany South
2	Bush Road (WEPB)
5	East Coast Road
6	Beach Road
7	SH18 Coatesville
8	Oteha Valley Road
9	Deep Creek Road
10	Upper Harbour Drive
12	Albany Hill
14	Vincent Street
16	O'Rorke Road
17	Church Street
19	Neilson Street
20	Mt Albert Road
24*	Southern M/way Ramarama
141	Northern M/way Northcote Road
148	Pakuranga Highway
149	Waipuna Road
150	Pakuranga Road (Howick)
152	Lunn Avenue
154	St Johns Road
156	Penrose Road
157	Gt South Road (Southdown)
158	Sylvia Park Road
159	Gt South Road (Greenlane)
163	Campbell Road
165	New North Road
167	Great North Road
168*	SH2 Bombay
169*	SH1 Huntly
171	Puhinui Road
300	East Coast Highway

Asphalt/Friction Course Sites

3	Sartors Avenue
4	Oak Tree Avenue
13	Dairy Flat (SH1)
15	Grafton Road on-ramps
18	Queenstown Road
21	Balmoral Road
22	Dominion Road
23*	SH1 Bombay
25	Southern M/way Manurewa
142	Southern M/way Market Road
143	North-western M/way W.Springs
145	Hobsonville Road
146	Dairy Flat
153	Lagoon Drive
151	Ellerslie Panmure Highway
155	College Road
162	Pah Road
164	St Lukes Road
166	Rata Street

* Off this map

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AUCKLAND
TAKAPUNA
Birkenhead
Northcote
Devonport
North Head
Helensville
Parakai
Te Pua
Wharepapa
Woodhill
Rewiti
Waimauku
Huapai
Kumeu
Riverhead
Whenuapai
Dairy Flat
Redvale
Okura
Glenvar
Albany
Coatesville
Paremoremo
Cuthill
Glenfield
Piripiri Point
Long Bay
Toroa Point
Torbay
Browns Bay
Rothesay Bay
Mairangi Bay
Campbells Bay
Castor Bay
Milford
Lake Pupuke
Shoal Bay
Rangitoto Island
Rangitoto Channel
Motutapu Island
Rakino Island
Rakino Channel
The Noises
Billy Goat Point
Home Bay
Motuihe Island
Emu Point
Park Pt
Browns Island
Musick Point
Bucklands Beach
Motukaraka Island
Beachlands
Tamaki River
Howick
Pakuranga
East Tamaki Heights
East Tamaki
Whitford
Otara
Flat Bush
Brookby
Manukau City Centre
Wiri
Manurewa
Alfriston
Ardmore
Takanini
Wattle Downs
Weymouth
Pahurehure Inlet
PAPAKURA
Red Hill
Papatoetoe
Mangere
Mangere Bridge
Otahuhu
Onehunga
Mt Wellington
Ellerslie
Glen Innes
Mission Bay
St Heliers
Orakei
Parnell
Newmarket
One Tree Hill
Mt Eden
Mt Albert
Mt Roskill
Avondale
New Lynn
Glen Eden
Kelston
Blockhouse Bay
Titirangi
Henderson
Te Atatu South
Te Atatu North
Massey
West Harbour
Hobsonville
Waitemata Harbour
Whau River
Point Chevalier
Pollen Island
Waitakere
Swanson
Ranui
Taupaki
Oratia
Waiatarua
Upper Nihotupu Reservoir
Lower Nihotupu Resvr
Huia Resvr
Lower Huia Resvr
Waitakere Resvr
WAITAKERE RANGES
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Laingholm
Laingholm Point
Cape Horn
Puketutu Island
Ihumatao
Te Tau Bank
Karore Bank
Manukau Harbour
Wiroa Island
Papakura Channel
Hikihiki Bank
Hangore Bank
Puponga Pt
Cornwallis
Little Huia
Huia
Huia Bank
Manukau Entrance
Mako Pt
Big Bay
Orua Bay
Wattle Bay
Grahams Beach
South Head
Whatipu
Karekare
Paratahi I
Piha
Lion Rock
Taitomo I
Anawhata
Te Henga
Raetahinga Point
Muriwai Beach
Oaia I
Muriwai Beach
Mokoroa Stm
Waitakere R
Kaipara River
Kumeu R
Waikoukou Valley
Tikokopu Stm
Waikoukou Stm
Araparera Stm
Rangitopuni Stream
Dairy Stm
Okura R
Sim
Dam
Hut
Rangitoto 260
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CENTRAL NORTH ISLAND SURVEY AREA

INDEX OF SURVEY SITES

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206	Waitoka		
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209	Hinemaiaia Hill		

Asphalt/Friction Course Sites

Map 1
205 SH1 Turangi

* Off map

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Lake Taupo
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Oruanui
Te Pouwhakatutu
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Orakeikorako
Waikato River
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Wairakei
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Aratiatia
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Motuoapa
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Tauranga-Taupo River
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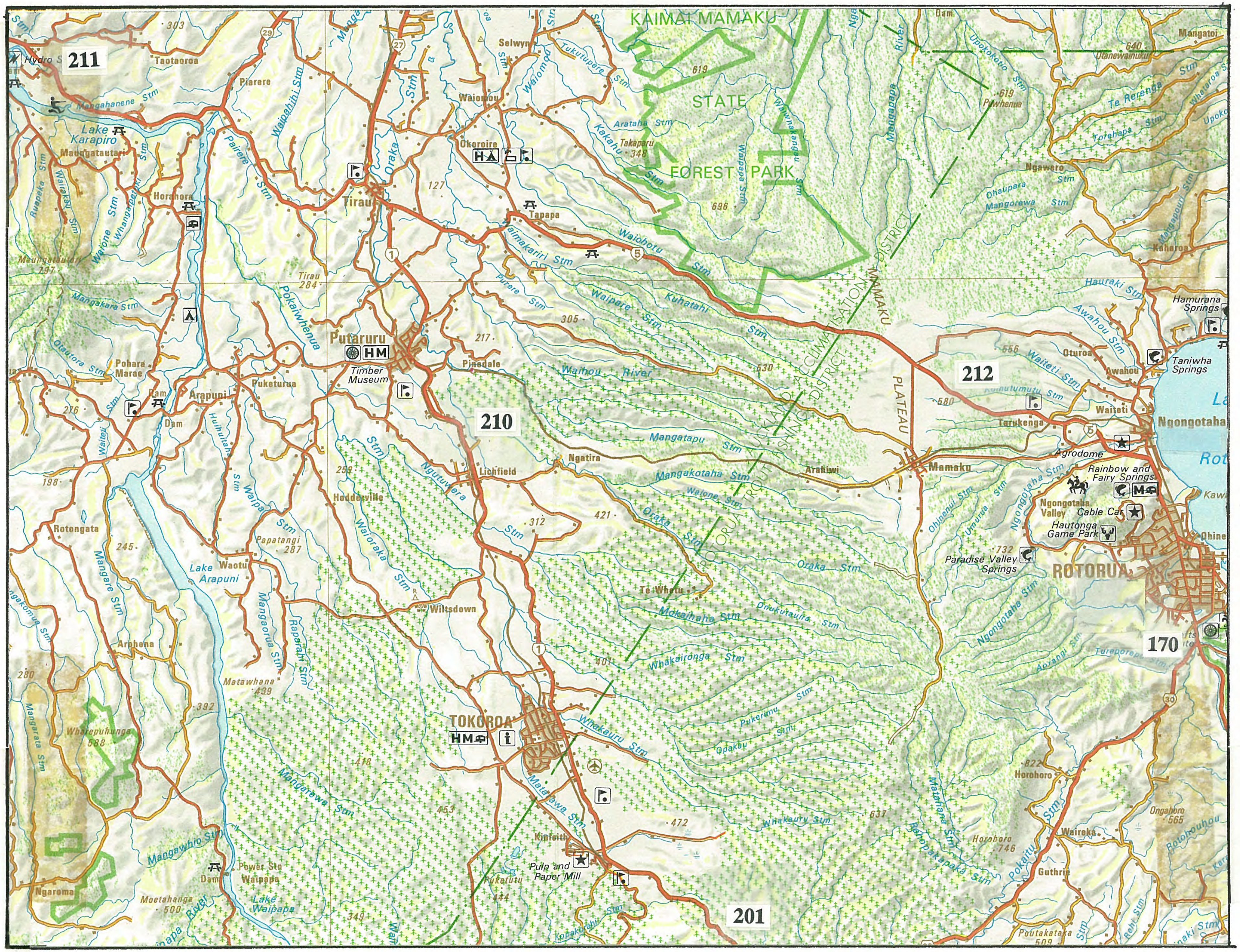

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Hamurana Springs
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Arapuni
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Taotaoroa
Rotongata
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Waipapa
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WELLINGTON SURVEY AREA

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*Not shown

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