University of Southern Queensland

Faculty of Engineering and Surveying

Life Cycle Maintenance of Low Volume Roads in the Alice Springs Region

A dissertation submitted by

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Abstract

1. INTRODUCTION

Low volume roads carry low volumes of traffic which can be anything from a bicycle to a fully loaded road train and these roads tend to be not well funded in comparison with the major roads.

The Northern Territory's road network consists of national and regional highways as well as other roads linking the remote areas and major centres and majority of the roads in the Alice Springs Region are low volume roads.

The aim of this project is to investigate and develop improvements to low volume road maintenance practices and procedures in the Alice Springs Region.

2. BACKGROUND

During wet weather the unsealed roads become impassable and the communities that rely on the roads become impatient if the roads are impassable for longer than two days. During long periods of dry weather patches of the unsealed roads deteriorate into bull dust and the pavement unravels due to the lack of moisture.

Funding for low volume roads are limited and the increase of the Cyclical Maintenance budget each financial year is in line with the CPI rate. Specific Maintenance projects are very limited and capital works are very rare.

3. OBJECTIVES

With limited funding and resources for low volume roads, effective maintenance management should be able to provide a road surface that is of an acceptable standard to the road user.

The methods researched will be used to examine the cost implications and resources availability.

4. METHOD

The stages involved in the execution of the project include:

- Review existing literature on road management practices, with particular emphasis on maintenance practices for low volume roads.
- Gather data on low volume roads in the Alice Springs Region and factors which influence the deterioration of the road.
- Collect and analyse data on the current maintenance practices in the region.
- Evaluate and propose innovative maintenance practices that improve effectiveness and efficiency, and promote sustainable use of materials.
- Interrogate and evaluate the implications of the cost and resources availability of applying selected maintenance innovations in the region.

5. CONCLUSION

There is scope for improvement of the current cyclic maintenance methods used even through there is associated problems with remoteness, availability of water and quality of gravel.

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Limitations of Use

Certification

I certify that the ideas, designs and experimental work, results, analyses and conclusions set out in this dissertation are entirely my own effort, except where otherwise indicated and acknowledged.

I further certify that the work is original and has not been previously submitted for assessment in any other course or institution, except where specifically stated.

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Signature

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Date

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Contents

List of Figures

List of Tables

Glossary

AADT – Annual Average Daily Traffic – The total yearly two way traffic volume divided by 365, expressed as vehicles per day.

ADT – Average Daily Traffic – The average 24 hour volume over the period of the traffic count.

Atterberg Limits – A set of arbitrarily defined boundary conditions in soil related to water content. The limits are as follows:

- Liquid limit – the moisture content at which a soil passes from the liquid state to the plastic state, as determined by a specific test procedure.
- Plastic limit – the moisture content at which a soil passes from the plastic state to the semi-solid state, as determined by a specific test procedure.
- Shrinkage limit – the moisture content from which a soil will continue to dry out without further change in volume.

Batter – The uniform side slope of walls, banks, cuttings etc

Carriageway – That portion of a road devoted particularly to the use of vehicles, that is between guide posts, kerbs, or barriers where they are provided, inclusive of shoulders and auxiliary lanes.

Chainage – The distance of a point along a control line, measured from a datum point.

Crown – The highest point on the cross-section of a carriageway with a two-way crossfall.

Crossfall – The slope, at right-angles to the alignment, of the surface of any part of a carriageway.

Cut – The depth from the natural surface of the ground down to the subgrade level.

Dry maintenance – no water other than occasional natural rainfall is available to add to the pavement.

Fill – The portion of road where the formation is above the natural surface.

Formation – The surface of the finished earthworks, excluding cut or fill batters.

Grader – A mechanized, wheeled machine with a moveable blade mounted centrally between the axles, used to shape or level surfaces.

Invert – The lowest portion of the internal surface of a drain or culvert.

Offlet drain – A diversion from a table drain to a point where the water will dissipate.

Pavement – That portion of a carriageway placed above the subgrade for the support of, and to form a running surface for, vehicular traffic.

Plasticity Index – The numerical difference between the value of the liquid limit and the value of the plastic limit of the soil.

Resheet – To recondition a pavement, by adding a new layer of material.

Rut – A vertical formation of a pavement surface formed by the wheels of vehicles.

Shoulder – The portion of the carriageway beyond the traffic lanes and contiguous and flush with the surface of the pavement.

Subgrade – The trimmed or prepared portion of the formation on which the pavement is constructed. Generally taken to relate to the upper line of the formation.

Table drain – The side drain of a road adjacent to the shoulders, having its invert lower than the pavement base and being part of the formation.

Table drain block – A block constructed in the table drain to divert water into the offlet drain.

Wearing course – That part of the pavement upon which the traffic travels.

Windrow – A shallow ridge of material formed by the action of a grader, or other blade, during in situ cutting or mixing operations.

Chapter 1

Introduction

What is a low volume road? The following references to low volume roads were found in the literature search:

- Any town road in a town where there is less than 150 people per square-mile, and the road carries less than 400 vehicles per day (Tug Hill Commission, 2003).
- Nearly 50% of the Southland State Highway network, like many other rural roading networks in New Zealand, carry less than 1000 vehicles per day (Faulkner).
- Roads with a traffic volume less than 1000 vehicles per day (Austroads, 2000).
- Roads carrying between 200 and 1500 vehicles per day (AS 1742.3 – 2002)
- Very low volume roads, roads carrying less than 200 vehicles per day (AS 1742.3 – 2002).

The author of this project definition of low volume roads is; low volume roads can have the classification form a Rural State Arterial through to a single user access and their Annual Average Daily Traffic (AADT) is less than 500.

Low volume roads carry low volumes of traffic which can be anything from a bicycle to a fully loaded road train weighing up to 115 tonnes and tend to be not well funded compared to the major roads.

The Northern Territory's road network consists of national and regional highways as well as other roads linking the remote areas.

In the Alice Springs Region the majority of the road network is classified as unsealed low volume roads and are in remote areas. These roads are essential for Aboriginal communities, Pastoralists, Mining, Tourists Attractions and Accommodation. The roads are vital links for various key players such as transport companies, tour companies, tourists and various government departments such as health, police and eduction. The road user expects a road surface that is similar to a seal road and that is travel able all year round.

With limited funding and resources for low volume roads, efficient maintenance management should aim to provide a road surface that is of an acceptable safe standard to road users.

For the Alice Springs Region to meet their road maintenance responsibilities they have to deal with numerous influences which include:

- An aging network;
- Changes in vehicle types and allowable vehicle loads;
- An increase in number of road users;
- An increase in the expectations of the road users;
- Road safety and litigation issues;
- Increasing competition for funds;
- Rising construction and maintenance costs;
- Remoteness.

The challenge is to deliver an acceptable level of service for the road user while addressing these many influences.

The aim of the project is to investigate and develop improvements to low volume road maintenance practices and procedures in the Alice Springs Region.

1.1 Dissertation Overview

The dissertation comprises of the following chapters listed below with a summary of what the chapter entails.

- Chapter 2 – Background.

  A brief discussion of the problems associated with low volume unsealed roads.

- Chapter 3 – Low Volume Roads in Alice Springs Region.

  Length and AADT of selected roads are tabled plus specific maintenance issues.

- Chapter 4 – Factors which influence the deterioration of unsealed roads.

  Explanation of selected parameters is discussed.

- Chapter 5 – Low volume road maintenance.

  Research of the current maintenance practices in the Alice Springs Region and elsewhere is documented.

- Chapter 6 – Research Methodology.

  This describes how the various issues were addressed.

- Chapter 7 – Innovation Maintenance Practices.

  Various innovation maintenance practices such as Road Cushion ®, Salt Stabilisation and wet maintenance are discussed.

- Chapter 8 – Availability of resources for applying of selected maintenance innovations in the Alice Springs Region.

  Discussions of the limited resources available and comparison of the life cycle maintenance of dry maintenance versus wet maintenance.

- Chapter 9 – Discussion of low volume roads.

  This chapter discusses how the various innovated maintenance practices are not or how they are complement each other.

- Chapter 10 – Conclusion.

Chapter 2

Background

Unsealed low volume roads are generally low cost, constructed to varying standards, using locally available materials.

The performance of unsealed roads is largely dependent on the quality of available materials, local environment conditions, maintenance policies, available resources and funds.

During wet weather the unsealed roads become impassable and the communities that depend on the roads became impatient if the roads are impassable for two days and longer. During long periods of dry weather sections of the unsealed roads unravels due to the lack of moisture or sections turn to bull dust which is safety hazard.

Alice Springs Region has been performing the same maintenance practices with limited research of innovative methods and investment in technology. The road network is vast and majority of the maintenance is remote. Due to the vast network that has to be covered supervision is limited.

Dry grading of the unsealed road network is preformed, with limited maintenance process of grade, water and roll been undertaken. With the area been arid it means that the only available water is ground water and the haul distance can be up to a distance of 40 kilometres.

Replenishing of the pavement under specific maintenance has been very limited and in areas nothing has been completed for up to 10 years. Spot gravelling is carried out under routine maintenance but unfortunately the gravel can be of a poor standard such as too many fines or a large percentage of the gravel been retained on the 37.5mm sieve or a Plastic Index over 20.

A number of roads have been graded to below the natural ground level, lost their cross falls and area over 9 metres wide due to the graders searching for material to drag across the pavement. Material is lost from the pavement through grading, passing traffic stirring up the dust which is then blown off from the pavement and rain washing the material off from the road.

Some of the innovation methods that have been trialled in the region have limited documentation. For example a section along the Plenty Highway which is an unsealed road has had a sand clay section stabilised with salt. The salt stabilised section preforms remarkably well in dry weather as the road deterioration is retarded because the salt absorbs moisture from the atmosphere into the pavement. The disadvantage is when it rains the section becomes very soft and is easily wheel tracked. This creates a problem if the wheel tracks are not removed before the pavement is dry as it is impossible to grade them out.

Peoples' perception of the condition of unsealed roads varies. Numerous complaints are received at the Alice Springs Regional office concerning the deterioration of the road pavement and requests for them to be graded. Different supervisors can inspect the road and their reports can vary. A research for a procedure of acceptable limits for the road surface needs to be undertaken as a management tool for the grading of the unsealed roads. Unfortunately the department only had the Roughometer for one month; therefore the author was unable to gather enough data to analysis. The data that was gathered using the Roughometer is in Appendix E.

All the above contributing factors plus other factors that have not been mentioned make it a challenge for maintaining a safe and trafficable surface with the available limited funds and resources.

Chapter 3

Low Volume Roads in Alice Springs Region

Central Australia is predominantly dry with brilliant blue skies especially from April to September. Rainfall usually occurs in the hottest months from October to March with a yearly average of only 275mm.

The average monthly rainfall and the average monthly maximum and minimum temperatures are given as wet weather and dry weather effect the deterioration of the low volume roads. From the data given it can be established when it is likely that wet and dry weather will effect the unsealed roads.

Table 3-1: Average monthly rainfall figures.

Month	Rainfall (mm)
January	35
February	42
March	33
April	13
May	21
June	15
July	15
August	10

Month	Rainfall (mm)
September	9
October	21
November	16
December	35

Temperatures in the low 40 degrees Celsius are not uncommon in the height of summer, while in winter overnight minimums sometimes drop to minus 7 degrees Celsius.

Table 3-2: Average monthly maximum and minimum temperatures.

Month	Maximum (^{o}C)	Minimum (^{o}C)
January	36	21
February	35	21
March	32	17
April	28	13
May	23	8
June	20	5
July	20	4
August	22	6

Month	Maximum (^{o}C)	Minimum (^{o}C)
September	27	10
October	31	15
November	34	18
December	35	20

Alice Springs Region has the responsibility for the management of approximately 8000 kilometres of roads with the majority been low volume unsealed roads. To appreciate the area that the road network covers a description is given. Taking Alice Springs as the reference point with the following distances given; North - 280 kilometres

South - 300 kilometres

West - 480 kilometres

East - 500 kilometres.

Territory Asset Management Services is responsible under contract to the Department of Infrastructure Planning and Environment for data collection, analysis and the operational management of the Departments traffic data acquisition program.

The Department of Infrastructure Planning and Environment utilises the traffic information for the following purposes:

- Road financing and budgeting
- Classification of roads and road network planning
- Development of programmes for the construction and maintenance of roads
- Development of road design standards

- The measurement of the level of service provided by the road system

Traffic data has been collated from the 2003 Annual Traffic Report to indicate that the majority of the roads in the Alice Springs Region are low volume roads. In table 3.3 an example of the roads with their Annual Average Daily Traffic (AADT) for 2003 and respective lengths are given such that an appreciation can be gained of the various lengths of roads with low volumes of traffic. The users of the unsealed low volume roads expect them to be trafficable, good riding qualities and open all year round. There are a number of other roads with less traffic than these given in the table 3.3 and single user accesses that can be up to 50 kilometres in length that are maintained by the department.

Table 3-3: Examples of some of the roads' classification, length, AADT and route in the Alice Springs Region for 2003 and (2002).

Road /Location of Counter	Length (km)	AADT	Route
Larapinta Drive 1km east of Larapinta/Namatjira junction 14km south of Meernie Oil Fields	Rural Secondary Seal: 129.04 Unseal: 191.93	 272 41	Alice Springs – Namatjira Intersection - Hermannsburg – Namatjira Intersection - Kings Canyon
Lasseter Highway 500m west of Stuart Highway 500m east of Yulara/Airport intersection	Rural-State Arterial Seal: 244.32	 356 418	Stuart Highway – Luritja Intersction - Yulara - Uluru (Ayers Rock)
Luritja Road 16km north of Lasseter Highway 500m east of Kings Canyon Ranger Station	Rural Secondary Seal: 167.11	 214(2002) 247	Lasseter Highway – Ernest Giles Road Intersection - Kings Canyon

Road /Location of Counter	**Length**	**AADT**	**Route**
Namatjira Drive 5km west of Larapinta/Namatjira Junction 5km south of Beer Can Corner	Rural Secondary Seal: 102 Unseal: 54.78	178 31	Larapinta Drive – Glen Helen – Beer Can Corner – Gosse Bluff – Larapinta Drive
Plenty Highway 16km east of Stuart Highway 56km east of Stuart Highway 10km east of Huckitta Station	Rural-State Arterial Seal: 96.87 Unseal: 402.02	128 77 25	Stuart Highway – Sandover Intersection – Harts Range – Queensland Border
Ross Highway 6.5km east of Stuart Highway	Rural Secondary Seal: 78.38	399	Stuart Highway – Ross River
Stuart Highway 3km north of Alice Springs 100km south of Alice Springs 200m north of Kulgera	Rural-National Highway Seal: 567.73	1060 513 321	Tennant Creek – Alice Springs – Lasseter Intersection – Kulgera-South Australia Border
Tanami Road 16km west of Stuart Highway 8km north of Kintore Road 50km west of Yuendumu	Rural-State Arterial Seal: 181.00 Unseal: 521.81	119 65(2002) 30(2002)	Stuart Highway – Kintore Intersection – Yuendumu – Granite Mine – Tanami Mine – Western Australia Border
Arapunya Road 8km north of Plenty Highway	Rural-Secodary Unseal: 153.50	11	Plenty Highway - Arapunya

Road/Location of Counter	**Length**	**AADT**	**Route**
Arltunga Road 5km north of Ross Highway	Rural-Secondary Unseal: 32.68	 39 (2002)	Ross Highway - Arltunga
Ernest Giles Road 2km west of Henbury Crater Intersection	Rural-Secondary Unseal: 99.09	 21(2002)	Stuart Highway – Henbury Carter Intersection – Luritja Road
Finke Road 10km east of Stuart Highway	Rural-Secondary Unseal: 249.28	 22(2002)	Stuart Highway - Finke
Kintore Road 32km west of Tanami Road	Rural Secondary Unseal: 379.80	 35(2002)	Tanami Road – Papunya – Kintore – Western Australia Border
Maryvale Road 16km south of Santa Teresa Road	Rural Secondary Unseal: 104.49	 56(2002)	Santa Teresa Road - Maryvale
Mulga Park Road 16km west of Stuart Highway 8km south of Lasseter Highway	Rural Secondary Unseal: 242.10	 24(2002) 18(2002)	Stuart Highway – Amata Access Intersection – Lasseter Highway
Namatjira/Kintore Link 5km west of Beer Can Corner	Rural Secondary Unseal: 61.87	 14(2002)	Namatjira Drive – Kintore Road
Ringwood Road 32km east of Ross Highway	Rural Secondary Unseal: 156.50	 14(2002)	Ross Highway – Colson Track

Road/Location of Counter	**Length**	**AADT**	**Route**
Sandover Highway 10km north of Plenty Highway	Rural Secondary Unseal: 217.24	26	Plenty Highway – Queensland Border
Santa Teresa Road 16km south of Maryvale Turnoff	Rural Secondary Unseal: 314.70	71(2002)	Stuart Highway – Maryvale Turnoff – Santa Teresa
Tjukaruru Road 32km west of Mount Olga Turnoff	Rural Secondary Unseal: 189.80	22	Kata Juta Road – Docker River – Western Australia Border

Dry weather deterioration of the unsealed roads is a problem in the Alice Springs Region:

- Wear and abrasion of the road surface which generates loose materials and develops ruts.
- Loss of the fines from the surface by traffic and wind.
- The movement of loose material into corrugations under traffic actions.
- Ravelling of the road surface caused by insufficient binding power of the material to keep an intact wearing course. This results in the forming of depressions which results in decreased riding qualities.

The most important parameter to influence ride quality and acceptability of unpaved roads are corrugations which appear on nearly all of The Alice Springs Region unsealed roads. The road surface is composed of granular material in heaps traverse to the direction of traffic at different wave lengths. They can cause considerable damage to vehicles suspension systems. Corrugations also lead to intermittent loss of contact between tyres and pavement, reducing the effectiveness of steering and braking, thus reducing considerably effective vehicle control.

Some causes of corrugation are:

- Stoney material.
- Material with high plasticity and weak specific gravity.
- Material with low cohesion.
- Areas of cornering, braking and acceleration.

'To predict the optimal blading frequency of unpaved roads it is important to know the roughness levels of the existing road network, the velocity of its degradation and efficiency of blading activates' (Dierks, 1992)

A Roughometer developed by ARRB was acquired by the department to trail and analyse how the results could be assist with the management of maintenance of the roads. From the results obtained a system was going to be developed to assess if the unsealed road required a grade or not. Unfortunately the Roughometer was with the Alice Springs Region for one month before it was returned to ARRB in Melbourne for an upgrade. A few trials runs were undertaken along the Maryvale Road. This particular road was chosen as it is close to Alice Springs which attracts ministerials and numerous complaints from the road users concerning the roughness of the pavement. Due to a few problems encountered the author could not achieve adequate conclusive data before the Roughometer was dispatched to ARRB. One of the problems encountered was the speed of the vehicle as this is important for accuracy and reliability of the results. The speed of travel is 50 – 60 km/h (ARRB Roughometer manual, 2003) but on a long length of road over 200 kilometres this can be very tedious for the operator. The information regarding the problems and results obtained is available in the Appendix E, Roughometer.

This next paragraph is an example of a maintenance issue that the Alice Springs Region has to contend with. Wet weather is not the only cause for a road to become impassable, extended periods of dry weather is a problem for the road pavement. Along the Plenty Highway from chainage 430 km to 500 km which is towards the Queensland border the road is breaking up and turning to bull dust in areas varying from 100 meters to 3km long. Vehicles have been getting dry bogged in some of the bull dust holes. There is no moisture left to bind the gravel in the pavement and formation because this area has been in a period of drought. For the past 2 years there has only been 60mm of rain. Another contributing factor has been that for the months of April, May and June there had been a lot of road trains over this area with the Pastoralists moving cattle. During the months of August and September 2004 the period contractor was repairing the bull dust holes, which had not been allowed for in the maintenance budget. The bull dust which varies from 300mm to 600mm in depth is been graded to the side of the road. The uneven surface is watered and the following day it is been ripped and recompacted to obtain an even surface. The bull dust which consists of sand clay and stones is brought back onto the compacted surface, mixed with water, spread and compacted in 150mm thick layers. If there is no rain within 3 months the road surface should be evaluated and if showing signs of stress, consideration should be given to the mobilisation of a water cart to the area. The theory behind this is to get moisture into the pavement to avoid it breaking up as road trains pass over this section. Sixty percent of the 2004/2005 maintenance budget for the Plenty Highway will be spend repairing the bull dust holes therefore one less maintenance grade will have to be done compared to last year and no other maintenance activities undertaken.

There has been a push by the tourism industry to attract more local tourists to visit Central Australia since the 11 September 2001 Twin Towers incident which led to a decrease in the number of international tourists. With the increase of local tourists and self drive tourists this is adding addition pressure on the recommended 4 wheel drive roads and the rural state arterial roads for the level of service that is expected on the roads. For example the Northern Territory Government has taken ownership of Owen Springs which use to be Pastoral land. A section belongs to the Parks and Wildlife Commission which is a 56 km long 4 wheel drive route from the Stuart Highway through to Larapinta Drive. This road is breaking up and whenever there are a few millimetres of rain there are scours across the road because there are no floodways. This road used to be a Pastoral road which would average 5 vehicles a week and now it is carrying over 80 vehicles a week. This road was never constructed for this amount of traffic, which is causing it to deteriorate rapidly.

Dust is another concern for the travelling public on unsealed roads for the following reasons:

- Visibility is greatly reduced.
- Dust is an important contributing factor to passenger discomfort.
- Dust increases the wear and tear in moving parts of a vehicle.
- Dust effects roadside vegetation in a negative way which still has to be quantified by research.

With the vast network that the Alice Springs Region has to maintain and the associated problems is a real challenge with the limited funds that are allocated. If efficient and innovative maintenance practices are researched which could be applied in the Region to enable a safer pavement, better value for the dollar and places less demand on the diminishing resources, this would be beneficial to all stakeholders.

Chapter 4

Factors which influence the deterioration of unsealed roads

The rate of deterioration of an unsealed road is influenced by one or more of the following factors:

- Climate
- Road geometry
- Road design
- Gravel material quality
- Construction standards
- Maintenance practices
- Drainage provisions
- Traffic volumes and type
- Age of the road

The severity of deficiencies which can be tolerated is influenced by the parameters listed above. Intervention levels need to define the severity levels for road defects at which either maintenance action is justified or at which rehabilitation is warranted.

4.1 Climate

In arid regions and times of drought the pavement is dried out excessively which leads to the pavement breaking up and sand clay pavements are prone in sections to turn to bull dust. This is the case as most unsealed roads depend on pore suction to bond the material together. With pore suction, water is lost by evaporation from the pavement surface and replaced by water from the lower levels in the pavement structure.

Dry season dust loss leads to the surface disintegrating, to be washed away during the rainy season.

A number of the unpaved surfaces are severely damaged when traversed by vehicles in wet weather. A common form of damage is the development of wheel ruts which are deepened and made worse by succeeding vehicles tracking plus the ruts themselves hold water. The surrounding pavement surface can appear to be dry but with vehicles tracking sub surface water can be brought to the surface by capillary action, which in turn makes the tracks very muddy and they hold water.

4.2 Road Geometry

The gravel surface of the road is not waterproof therefore the crossfall should be between four to six percent. This is to enable the removal of the surface water as quick as possible from the unpaved formation. The other problem is a steep crossfall that leads to a unsafe condition in which the travelling public does not feel comfortable staying in the correct lane. Because of the excessive crown, drivers begin to feel a slight loss of control of the vehicle as it wants to slide towards the shoulder. For this reason the drivers will tend to drive down the middle of the road regardless of how wide the road is.

Pondering of water in depressions in the pavement can have serious results because of the consequent weakening of the pavement material and its displacement under wheel loading. Not only do the deepened depressions become potholes but they also assist the entry of the water to the subgrade, thus leading to subsidence of the pavement surrounding the pothole.

> 'It is best to aim for a poor road pavement on a good alignment than to have a good road pavement on a poor alignment. Road pavements can be improved over time but once the alignment is set it is a more difficult task to correct deficiencies later.'(ARRB, 2000, Pg 4.6)

According to the ARRB Unsealed Roads Manual, unsealed roads with longitudinal grades >6% are more subjected to longitudinal scour than roads of flatter grades. Scouring leads to sediment build up in table drains plus the scouring is of a safety concern to the travelling public.

Horizontal curves on unsealed roads may require superelevation to maintain driver comfort and safety. Superelevated roads have high crossfalls, which increase the potential erosion risk. Careful management of superelevated roads will reduce their impact as well as the use of good quality pavement material if available to minimise the erosion around the curve.

4.3 Road design

Road design is concerned with the structural strength of the road. Rutting can be caused through failure of subgrade, basecourse or surface material as a result of excessive quantities of water entering the pavement and/or subgrade or insufficient pavement depth.

Vehicles have increased in size and horsepower. The effect of the larger and heavier vehicles on paved roads is well understood. There is a definite need to build stronger bases and pavements but the effect on gravels roads is just as serious and often not recognised. The strength of the subgrade and depth of material required to carry today’s heavy loads must be considered.

Grading frequency is highly dependent on the quality of the base material therefore a well designed base needs less grading.

4.4 Gravel material quality

There is significant gravel loss experienced due to the loosened pavement because of poor gravel, moisture and maintenance procedures.

Most unpaved roads are composed of the natural material which is often marginal or non-standard is found in the top layers of the ground over which the road passes. The material quality varies over a wide range from plastic clays that are unstable when wet to natural gravels that are capable of supporting traffic under all weather conditions, provided they have been properly compacted.

Potholing is a common defect because the surface material may vary widely in quality with numerous unstable patches.

According to a study conducted by Ms. Anne Valkonen from Tampere University of Technology in Finland (Valkonen, 2001), the particle size distribution of coarse material (0.063 – 16 mm) does not explain the surface quality of gravel road: there were the same kind of materials in different roads and they did not perform equally, even on the same road the same material performed differently depending on the surroundings. There are supposed to be more powerful factors than particle size distribution of coarse material which affect the deterioration of the surface layer. Clay content (amount of particles finer than 0.002mm) of surface material explained deterioration in some cases quite well. Low clay content, in dry conditions, indicates ravelling and dusting, whereas high clay content in moist conditions indicates potholes and ruts.

For the ease of grading and compaction and for the safety and comfort of traffic, it is desirable that 100% of stone should pass 26.5mm (or preferably 20mm if economical).

4.5 Construction standards

Adhere to good construction standards and procedures and not to be relaxed because it is a low volume unsealed road. The pavement of an unsealed road has to carry the same type of vehicles and loads as other roads plus the expectation of the road user is similar to other roads.

To compact road materials effectively, the minimum depth of the layer should be 2.5 times the nominal stone size.

With unsealed low volume roads limited density tests and pavement layer thickness checks are carried out on the pavement. This means that there is not adequate control on the conformance of the gravel and may initial look good but a few months later the pavement can be liable to failure.

Road construction sites have the potential to significantly affect the local environment. It is very important to clear only what is necessary. Over-clearing increases the impact of the road on the environment, as well as increasing the construction costs and future maintenance costs.

Once a site has been disturbed for construction, it becomes susceptible to erosion which has the potential to become a maintenance issue, placing an addition burden on the limited available funds.

4.6 Maintenance practices

> 'Grading, irrespective of the task being undertaken, is the single most important function in maintaining an unsealed road network. It achieves the standard set by the maintenance policy.' (ARRB,2000, Pg2.19)

The widths of some of the unsealed roads are up to 16 metres wide. This has come about from a combination of gravel been pushed to the side by passing traffic and the graders working beyond the original road width searching for material to drag across the road surface. This is a common problem with the dry grading technique which increases the area of the road to be maintained and encourages excessive speeds along the straight sections of the road. Another problem is not maintaining the crossfall of the pavement.

According to the Gravel Roads Maintenance and Design Manual produced by the U.S. Department of Transport, the grader is the primary machine for the maintenance of the unsealed road surface (U.S. Department of Transport, 2000). Operating speed of the grading operation must not be excessive as this has caused problems on many roads. It is virtually impossible to do good work above a top speed of 5 to 8 km/h. When the grader begins to lope or bounce, it will cut depressions and leave ridges in the road surface. Other factors affecting the speed of the grader are material, moisture and subgrade stability.

Gravel for patching is obtained from nearby pits and creeks, fines (clay) are used as a binder when available. Water is not used for the dry maintenance procedures. Very little rolling is carried out and would be basically ineffective except after wet periods.

With the dry maintenance procedure a full resheet or reconstruction of the pavement is required about every seven years. Maintaining a vast unseal road network the full resheet or reconstruction of the pavement is often not carried out when it is required because of inadequate funding.

4.7 Drainage provisions

One of the most important aspects of a road design is the provision made for protecting the road pavement from surface and ground water.

The road must be constructed with a 4 - 6% crossfall and shaped to a crown to effectively shed surface water.

The pavement is weakened by water penetrating it which makes the pavement more susceptible to damage by traffic.

In rural situations drainage of the roadside is undertaken primarily to prevent water lying in depressions where it could cause damage to the road formation.

The function of the table drain is to collect water that has fallen on the carriageway or the batters of the cutting and flowed to the edge of the formation. Table drains require frequent maintenance to remove silt, plant growth and other debris that may easily block the flow, and to be restored to the original shape. Poor maintenance of table drains causes pondering of water after rain which in turn is liable to soak into the road formation.

Poor table drain and pavement drainage design can lead soil erosion.

4.8 Traffic volumes and type

Some of the unsealed roads have low traffic volumes but high wear from heavy freight road trains. There is the seasonal change of the traffic volume such as tourism, cattle movement and crops.

4.9 Age of the road

Roads have a limited life span and as they get older they require more maintenance than a young road. This can be due to the following mentioned parameters but not limited for example; the road has lost its shape, depressions caused through the gravel failure, material unravelling and no base left which means that the vehicles are travelling on top of the subgrade.

Chapter 5

Low Volume Road maintenance practices

5.1 Current Maintenance Practices in the Alice Springs Region

In the Northern Territory contracting out of Repairs and Maintenance commenced in 1983/84 and transitioned from a mix of Day Labour/Plant Hire to full contract maintenance by 1991. 100% of work is contracted out on a competitive basis for Repairs and Maintenance, Specific and Capital Works. There is no in-house bidding or use of municipalities to provide construction and maintenance services.

The Alice Springs Region is spilt into four maintenance regions with Alice Springs been the central point; South East, North East, South West, North West and there is a field supervisor responsible for each region. An example of a road from each region is given below so that an appreciation of the area that has to be maintained with the limited funding for the financial year 2004/2005 is gained and the challenge that is faced.

- Northwest Region – Tanami Road – 702.81km - $800,000.00 – $1,139.31/km
- Northeast Region – Plenty Highway – 498.89km - $320,000.00 - $641.42/km
- Southwest Region – Tjukaruru Road (Docker River) – 189.80km - $80,000.00 - $421.50/km
- Southeast Region – Maryvale Road – 104.49km – $50,000.00 - $478.51/km

> ‘A typical range for maintenance costs of rural roads built to Austroads design requirements should be in the order of $750 to $2,000.00 per km.’ (Murphy 2001, vol.7.2)

For the management of the period contracts the Alice Springs Region is split into the Western Region and Eastern Region with the Stuart Highway being the dividing line which is demonstrated on the regional maps in Appendix B.

The following period maintenance contracts are in place:

- Western Region 12 months Period Contract Maintenance of Roadside Furniture, Concrete works and Minor Plant Hire.
- Eastern Region 12 months Period Contract Maintenance of Roadside Furniture, Concrete works and Minor Plant Hire.
- Western Region 12 months Period Contract Maintenance Grading.
- Eastern Region 12 months Period Contract Maintenance Grading.
- Western Region 12 months Period Contract – Roads Recompaction and Gravel Resheeting.
- Eastern Region 12 months Period Contract – Roads Recompaction and Gravel Resheeting.

The contracts are initially awarded for 12 months and are renewable for a further 2 x 12 months. At the end of the contract period, public tenders are sought from private enterprise.

All maintenance work to be undertaken is scoped by the field supervisor and he will discuss this with the project officer to establish if it is appropriate, how it fits in with the priority list and available funds. Once the scope of works has been agreed with, the supervisor will complete the necessary documentation and liaise with the appropriate period contractor.

Grading of the unsealed roads in the Alice Springs Region are dry graded resulting in excessive amount of loose material on the road surface, insufficient crossfall, pavement wider than 8 metres, a number of roads below natural surface level and minimal pavement material left, average of 30mm. Specific maintenance of the unsealed road network to resheet sections of pavement or lift and compact is up against major competition with the rest of the Northern Territory limited road budget. With the specific maintenance areas are done that have the best value for money or as it is said in the region ‘best bang for the buck’. The following criteria is taken into consideration when nominating and allocating funds for a specific maintenance project; AADT, who the road services, who uses the road and destination. A number of roads are behind on their program to be resheeted and the vehicles are travelling along the subgrade.

The grading is done on a rotational schedule which is influenced by the budget plus the ‘squeaky wheel syndrome’, which is when a road user complains about the roughness of the road and the road is graded because of the complaint and not good maintenance decisions based on measurable data such as the roughness of the pavement.

Typically dry maintenance grading is performed approximately every 2 – 3 months on Rural – State Arterial Class Roads and approximately every 4 – 6 months on Rural – Secondary Class Roads. Opportunity is taken of the wet periods when they occur, however these can be very limited as they are generally only short periods of wet and there is a vast network of unseal roads to be maintained.

Moisture greatly influences the effectiveness of the grading operation with best results when the surface is reasonably firm and when there is enough moisture retained to facilitate cutting, moving and compacting materials.

For works associated with maintenance grading of unsealed roads and verges the following table which is included in the grading specifications indicates the expected achievable minimum daily production under normal weather conditions.

Table 5-1-1: Expected achievable minimum daily production extracted from the departmental grading specification

Opening Grade	40km
Carriageway Grade	15km
Grade between inverts	10km
Grade between batters	5km
Full Maintenance Grade	5km

Grade and Roll	3km
Grade Water and Roll	2km
Rip and Recompact	1km

During the grading maintenance gravel for patching is obtained from near by pits and creeks. Very little rolling is carried out and would be basically ineffective except after wet periods when there is in situ moisture available.

With the grading process additional material is brought in from the pavement edge as required which has resulted in an increase of the pavement width. The formation width which should be up to 9 metres wide depending on the road classification can be up 16 metres wide in areas. Wide pavements are created by hunting for fine material from the pavement edge. With the wider formation width it can take 8 – 9 passes of the grader to dry grade plus more material to replace, compared to the 5 passes for a standard formation. This adds to the cost of maintenance because of the additional passes that the grader has to undertake and a waste of time. Another problem with wide pavements is that it encourages excessive speeds along the straight sections of the road which is a safety issue as the condition of the pavement can suddenly change. A widening pavement means increased environmental impacts.

Cutting of the existing pavement surface is to be avoided when dry grading a road as this could lead to the break up of the pavement surface. Plucking of stones from the existing pavement surface by the grader is of assistance to the damage of the surface.

Dust is a considerable problem. In windless conditions the dust cloud can hung for long periods after the passage of vehicles causing associated visibility/safety problems. Dust is contributing factor to gravel loss from the pavement.

Minimal grade, water and roll or rip and recompact are undertaken. Water is supplied from bores and in areas it can be up to 50 kilometres between the water points which are vast lead distances for the haulage of the water and are uneconomical. ‘An economic haul distance from a bore is about 10km maximum and bores are therefore required roughly every 20km' (ARRB, 2000).

Where the surface of the roads are to be resheeted existing gravel pits are utilised. Majority of the gravel pits are at the end of their life or the material is not of good quality and does not meet the gravel specification. Some of the material is very slippery when it becomes wet with a Plasticity Index over 12% or there is a large portion of gravel retained on the 19.0mm sieve. In the Department's specification for gravel properties it is stated that for an unsealed base the Plasticity Index is to be between 4 – 12%. Minimal testing of the materials is performed.

5.2 Maintenance Practices Elsewhere

In Botswana extensive use is made of a process called Road Cushion ® which is of similar climate to Central Australia and is believed to preform best where the annual rainfall is less than 600mm. The annual average rainfall in Central Australia is 275mm. Road Cushion ® is not intended to improve poor quality roads but rather to preserve roads of good quality (Jones 2002). Road Cushion ® involves the placing of a sacrificial layer of non-plastic fine material on top of the road base and maintaining the layer thickness between 10mm and 40mm and maximum particle size in the cushion of 20mm across the full pavement. This is followed by regular maintenance of the sacrificial layer by "tyre dragging" and occasional grading to replenish the road cushioning which is obtained from the batter. The "tyre dragging" is executed using a series of truck tyres which are pulled behind a vehicle at a speed of between 20 to 30 km/h. If the speed of dragging is too quick it will cause the tyre drag to skip which will be inefficient in re distributing the material. The frequency of "tyre dragging" is depended on the volume of traffic and type, which could be every 5 days to 14 days.

The Department of Infrastructure Planning and Environment Road Projects preformed trials on the Road Cushion ® at three selected locations in the Northern Territory in conjunction with ARRB Transport Research Ltd as the consultant over a one year period. The field trials were completed in March 2004.

Stabilisation of the base course with salt is used to prevent gravel been lost and to hold the base course together. Salt absorbs moisture from the atmosphere due to hygroscopic properties, which then reduces the tendency to loose fine materials which then ultimately leads to ravelling and loss of gravel.

> 'Atlantic Coast Salt Gravel Roads – The excellent and dust free riding quality of the salt-gravel roads is not only a function of the specific gravel materials used in this technique but also one of moisture conditions of the coastal mist. During the absence of the hygroscopic moisture during east wind conditions, rutting or ravelling in the wearing course of the salt-gravel pavement with a resulting deteriorating riding quality is the consequence. The contrary effect is achieved if isolated rainfalls are occurring with resulting slipperiness and after

> the drying–out process of the wearing course as very uneven, rough road surface.' (Dierks, 1992)

In the literature research the author was unable to locate documentation concerning the environmental effects the salt would have on the surrounding environment and if the salt leaches out of the pavement over time. Literature is available about the use of salt for winter road maintenance concerning the de-icing of the surface which explains the environmental impact of salt. There is a great difference between the amount of salt that is used for salt stabilisation and application of salt on the road way for winter maintenance. Another difference is that with salt stabilisation the salt is mixed into the gravel of the base course which is then compacted, where as for the winter maintenance the salt is spread on the surface of the road. The Transportation Association of Canada has a code of practice for salt management plans for winter maintenance dated July 2002.

In order to find optimal material properties for the salt stabilisation of roads, a correlation between the riding quality and adjacent material properties have to be established.

According to the Alice Springs Maintenance Manager during the year of 2001 along the Plenty Highway from chainage 345 kilometres to 351 kilometres a trail of salt stabilisation of the pavement was constructed to analysis the behaviour of the pavement. Calcrete gravel was stabilised with 2% salt by mass mixed in with the top 150mm layer. On the 14/08/2004 the author inspected the site and the ride quality was good with minimal dust. The surface still has its shape but is beginning to loose its fines from between the stones. So far there have been no problems according to the maintenance supervisor and the Pastoralists in the area, when the surface has been wet.

A sand clay section was salt stabilised along the Plenty Highway and in the dry weather has performed well. When it rains the section is extremely slippery and wheel marks very easily according to the maintenance supervisor which was confirmed by the Pastoralists in the area. After wet weather the graders have to be available to work the section, otherwise if the sand clay section dries out it is impossible to grade out the wheel ruts and if left would be a safety issue for the road user. To remove the dried wheel ruts from the pavement, the pavement has to be ripped, watered and recompacted. This places unnecessary expenses on the budget.

Pavement stabilisation is utilised in unsealed roads usually to reduce the maintenance costs, improve material properties and to provide a better all-weather pavement. Stabilisation rectifies deficiencies in materials which allow unsuitable materials to be used in the pavement. Stabilisation has the benefits of improving the surface condition through less dust, rutting, potholes and corrugation which can contribute to reduced road user costs.

The correct use of stabilisation requires that the material property for improvement be clearly identified.

The most important properties are:

- strength
- volume stability
- abrasion resistance
- permeability
- durability

These parameters are important as they increase the life of the pavement, a surface that does not deteriorate rapidly, safe surface for the road user to travel along and reduced maintenance costs but the initial costs are high to construct compared to an unstabilised pavement.

Most stabilisation treatments will have an effect on all these properties; however each property is influenced to differing degrees by the various stabilisers.

Another alternative aimed at reducing the life-cycle cost of unsealed roads is to create a wearing course on top of the road base by using a mildly plastic material with a Plastic Index of between 10 and 15. The intention is to create a hard cap over the road base in order to prevent gravel from being lost which in turn causes the road base to lose its shape.

Wet maintenance is a heavier grade where water is added to the surface materials and compacted in the maintenance grading process. For wet maintenance the following machinery is required; grader, water cart and roller where as for dry maintenance only a grader is required. An average of 2 kilometres a day is completed by means of wet maintenance compared to dry maintenance an average distance of 10 kilometres is graded a day.

The wet maintenance procedure is where the pavement is ripped, reformed and fines recombined in the pavement layer and compacted, reducing the required number of routine maintenance cycles by providing a tighter and more compact and coherent surface. This reduction can be from as many as six or more grades per year to only one or two. Graders should operate with an even number of passes to avoid cutting over the centreline, removing the crown of the road.

Chapter 6

Research Methodology

Reviewed existing literature obtained from libraries, manufactures, internet research, Main Road authorities and various associations on road maintenance practices. The areas of interest were factors which influence the deterioration of roads, grading, gravel behaviour, maintenance techniques and innovative maintenance practices for low volume roads. Researched low volume road maintenance practices of countries with similar climate and issues as Australia.

The Alice Springs Maintenance Manager and field supervisors were consulted with reference to the maintenance practices in the region plus the problems associated with maintenance in an arid region.

Examination of current maintenance techniques used on unsealed roads in the Alice Springs Region was conducted.

Field inspections of the road sections that were used as trails for the prediction of the behaviour of gravel were undertaken.

Evaluated the information obtained from the literature research and proposed innovative maintenance practices that improve effectiveness and efficiency in consultation with the Maintenance Manager and field supervisors.

Interrogated and evaluated the implications of the life cycle costs and resources availability of applying selected maintenance innovations in the Alice Springs Region.

Chapter 7

Innovative Maintenance Practices

Knowing the behaviour of the material is of assistance to be able to plan where it is placed along the road. For example if the material is erodible then consideration would have to be given to the crossfall of the road and the superelevation on the curves. This is so that they are not too steep that the velocity of the water flowing off the pavement would erode the pavement leaving scours. This could be a saving to the maintenance budget if the correct balance is achieved as it would not have to be repaired every time it rains.

The material that is used for the pavement we are unable to predict with certainty how it will perform apart from experience. It is important to be able to predict how the material will preform as this will effect the maintenance of the road as well as how often and what type of maintenance is undertaken. Performance models 'work undertaken by Paige Green developed relationships between sheeting material performance and classification parameters' (Andrew, 2001) is where the grading properties and linear shrinkage of material is applied in a formula and then plotted onto a graph to establish the performance of the material. This is a relatively cheap and simple way to establish how a particular material will behave under traffic. It could be of higher costs to place material who's preformance is rated good compared to one that is rated erodible but there would be savings in the maintain of the pavement. The behaviour of the pavement material effects the ride ability which is important to the travelling public and can be a safety issue.

The relationship between Shrinkage Product and Grading Coefficient preform is illustrated in figure 7.1.

Shrinkage Product: $S_p = L_s \cdot P_{0.425}$ (L_s = Linear Shrinkage, $P_{0.425}$ = Percentage passing 0.425mm sieve)

Grading Coefficient: $G_c = (P_{26.5} - P_{2.0}) * P_{4.75} / 100$ ($P_{26.5}$, $P_{4.75}$, $P_{2.0}$ = Percentage passing sieve sizes)

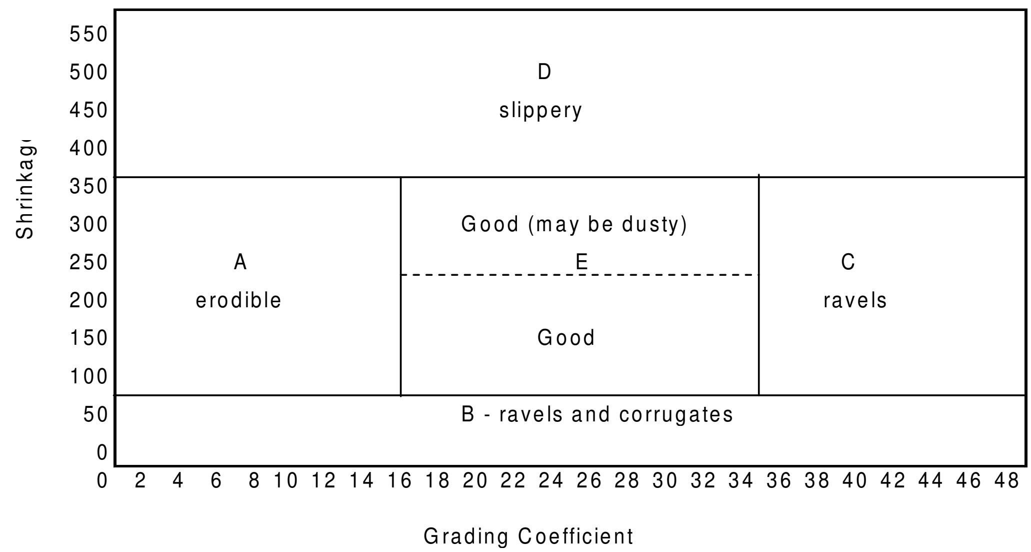

Figure 7-1: Relationship between shrinkage product and grading coefficient. (Paige-Green 1996)

The following conclusions can be drawn about each zone (A to E) on the figure about the materials:

A. Generally preform satisfactorily but are finely graded and particularly prone to erosion: they should be avoid if possible, especially on steep grades and sections with steep crossfalls and superelevations.

B. Generally lack cohesion and are highly susceptible to the formation of loose material and corrugations.

C. Generally comprise fine, gap-graded gravels lacking adequate cohesion, resulting in ravelling and the production of loose material.

D. Materials with a shrinkage product in excess of 365 tend to be slippery when wet.

E. Materials in this zone perform well in general, provided the oversize is restricted to the recommended limits.

Samples of material were obtained from three sites where resheeting of the pavement was been undertaken to assess the predicted behaviour of the material once completed and plotted onto the graph in figure 7.1. The author visited the sites four months after the samples were taken to assess the behaviour of the pavement. Unfortunately this project will be completed before another site visit is undertaken. The sites should be monitored for 2 years at least to ascertain how the material behaviour in different weather conditions, traffic patterns and over time.

The calculations have been completed with the material passing the 2.36mm and not the 2.0mm sieve. The Particle Size Distribution is preformed to Australian Standards and the 2.0mm sieve is not part of the test.

The Particle Size Distribution graphs and Atterberg Limits for all the samples taken are available in Appendix A.

Four samples were taken between chainage 435.9 km to 437.1 km on the Tanami Road on the 18/03/2004.

Sample Number: 18107 Calcrete Gravel

Shrinkage Product: $S_p = L_s . P_{0.425} = 6 \times 34 = 204$

Grading Coefficient: $G_c = (P_{26.5} – P_{2.0}) * P_{4.75} / 100 = (97 – 46) \times 54/100 = 28$

Zone E – Good

Plasticity Index (PI) – 10

Sample Number: 18108 Calcrete Gravel

$S_p = L_s . P_{0.425} = 5.5 \times 36 = 198$

$G_c = (P_{26.5} – P_{2.0}) * P_{4.75} / 100 = (91 – 51) \times 58/100 = 23$

Good

PI – 12

<u>Sample Number: 18109</u> Calcrete Gravel

$S_p = L_s \, . \, P_{0.425} = 5.5 \times 35 = 192.5$

$G_c = (P_{26.5} - P_{2.0}) * P_{4.75} / 100 = (96 - 48) \times 56/100 = 27$

Good

PI – 11

<u>Sample Number: 18110</u> Calcrete Gravel

$S_p = L_s \, . \, P_{0.425} = 4.5 \times 36 = 162$

$G_c = (P_{26.5} - P_{2.0}) * P_{4.75} / 100 = (94 - 48) \times 56/100 = 26$

Good

PI – 7

The site was inspected on the 13/08/2004. Surface was tight and had its shape. No evidence of ravelling and very minimal dust. This agreed with the chart in figure 7.1.

One sample was taken in the sand clay section at chainage 222.8 km on the 5/05/2004. This was a repair of a depression of a length of 200 metres. This is in a 30 kilometre section of sand clay.

<u>Sample Number: 18479</u> Red/brown sand clay

$S_p = L_s \, . \, P_{0.425} = 1.0 \times 67 = 67$

$G_c = (P_{26.5} - P_{2.0}) * P_{4.75} / 100 = (100 - 100) \times 100/100 = 0$

Ravels and corrugates

PI – 6

This site was inspected on the 12/08/2004. There was a loose layer of sand covering the pavement which had unravelled from the sand clay and corrugations had formed. A lot of dust was stirred up by passing traffic. This agrees with the chart in figure 7.1.

Four samples were taken between chainage 296.2 km to 297.6 km on the Plenty Highway on the 23/04/2004.

Sample Number: 18406 Red/Brown Clayey Calcrete Gravel

$S_p = L_s . P_{0.425} = 7 \text{ x } 46 = 322$

$G_c = (P_{26.5} – P_{2.0}) * P_{4.75} / 100 = (97 – 59) \text{ x } 68/100 = 26$

E – Good

PI – 15

Sample Number: 18407 Red/Brown Clayey Calcrete Gravel

$S_p = L_s . P_{0.425} = 7 \text{ x } 47 = 329$

$G_c = (P_{26.5} – P_{2.0}) * P_{4.75} / 100 = (96 – 62) \text{ x } 73/100 = 25$

E – Good

PI – 16

Sample Number:18408 Red/Brown Clayey Calcrete Gravel

$S_p = L_s . P_{0.425} = 8 \text{ x } 44 = 352$

$G_c = (P_{26.5} – P_{2.0}) * P_{4.75} / 100 = (98 – 60) \text{ x } 70/100 = 27$

E – Good on the border of D – slippery

PI – 18

Sample Number: 18411 Red/Brown Clayey Calcrete Gravel

$S_p = L_s . P_{0.425} = 10.5 \times 35 = 367.5$

$G_c = (P_{26.5} - P_{2.0}) * P_{4.75} / 100 = (91 - 51) \times 61/100 = 24$

D – Slippery

PI – 21

On the 18/08/2004 this section of the road was inspected. There was evidence of ravelling in areas and a bit of dust caused by vehicles travelling over the pavement which was tight and had its shape. There had been no rain to date and it would be recommended to monitor the behaviour of the gravel when wet. The gravel has a high Plasticity Index and it is recommended that the Plasticity Index should be below 12% for unsealed roads.

From the tests conducted and monitoring their behaviour on the road, they correspond with the zones on the chart. This is a useful tool to be used if a Particle Size Distribution, Atterberg Limits tests are preformed and then the Shrinkage Product and Grading Coefficient can be calculated. This is then plotted onto the relationship between shrinkage product and grading coefficient graph to ascertain the behaviour of the material.

Chapter 8

Availability of resources for the applying of selected maintenance innovations in the Alice Springs Region

8.1 Life Cycle Costs

With the region been vast and arid, majority of the water is obtained from bores. Along majority of the roads there are bores that are over 20 kilometres apart giving a lead distance of over 10 kilometres making it uneconomical to utilise the bore. Unfortunately they have to be used as there are no other alternative sources of water. In some instances the bores are shared with the Pastoralists who require water for their live stock, therefore a limited amount of water can be used.

A number of existing gravel pits are exhausted or the gravel is not of the specified grade. The other problem is that in some areas the gravel pits are over 20 kilometres apart.

Dry maintenance is utilised in the Alice Springs Region due to the limited funds and a vast network to maintain. With dry maintenance the pavement needs to be resheeted every 5 to 7 years (ARRB, 2000) but this is not achievable in the Alice Springs Region. For the 2004/2005 financial year there are funds to resheet 15 kilometres on the Plenty Highway and a 20 kilometre lift and compact sand clay section on the Tanami Road.

Assuming that each road would have 10% of its length resheeted each year meaning that every 10 years the road is resheeted. This would mean that the Plenty Highway would need 40 kilometres per year and the Tanami Road would need 50 kilometres per year to be resheeted, which is not been achieved. The rate to resheet a 1 kilometre length by 9 meter wide is $28,800.00 where there is no problem with the availability of water and gravel. This value has been calculated from the average contract values in the Alice Springs Region.

A comparison of the life cycle maintenance cost for 1 kilometre of the Plenty Highway over 30 year period for dry and wet maintenance is calculated in table 8.1. According to ARRB (ARRB, 2000) the interval for resheeting where wet maintenance is preformed is 20 – 25 years. The life cycle maintenance is calculated with a resheet every 10 years for dry maintenance and every 30 years for the wet maintenance. Wet maintenance has been stretched beyond the recommended 25 years as the dry maintenance is extended past the recommended 7 years due to the assumption that the 10% of the road would be resheeted each year. This means that with the dry maintenance a section of road would be resheeted every 10 years. The dry maintenance grading cycle is 4 per year and the wet maintenance frequency is every 9 months. The Plenty Highway is graded 4 times per year but with the available funds decreasing and the maintenance cost increasing will include a calculation for dry maintenance grading cycle of 3 per year. With the roads been of great lengths and the wet maintenance averages 2 kilometres a day would have to consider that the sections ahead of the wet maintenance will require a dry grade if the pavement has deteriorated but this will not be considered in the comparison. No consideration is given to the sections where the lead distance for the water and gravel is greater than 10 kilometres as this will increase the rate for the grade water roll and resheet.

For the calculation of the life cycle costs of dry maintenance versus wet maintenance the average of the current contract rates are utilised. The analysis has been calculated without discounting future values. This analysis has been to compare total costs rather than present and future values.

For a full maintenance grade, the following works are to be preformed. Grade the road formation width between the tops of both outer batters. Remove vegetation from the areas to be graded, and remove windrows which contain vegetation or other unsuitable materials by spreading them evenly outside of the outer batters. Win material from windrows which contain suitable material and the area back to the shoulder. Ensure that vegetation material is not included. Cut the pavement and shoulders to remove all corrugations and fill in all ruts, holes and depressions. Spread the accumulated material uniformly over the pavement and shoulders to fill depressions and to obtain a cross section with the appropriate cross fall. Prevent any excess material from washing back into the table drains, offlet drains and culverts. Reinstate table drains, offlet drains and table drain blocks and cut new offlet drains where water ponds.

For a pavement grade, the following works are to be preformed. Grade the area between the inverts of both table drains. Remove all vegetation from area to be graded. Win material from the area between the inverts of both table drains and the edges of the shoulder ensuring that vegetation is not included. Cut the pavement and shoulders to remove all corrugations and fill in all ruts, holes and depressions. Spread the accumulated material uniformly over the pavement and shoulders to fill depressions and to obtain a cross section with the appropriate cross fall. Reinstate table drain blocks.

For a grade water and roll, the following works are to be performed. Grade the area between the inverts of both table drains. Remove all vegetation from area to be graded. Win material from the area between the inverts of both table drains and the edges of the shoulder ensuring that vegetation is not included. Cut the pavement and shoulders to remove all corrugations and fill in all ruts, holes and depressions. Spread the accumulated material uniformly over the pavement and shoulders to fill depressions and to obtain a cross section with the appropriate cross fall. Wet mix and roll to produce a uniform and tightly bound surface free of ridges and depressions. Generally 10 or more passes of a 15 tonne multi tyred roller will be acceptable. Reinstate table drain blocks.

For the reinstate of a 150mm layer subgrade, allow for all works required for the reinstatement of the subgrade including but not limited to;

- Clear the batters and table drains of silt and growth.
- Removal of excess loose sand, ripping, reworking and recompacting.
- Heavy watering of subgrade area and reconstruction.
- Haul place and compact additional subgrade material in depressions and holes.
- Placement and compaction of won material from table drains.

- Grade water and roll to achieve subgrade surface.

For a pavement of 150mm lift, import new gravel. Mix, spread, trim and compact in one layer to the specified pavement width and crossfall. Maintain the subgrade surface during the trucking in of the pavement material.

The comparison is for a length of 1 kilometre length by a 9 metres wide pavement.

Dry Maintenance (3 grades)

Full maintenance grade	1 x $160 = $160
Pavement grade	2 x $115 = $230
Total	$390

Dry Maintenance (4 grades)

Full maintenance grade	1 x $160 = $160
Pavement grade	3 x $115 = $345
Total	$505

Wet Maintenance – Grade Water Roll

9000m^2 x $0.3267/m^2 = $2,940

Resheet 150mm layer (9000m^2)

Subgrade 150mm layer reinstate	$1.00/m^2 = $9,000
Pavement 150mm resheet	$2.20/m^2 = $19,800
	$28,000

The comparison is only considering the cost to the department and not the cost to the road user. The road is not brought to similar average surface conditions. It can be assumed that with the wet maintenance the cost to the road user would be less than the dry maintenance due to the fact that the road pavement is tighter, a uniform surface with its shape giving a smoother ride and less dust.

Table 8-1: Life Cycle Costs - Dry versus Wet Maintanance

Year	Process	Dry (3)	Dry (4)	Process	Wet
1	Resheet	$28,800	$28,800	Resheet	$28,800
1	Maintenance	$390	$505	Maintenance	$2,940
2	Maintenance	$390	$505	Maintenance	$2,940
3	Maintenance	$390	$505	Maintenance	$5,880
4	Maintenance	$390	$505	Maintenance	$2,940
5	Maintenance	$390	$505	Maintenance	$2,940
6	Maintenance	$390	$505	Maintenance	$5,880
7	Maintenance	$390	$505	Maintenance	$2,940
8	Maintenance	$390	$505	Maintenance	$2,940
9	Maintenance	$390	$505	Maintenance	$5,880
10	Resheet	$28,800	$28,800		

Year	Process	Dry (3)	Dry (4)	Process	Wet
10	Maintenance	$390	$505	Maintenance	$2,940
11	Maintenance	$390	$505	Maintenance	$2,940
12	Maintenance	$390	$505	Maintenance	$5,880
13	Maintenance	$390	$505	Maintenance	$2,940
14	Maintenance	$390	$505	Maintenance	$2,940
15	Maintenance	$390	$505	Maintenance	$5,880
16	Maintenance	$390	$505	Maintenance	$2,940
17	Maintenance	$390	$505	Maintenance	$2,940
18	Maintenance	$390	$505	Maintenance	$5,880
19	Maintenance	$390	$505	Maintenance	$2,940
20	Resheet	$28,800	$28,800		
20	Maintenance	$390	$505	Maintenance	$2,940

Year	Process	Dry (3)	Dry (4)	Process	Wet
21	Maintenance	$390	$505	Maintenance	$5,880
22	Maintenance	$390	$505	Maintenance	$2,940
23	Maintenance	$390	$505	Maintenance	$2,940
24	Maintenance	$390	$505	Maintenance	$5,880
25	Maintenance	$390	$505	Maintenance	$2,940
26	Maintenance	$390	$505	Maintenance	$2,940
27	Maintenance	$390	$505	Maintenance	$5,880
28	Maintenance	$390	$505	Maintenance	$2,940
29	Maintenance	$390	$505	Maintenance	$2,940
30	Resheet	$28,800	$28,800	Resheet	$28,800
30	Maintenance	$390	$505	Maintenance	$2,940
Total life:	$/km	**$126,900**	**$130,350**		**$172,260**

For the whole of life cost analysis the wet maintenance is the more expensive option over the 30 years. This could be due to the fact that water is not readily available plus there is an additional two items of plant. With wet maintenance the previous day's work requires to be back watered.

On the positive side there is less gravel used in wet maintenance due to the fact it is resheeted twice in a 30 year period compared to the dry maintenance where it is resheeted four times. There is a saving on the gravel which is becoming a scarce commodity and less of the land scape is scared due to the existing gravel pits been extended or opening of new gravel pits. The pavement is tight after the wet maintenance with no loose material on the pavement which will give a better ride ability and safer than the dry maintenance. The cost to the road user should be less than the dry maintenance as the surface deteriorates quicker than the wet maintenance.

For the establishment of new gravel pits it is an environmental issue as the vegetation is destroyed and have to ensure that the drainage of the area or water courses are not affected. Other issues that have to be checked and cleared is scared and heritage sites. Once the existing gravel pit is depleted there is a scar left on the landscape. A lot of time, effort and money have to be spent on the rehabilitation of the area which is an additional expense on the limited funds for road maintenance.

On the negative side the budget would not allow an entire road to be have wet maintenance for example the Plenty Highway which consists of 402 kilometres of unseal pavement.

Wet Maintenance would cost $1,181,880 (402km x $2,940) and a duration of 201 days calculated at 2 kilometres per day. This is 3.7 times the budget for the Plenty Highway and no other maintenance activities would be able to be undertaken. The author feels that if this length of work was put out to tender a competitive price would be obtained and could requested at least two grade water roll teams but would still be over budget.

Dry Maintenance for 4 grades a year is $203 010 (402km x $505) which is within the budget and enables other maintenance activities to be undertaken.

The financial benefit to the department between the wet and dry maintenance makes the dry maintenance very attractive even through there is no benefit the road.

8.2 Net Present Value

A brief investigation of Net Present Value which is also known as Present Worth for the maintenance of unsealed roads is discussed below.

To use the net present value method the following information is required; an assessment of the capital and maintenance costs and user benefits attributed to the road. The economic life of the project which for this analysis will be 10 years as that is when the road is due for a resheet utilising the dry maintenance method. The value of the rate of interest to be applied to the scheme is 5%.

The formula that will be used is:

$$NPV = Sum(A_t / (1+r)^t) - K$$

where A_t – user benefits, maintenance costs accruing in each time period,

K – capital expenditure,

r – rate of interest to be applied,

t – number of years ahead at which each benefit will accrue.

The vehicle operating costs were extracted from a trial that was undertaken on the Tanami Road in conjunction with ARRB for one year which concluded at the end of April 2004. The trial was to investigate the technical merit and cost benefit of various pavement maintenances of unsealed roads. The vehicle operating costs from this trial have been chosen as the AADT along the Tanami Road is similar to the Plenty Highway.

The vehicle operating costs incurred was calculated by AARB using HDM IV technology calibrated for Australia (ARRB, 2004). The vehicle operating costs over the year per vehicle for dry maintenance and wet maintenance is given in table 8.2.1. The vehicle operating costs for wet maintenance have adapted the wearing course vehicle operating cost as the wet maintenance has a tight pavement and not much loss gravel which is similar to the wearing course.

Table 8-2: Vehicle operating costs

Vehicle	Dry Maintenance	Wet Maintenance
Car	$3,981	$3,921
Ute	$370	$357
Light truck	$1,438	$1,399
Articulated truck	$735	$709
Road train	$3,564	$3,450
Total	**$10,088**	**$9,836**

Value of material that is lost needs to be considered.

Assuming that 10% gravel is lost each year with dry maintenance which means that after 10 years there would be no base course left; 10% of $28,800 = $2,880

Have assumed that there is no base course left after 30 years for wet maintenance; 3.3% of $28,800 = $950.

A total annual cost for dry maintenance is $10,088 + $2,880 + $505 = $13,473.

A total annual cost for one wet maintenance is $9,836 + $950 + $2,940 = $13,726.

A total annual cost for two wet maintenance is $9,836 + $950 + $5,880 = $16,660.

Table 8-3: Net Present Values - Dry versus Wet Maintenance

Year	Dry Total Cost	NPV Dry	Wet Total Cost	NPV Wet
1	$13,473.00	$12,831.43	$13,726.00	$13,072.38
2	$13,473.00	$12,220.41	$13,726.00	$12,449.89
3	$13,473.00	$11,638.48	$16,660.00	$14,391.53
4	$13,473.00	$11,084.27	$13,726.00	$11,292.41
5	$13,473.00	$10,556.45	$13,726.00	$10,754.68
6	$13,473.00	$10,053.76	$16,660.00	$12,431.95
7	$13,473.00	$9,575.01	$13,726.00	$9,754.81
8	$13,473.00	$9,119.06	$13,726.00	$9,290.30
9	$13,473.00	$8,684.82	$16,660.00	$10,739.18
10	$13,473.00	$8,271.25	$13,726.00	$8,426.57
	Sum:	$104,034.93	Sum:	$112,603.71
	NPV:	$75,234.93	NPV:	$83,803.71

From the net present values comparison calculations the dry maintenance is the cheaper of the two options and the cost to the department is less than the wet maintenance. This is constant with the dry maintenance versus wet maintenance life cycle costs. The road user does not benefit from the dry maintenance as their vehicle operating costs is higher than the wet maintenance. The other problem is that the dry maintenance loss of gravel is quicker than the wet maintenance.

Chapter 9

Discussion of maintenance of low volume roads

Alice Springs Region has approximately 8000 kilometres of low volume roads to maintain with a limited budget. Of this approximately 80 percent are unsealed low volume roads giving a length of around 6400 kilometres. Over 50 percentage of the unsealed roads are below the natural ground level which becomes a water way when it rains which in turn saturates the pavement or sections of the pavement is washed away which becomes a safety hazard.

From the examples of road classification, length and AADT given in Chapter 3 it can be seen that the majority of the unsealed sections have an AADT which is below 50 vehicles per day. With the roads having a very low AADT it is a very difficult task to justify why the maintenance funds have to be increased when compared with other roads with much higher AADT. Therefore smarter and innovative procedures have to be applied to obtain more value from the dollar for the department and road user.

There are factors that cause the deterioration of the unsealed roads that the Alice Springs Region has to contend with which place-added pressure on the limited funds. The factors been:

- Climate;
- Road geometry;
- Gravel material quality;
- Construction standards;
- Maintenance practices;
- Drainage provisions;
- Traffic volumes and type;
- Age of road.

For the Alice Springs Region to meet their road maintenance responsibilities and supply an acceptable level of service for the road user, they have to deal with numerous influences that include:

- An aging network;
- Changes in vehicle types and allowable vehicle loads;
- An increase in number of road users;
- An increase in the expectations of the road users;
- Road safety and litigation issues;
- Increasing competition for funds;
- Rising construction and maintenance costs;
- Limited resources such as water and gravel;
- Remoteness;
- Increasing environmental issues.

Existing gravel pits are used in the Alice Springs Region and the gravel is of a poor quality or the gravel pit is exhausted. Very limited conforming testing is done of the gravels. The department does not have its own soil-testing laboratory; therefore all soil testing is conducted by a private laboratory. The field supervisors who have been in the region for at least 10 years have acquired the knowledge of how the gravels will behave on the road. There are times when the gravel behaves differently to what is anticipated by the field supervisors and it is of a concern to them. The behaviour of the material was checked using the relationship between shrinkage product and grading coefficient developed by Paige Green in South Africa and was evaluated against 10 sites along two roads. The gravel had been tested and the necessary information extracted from the laboratory tests and plotted on the relationship between shrinkage product and grading coefficient graph. Four months after the initial tests a field trip was undertaken to the sites and the behaviour of the material was checked in the field, which was compared to the initial plotted results obtained. The field results agreed with the theoretical results. This is a useful tool for obtaining information about how the material will behave with traffic passing over it before it is used on the road. The testing is relevantly cheap if the field supervisors obtain a few samples from the gravel pit and deliver them to the soil testing laboratory before the material is placed on the road. This would enable the maintenance personnel to know how the gravel is going to behaviour and the appropriate placing of the material, such as to avoid gravel that lacks cohesion and is highly susceptible to the formation of loose material and corrugations on a horizontal curve. Need to avoid loose material and corrugations on a curve as this makes it difficult to control a vehicle and is of a safety concern.

Concerning maintenance practices from elsewhere, Road Cushion ® was studied and a trial in conjunction with ARRB Transport Research Ltd was conducted over a one-year period that was completed in March 2004. Road Cushion ® is utilized extensively in Botswana that has a similar climate to Central Australia and is believed to perform best where the annual rainfall is less than 600mm. Alice Springs Region has an average annual rainfall of 275mm, which was one of the deciding factors to evaluate the Road Cushion ®. Road Cushion ® is intend to protect the pavement so that the road user has a comfort surface to travel along, that minimum gravel is lost from the pavement and the shape of the pavement is not lost from grading. With minimum gravel lost from the pavement this would extent the period between resheets of the pavement, thus saving gravel, water and funds.

Salt stabilisation is used to prevent gravel from been lost and to hold the pavement together. The salt stabilised pavement is extremely hard and is a smooth surface plus dust is not a problem. Minimal maintenance is required, as the pavement does not require grading. If there is no moisture in the air then the occasional pass with the water cart would be required to hold the pavement together as the salt would not be obtaining the moisture from the atmosphere due to its hygroscopic properties.

The initial cost of salt stabilisation would be high but then the life cycle costs should be less than dry grading. Research is required on the maintenance regime and the expected life span of the pavement to analysis the life cycle costs compared to the dry maintenance. Another area of research is what environmental effect does salt stabilisation has on the surrounding area and the properties of the salt to be used.

Salt stabilisation is not to be used in conjunction with Road Cushion ® as they are individual methods that are to be used independently. The Road Cushion ® would be a barrier on top of the salt stabilised pavement thus preventing the salt from absorbing moisture from the atmosphere.

Road Cushion ® and salt stabilisation are able to extend the life cycle maintenance of unsealed roads as the pavement is given protection in the Road Cushion ® case and the pavement is held together in the salt stabilisation case. No costs were calculated as a 'tyre dragging' frequency has to be established for a particular road that the Road Cushion ® is used on plus how often the cushion has to be replenished. Another area that needs to be researched is how the pavement behaviours over time and what is the expected life span of the pavement which depends on the various gravels been used plus the type and volume of traffic.

Dry maintenance is used extensively in the Alice Springs Region and the main reason behind this is the cost compared to wet maintenance that makes it very attractive. Dry maintenance has a low affect on the funds and more area can be maintained in the short term, whereas other treatments have a high impact on the budget and less area can be maintained in the short term. Unfortunately with the funds received for maintenance it only allows for short-term solutions and long-term solutions costs make them undesirable to use even through they have many good advantages such as a safer surface, less user costs and saving of the resources.

There are a number of problems associated with dry grading. Over the years with dry grading a number of roads have been graded to below the natural ground surface, which is a problem when it rains. Another problem is through the sand dune country where the sand from the batters is blown onto the pavement and the graders are unable to grade the sand away from the road and over the batters due to the height of the batters. The sand remains in large windrows along the side of the road restricting the width of the carriageway and is a safety hazard to the road user.

The widths of various roads have been graded up to 16 meters wide where the maximum width should only be 9 meters wide depending on the classification of the road. This is due to the graders searching for material to spread across the pavement. Vegetation is unnecessarily destroyed and gravel is lost which is becoming a scare commodity. With wider pavements there is more surface area from where gravel is lost. Wider pavements add to the maintenance costs due to the increased number of times that a grader has to pass over that section of road. Another problem with excessively wide pavements is that it encourages speeding along the straight sections of the road, which lessens the control that the driver has of the vehicle. Over time the crossfall from the pavements are graded flat or a negative crossfall which means that when ever it rains the water lies on the pavement and cannot get away. This is due to the factor that grader operators do not pay particular attention to the fact that a even number of passes are required so as to avoid cutting the crown of the pavement. The crossfall should be maintained so that the water can be removed from the pavement quickly whenever it rain, so that the pavement does not become saturated.

With wet maintenance the width and crossfall of the pavement would be maintained plus the surface would be smoother than the dry maintenance. There would be less loose material and dust making it safer and a smoother ride for the road user. The user cost should be cheaper due to the pavement been smoother and less dust available effecting the working parts of a vehicle which will help to decrease the vehicle maintenance costs.

From the comparison that was calculated between the dry grade maintenance and wet maintenance over a 30-year period the dry maintenance is the cheaper option to the department but not necessarily the better option for the environment and the road user. One of the problems with the wet maintenance in some areas would be the availability of water and the question is what demand would it be placing on the water aquifer?

Chapter 10

Conclusion

It is a huge challenge for the Alice Springs Region to be able to maintain the vast road network that they are responsible for with the limited funds that they receive.

There are numerous factors that affect the deterioration of the low volume road plus the availability of resources is a problem. Gravel and water is becoming a depleted commodity that is adding to the challenges of maintaining unsealed roads. Maintenance funds per kilometre are below the value recommended by Austroads, which means that the roads are not receiving adequate maintenance.

In this project innovative maintenance practices have been researched and only the costs for wet maintenance versus dry maintenance have been calculated. It would be safe to say that the initial cost for setting up the innovative maintenance practices would be over the budget of the Alice Springs Region. An advantage with the innovative maintenance practices is that a better quality surface would be available for the travelling public therefore the user costs would be less compared to the dry maintenance of the road. Unfortunately with an inadequate budget it is the cost of maintaining the road that is important to the Department and not the cost to the road user.

In the Alice Springs Region there is scope for the improvement for the managing of the maintenance of low volume roads. A 10-year strategic plan for the maintenance that is required along the road needs to be plotted out with the required estimated funds. Ten years is to be considered as that is the required duration between resheets calculated that ten percentage of the road will be resheeted each year.

Fine tuning of the intervals between the dry maintenance of the unsealed roads would lead to a saving which could be utilised in other maintenance actives. This is why it is important to develop a strategic plan.

Further work is required on the environmental impact that salt stabilisation has or has not on the surrounding area, the quality of the salt to be considered, the costs to the Department and the road user, maintenance that is required and the predicted life span of the pavement.

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Appendix A

Project Specification

University of Southern Queensland
Faculty of Engineering and Surveying

ENG 4111/2 Research Project

PROJECT SPECIFICATION

ISSUE A – 18 March 2004

FOR:	Richard Underhill
TOPIC:	LIFE CYCLE MAINTENANCE OF LOW VOLUME ROADS
SUPERVISORS:	Dr David Thorpe
	Glen Auricht, Northern Territory Department of Infrastructure Planning and Environment – Road Projects

AIM:
Investigate and develop improvements to low volume road maintenance practices and procedures in the Alice Springs Region.

BACKGROUND:
With limited funding and resources for low volume roads, efficient maintenance management should be able to provide a road surface that is of an acceptable standard to the road users. Alice Springs Region has been performing the same maintenance practices with limited research of innovative methods. The methods researched will be used to examine the cost implications and resources availability.

PROGRAMME:

1. Review existing literature on road management practices, with particular emphasis on maintenance practices for low volume roads.
2. Gather data on low volume roads in the Alice Springs Region and factors which influence the deterioration of the road.
3. Collect and analyse data on current maintenance practices in the region.
4. Evaluate and propose innovative maintenance practices that improve effectiveness and efficiency, and promote sustainable use of materials.
5. Interrogate and evaluate the implications of the cost and resources availability of applying selected maintenance innovations in the region.
6. Report findings to peer group via oral presentations and in the required written format.

If time permits:

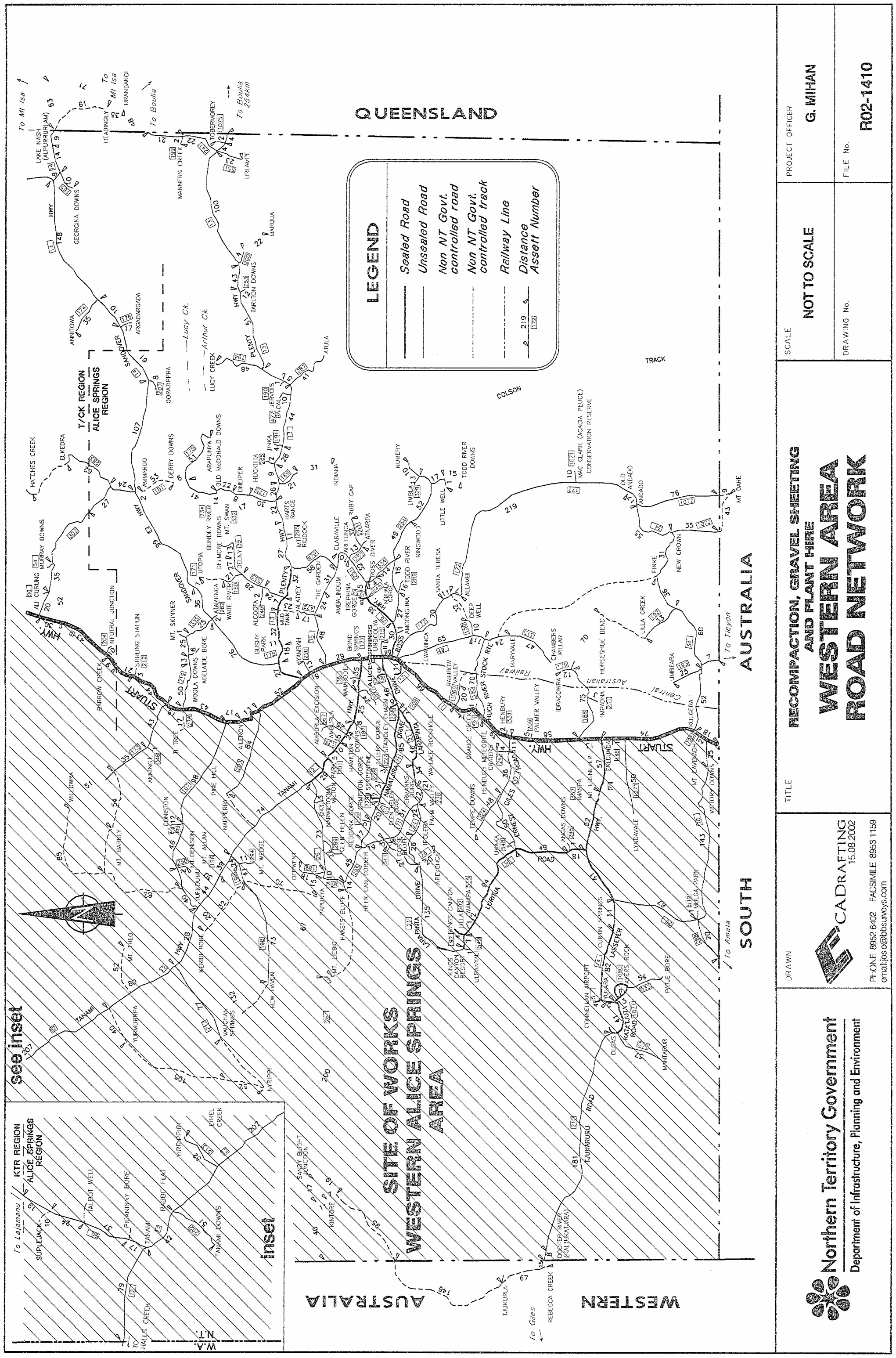
7. Evaluate and propose changes to the maintenance program to incorporate the proposed improvements to practices and procedures.

AGREED:
(Student) , (Supervisors)

18/03/04 18/3/04 26/3/04

Appendix B

Region Maps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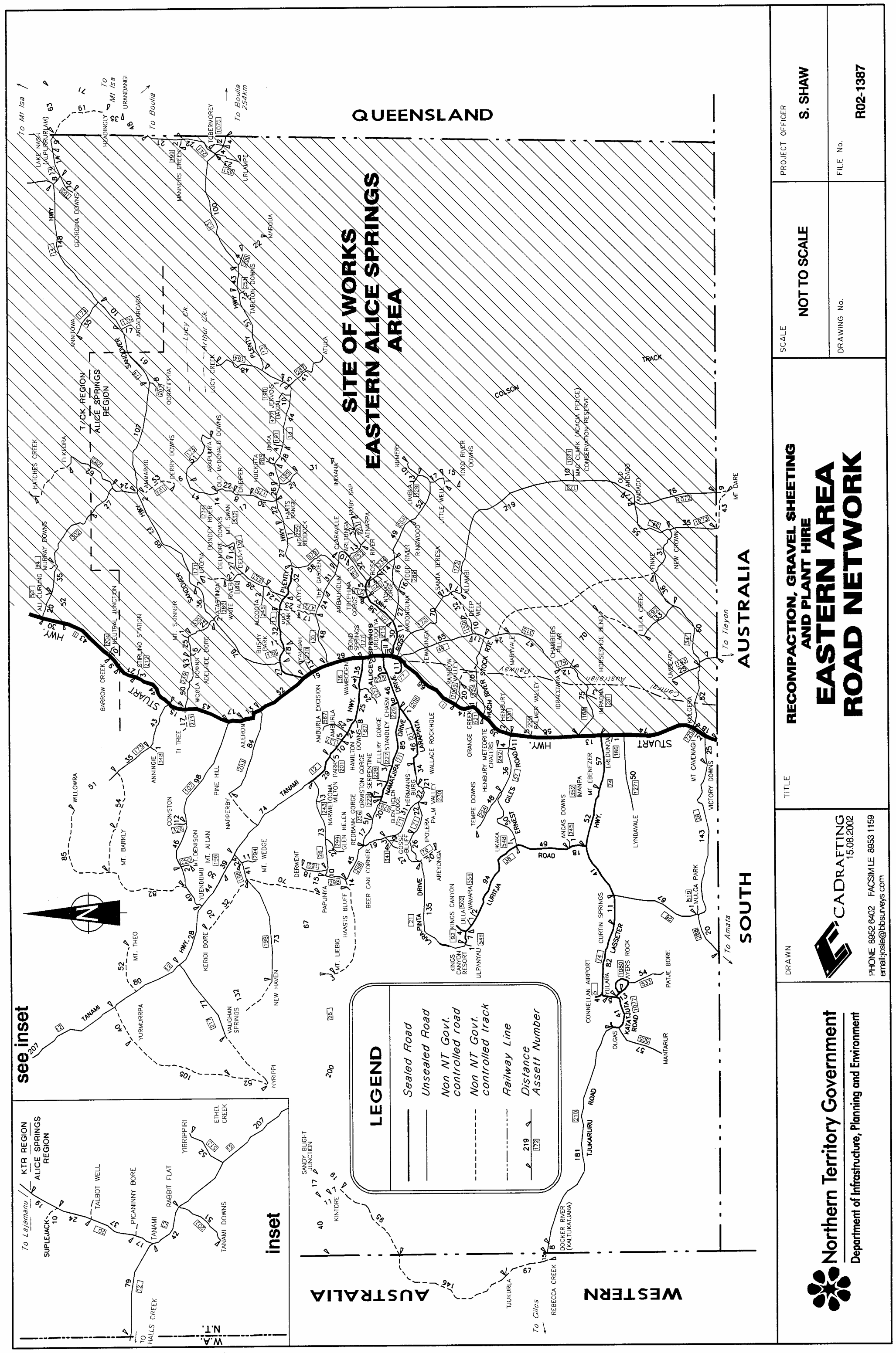
LEGEND
Sealed Road
Unsealed Road
Non NT Govt. controlled road
Non NT Govt. controlled track
Railway Line
Distance Assett Number
SOUTH AUSTRALIA
WESTERN AUSTRALIA
SITE OF WORKS
WESTERN ALICE SPRINGS AREA
see inset
inset
T/CK REGION
ALICE SPRINGS REGION
KTR REGION
ALICE SPRINGS REGION
ALICE SPRINGS
STUART HWY
TANAMI
PLENTY HWY
SANDOVER HWY
LASSETER HWY
RECOMPACTION, GRAVEL SHEETING AND PLANT HIRE
WESTERN AREA ROAD NETWORK
NOT TO SCALE
PROJECT OFFICER
G. MIHAN
FILE No.
R02-1410
CADRAFTING
15.08.2002
Northern Territory Government
Department of Infrastructure, Planning and Environment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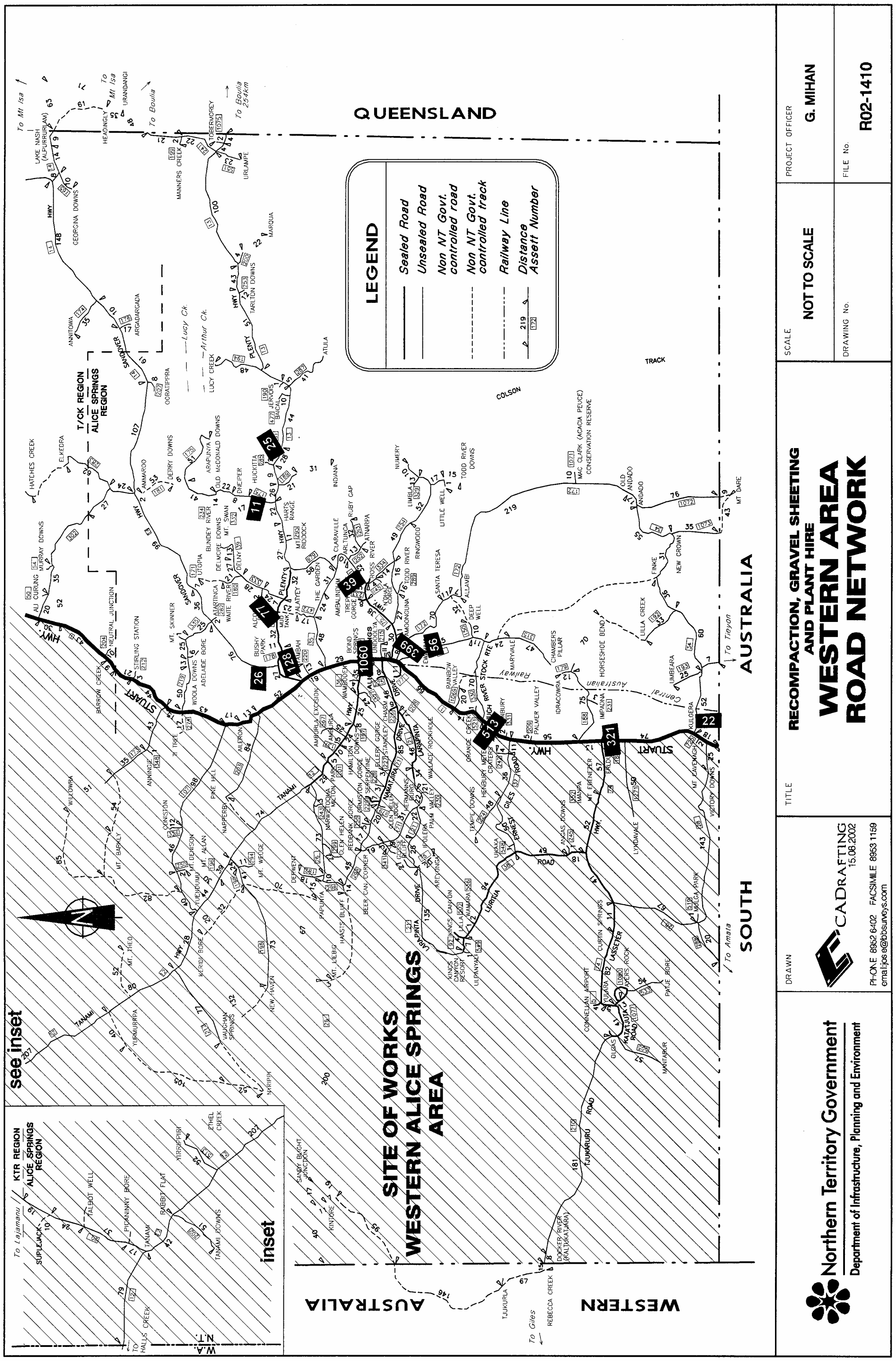
SITE OF WORKS
EASTERN ALICE SPRINGS
AREA
SOUTH AUSTRALIA
WESTERN AUSTRALIA
see inset
inset
LEGEND
Sealed Road
Unsealed Road
Non NT Govt. controlled road
Non NT Govt. controlled track
Railway Line
Distance
Asset Number
STUART HWY.
Northern Territory Government
Department of Infrastructure, Planning and Environment
CADRAFTING
15.08.2002
RECOMPACTION, GRAVEL SHEETING AND PLANT HIRE
EASTERN AREA ROAD NETWORK
SCALE
NOT TO SCALE
PROJECT OFFICER
S. SHAW
FILE No.
R02-1387

Appendix C

Regional Maps with vehicle count station positions and AADT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Sealed Road
Unsealed Road
Non NT Govt. controlled road
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SITE OF WORKS WESTERN ALICE SPRINGS AREA
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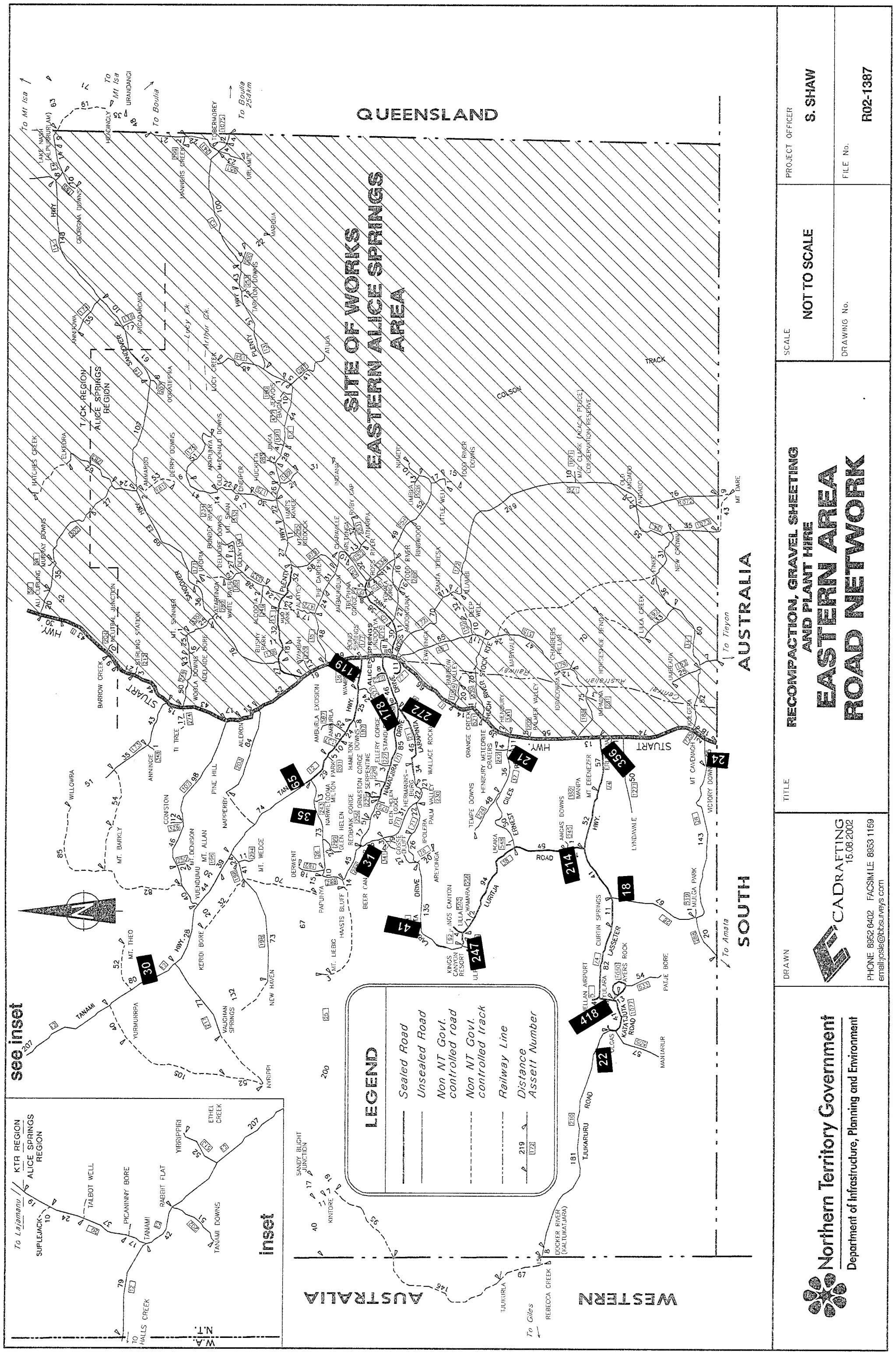
CADRAFTING 15.08.2002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SOUTH AUSTRALIA
WESTERN AUSTRALIA
SITE OF WORKS
EASTERN ALICE SPRINGS AREA
LEGEND
Sealed Road
Unsealed Road
Non NT Govt. controlled road
Non NT Govt. controlled track
Railway Line
Distance Asset Number
see inset
inset
TITLE
RECOMPACTION, GRAVEL SHEETING AND PLANT HIRE
EASTERN AREA ROAD NETWORK
SCALE
NOT TO SCALE
PROJECT OFFICER
S. SHAW
DRAWING No.
FILE No.
R02-1387
DRAWN
CADRAFTING 15.08.2002
Northern Territory Government
Department of Infrastructure, Planning and Environment

Appendix D

Soil Graphs – Particle Size Distribution

Particle Size Distribution

STS-03 Rev 2-9/00

Report No: 5267

Sample No: 18107

Client: DEPT. INFRASTRUCTURE PLANNING & ENVIRONMENT

Project: TANAMI ROAD UPGRADE GRAVEL RESHEET

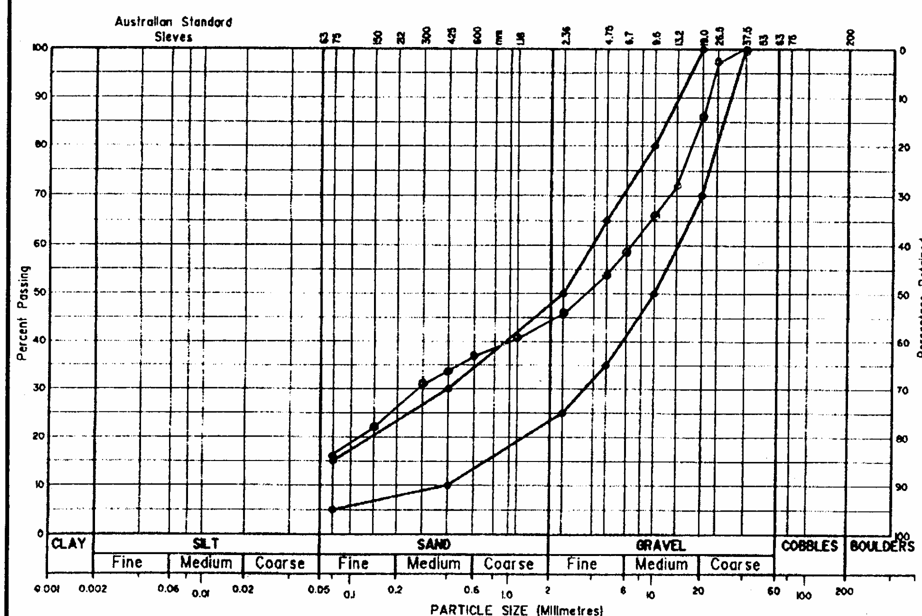
Location: TANAMI ROAD CH: 432-476km

Sample Identification: HOLE # 2, CH:435.965km, 1.5mR, BASE COURSE

Job No: STS-949

Sheet: 2 of 9

Date: 18/03/2004



AS Sieve Size	Percentage Passing	Specification GRADING 2
150mm		
75mm		
63mm		
53mm		
37.5mm	100	100
26.5mm	97	
19mm	86	70 - 100
13.2mm	73	
9.5mm	66	50 -80
6.7mm	59	
4.75mm	54	35 - 65
2.36mm	46	25 - 50
1.18mm	41	
600 microns	37	
425 microns	34	10 - 30
300 microns	31	
150 microns	23	
75 microns	16	4 - 16

Liquid Limit	%	24	*
Plastic limit	%	14	*
Plasticity index	%	10	
Linear shrinkage	%	6.0	**!
Natural moisture	%	5.5	

Test Procedure: AS 1289 2.1.1-1992, 3.6.1,3.1.1 3.2.1, 3.3.1, 3.4.1

Tested by: B. COLOMBET

Checked by: B. COLOMBET

Material Description: Calcrete Gravel.

* Air dried, wet preparation methods used.

** Mold length - 250mm

! = ~~Crumbling/~~Curling occurred

SOIL TESTING SERVICES A.B.N 87 059 127 721
SHED 12, 66A SMITH STREET,"SMITH STREET TRADE CENTRE"
P.O.BOX 1754,ALICE SPRINGS N.T.0871
PHONE/FAX (08) 8953 4880 MOBILE 0412 797 747

NATA Accredited Laboratory
Number: 3280
This laboratory is accredited by the National Association of Testing Authorities, Australia. The tests reported herein have been performed in accordance with its terms of accreditation.

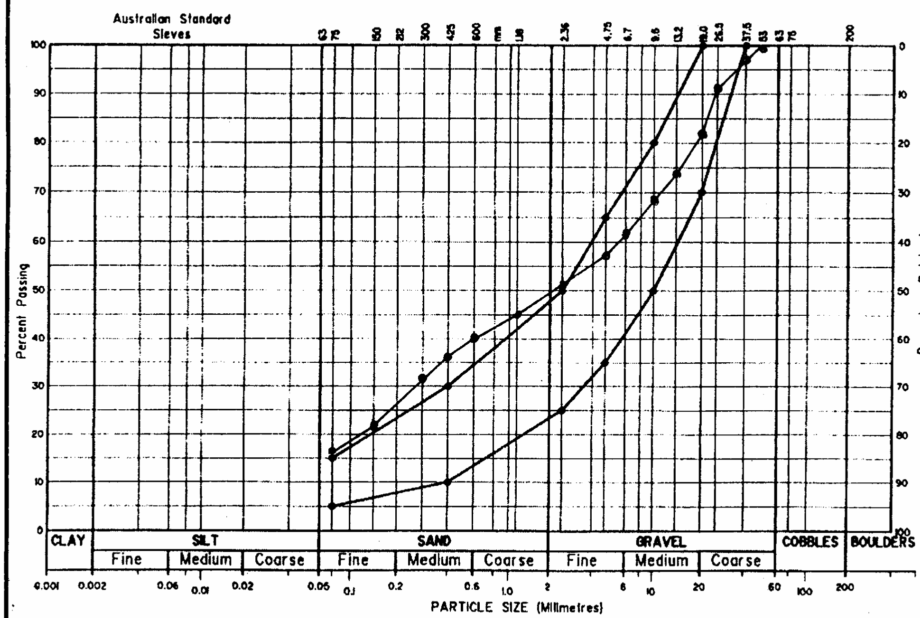
Approved Signatory
(B. COLOMBET)

Particle Size Distribution

STS-03 Rev 2-9/00

Report No:	5267	Client:	DEPT. INFRASTRUCTURE PLANNING & ENVIRONMENT
Sample No:	18108	Project:	TANAMI ROAD UPGRADE GRAVEL RESHEET
		Location:	TANAMI ROAD CH: 432-476km
		Sample Identification:	HOLE # 3, CH:436.576km, 7.6mR, BASE COURSE

Job No:	STS-949
Sheet	3 of 9
Date:	18/03/2004



AS Sieve Size	Percentage Passing	Specification GRADING 2
150mm		
75mm		
63mm		
53mm	100	
37.5mm	97	100
26.5mm	91	
19mm	83	70 - 100
13.2mm	74	
9.5mm	68	50 -80
6.7mm	62	
4.75mm	58	35 - 65
2.36mm	51	25 - 50
1.18mm	45	
600 microns	40	
425 microns	36	10 - 30
300 microns	32	
150 microns	23	
75 microns	17	4 - 16

Liquid Limit	%	26	*
Plastic limit	%	14	*
Plasticity index	%	12	
Linear shrinkage	%	5.5	**!
Natural moisture	%	5.9	

Test Procedure: AS 1289 2.1.1-1992, 3.6.1,3.1.1 3.2.1, 3.3.1, 3.4.1

Tested by: B. COLOMBET

Checked by: B. COLOMBET

Material Description: Calcrete Gravel.

* Air dried, wet preparation methods used.

** Mold length - 250mm

! = ~~Crumbling~~/Curling occurred

SOIL TESTING SERVICES A.B.N 87 059 127 721
SHED 12, 66A SMITH STREET,"SMITH STREET TRADE CENTRE"
P.O.BOX 1754,ALICE SPRINGS N.T.0871
PHONE/FAX (08) 8953 4880 MOBILE 0412 797 747

NATA Accredited Laboratory
Number: 3280
This laboratory is accredited by the National Association of Testing Authorities, Australia. The tests reported herein have been performed in accordance with its terms of accreditation.

Approved Signatory
(B. COLOMBET)

Particle Size Distribution

STS-03 Rev 2-9/00

Report No: 5267

Sample No: 18109

Client: DEPT. INFRASTRUCTURE PLANNING & ENVIRONMENT

Project: TANAMI ROAD UPGRADE GRAVEL RESHEET

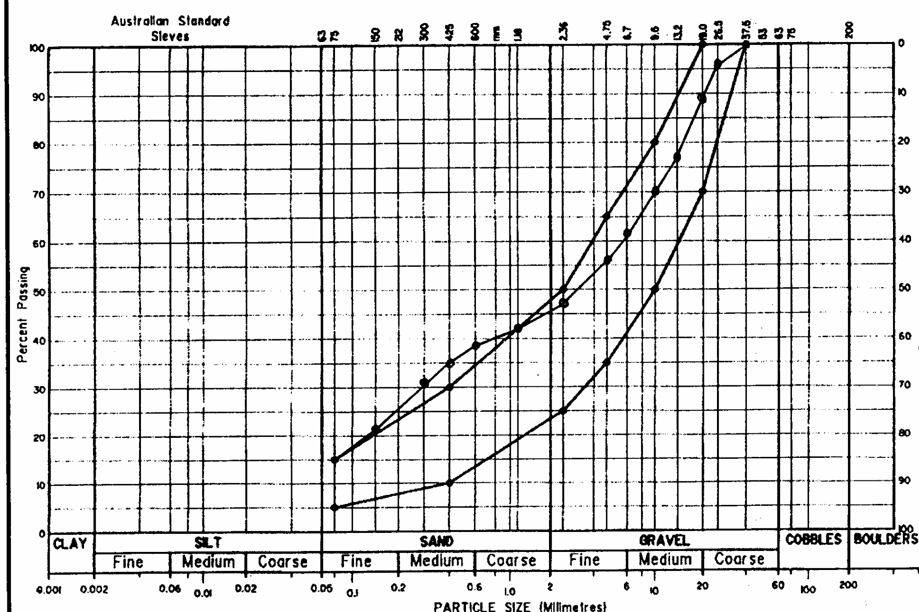
Location: TANAMI ROAD CH: 432-476km

Sample Identification: HOLE # 4, CH:436.832km, 4.4mR, BASE COURSE

Job No: STS-949

Sheet 4 of 9

Date: 18/03/2004



AS Sieve Size	Percentage Passing	Specification GRADING 2
150mm		
75mm		
63mm		
53mm		
37.5mm	100	100
26.5mm	96	
19mm	89	70 - 100
13.2mm	77	
9.5mm	70	50 -80
6.7mm	62	
4.75mm	56	35 - 65
2.36mm	48	25 - 50
1.18mm	43	
600 microns	39	
425 microns	35	10 - 30
300 microns	31	
150 microns	22	
75 microns	15	4 - 16

Liquid Limit	%	25	*
Plastic limit	%	14	*
Plasticity index	%	11	
Linear shrinkage	%	5.5	**!
Natural moisture	%	5.8	

Test Procedure: AS 1289 2.1.1-1992, 3.6.1,3.1.1 3.2.1, 3.3.1, 3.4.1

Tested by: B. COLOMBET

Checked by: B. COLOMBET

Material Description: Calcrete Gravel.

* Air dried, wet preparation methods used.

** Mold length - 250mm

! = ~~Crumbling~~/Curling occurred

SOIL TESTING SERVICES A.B.N 87 059 127 721
SHED 12, 66A SMITH STREET,"SMITH STREET TRADE CENTRE"
P.O.BOX 1754,ALICE SPRINGS N.T.0871
PHONE/FAX (08) 8953 4880 MOBILE 0412 797 747

NATA Accredited Laboratory
Number: 3280
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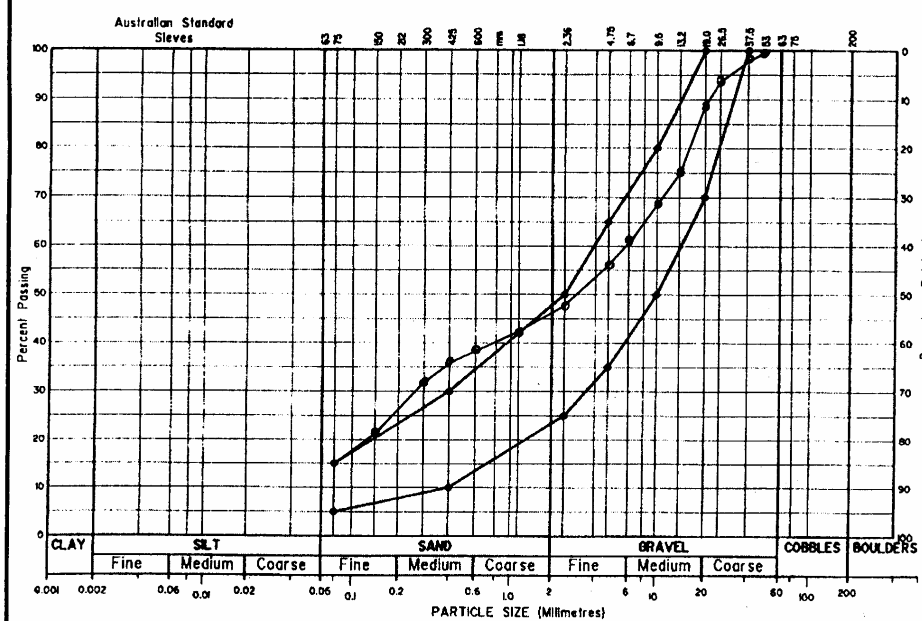
Approved Signatory
(B. COLOMBET)

Particle Size Distribution

STS-03 Rev 2-9/00
Report No: 5267
Sample No: 18110

Client: DEPT. INFRASTRUCTURE PLANNING & ENVIRONMENT
Project: TANAMI ROAD UPGRADE GRAVEL RESHEET
Location: TANAMI ROAD CH: 432-476km
Sample Identification: HOLE # 5, CH:437.026km, 3.7mR, BASE COURSE

Job No: STS-949
Sheet 5 of 9
Date: 18/03/2004



AS Sieve Size	Percentage Passing	Specification GRADING 2
150mm		
75mm		
63mm		
53mm	100	
37.5mm	99	100
26.5mm	94	
19mm	89	70 - 100
13.2mm	75	
9.5mm	69	50 -80
6.7mm	61	
4.75mm	56	35 - 65
2.36mm	48	25 - 50
1.18mm	43	
600 microns	39	
425 microns	36	10 - 30
300 microns	32	
150 microns	22	
75 microns	15	4 - 16

Liquid Limit	%	23	*
Plastic limit	%	16	*
Plasticity index	%	7	
Linear shrinkage	%	4.5	**!
Natural moisture	%	7.2	

Test Procedure: AS 1289 2.1.1-1992, 3.6.1,3.1.1 3.2.1, 3.3.1, 3.4.1
Tested by: B. COLOMBET
Checked by: B. COLOMBET

Material Description: Calcrete Gravel.

* Air dried, wet preparation methods used.
** Mold length - 250mm
! = ~~Crumbling/Curling occurred~~

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Particle Size Distribution

STS-04 Rev 2-9/00

Report No: 5356

Sample No: 18406

Client: DEPT. INFRASTRUCTURE PLANNING & ENVIRONMENT

Project: PLENTY HIGHWAY GRAVEL RESHEET

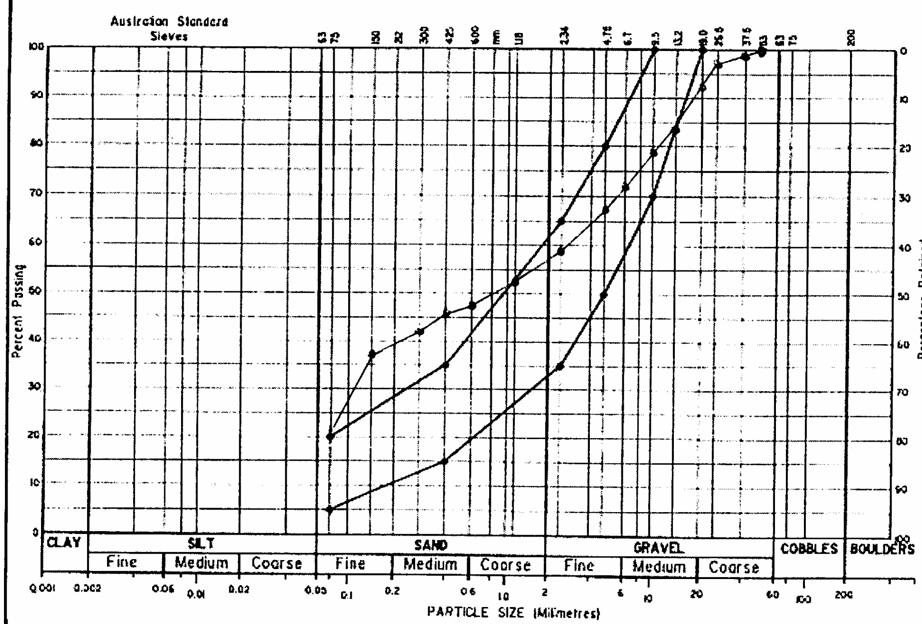
Location: PLENTY HIGHWAY, N.T.

Sample Identification: SAMPLE# 1 LOT BC02, CH:296.270km, 6.6m RIGHT

Job No: STS-947

Sheet 1 of 6

Date: 23/04/2004



AS Sieve Size	Percentage Passing	Specification GRADING 3
150mm		
75mm		
63mm		
53mm	100	
37.5mm	99	
26.5mm	97	
19mm	93	100
13.2mm	84	
9.5mm	79	70 - 100
6.7mm	73	
4.75mm	68	50 - 80
2.36mm	59	35 - 65
1.18mm	52	
600 microns	48	
425 microns	46	15 - 35
300 microns	43	
150 microns	37	
75 microns	21	6 - 20

Liquid Limit	%	33	*
Plastic limit	%	18	*
Plasticity index	%	15	
Linear shrinkage	%	7.0	**!
Natural moisture	%	9.1	

Test Procedure: AS 1289 2.1.1-1992
3.6.1, 3.1.1,3.2.1,3.3.1,3.4.1

Tested by: M. PLATT / A. McLAY

Checked by: B. COLOMBET

Material Description: Red / brown clayey calcrete gravel. Base Couse.

* Air dried, wet preparation methods used.

** Mold length - 250mm

! = ~~Crumbling~~/Curling occurred

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PHONE/FAX (08) 8953 4880 MOBILE 0412 797 747

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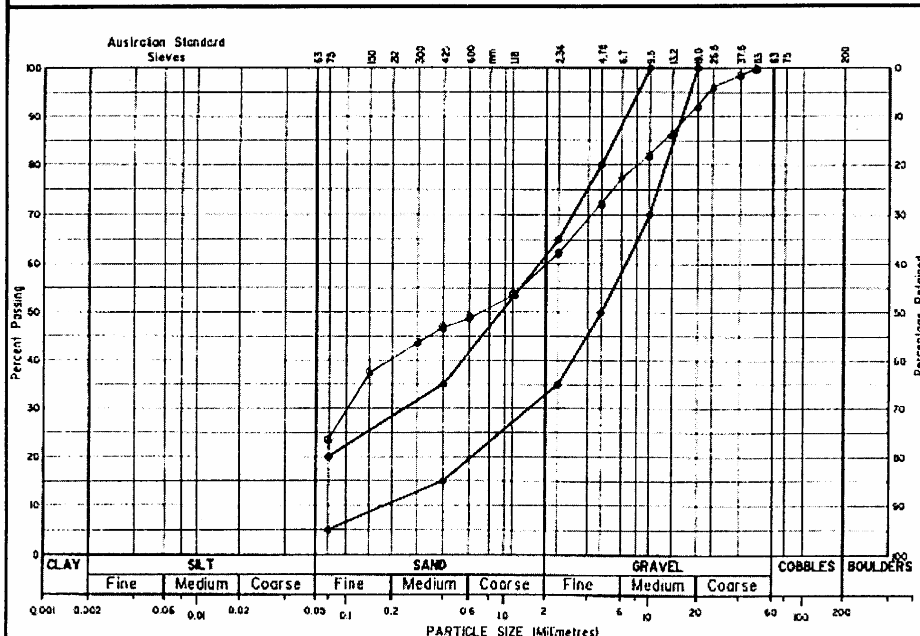
(B. COLOMBET)

Particle Size Distribution
STS-04 Rev 2-9/00

Report No: 5356	**Client:** DEPT. INFRASTRUCTURE PLANNING & ENVIRONMENT	**Job No:**	STS-947
Sample No: 18407	**Project:** PLENTY HIGHWAY GRAVEL RESHEET	**Sheet**	2 of 6
	Location: PLENTY HIGHWAY, N.T.	**Date:**	23/04/2004
	Sample Identification: SAMPLE# 2 LOT BC02, CH:296.708km, 4.1m RIGHT		



AS Sieve Size	Percentage Passing	Specification
		GRADING 3
150mm		
75mm		
63mm		
53mm	100	
37.5mm	99	
26.5mm	96	
19mm	93	100
13.2mm	86	
9.5mm	83	70 - 100
6.7mm	78	
4.75mm	73	50 - 80
2.36mm	62	35 - 65
1.18mm	54	
600 microns	49	
425 microns	47	15 - 35
300 microns	44	
150 microns	38	
75 microns	24	6 - 20

Liquid Limit	%	35	*
Plastic limit	%	19	*
Plasticity index	%	16	
Linear shrinkage	%	7.0	**!
Natural moisture	%	10.0	

Test Procedure: AS 1289 2.1.1-1992
3.6.1, 3.1.1,3.2.1,3.3.1,3.4.1

Tested by: M. PLATT / A. McLAY

Checked by: B. COLOMBET

Material Description: Red / brown clayey calcrete gravel. Base Couse.

* Air dried, wet preparation methods used.

** Mold length - 250mm

! = ~~Crumbling~~/Curling occurred

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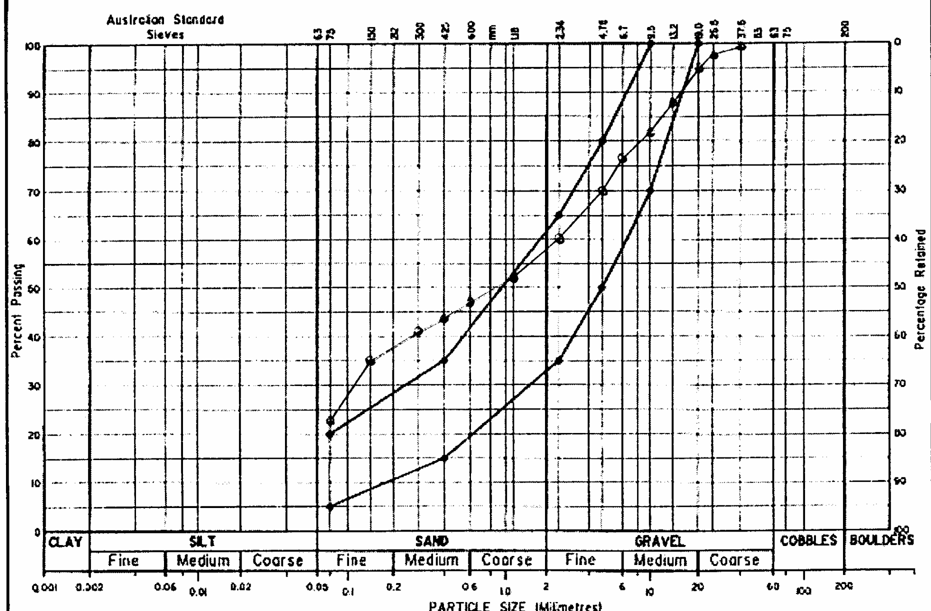
Particle Size Distribution
STS-04 Rev 2-9/00
Report No: 5356
Sample No: 18408

Client: DEPT. INFRASTRUCTURE PLANNING & ENVIRONMENT
Project: PLENTY HIGHWAY GRAVEL RESHEET
Location: PLENTY HIGHWAY, N.T.
Sample Identification: SAMPLE# 3 LOT BC02, CH:296.875km, 4.7m RIGHT

Job No: STS-947
Sheet 3 of 6
Date: 23/04/2004



AS Sieve Size	Percentage Passing	Specification GRADING 3
150mm		
75mm		
63mm		
53mm		
37.5mm	100	
26.5mm	98	
19mm	95	100
13.2mm	88	
9.5mm	82	70 - 100
6.7mm	76	
4.75mm	70	50 - 80
2.36mm	60	35 - 65
1.18mm	52	
600 microns	47	
425 microns	44	15 - 35
300 microns	41	
150 microns	35	
75 microns	23	6 - 20

Liquid Limit	%	39	*
Plastic limit	%	21	*
Plasticity index	%	18	
Linear shrinkage	%	8.0	**!
Natural moisture	%	10.4	

Test Procedure: AS 1289 2.1.1-1992
3.6.1, 3.1.1,3.2.1,3.3.1,3.4.1
Tested by: M. PLATT / A. McLAY
Checked by: B. COLOMBET

Material Description: Red / brown clayey calcrete gravel. Base Couse.

* Air dried, wet preparation methods used.
** Mold length - 250mm
! = ~~Grumbling~~/Curling occurred

SOIL TESTING SERVICES A.B.N 87 059 127 721
SHED 12, 66A SMITH STREET,"SMITH STREET TRADE CENTRE"
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PHONE/FAX (08) 8953 4880 MOBILE 0412 797 747

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Particle Size Distribution

STS-04 Rev 2-9/00

Report No: 5356

Sample No: 18411

Client: DEPT. INFRASTRUCTURE PLANNING & ENVIRONMENT

Project: PLENTY HIGHWAY GRAVEL RESHEET

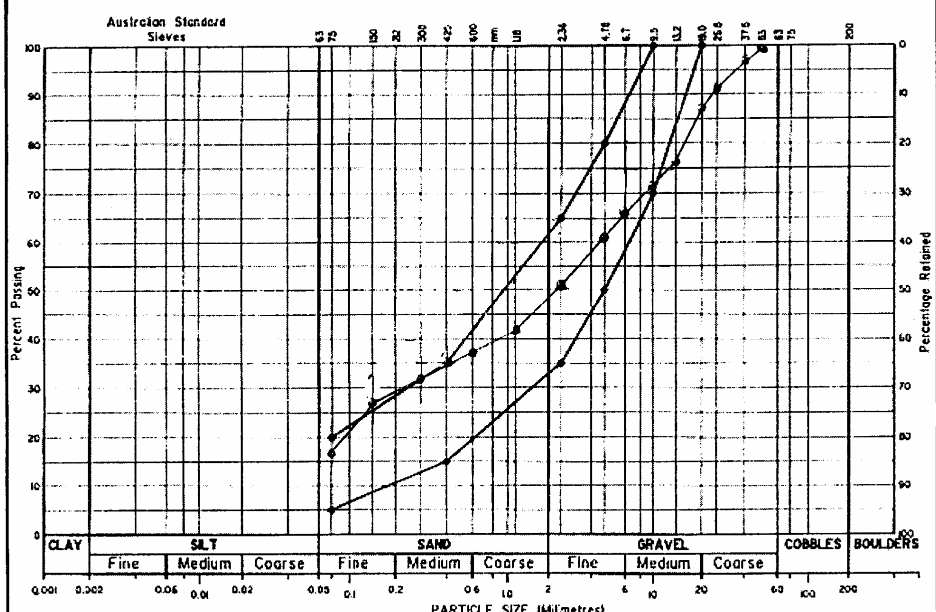
Location: PLENTY HIGHWAY, N.T.

Sample Identification: SAMPLE# 6 LOT BC01, CH:297.554km, 0.2m RIGHT

Job No: STS-947

Sheet 6 of 6

Date: 23/04/2004



AS Sieve Size	Percentage Passing	Specification GRADING 3
150mm		
75mm		
63mm		
53mm	100	
37.5mm	97	
26.5mm	91	
19mm	88	100
13.2mm	76	
9.5mm	72	70 - 100
6.7mm	66	
4.75mm	61	50 - 80
2.36mm	51	35 - 65
1.18mm	43	
600 microns	37	
425 microns	35	15 - 35
300 microns	32	
150 microns	27	
75 microns	17	6 - 20

Liquid Limit	%	46	*
Plastic limit	%	25	*
Plasticity index	%	21	
Linear shrinkage	%	10.5	**!
Natural moisture	%	12.7	

Test Procedure: AS 1289 2.1.1-1992
3.6.1, 3.1.1,3.2.1,3.3.1,3.4.1

Tested by: M. PLATT / A. McLAY

Checked by: B. COLOMBET

Material Description: Red / brown clayey calcrete gravel. Base Couse.

* Air dried, wet preparation methods used.

** Mold length - 250mm

! = ~~Crumbling~~/Curling occurred

SOIL TESTING SERVICES A.B.N 87 059 127 721
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PHONE/FAX (08) 8953 4880 MOBILE 0412 797 747

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(B. COLOMBET)

Particle Size Distribution

STS-02 Rev 2-9/00

Report No: 5390

Sample No: 18479

Client: D.I.P.E. ALICE SPRINGS

Project: TANAMI ROAD UPGRADE

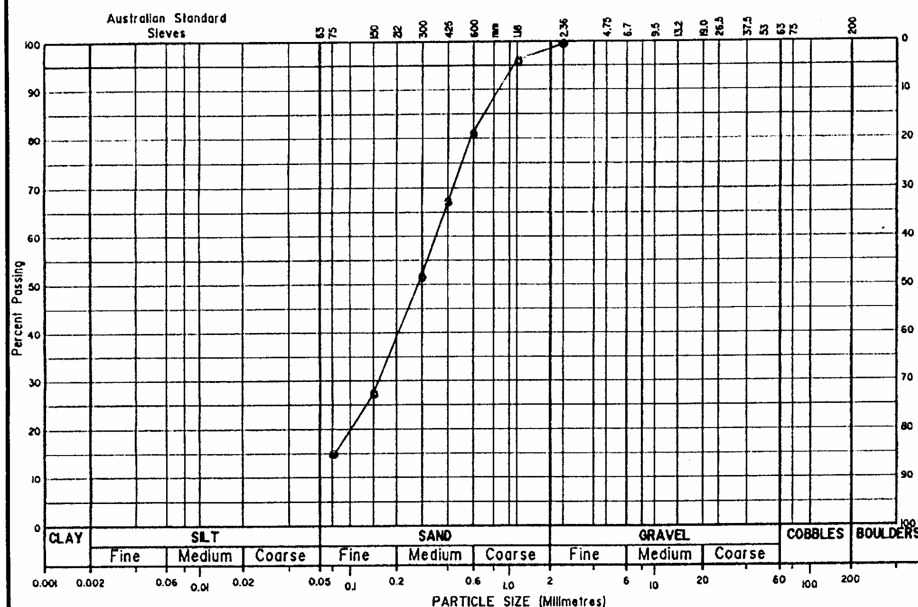
Location: TANAMI ROAD, N.T.

Sample Identification: SAMPLE # 1 CH:222.80km

Job No: STS-949

Sheet 1 of 1

Date: 5/05/2004



AS Sieve Size	Percentage Passing	Specification
150mm		
75mm		
63mm		
53mm		
37.5mm		
26.5mm		
19mm		
13.2mm		
9.5mm		
6.7mm		
4.75mm		
2.36mm	100	
1.18mm	96	
600 microns	81	
425 microns	67	
300 microns	52	
150 microns	28	
75 microns	15	

Liquid Limit	%	17	*
Plastic limit	%	11	*
Plasticity index	%	6	
Linear shrinkage	%	1.0	**!
Natural moisture	%	1.4	

Test Procedure: AS 1289 2.1.1
3.6.1, 3.1.1, 3.2.1, 3.3.1, 3.4.1

Tested by: M. PLATT

Checked by: B. COLOMBET

Material Description: Red / brown sand clay. Sampled by Client. Sample tested as received.

* Air dried, wet preparation methods used.

** Mold length - 250mm

! = ~~Crumbling/Curling occurred~~

SOIL TESTING SERVICES A.B.N 87 059 127 721
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Approved Signatory
(B. COLOMBET)

Appendix E

Roughometer

The intervention levels of grading of roads are often by the "squeaky wheel" syndrome otherwise the road is graded during the grading circuit. Perceptions of the ride comfort of unsealed roads and travel speed vary between road users and maintenance supervisors. A system is needed to be established where the road surface can be measured for the ride comfort and what is the acceptable comfort level before the road requires a grade.

The author had initial planned to utilise a Roughometer that had been developed by ARRB which the department had acquired. The Maryvale Road had been selected for the trail to establish a system where by it can be determined if the road required a grade and when the grade is completed how efficient the grade was. This particular road was selected as it is close to town plus it receives lots of complaints from the residents along the road and the community that it serves. Another reason why this road was selected is that it is close to town which meant that it could have easily have been monitored and there was no great distance to travel to collect the necessary data. Unfortunately the Roughometer was only available in the Alice Springs Region for one month before it was returned to ARRB for an upgrade. The Roughometer had been returned to the Region at the beginning of October. This meant that there was not an adequate period of time to preform trials and analysis the data by the due date that the dissertation had to be submitted.

The Roughometer was fitted to a Toyota Hi-Lux 4 x 4 double cab.

The speed of travel of the vehicle is important for accurate and reliable results. The speed of travel is 50 – 60 km/h (ARRB, 2003) but on long lengths of road over 200 kilometres this can be very tedious for the operator.

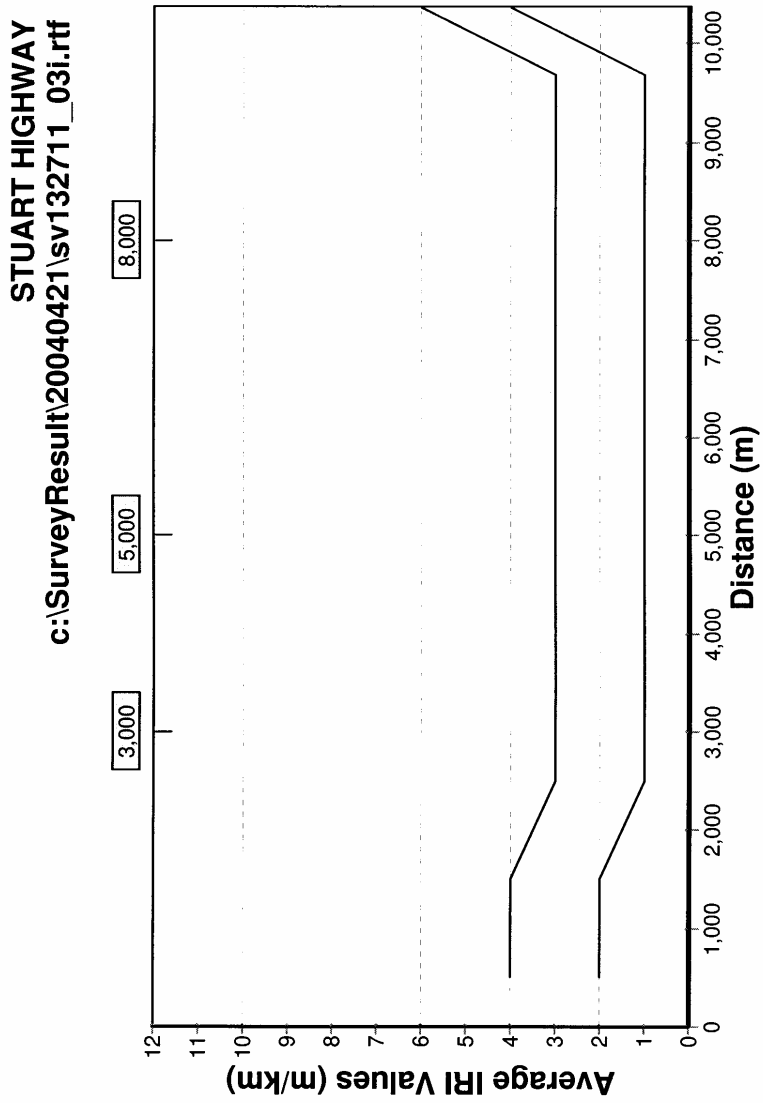
Attached are the few field measurements that were done with the Roughometer to demonstrate that if the measuring vehicle speed is over 60 km/h the results are unreliable. A 10 kilometre stretch along the Stuart Highway which is sealed was selected where one run was undertaken with the highest speed in that section been 74.2km/h. The graph for this run is sv132711_03i.rtf with its relevant information and it can be seen that graph is smooth. Another run was completed with an average speed of approximately 80km/h with a top speed of 100.8km/h. This graph sv104409_06i.rtf is not smooth and there are a number of spikes along the plot. The results are not reliable which indicates how important it is to travel at the recommended speed to have reliable results to analyse.

Included are roughness results for 20 kilometres of the Maryvale Road travelling south and north. There are two sets of results for each direction with one travel speed been 60 km/h and the other travel speed been 80 km/h. The thought behind the 80 km/h was to establish if there was much of a difference from the 60 km/h. From the results it can be seen that there is a difference between the two speeds and that even for the 60 km/h the road is very rough. The IRI value for the 60 km/h run was an average value of 10 – 12 and the 80 km/h run was an average value of 13 - 15. The author was a bit surprised with the results for the 60 km/h as he felt that the road was comfortable at 80 km/h. Unfortunately at the time it did not occur to the author to undertake a run at 50 km/h to compare the results. The International Roughness Index values for unsealed roads serviceability which would have to be utilised in conjunction with the data from the Roughometer are given in the table below.

m/km **IRI**	**Serviceability Description**
1.5 – 2.5	Recently bladed surface of fine gravel, or soil surface with excellent longitudinal and transverse profile.
3.5 – 4.5	Ride comfortable up to 80 -100 km/h. Aware of gentle undulations or swaying. Negligible depressions (e.g. <5mm/3m) and no pot-holes
7.5 – 9.0	Ride comfortable up to 70 – 80 km/h but aware of sharp movements and some wheel bounce. Frequent shallow moderate depressions or shallow pot-holes (e.g 6 – 30 mm/3m with frequency 5 – 10 per 50m). Moderate corrugations (e.g. 6 – 20 mm/ 0.7 – 1.5 m)
11.5 – 13.5	Ride comfortable at 50 km/h (or 40 -70 km/h on specific sections). Frequent moderate transverse depressions

	(e.g. 20 – 40 mm/ 3 – 5m at frequency of 10 – 20 per 50m) or occasional deep depressions or pot-holes (e.g. 40 – 80 mm/ 3m with frequency less than 5 per 50m). Strong corrugations (e.g. <20 mm/0.7 – 1.5m)
16.0 – 17.5	Ride comfortable at 30 – 40 km/h. Frequent deep transverse depressions and/or pot-holes (e.g. 40 – 80 mm/1 – 5m with frequency less than 5 per 50m) with other shallow depressions. Not possible to avoid all the depressions expect the worst.
20.0 – 22.0	Ride comfortable at 20 – 30 km/h. Speeds higher than 40 km/h would cause extreme discomfort and possible damage to the car. On a good general profile: frequent deep depressions and/or pot-holes (e.g. 40 – 80 mm/1 – 5m at a frequency of 10 – 15 per 50m) and occasional very deep depressions (e.g. <80mm/0.6 – 2m). On a poor general profile: frequent moderate defects and depressions (e.g. poor earth surface).

Once a system has been established it will assist with the decision if a road needs to be graded when complaints are received. With a measuring instrument it can help with the aim of there been a consistency with the grading of roads and not responding to each complaint with the grader which in turn will assist to relieve the pressure on the maintenance funds. The Roughometer can travel over the road when there is a complaint and from the data it can assist with the decision on wether the road is to be grader or not.


STUART HIGHWAY
c:\SurveyResult\20040421\sv132711_03i.rtf
3,000
5,000
8,000
Average IRI Values (m/km)
Distance (m)

April 21, 2004, 04:00 PM
c:\SurveyResult\20040421\sv132711_03i.rtf

Field Data Sheet

ROAD NAME: STUART HIGHWAY

SECTION: FROM: ADELAIDE INTERSECTION TO: LARAPINTA DRIVE

SURVEY DATE: 21/04/2004 TIME: 13:27:11

TRAVEL DIRECTION: NORTH

REFERENCE: R0001 21/04/04

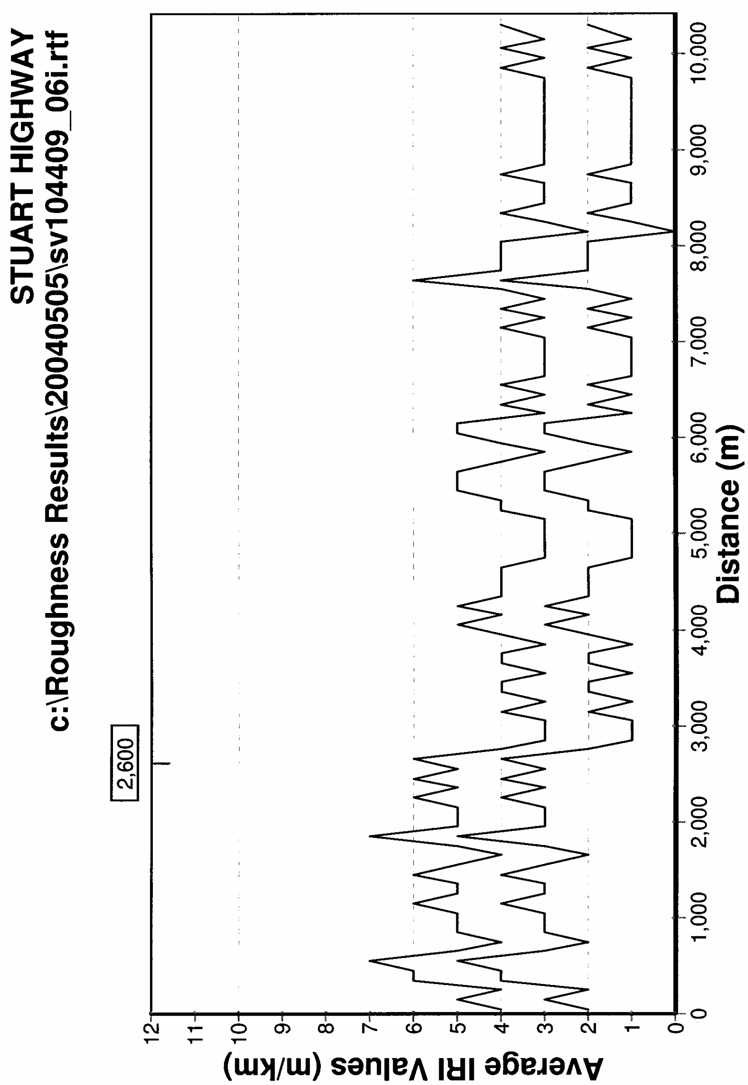
VEHICLE: HI LUX 815-820

OPERATOR: RICHARD UNDERHILL

COMMENTS: ....

Roughness Value

SecID	SubDist	TotDist	IRI-Min	IRI-Max	Speed	Event
1	1,000	1,000	2	4	67.9	
1	2,000	2,000	2	4	69.4	
1	3,000	3,000	1	3	70.2	Arid Zone
1	4,000	4,000	1	3	74.2	
1	5,000	5,000	1	3	71.6	Llparpa
1	6,000	6,000	1	3	65.9	
1	7,000	7,000	1	3	62.9	
1	8,000	8,000	1	3	42.1	Tom Browm
1	9,000	9,000	1	3	57.8	
1	10,361	10,361	1	3	52.4	
2	1	10,363	4	6	6.0	
Average Value			**1**	**3**		


STUART HIGHWAY
c:\Roughness Results\20040505\sv104409_06i.rtf
2,600
Average IRI Values (m/km)
Distance (m)

May 7, 2004, 11:39 AM
c:\Roughness Results\20040505\sv104409_06i.rtf

Field Data Sheet

ROAD NAME: STUART HIGHWAY

SECTION: FROM: ADELAIDE INTERSECTION TO: LARAPINTA INTERSECTION

SURVEY DATE: 05/05/2004 TIME: 10:44:09

TRAVEL DIRECTION: NORTH

REFERENCE: ....

VEHICLE: HI LUX 815-820

OPERATOR: RICHARD UNDERHILL

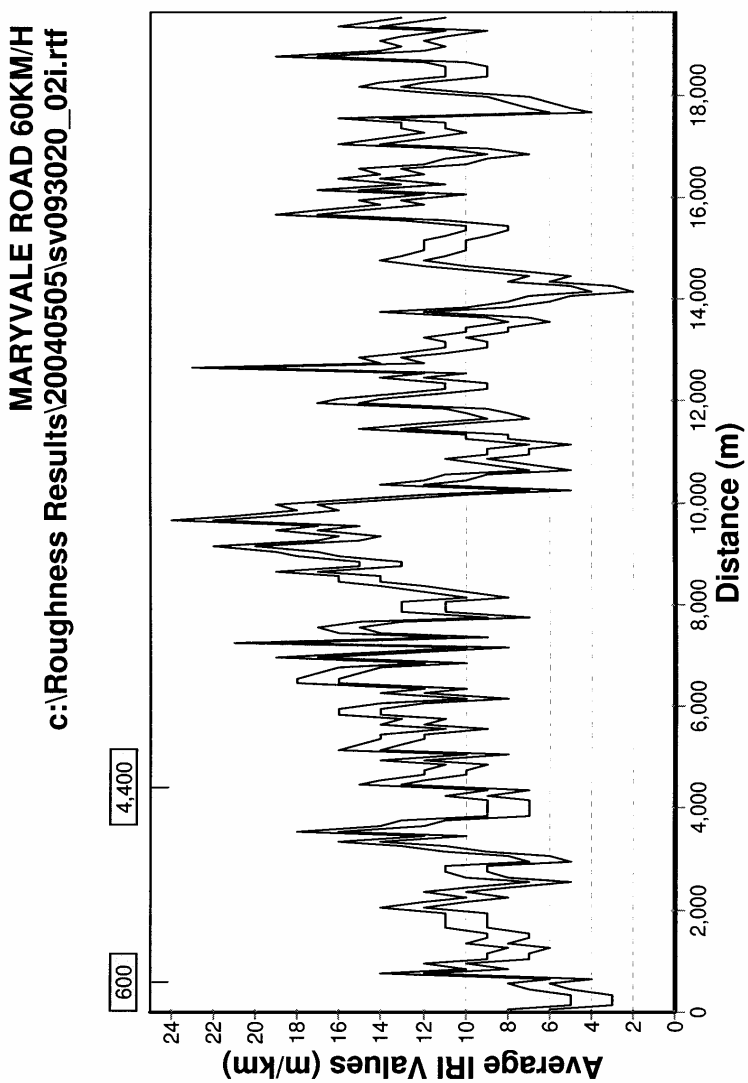
COMMENTS: ....

Roughness Value

SecID	SubDist	TotDist	IRI-Min	IRI-Max	Speed	Event
1	100	100	2	4	79.9	
1	200	200	3	5	88.2	
1	300	300	2	4	94.7	
1	400	400	4	6	97.7	
1	500	500	4	6	100.3	
1	600	600	5	7	98.6	
1	700	700	3	5	96.7	
1	800	800	2	4	93.1	
1	900	900	3	5	93.2	
1	1,000	1,000	3	5	95.0	
1	1,100	1,100	3	5	97.0	
1	1,200	1,200	4	6	96.7	
1	1,300	1,300	3	5	94.8	
1	1,400	1,400	3	5	95.9	
1	1,500	1,500	4	6	97.0	
1	1,600	1,600	3	5	96.3	
1	1,700	1,700	2	4	95.6	
1	1,800	1,800	3	5	95.4	
1	1,900	1,900	5	7	95.7	
1	2,000	2,000	3	5	96.7	
1	2,100	2,100	3	5	97.6	
1	2,200	2,200	3	5	100.1	
1	2,300	2,300	4	6	100.8	
1	2,400	2,400	3	5	99.8	
1	2,500	2,500	4	6	98.5	
1	2,600	2,600	3	5	96.7	Arid Zone
1	2,700	2,700	4	6	89.9	
1	2,800	2,800	2	4	81.1	
1	2,900	2,900	1	3	78.2	
1	3,000	3,000	1	3	76.1	
1	3,100	3,100	1	3	74.0	
1	3,200	3,200	2	4	73.5	
1	3,300	3,300	1	3	75.4	
1	3,400	3,400	2	4	78.8	
1	3,500	3,500	2	4	78.8	
1	3,600	3,600	1	3	78.3	

1	3,700	3,700	2	4	75.9
1	3,800	3,800	2	4	74.0
1	3,900	3,900	1	3	74.6
1	4,000	4,000	2	4	76.3
1	4,100	4,100	3	5	76.5
1	4,200	4,200	2	4	76.0
1	4,300	4,300	3	5	79.1
1	4,400	4,400	2	4	78.6
1	4,500	4,500	2	4	78.9
1	4,600	4,600	2	4	80.3
1	4,700	4,700	2	4	80.6
1	4,800	4,800	1	3	83.0
1	4,900	4,900	1	3	83.5
1	5,000	5,000	1	3	83.0
1	5,100	5,100	1	3	83.4
1	5,200	5,200	1	3	81.9
1	5,300	5,300	2	4	81.9
1	5,400	5,400	2	4	82.2
1	5,500	5,500	3	5	81.4
1	5,600	5,600	3	5	79.9
1	5,700	5,700	3	5	80.0
1	5,800	5,800	2	4	82.3
1	5,900	5,900	1	3	82.7
1	6,000	6,000	2	4	82.1
1	6,100	6,100	3	5	83.9
1	6,200	6,200	3	5	83.6
1	6,300	6,300	1	3	82.5
1	6,400	6,400	2	4	81.6
1	6,500	6,500	1	3	80.8
1	6,600	6,600	2	4	79.6
1	6,700	6,700	1	3	77.7
1	6,800	6,800	1	3	77.0
1	6,900	6,900	1	3	76.5
1	7,000	7,000	1	3	75.5
1	7,100	7,100	1	3	76.0
1	7,200	7,200	2	4	77.7
1	7,300	7,300	1	3	74.4
1	7,400	7,400	2	4	69.6
1	7,500	7,500	1	3	72.3
1	7,600	7,600	2	4	75.8
1	7,700	7,700	4	6	73.1
1	7,800	7,800	2	4	67.1
1	7,900	7,900	2	4	47.3
1	8,000	8,000	2	4	46.8
1	8,100	8,100	2	4	61.3
1	8,200	8,200	0	2	73.6
1	8,300	8,300	1	3	79.9
1	8,400	8,400	2	4	81.0
1	8,500	8,500	1	3	80.3
1	8,600	8,600	1	3	80.8
1	8,700	8,700	1	3	80.3
1	8,800	8,800	2	4	79.3
1	8,900	8,900	1	3	77.6
1	9,000	9,000	1	3	78.0
1	9,100	9,100	1	3	77.2
1	9,200	9,200	1	3	76.5
1	9,300	9,300	1	3	78.0
1	9,400	9,400	1	3	78.9
1	9,500	9,500	1	3	78.2
1	9,600	9,600	1	3	69.7
1	9,700	9,700	1	3	62.1
1	9,800	9,800	1	3	61.5
1	9,900	9,900	2	4	58.8
1	10,000	10,000	1	3	57.3
1	10,100	10,100	2	4	57.1
1	10,200	10,200	1	3	56.7
1	10,399	10,399	2	4	43.7

Average Value	**2**	**4**


MARYVALE ROAD 60KM/H
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Average IRI Values (m/km)
Distance (m)
600
4,400
0
2
4
6
8
10
12
14
16
18
20
22
24
0
2,000
4,000
6,000
8,000
10,000
12,000
14,000
16,000
18,000

May 7, 2004, 02:01 PM
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Field Data Sheet

ROAD NAME:	MARYVALE ROAD 60KM/H
SECTION:	FROM: SANTA TERESA ROAD TO: GRID 20KM
SURVEY DATE:	05/05/2004 TIME: 09:30:20
TRAVEL DIRECTION:	SOUTH
REFERENCE:	....
VEHICLE:	HI LUX 815-820
OPERATOR:	RICHARD UNDERHILL
COMMENTS:	....

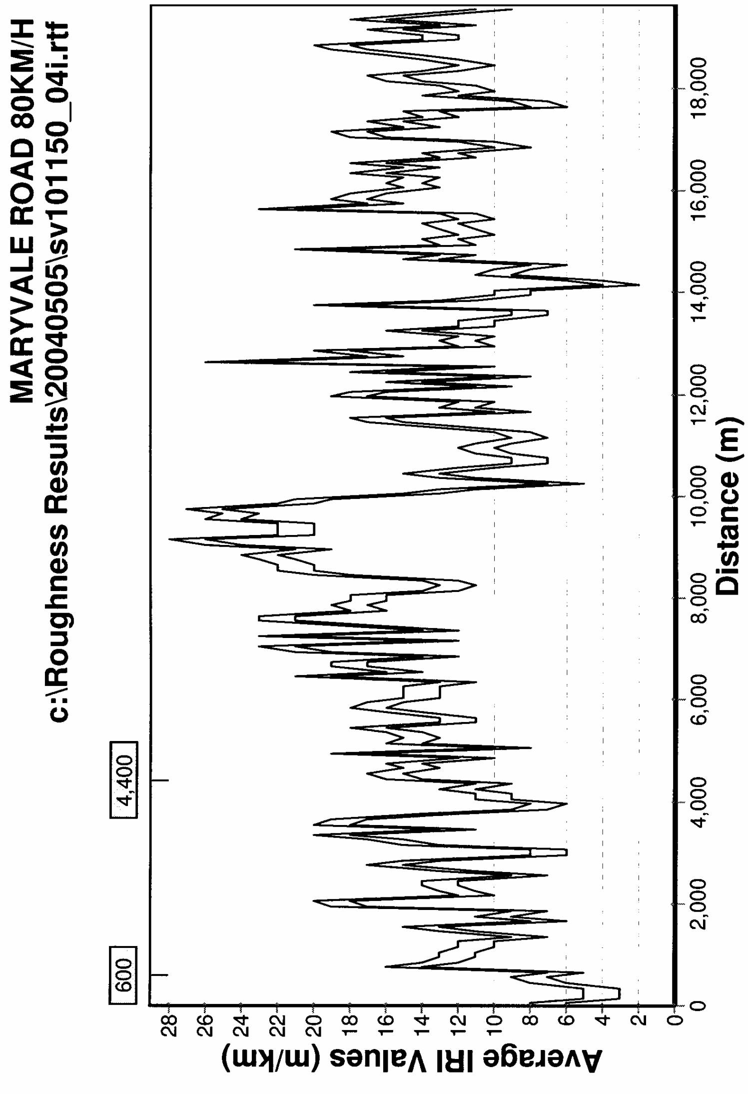
Roughness Value

SecID	SubDist	TotDist	IRI-Min	IRI-Max	Speed	Event
1	100	100	6	8	42.2	
1	200	200	3	5	59.7	
1	300	300	3	5	58.6	
1	400	400	3	5	57.5	
1	500	500	5	7	53.6	
1	600	600	6	8	41.8	End seal
1	700	700	4	6	51.0	
1	800	800	12	14	57.1	
1	900	900	8	10	57.2	
1	1,000	1,000	10	12	57.7	
1	1,100	1,100	7	9	57.9	
1	1,200	1,200	7	9	60.1	
1	1,300	1,300	6	8	61.4	
1	1,400	1,400	8	10	59.5	
1	1,500	1,500	7	9	60.3	
1	1,600	1,600	7	9	61.1	
1	1,700	1,700	9	11	60.2	
1	1,800	1,800	9	11	60.3	
1	1,900	1,900	9	11	62.1	
1	2,000	2,000	9	11	58.6	
1	2,100	2,100	12	14	58.6	
1	2,200	2,200	10	12	59.7	
1	2,300	2,300	8	10	60.2	
1	2,400	2,400	10	12	58.4	
1	2,500	2,500	8	10	58.8	
1	2,600	2,600	5	7	59.0	
1	2,700	2,700	8	10	58.6	
1	2,800	2,800	9	11	59.5	
1	2,900	2,900	9	11	59.5	
1	3,000	3,000	5	7	60.2	
1	3,100	3,100	6	8	60.6	
1	3,200	3,200	9	11	60.3	
1	3,300	3,300	11	13	59.4	
1	3,400	3,400	14	16	59.0	
1	3,500	3,500	10	12	61.5	
1	3,600	3,600	16	18	61.1	

1	3,700	3,700	12	14	60.5	
1	3,800	3,800	11	13	62.3	
1	3,900	3,900	7	9	62.2	
1	4,000	4,000	7	9	61.8	
1	4,100	4,100	7	9	60.1	
1	4,200	4,200	7	9	59.9	
1	4,300	4,300	9	11	60.0	
1	4,400	4,400	7	9	56.9	Grid
1	4,500	4,500	13	15	53.5	
1	4,600	4,600	12	14	57.6	
1	4,700	4,700	10	12	58.5	
1	4,800	4,800	10	12	59.8	
1	4,900	4,900	9	11	59.5	
1	5,000	5,000	12	14	59.0	
1	5,100	5,100	8	10	60.2	
1	5,200	5,200	14	16	59.2	
1	5,300	5,300	13	15	58.1	
1	5,400	5,400	12	14	59.5	
1	5,500	5,500	12	14	59.9	
1	5,600	5,600	9	11	60.2	
1	5,700	5,700	12	14	58.0	
1	5,800	5,800	11	13	57.0	
1	5,900	5,900	14	16	57.0	
1	6,000	6,000	14	16	58.9	
1	6,100	6,100	12	14	59.6	
1	6,200	6,200	8	10	60.2	
1	6,300	6,300	12	14	59.5	
1	6,400	6,400	10	12	56.3	
1	6,500	6,500	16	18	52.4	
1	6,600	6,600	16	18	58.4	
1	6,700	6,700	15	17	58.9	
1	6,800	6,800	14	16	60.3	
1	6,900	6,900	10	12	61.2	
1	7,000	7,000	17	19	60.1	
1	7,100	7,100	13	15	60.8	
1	7,200	7,200	8	10	61.0	
1	7,300	7,300	19	21	60.5	
1	7,400	7,400	9	11	60.1	
1	7,500	7,500	14	16	60.3	
1	7,600	7,600	15	17	62.6	
1	7,700	7,700	13	15	61.4	
1	7,800	7,800	7	9	59.9	
1	7,900	7,900	11	13	61.4	
1	8,000	8,000	11	13	61.0	
1	8,100	8,100	11	13	59.7	
1	8,200	8,200	8	10	59.7	
1	8,300	8,300	10	12	59.6	
1	8,400	8,400	12	14	57.8	
1	8,500	8,500	14	16	57.5	
1	8,600	8,600	14	16	58.5	
1	8,700	8,700	17	19	59.2	
1	8,800	8,800	13	15	59.1	
1	8,900	8,900	13	15	58.0	
1	9,000	9,000	16	18	58.4	
1	9,100	9,100	17	19	59.0	
1	9,200	9,200	20	22	60.1	
1	9,300	9,300	15	17	60.1	
1	9,400	9,400	14	16	59.3	
1	9,500	9,500	17	19	59.7	
1	9,600	9,600	15	17	60.8	
1	9,700	9,700	22	24	61.0	
1	9,800	9,800	19	21	59.1	
1	9,900	9,900	16	18	59.3	
1	10,000	10,000	17	19	61.1	
1	10,100	10,100	14	16	59.1	
1	10,200	10,200	10	12	60.6	
1	10,300	10,300	5	7	63.6	
1	10,400	10,400	12	14	63.9	

1	10,500	10,500	10	12	58.9
1	10,600	10,600	9	11	58.8
1	10,700	10,700	5	7	60.7
1	10,800	10,800	7	9	60.4
1	10,900	10,900	9	11	60.1
1	11,000	11,000	7	9	59.4
1	11,100	11,100	7	9	58.8
1	11,200	11,200	5	7	58.8
1	11,300	11,300	8	10	55.8
1	11,400	11,400	8	10	55.9
1	11,500	11,500	13	15	55.1
1	11,600	11,600	10	12	55.0
1	11,700	11,700	7	9	57.5
1	11,800	11,800	8	10	58.0
1	11,900	11,900	9	11	57.9
1	12,000	12,000	15	17	57.6
1	12,100	12,100	14	16	56.4
1	12,200	12,200	11	13	58.7
1	12,300	12,300	9	11	58.8
1	12,400	12,400	9	11	58.8
1	12,500	12,500	12	14	58.3
1	12,600	12,600	10	12	58.2
1	12,700	12,700	21	23	57.5
1	12,800	12,800	12	14	58.6
1	12,900	12,900	13	15	60.1
1	13,000	13,000	11	13	59.2
1	13,100	13,100	9	11	58.1
1	13,200	13,200	9	11	60.4
1	13,300	13,300	10	12	60.5
1	13,400	13,400	8	10	58.2
1	13,500	13,500	8	10	58.4
1	13,600	13,600	6	8	60.2
1	13,700	13,700	7	9	59.6
1	13,800	13,800	12	14	58.1
1	13,900	13,900	8	10	56.8
1	14,000	14,000	6	8	55.9
1	14,100	14,100	5	7	55.3
1	14,200	14,200	2	4	58.0
1	14,300	14,300	3	5	57.5
1	14,399	14,399	6	8	56.7
1	14,499	14,499	5	7	61.2
1	14,599	14,599	7	9	61.9
1	14,699	14,699	10	12	60.6
1	14,799	14,799	12	14	58.3
1	14,899	14,899	11	13	56.5
1	14,999	14,999	10	12	57.5
1	15,099	15,099	10	12	58.8
1	15,199	15,199	10	12	60.2
1	15,299	15,299	9	11	60.0
1	15,399	15,399	8	10	59.4
1	15,499	15,499	8	10	58.4
1	15,599	15,599	11	13	59.4
1	15,699	15,699	17	19	59.4
1	15,799	15,799	15	17	58.5
1	15,899	15,899	12	14	58.6
1	15,999	15,999	13	15	58.5
1	16,099	16,099	10	12	57.0
1	16,199	16,199	15	17	57.8
1	16,299	16,299	11	13	58.2
1	16,399	16,399	14	16	55.9
1	16,499	16,499	12	14	60.7
1	16,599	16,599	13	15	60.0
1	16,699	16,699	10	12	59.2
1	16,799	16,799	9	11	58.5
1	16,899	16,899	7	9	58.6
1	16,999	16,999	9	11	59.0
1	17,099	17,099	14	16	57.2
1	17,199	17,199	12	14	56.7

1	17,299	17,299	10	12	57.6
1	17,399	17,399	11	13	57.9
1	17,499	17,499	11	13	57.4
1	17,599	17,599	14	16	58.2
1	17,699	17,699	4	6	58.0
1	17,799	17,799	5	7	58.9
1	17,899	17,899	6	8	58.5
1	17,999	17,999	7	9	59.6
1	18,099	18,099	10	12	60.1
1	18,199	18,199	13	15	57.7
1	18,299	18,299	12	14	56.6
1	18,399	18,399	9	11	58.8
1	18,499	18,499	9	11	61.2
1	18,599	18,599	9	11	62.5
1	18,699	18,699	10	12	62.7
1	18,799	18,799	17	19	61.6
1	18,899	18,899	12	14	60.8
1	18,999	18,999	11	13	60.5
1	19,099	19,099	12	14	60.1
1	19,199	19,199	11	13	60.8
1	19,299	19,299	9	11	64.1
1	19,399	19,399	14	16	62.3
1	19,590	19,590	11	13	42.9
Average Value			**10**	**12**	


MARYVALE ROAD 80KM/H
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600
4,400
Average IRI Values (m/km)
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
Distance (m)
0
2,000
4,000
6,000
8,000
10,000
12,000
14,000
16,000
18,000

May 7, 2004, 01:47 PM
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Field Data Sheet

ROAD NAME: MARYVALE ROAD 80KM/H

SECTION: FROM: SANTA TERESA ROAD TO: GRID 20KM

SURVEY DATE: 05/05/2004 TIME: 10:11:50

TRAVEL DIRECTION: SOUTH

REFERENCE: ....

VEHICLE: HI LUX 815-820

OPERATOR: RICHARD UNDERHILL

COMMENTS: ....

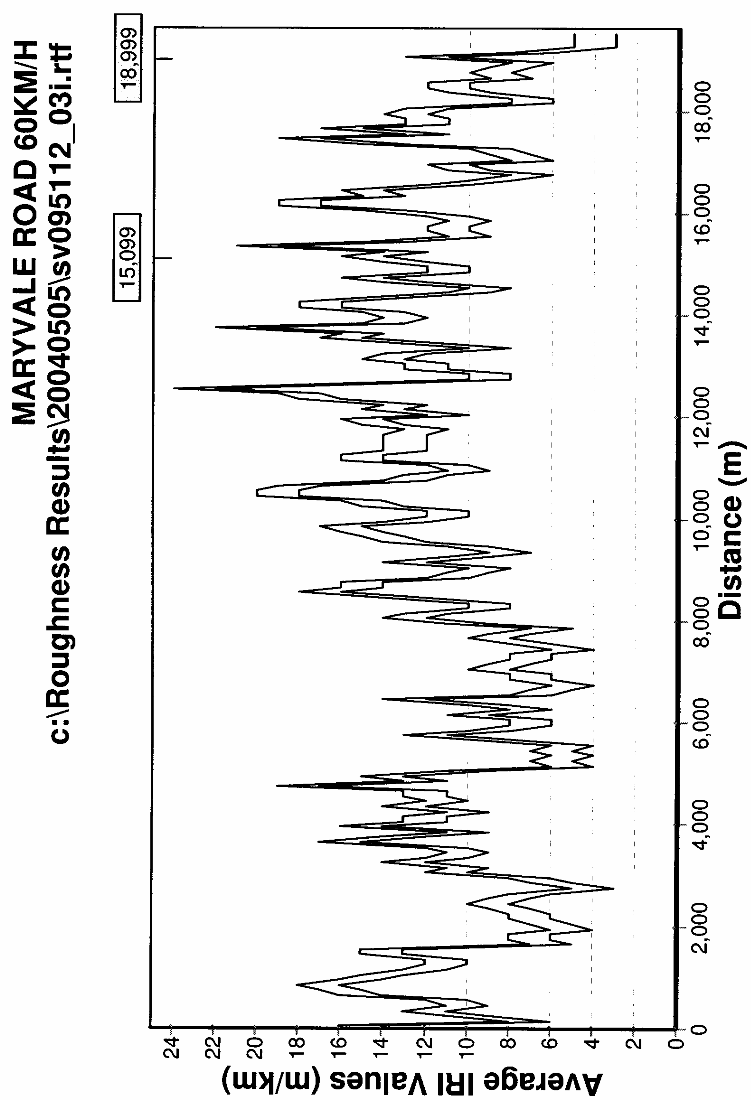
Roughness Value

SecID	SubDist	TotDist	IRI-Min	IRI-Max	Speed	Event
1	100	100	6	8	38.2	
1	200	200	3	5	60.4	
1	300	300	3	5	61.5	
1	400	400	3	5	64.9	
1	500	500	6	8	65.2	
1	600	600	7	9	51.5	End Seal
1	700	700	5	7	56.2	
1	800	800	14	16	68.9	
1	900	900	12	14	75.8	
1	1,000	1,000	11	13	76.7	
1	1,100	1,100	11	13	77.5	
1	1,200	1,200	10	12	78.6	
1	1,300	1,300	10	12	80.4	
1	1,400	1,400	7	9	81.0	
1	1,500	1,500	11	13	80.4	
1	1,600	1,600	13	15	78.9	
1	1,700	1,700	6	8	79.2	
1	1,800	1,800	9	11	78.3	
1	1,900	1,900	7	9	79.4	
1	2,000	2,000	17	19	81.3	
1	2,100	2,100	18	20	80.3	
1	2,200	2,200	10	12	78.6	
1	2,300	2,300	11	13	79.7	
1	2,400	2,400	12	14	81.4	
1	2,500	2,500	12	14	83.1	
1	2,600	2,600	7	9	80.6	
1	2,700	2,700	11	13	80.1	
1	2,800	2,800	15	17	79.3	
1	2,900	2,900	13	15	79.7	
1	3,000	3,000	6	8	81.0	
1	3,100	3,100	6	8	80.9	
1	3,200	3,200	13	15	80.4	
1	3,300	3,300	15	17	79.3	
1	3,400	3,400	18	20	78.4	
1	3,500	3,500	11	13	79.0	
1	3,600	3,600	18	20	78.5	

1	3,700	3,700	17	19	78.2	
1	3,800	3,800	12	14	79.9	
1	3,900	3,900	7	9	81.8	
1	4,000	4,000	6	8	81.2	
1	4,100	4,100	9	11	80.7	
1	4,200	4,200	9	11	80.7	
1	4,300	4,300	11	13	79.2	
1	4,400	4,400	9	11	73.6	Grid
1	4,500	4,500	14	16	72.5	
1	4,600	4,600	15	17	76.3	
1	4,700	4,700	13	15	77.1	
1	4,800	4,800	14	16	79.3	
1	4,900	4,900	10	12	78.3	
1	5,000	5,000	17	19	77.1	
1	5,100	5,100	8	10	77.5	
1	5,200	5,200	14	16	78.6	
1	5,300	5,300	13	15	75.8	
1	5,400	5,400	14	16	76.6	
1	5,500	5,500	16	18	77.8	
1	5,600	5,600	11	13	78.3	
1	5,700	5,700	11	13	77.8	
1	5,800	5,800	14	16	79.6	
1	5,900	5,900	16	18	79.6	
1	6,000	6,000	15	17	80.0	
1	6,100	6,100	13	15	81.4	
1	6,200	6,200	13	15	82.2	
1	6,300	6,300	13	15	81.1	
1	6,400	6,400	11	13	76.7	
1	6,500	6,500	19	21	71.3	
1	6,600	6,600	14	16	73.3	
1	6,700	6,700	17	19	76.1	
1	6,800	6,800	17	19	78.0	
1	6,900	6,900	12	14	79.5	
1	7,000	7,000	19	21	78.7	
1	7,100	7,100	21	23	76.0	
1	7,200	7,200	12	14	74.5	
1	7,300	7,300	21	23	75.4	
1	7,400	7,400	12	14	77.6	
1	7,500	7,500	16	18	79.1	
1	7,600	7,600	21	23	79.4	
1	7,700	7,700	21	23	79.4	
1	7,800	7,800	16	18	78.9	
1	7,900	7,900	17	19	78.8	
1	8,000	8,000	16	18	80.4	
1	8,100	8,100	16	18	80.2	
1	8,200	8,200	12	14	80.1	
1	8,300	8,300	11	13	80.8	
1	8,400	8,400	12	14	79.1	
1	8,500	8,500	18	20	75.3	
1	8,600	8,600	20	22	76.5	
1	8,700	8,700	20	22	77.4	
1	8,800	8,800	21	23	79.1	
1	8,900	8,900	22	24	79.7	
1	9,000	9,000	19	21	79.7	
1	9,100	9,100	24	26	80.1	
1	9,200	9,200	26	28	80.6	
1	9,300	9,300	20	22	79.6	
1	9,400	9,400	20	22	80.0	
1	9,500	9,500	20	22	80.0	
1	9,600	9,600	24	26	80.0	
1	9,700	9,700	23	25	81.1	
1	9,800	9,800	25	27	79.9	
1	9,900	9,900	20	22	78.0	
1	10,000	10,000	19	21	79.1	
1	10,100	10,100	13	15	79.4	
1	10,200	10,200	11	13	79.6	
1	10,300	10,300	5	7	82.2	
1	10,400	10,400	11	13	81.7	

1	10,500	10,500	13	15	79.2
1	10,600	10,600	10	12	78.7
1	10,700	10,700	7	9	80.9
1	10,800	10,800	7	9	81.5
1	10,900	10,900	9	11	82.0
1	11,000	11,000	10	12	81.3
1	11,100	11,100	9	11	82.5
1	11,200	11,200	7	9	81.3
1	11,300	11,300	8	10	80.0
1	11,400	11,400	11	13	78.4
1	11,500	11,500	15	17	78.1
1	11,600	11,600	16	18	77.3
1	11,700	11,700	8	10	79.3
1	11,800	11,800	11	13	80.8
1	11,900	11,900	10	12	81.4
1	12,000	12,000	17	19	79.8
1	12,100	12,100	16	18	78.2
1	12,200	12,200	9	11	80.9
1	12,300	12,300	14	16	81.7
1	12,400	12,400	8	10	81.0
1	12,500	12,500	16	18	81.1
1	12,600	12,600	10	12	79.4
1	12,700	12,700	24	26	77.7
1	12,800	12,800	15	17	78.9
1	12,900	12,900	18	20	81.0
1	13,000	13,000	10	12	80.7
1	13,100	13,100	11	13	81.2
1	13,200	13,200	10	12	82.1
1	13,300	13,300	14	16	80.7
1	13,400	13,400	10	12	79.1
1	13,500	13,500	10	12	79.9
1	13,600	13,600	7	9	81.7
1	13,700	13,700	7	9	81.6
1	13,800	13,800	18	20	79.7
1	13,900	13,900	11	13	78.2
1	14,000	14,000	8	10	79.2
1	14,100	14,100	8	10	81.0
1	14,200	14,200	2	4	81.8
1	14,300	14,300	4	6	79.9
1	14,399	14,399	9	11	79.6
1	14,499	14,499	8	10	80.5
1	14,599	14,599	6	8	82.4
1	14,699	14,699	13	15	80.3
1	14,799	14,799	11	13	78.7
1	14,899	14,899	19	21	75.8
1	14,999	14,999	11	13	75.8
1	15,099	15,099	12	14	78.7
1	15,199	15,199	10	12	80.0
1	15,299	15,299	11	13	80.9
1	15,399	15,399	12	14	79.8
1	15,499	15,499	10	12	78.0
1	15,599	15,599	11	13	77.3
1	15,699	15,699	21	23	75.3
1	15,799	15,799	15	17	75.4
1	15,899	15,899	17	19	76.6
1	15,999	15,999	16	18	76.9
1	16,099	16,099	13	15	76.5
1	16,199	16,199	14	16	77.9
1	16,299	16,299	13	15	79.1
1	16,399	16,399	16	18	78.2
1	16,499	16,499	13	15	79.1
1	16,599	16,599	16	18	78.5
1	16,699	16,699	11	13	79.9
1	16,799	16,799	12	14	80.5
1	16,899	16,899	8	10	81.0
1	16,999	16,999	10	12	80.9
1	17,099	17,099	16	18	79.5
1	17,199	17,199	17	19	78.0

1	17,299	17,299	13	15	78.6
1	17,399	17,399	15	17	80.0
1	17,499	17,499	12	14	79.5
1	17,599	17,599	13	15	76.2
1	17,699	17,699	6	8	75.1
1	17,799	17,799	7	9	78.4
1	17,899	17,899	12	14	80.2
1	17,999	17,999	10	12	80.4
1	18,099	18,099	11	13	81.0
1	18,199	18,199	14	16	80.3
1	18,299	18,299	15	17	77.4
1	18,399	18,399	12	14	78.5
1	18,499	18,499	10	12	80.2
1	18,599	18,599	12	14	82.7
1	18,699	18,699	14	16	82.3
1	18,799	18,799	17	19	79.2
1	18,899	18,899	18	20	78.2
1	18,999	18,999	12	14	77.9
1	19,099	19,099	12	14	78.7
1	19,199	19,199	15	17	78.2
1	19,299	19,299	11	13	79.0
1	19,399	19,399	16	18	77.3
1	19,499	19,499	12	14	70.6
1	19,601	19,601	9	11	46.2
Average Value			**13**	**15**	


MARYVALE ROAD 60KM/H
c:\Roughness Results\20040505\sv095112_03i.rtf
15,099
18,999
Average IRI Values (m/km)
Distance (m)

May 7, 2004, 02:05 PM
c:\Roughness Results\20040505\sv095112_03i.rtf

Field Data Sheet

ROAD NAME: MARYVALE ROAD 60KM/H

SECTION: FROM: GRID 20KM TO: SANTA TERESA ROAD

SURVEY DATE: 05/05/2004 TIME: 09:51:12

TRAVEL DIRECTION: NORTH

REFERENCE: ....

VEHICLE: HI LUX 815-820

OPERATOR: RICHARD UNDERHILL

COMMENTS: ....

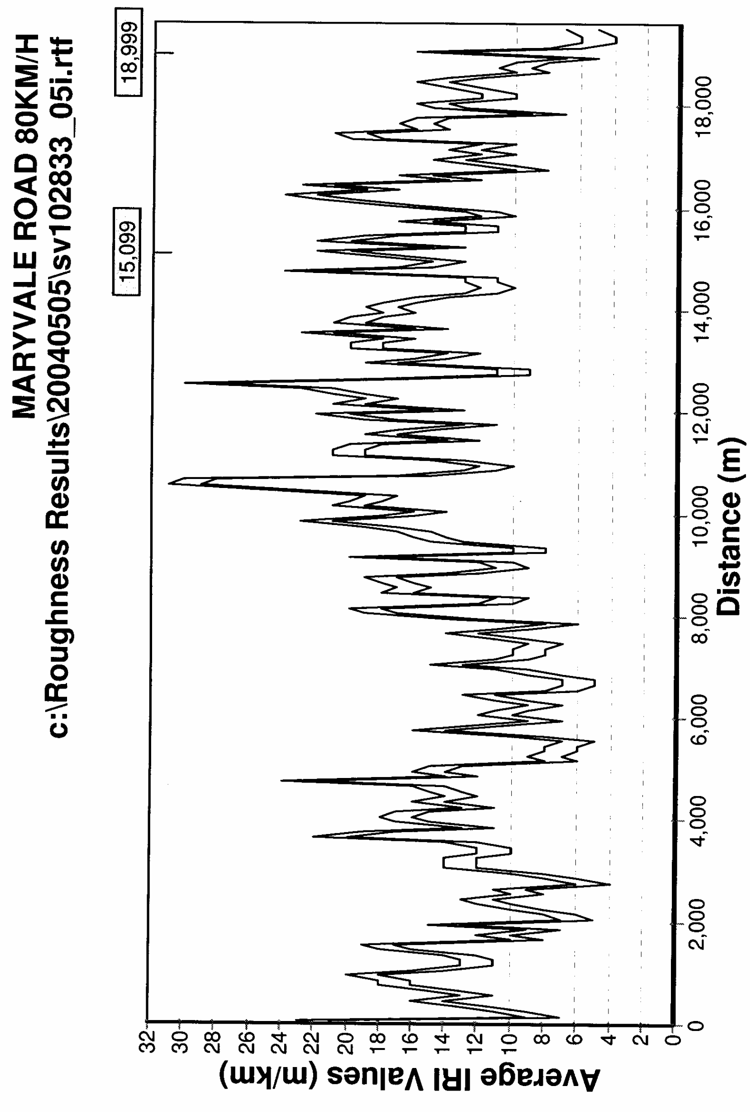
Roughness Value

SecID	SubDist	TotDist	IRI-Min	IRI-Max	Speed	Event
1	100	100	14	16	31.7	
1	200	200	6	8	52.8	
1	300	300	9	11	55.5	
1	400	400	11	13	60.0	
1	500	500	9	11	58.5	
1	600	600	10	12	55.9	
1	700	700	14	16	56.3	
1	800	800	15	17	56.1	
1	900	900	16	18	57.5	
1	1,000	1,000	14	16	60.1	
1	1,100	1,100	13	15	59.1	
1	1,200	1,200	11	13	59.6	
1	1,300	1,300	10	12	59.2	
1	1,400	1,400	10	12	58.0	
1	1,500	1,500	13	15	57.2	
1	1,600	1,600	13	15	56.8	
1	1,700	1,700	5	7	57.4	
1	1,800	1,800	6	8	58.6	
1	1,900	1,900	6	8	59.1	
1	2,000	2,000	4	6	59.8	
1	2,100	2,100	5	7	60.9	
1	2,200	2,200	6	8	59.7	
1	2,300	2,300	6	8	61.0	
1	2,400	2,400	7	9	60.7	
1	2,500	2,500	8	10	59.3	
1	2,600	2,600	7	9	59.1	
1	2,700	2,700	6	8	59.1	
1	2,800	2,800	3	5	59.4	
1	2,900	2,900	5	7	59.6	
1	3,000	3,000	6	8	61.2	
1	3,100	3,100	10	12	61.6	
1	3,200	3,200	9	11	60.7	
1	3,300	3,300	12	14	58.7	
1	3,400	3,400	10	12	61.3	
1	3,500	3,500	9	11	60.0	
1	3,600	3,600	10	12	60.1	

1	3,700	3,700	15	17	60.4
1	3,800	3,800	12	14	59.4
1	3,900	3,900	9	11	60.3
1	4,000	4,000	14	16	60.7
1	4,100	4,100	11	13	60.6
1	4,200	4,200	11	13	60.6
1	4,300	4,300	9	11	60.0
1	4,400	4,400	12	14	59.8
1	4,500	4,500	10	12	57.1
1	4,600	4,600	11	13	57.1
1	4,700	4,700	11	13	55.1
1	4,800	4,800	17	19	56.3
1	4,900	4,900	11	13	59.2
1	5,000	5,000	13	15	59.2
1	5,100	5,100	9	11	60.1
1	5,200	5,200	4	6	59.8
1	5,300	5,300	5	7	59.9
1	5,400	5,400	4	6	61.9
1	5,500	5,500	5	7	61.4
1	5,600	5,600	4	6	58.8
1	5,700	5,700	7	9	57.9
1	5,800	5,800	11	13	57.1
1	5,900	5,900	8	10	56.6
1	6,000	6,000	6	8	58.8
1	6,100	6,100	6	8	58.8
1	6,200	6,200	9	11	56.9
1	6,300	6,300	6	8	58.8
1	6,400	6,400	8	10	60.0
1	6,500	6,500	12	14	59.6
1	6,600	6,600	6	8	58.8
1	6,700	6,700	5	7	59.3
1	6,800	6,800	4	6	59.2
1	6,900	6,900	6	8	58.8
1	7,000	7,000	6	8	59.4
1	7,100	7,100	8	10	61.0
1	7,200	7,200	7	9	62.2
1	7,300	7,300	6	8	62.1
1	7,400	7,400	6	8	60.8
1	7,500	7,500	4	6	60.6
1	7,600	7,600	6	8	59.2
1	7,700	7,700	8	10	60.1
1	7,800	7,800	7	9	60.1
1	7,900	7,900	5	7	60.5
1	8,000	8,000	9	11	61.9
1	8,100	8,100	12	14	60.5
1	8,200	8,200	11	13	58.6
1	8,300	8,300	8	10	58.0
1	8,400	8,400	8	10	58.0
1	8,500	8,500	12	14	59.8
1	8,600	8,600	16	18	60.1
1	8,700	8,700	14	16	60.6
1	8,800	8,800	14	16	60.1
1	8,900	8,900	10	12	61.7
1	9,000	9,000	9	11	61.2
1	9,100	9,100	8	10	60.8
1	9,200	9,200	12	14	60.8
1	9,300	9,300	9	11	59.4
1	9,400	9,400	7	9	60.2
1	9,500	9,500	9	11	59.2
1	9,600	9,600	12	14	57.9
1	9,700	9,700	13	15	58.6
1	9,800	9,800	14	16	58.7
1	9,900	9,900	15	17	59.1
1	10,000	10,000	12	14	58.4
1	10,100	10,100	10	12	58.1
1	10,200	10,200	10	12	56.6
1	10,300	10,300	13	15	56.8
1	10,400	10,400	14	16	56.8

1	10,500	10,500	18	20	57.6	
1	10,600	10,600	18	20	58.0	
1	10,700	10,700	17	19	57.7	
1	10,800	10,800	12	14	58.8	
1	10,900	10,900	11	13	60.1	
1	11,000	11,000	9	11	62.1	
1	11,100	11,100	10	12	58.1	
1	11,200	11,200	14	16	55.9	
1	11,300	11,300	14	16	58.3	
1	11,400	11,400	12	14	59.6	
1	11,500	11,500	12	14	59.2	
1	11,600	11,600	12	14	57.9	
1	11,700	11,700	12	14	57.2	
1	11,800	11,800	11	13	58.5	
1	11,900	11,900	13	15	60.2	
1	12,000	12,000	14	16	59.2	
1	12,100	12,100	10	12	58.6	
1	12,200	12,200	13	15	59.8	
1	12,300	12,300	12	14	59.9	
1	12,400	12,400	16	18	59.6	
1	12,500	12,500	17	19	60.1	
1	12,600	12,600	22	24	59.7	
1	12,700	12,700	14	16	60.8	
1	12,800	12,800	8	10	60.5	
1	12,900	12,900	8	10	58.7	
1	13,000	13,000	11	13	57.9	
1	13,100	13,100	11	13	58.0	
1	13,200	13,200	13	15	58.7	
1	13,300	13,300	12	14	60.7	
1	13,400	13,400	8	10	60.5	
1	13,500	13,500	11	13	61.9	
1	13,600	13,600	15	17	60.1	
1	13,700	13,700	14	16	59.0	
1	13,800	13,800	20	22	57.2	
1	13,900	13,900	13	15	60.2	
1	14,000	14,000	12	14	61.5	
1	14,100	14,100	13	15	61.0	
1	14,200	14,200	16	18	59.1	
1	14,300	14,300	16	18	58.1	
1	14,399	14,399	13	15	56.7	
1	14,499	14,499	9	11	60.0	
1	14,599	14,599	8	10	60.9	
1	14,699	14,699	12	14	60.6	
1	14,799	14,799	14	16	59.2	
1	14,899	14,899	10	12	58.8	
1	14,999	14,999	10	12	59.1	
1	15,099	15,099	12	14	58.7	Grid
1	15,199	15,199	14	16	47.8	
1	15,299	15,299	12	14	53.8	
1	15,399	15,399	19	21	58.2	
1	15,499	15,499	13	15	59.4	
1	15,599	15,599	9	11	60.9	
1	15,699	15,699	10	12	61.2	
1	15,799	15,799	10	12	61.1	
1	15,899	15,899	9	11	59.9	
1	15,999	15,999	10	12	59.6	
1	16,099	16,099	13	15	60.3	
1	16,199	16,199	17	19	60.0	
1	16,299	16,299	17	19	58.4	
1	16,399	16,399	13	15	58.1	
1	16,499	16,499	14	16	58.7	
1	16,599	16,599	10	12	60.8	
1	16,699	16,699	8	10	60.9	
1	16,799	16,799	6	8	61.3	
1	16,899	16,899	9	11	62.0	
1	16,999	16,999	10	12	60.4	
1	17,099	17,099	6	8	60.5	
1	17,199	17,199	7	9	61.1	

1	17,299	17,299	8	10	60.8	
1	17,399	17,399	13	15	61.2	
1	17,499	17,499	17	19	61.0	
1	17,599	17,599	11	13	61.4	
1	17,699	17,699	15	17	61.1	
1	17,799	17,799	11	13	60.1	
1	17,899	17,899	11	13	61.6	
1	17,999	17,999	12	14	60.7	
1	18,099	18,099	11	13	59.9	
1	18,199	18,199	6	8	60.5	
1	18,299	18,299	6	8	61.9	
1	18,399	18,399	9	11	60.3	
1	18,499	18,499	10	12	58.9	
1	18,599	18,599	10	12	60.4	
1	18,699	18,699	7	9	59.8	
1	18,799	18,799	8	10	59.0	
1	18,899	18,899	7	9	59.3	
1	18,999	18,999	6	8	54.2	Start Seal
1	19,099	19,099	11	13	51.4	
1	19,199	19,199	6	8	58.6	
1	19,299	19,299	3	5	57.0	
1	19,399	19,399	3	5	53.5	
1	19,592	19,592	3	5	38.7	
Average Value			**10**	**12**		


MARYVALE ROAD 80KM/H
c:\Roughness Results\20040505\sv102833_05i.rtf
15,099
18,999
Average IRI Values (m/km)
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
Distance (m)
0
2,000
4,000
6,000
8,000
10,000
12,000
14,000
16,000
18,000

May 7, 2004, 01:54 PM
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Field Data Sheet

ROAD NAME: MARYVALE ROAD 80KM/H

SECTION: FROM: GRID 20KM TO: SANTA TERESA ROAD

SURVEY DATE: 05/05/2004 TIME: 10:28:33

TRAVEL DIRECTION: NORTH

REFERENCE: ....

VEHICLE: HI LUX 815-820

OPERATOR: RICHARD UNDERHILL

COMMENTS: ....

Roughness Value

SecID	SubDist	TotDist	IRI-Min	IRI-Max	Speed	Event
1	100	100	21	23	32.4	
1	200	200	7	9	64.1	
1	300	300	9	11	74.1	
1	400	400	11	13	77.8	
1	500	500	14	16	76.7	
1	600	600	11	13	75.7	
1	700	700	13	15	75.7	
1	800	800	16	18	77.2	
1	900	900	16	18	78.3	
1	1,000	1,000	18	20	79.8	
1	1,100	1,100	14	16	79.7	
1	1,200	1,200	11	13	79.8	
1	1,300	1,300	11	13	78.4	
1	1,400	1,400	12	14	75.9	
1	1,500	1,500	16	18	68.9	
1	1,600	1,600	17	19	68.3	
1	1,700	1,700	8	10	71.2	
1	1,800	1,800	10	12	73.8	
1	1,900	1,900	7	9	76.5	
1	2,000	2,000	13	15	80.4	
1	2,100	2,100	5	7	82.1	
1	2,200	2,200	6	8	82.2	
1	2,300	2,300	8	10	81.0	
1	2,400	2,400	10	12	80.6	
1	2,500	2,500	11	13	80.6	
1	2,600	2,600	8	10	81.2	
1	2,700	2,700	9	11	81.7	
1	2,800	2,800	4	6	82.4	
1	2,900	2,900	6	8	81.5	
1	3,000	3,000	8	10	81.8	
1	3,100	3,100	12	14	80.8	
1	3,200	3,200	12	14	80.7	
1	3,300	3,300	12	14	80.8	
1	3,400	3,400	10	12	81.4	
1	3,500	3,500	10	12	81.1	
1	3,600	3,600	12	14	81.7	

1	3,700	3,700	20	22	81.5
1	3,800	3,800	17	19	81.5
1	3,900	3,900	11	13	81.6
1	4,000	4,000	15	17	81.3
1	4,100	4,100	16	18	81.5
1	4,200	4,200	15	17	82.2
1	4,300	4,300	11	13	82.6
1	4,400	4,400	14	16	81.4
1	4,500	4,500	12	14	79.7
1	4,600	4,600	13	15	79.5
1	4,700	4,700	14	16	77.2
1	4,800	4,800	22	24	76.9
1	4,900	4,900	12	14	78.3
1	5,000	5,000	14	16	80.1
1	5,100	5,100	13	15	79.4
1	5,200	5,200	6	8	79.1
1	5,300	5,300	7	9	78.8
1	5,400	5,400	6	8	82.3
1	5,500	5,500	6	8	84.1
1	5,600	5,600	5	7	82.1
1	5,700	5,700	8	10	80.3
1	5,800	5,800	14	16	78.8
1	5,900	5,900	11	13	78.0
1	6,000	6,000	7	9	79.4
1	6,100	6,100	10	12	78.9
1	6,200	6,200	9	11	77.6
1	6,300	6,300	7	9	79.3
1	6,400	6,400	9	11	80.7
1	6,500	6,500	11	13	80.6
1	6,600	6,600	6	8	80.2
1	6,700	6,700	5	7	82.5
1	6,800	6,800	5	7	82.3
1	6,900	6,900	7	9	81.4
1	7,000	7,000	9	11	82.2
1	7,100	7,100	13	15	81.3
1	7,200	7,200	9	11	81.2
1	7,300	7,300	8	10	83.8
1	7,400	7,400	8	10	82.8
1	7,500	7,500	7	9	80.4
1	7,600	7,600	9	11	79.5
1	7,700	7,700	12	14	79.3
1	7,800	7,800	9	11	79.1
1	7,900	7,900	6	8	78.6
1	8,000	8,000	12	14	76.6
1	8,100	8,100	17	19	77.5
1	8,200	8,200	18	20	78.5
1	8,300	8,300	10	12	80.9
1	8,400	8,400	9	11	83.9
1	8,500	8,500	16	18	83.9
1	8,600	8,600	15	17	80.3
1	8,700	8,700	16	18	81.6
1	8,800	8,800	17	19	82.1
1	8,900	8,900	12	14	82.3
1	9,000	9,000	9	11	81.1
1	9,100	9,100	10	12	80.5
1	9,200	9,200	18	20	80.8
1	9,300	9,300	8	10	80.7
1	9,400	9,400	8	10	81.8
1	9,500	9,500	13	15	79.3
1	9,600	9,600	14	16	77.1
1	9,700	9,700	15	17	77.7
1	9,800	9,800	17	19	78.2
1	9,900	9,900	21	23	79.2
1	10,000	10,000	16	18	78.7
1	10,100	10,100	14	16	79.0
1	10,200	10,200	19	21	78.9
1	10,300	10,300	18	20	79.8
1	10,400	10,400	17	19	79.2

1	10,500	10,500	22	24	78.9	
1	10,600	10,600	29	31	80.0	
1	10,700	10,700	28	30	80.0	
1	10,800	10,800	15	17	80.7	
1	10,900	10,900	11	13	81.5	
1	11,000	11,000	10	12	82.2	
1	11,100	11,100	13	15	78.5	
1	11,200	11,200	19	21	76.4	
1	11,300	11,300	19	21	78.0	
1	11,400	11,400	18	20	79.1	
1	11,500	11,500	12	14	79.7	
1	11,600	11,600	17	19	79.5	
1	11,700	11,700	15	17	79.0	
1	11,800	11,800	11	13	78.2	
1	11,900	11,900	17	19	79.0	
1	12,000	12,000	20	22	79.3	
1	12,100	12,100	13	15	78.1	
1	12,200	12,200	19	21	78.4	
1	12,300	12,300	17	19	79.0	
1	12,400	12,400	19	21	78.9	
1	12,500	12,500	21	23	79.9	
1	12,600	12,600	28	30	80.2	
1	12,700	12,700	16	18	81.0	
1	12,800	12,800	9	11	81.6	
1	12,900	12,900	9	11	78.8	
1	13,000	13,000	17	19	77.3	
1	13,100	13,100	14	16	79.1	
1	13,200	13,200	12	14	79.8	
1	13,300	13,300	18	20	81.4	
1	13,400	13,400	18	20	80.9	
1	13,500	13,500	16	18	80.5	
1	13,600	13,600	21	23	80.0	
1	13,700	13,700	14	16	79.8	
1	13,800	13,800	19	21	77.8	
1	13,900	13,900	18	20	79.6	
1	14,000	14,000	16	18	81.5	
1	14,100	14,100	17	19	83.1	
1	14,200	14,200	16	18	82.2	
1	14,300	14,300	14	16	78.9	
1	14,399	14,399	11	13	78.2	
1	14,499	14,499	10	12	80.7	
1	14,599	14,599	11	13	84.0	
1	14,699	14,699	11	13	84.4	
1	14,799	14,799	22	24	80.4	
1	14,899	14,899	15	17	78.2	
1	14,999	14,999	13	15	78.3	
1	15,099	15,099	16	18	74.2	Grid
1	15,199	15,199	20	22	64.1	
1	15,299	15,299	13	15	68.7	
1	15,399	15,399	20	22	74.0	
1	15,499	15,499	17	19	78.6	
1	15,599	15,599	11	13	81.7	
1	15,699	15,699	11	13	82.8	
1	15,799	15,799	15	17	81.7	
1	15,899	15,899	10	12	81.0	
1	15,999	15,999	11	13	80.7	
1	16,099	16,099	16	18	80.7	
1	16,199	16,199	20	22	79.8	
1	16,299	16,299	22	24	77.7	
1	16,399	16,399	17	19	77.9	
1	16,499	16,499	21	23	77.3	
1	16,599	16,599	12	14	80.1	
1	16,699	16,699	15	17	81.9	
1	16,799	16,799	8	10	81.0	
1	16,899	16,899	10	12	81.3	
1	16,999	16,999	13	15	80.6	
1	17,099	17,099	10	12	81.8	
1	17,199	17,199	12	14	81.3	

1	17,299	17,299	10	12	81.0	
1	17,399	17,399	18	20	79.9	
1	17,499	17,499	19	21	78.9	
1	17,599	17,599	14	16	79.8	
1	17,699	17,699	15	17	79.7	
1	17,799	17,799	14	16	78.5	
1	17,899	17,899	7	9	79.7	
1	17,999	17,999	13	15	82.0	
1	18,099	18,099	14	16	81.6	
1	18,199	18,199	10	12	81.3	
1	18,299	18,299	10	12	82.0	
1	18,399	18,399	12	14	81.4	
1	18,499	18,499	14	16	77.9	
1	18,599	18,599	12	14	77.3	
1	18,699	18,699	8	10	78.3	
1	18,799	18,799	9	11	79.5	
1	18,899	18,899	8	10	78.7	
1	18,999	18,999	5	7	68.8	Start Seal
1	19,099	19,099	14	16	58.1	
1	19,199	19,199	6	8	67.5	
1	19,299	19,299	4	6	75.5	
1	19,399	19,399	4	6	78.1	
1	19,585	19,585	5	7	48.7	
Average Value			**13**	**15**		