Determination of the Structural Number of Pavements on Volcanic Subgrades

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Determination of the Structural Number of Pavements on Volcanic Subgrades

R. Bailey
J. E. Patrick

Opus International Consultants Ltd
Opus Central Laboratories
PO Box 30 845
LOWER HUTT

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PO Box 2331, Lambton Quay, Wellington, New Zealand
Telephone 64-4-473-0220; Facsimile 64-4-499-0733

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An Important Note for the Reader

The research detailed in this report was commissioned by Transfund New Zealand.

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Executive Summary

Pavements constructed on volcanic subgrades typically have higher deflections under load than similarly performing pavements constructed on other subgrades. This has created a difficulty in determining the structural strength of these types of pavements based on their deflection response when determined by instruments such as the falling weight deflectonmeter (FWD). The anomalous behaviour of volcanic subgrades means the standard methods used for assigning strength based on FWD readings cannot be used. The relationship between the *in situ* CBR (California bearing ratio) and FWD modulus of volcanic soils was investigated.

Past work was reviewed together with geological maps regarding the engineering properties and distribution of the volcanic soils within the North Island.

An attempt to class the volcanic soils into three main soil types was carried out. The location of 15 *in situ* test sites was then obtained. Site location was based on the amount of past work and the classification.

The performance of the 15 sites was investigated using the FWD, test pits, *in situ* CBR and other standards tests; and the Allophane content was also obtained.

From the results of the testing it was found that three correlations between the *in situ* CBR and the isotropic modulus were apparent.

These relationships were then used to derive a robust method to assess the structural number of pavements constructed on volcanic subgrades. Factors were presented based on the relationships and the process to enable the structural number to be calculated.

Factors for the use in Austroads pavement design were also presented.

To enable the Tonkin & Taylor method of indirect measurement of the structural number (SN) to be calculated on volcanic soils the addition of a constant was suggested (SNC), which should allow for the main differences between volcanic soils.

It is recommended that on volcanic soils a *possible* correlation between the FWD modulus and *in situ* CBR for volcanic soils on a network basis maybe:

- Isotropic Modulus = 1 × CBR, typically for pumice/sandy soils,
- Isotropic Modulus = 3 × CBR, mixture of Silty soils and Brown ash, (however, the relationship not well defined)
- Isotropic Modulus = 10 × CBR, typically includes clayey ash soils,
- That the above correlations be used to determine the CBR, which can be then used to calculate the SNC.
- That within the above relationship the modulus should be *multiplied* by 1.5 to obtain the vertical anisotropic modulus for use in Austroads design.
- That the T&T method for network surveys should be modified by the *addition* of 1.5, when using on pumiceous subgrades.
- That further research be performed to define the relationship between the FWD modulus and *in situ* CBR for volcanic silty soils.

Abstract

Pavements constructed on volcanic soils behave differently to non-volcanic soils and have higher deflections when dynamically loaded. Past relationships between CBR and modulus may therefore not be applicable. Fast non-destructive methods currently being used rely on these relationships and therefore relationship(s) between the CBR and modulus need to be obtained for volcanic soils. The project investigated the various volcanic soils within the North Island and attempted to classify the various types into three groups, initially based on the geological description and past work. *In situ* testing of the volcanic subgrades was conducted using the falling weight deflectonmeter (FWD) test and *in situ* CBR (California bearing ratio) together with other standard tests. From the *in situ* testing three correlations were identified for volcanic soils, however the third was not well defined. The volcanic soil types represented by the correlations were, clayey, pumiceous and silty/brown ash. To enable the structural number of pavements on volcanic soils to be determined, factors were presented, based on the identified relationships and the procedure for determining the structural number of pavement from the FWD modulus suggested. A modification of the Tonkin & Taylor method of determining the structural number was included which allowed for the use on volcanic subgrades. Also included were factors that allowed the volcanic relationships to be used in Austroads pavement design.

1 Introduction

1.1 Background

Pavements constructed on volcanic subgrades typically have higher deflections under load than similarly performing pavements constructed on other subgrades. This has created a difficulty in determining the structural strength of these types of pavements based on their deflection response when determined by instruments such as the falling weight deflectonmeter (FWD). The FWD is being used to obtain a measure of the pavement strength for use in pavement deterioration modelling as this is a rapid relatively inexpensive method suitable for network surveys. The anomalous behaviour of volcanic subgrades means the standard methods used for assigning strength based on FWD readings cannot be used.

As a large area in the Central North Island has volcanic subgrades and many of these areas are experiencing significant traffic growth, the application of pavement deterioration models in these areas will be constrained until an appropriate method is derived to determine their structural performance.

The concept of describing the strength of a pavement in terms of one number, called the structural number (SN), was developed from the AASHO road test published in 1962. The modified structural number (SNC) was developed to incorporate the contribution to the strength from the subgrade. The original definition of the SNC was based on the determination of the California bearing ratio (CBR) of the various pavement layers including the subgrade. The CBR test gives an indication of the shear strength of a material. Each pavement layer is then given a weighting based on its strength and thickness. The summation of these factors for each layer and the subgrade gives the SNC. The method for calculating the input into the modified structural number equation can be carried out either directly (CBR) or non-directly, using non-destructive methods.

The *in situ* determination of the CBR requires the digging of test pits and thus it is an expensive exercise. In order to obtain a faster and cheaper method the FWD has been used to calculate the modulus of the pavement layers and subgrade and then use a standard relationship between modulus and CBR to assign a strength factor to each layer. The FWD technique therefore, relies on the relationship between CBR and modulus.

Previous research performed by Central Laboratories on Taranaki brown ash demonstrated that the relationship between the CBR and modulus does not correspond to the standard relationship, which may lead to pavements being over-designed and the above non-destructive method to determine the SNC not applicable to volcanic soils. This has also been recognised by the RIMS group in their dTIMS implementation document "Establishing Pavement Strength for use with dTIMS" where the anomalous behaviour of volcanic subgrades has been highlighted. Therefore, for volcanic subgrades, the CBR FWD modulus relationship – to enable non-destructive methods to be used – needs to be determined.

The research project's aim was to develop a relationship between the subgrade CBR and FWD determined modulus so that this technique can be used for network surveys of pavement strength, the *structural number*.

Various studies have investigated different ways to determine the modified structural number. Salt and Stevens (2001) carried out a study to investigate the validity of the different methods, to determine which were applicable to New Zealand roads and developed an equation to determine the structural number from FWD non-destructive testing. This relationship however, was also derived form the standard CBR modulus relationship, and therefore to enable the equation to be used on volcanic subgrades an investigation to assess if the difference is significant must be carried out.

The results of this research will also be of benefit to pavement designers who at present accept that the performance of pavements on volcanic subgrades does not conform to the Austroads Pavement Design Guide. Although previous research reported in Transfund NZ Research Report No. 128 has given pavement designers information for areas on brown ash, for other volcanic subgrades the information is lacking. This research project will allow the expansion of the analysis performed in the previous research to be applied to other types of volcanic subgrades.

1.2 Objectives Of the Research

The objectives of this research were:

- To develop a relationship between the CBR and modulus derived from the FWD of volcanic soils;
- To use this relationship to derive a robust method to assess the structural number of pavements constructed on volcanic subgrades.

2 Background on Volcanic Soils

Volcanic ash showers have coated large areas of the North Island of New Zealand during the last 100,000 years Gibbs (1968). Some of the deposits have been removed by the elements or buried, but the ash deposits remaining are the principal soil-forming materials of the North Island. These deposits of volcanic ash have had a far-reaching effect, especially on soils and land use in the North Island. Slopes are generally smoother, and the soils more permeable, more friable, and more responsive to human management, than they would have been on land formed from the underlying rocks.

The principle centres of soil-forming ash showers in New Zealand are Mt. Egmont, Mt. Ruapehu, Mt. Ngauruhoe, Mt. Tongariro, Mt. Tarawera, and craters near Taupo, Rotorua, and the Bay of Plenty.

Two broad types of ash beds are recognised (Taylor 1933):

1. Intermittent type, in which materials are ejected on numerous occasions over a period of years. The materials are generally andesitic or basaltic and gradually build up a cone around the vent.
2. Paroxysmal type, in which materials are belched out in sudden explosions at long intervals. These materials are generally rhyolitic and are ejected from craters or rifts.

Most volcanic soils are best described as silty clays or clayey silts, despite the fact that they plot well below the Casagrande A-line on the placticity chart (i.e. are clearly in the silt zone).

Gibbs (1968) grouped New Zealand volcanic soils into five representative soil types. These were: recent soils from volcanic ash, yellow-brown pumice soils, yellow-brown loams, brown granular loams, and red loams and brown loams. These soil types were useful as a base to begin to determine the classification of volcanic soils discussed in the next section.

Some volcanic ashes have been named to collectively describe the Andesitic tephras which were deposited during the Taranaki eruptions, e.g. the Taranaki brown Ash, which frequently occurs in thick weak to strongly weathered beds. This weathering process produces a succession of 'clay minerals' with initially allophane being formed, which in time (say 20,000 years) changes to halloysites and finally kaolin. Other groups include the Hamilton ashes and the Taupo pumice. The ashes are given their name from either the locality of the vent or the locality of where the ash is extensively exposed at the surface.

3 Classification of Volcanic Soil Types

3.1 General

To try and define possible areas of similar volcanic soil that could then be tested in their various groups, previous OPUS research and projects were reviewed, and other work was also taken into consideration. The engineering properties were collated and used to develop a broad classification for the various volcanic soils. A number of tests were used to develop the classification: a few of these were the geological description, the particle size distribution, atterburg limits and the CBR test. A summary of the findings regarding the engineering properties of volcanic soils is detailed below.

3.2 Engineering Properties of Volcanic Soils

It has been found from previous studies [Fullarton, (1978), Jacquet, (1987),(1988), Miller, (undated), Parton, and Olsen, (1980) Sutherland, et al. (1997) White, (1982), Pender, (1996), Wesley and Chan, (1991), Wesley, L.D. (1999)], that volcanic soils engineering properties are wide ranging. Some volcanic soils, for example the brown ashes, tend to be sensitive to remoulding, and some volcanic soils can also physically change their properties when remoulded and/or dried, the soil altering its particle size distribution (psd).

It has been reported that the clay mineral 'allophane' and to a lesser extent halloysite are in a large part responsible for the unusual psd changing properties. Allophane contributes to the greasy feel of the soil. The change in the psd occurs due to the effect of the water being expelled from the molecular particle structure by bond-breakdown analogous to the way ice becomes water. The gel-like structure of the clay minerals collapse and form aggregations, which in turn makes the soils 'grity'. These new aggregates are reported to have a relatively high stability.

The sensitivity to remoulding of these soils may be due to the oxidation of iron in the ash. Iron oxide has been reported to form a 'structure' between the particles, which is broken-down when remoulded.

Most undisturbed volcanic soils tend to have high bearing capacities, as high pre-consolidation pressures have been measured on undisturbed volcanic ash, accompanied by irregular variations with depth. As there is no geological evidence as to why these soils have a high over-consolidation ratio, it is thought that this is due to the oxidation of iron forming a type of structure within the soil matrix. Once this pre-consolidation pressure is reached the soils rapidly lose strength and are highly compressible, i.e. the structure has broken-down.

Apparent pre-consolidation pressures can vary markedly. It was reported by Miller (undated) that a brown ash material (grey in its reduced state) effectively exhibited no pre-consolidation and was recovered from within a local poorly drained area. Jacquet (1987) reported that the pre-consolidation pressure was directly proportional to the shear strength. The strength characteristics of the ash were also reported to vary depending on the degree of weathering, oxidation (drainage conditions) and saturation, Miller (undated). Therefore an oxidised ash, with the iron structural matrix developed may be stronger up to the pre-consolidation pressure than an ash in its reduced state.

Pumice soils however, tend to be less sensitive to remoulding. This may be due to the kind of deposition and then cementation of the pumice grains, although some pumice soils still exhibit fairly high sensitivities, possibly due to larger amounts of iron present in some areas. Pumice soils also tend to be sandy and contain smaller amounts of the Allophane clay mineral: and therefore after remoulding, any change within the Allophane will be small and less likely to change the overall particle size distribution compared to such soils as clays.

In general, volcanic materials have been reported as having; a high particle density, due to the presence of heavy minerals, and a low dry density due to the high volume of voids. These voids have been found to be discrete internal voids within the particles themselves, and the particle shapes are angular, together with the rough microtexure which causes a high shear strength/friction angle. The soils also usually exhibit some cohesion. The natural moisture content of many of the soils, especially the brown ash soils, tends to be high, and in some case have been higher then the liquid limit. The liquid limit of the soils is also high compared to non-volcanic soils.

Care has to be taken in the interpretation of laboratory test results, as it has been found in New Zealand ashes that four different moisture/density relationships can be obtained, depending on whether a wet or dry soil is the starting point, and whether the same soil is used throughout or a fresh sample is taken for each compaction Jacquet (1987). The clay mineral Allophane may be responsible for these relationships. However, for pumice soils their particle size distribution may change under compaction activities due to their soft (low crushing resistance) character and the presence of Allophane.

3.3 Broad Groupings

During the review of the existing data, it was found that the test results were wide ranging with overlapping of results making the defining of the volcanic soils difficult. In general a broad grouping of the pumice soils/sands and the brown ashes could be considered reasonable due to their difference in behaviour and engineering properties as discussed above.

An investigation into whether a possible relationship between the shear strength and the modulus of the volcanic soils already tested in the existing studies was conducted. The existing data was gathered together and a graph of modulus versus shear strength (equivalent CBR) was developed. It was found that two relationships were possibly forming, as shown in Figure 3.1.

Some correlation was observed in this figure, i.e.,

- Modulus = 6 × CBR (3.1)
- Modulus = 3 × CBR (3.2)

It can be seen that these relationships are different from the AUSTROADS relationship of ten times the CBR value. It was decided however, for purposes of the site selection, to group the various volcanic soils by their main geological description i.e., Hamilton ashes, Taranaki brown ash and Taupo pumice. This was due to the previous data on volcanic soils in some cases shown in Fig 3.1 being incomplete and variable, and therefore inconclusive. By initially grouping the volcanic soils into their geological grouping it helped to make a base for the site testing and made the location of the site testing simpler. However, after the site testing we were open to other correlations which may develope, which was found to be the case as reported in section 6.5.

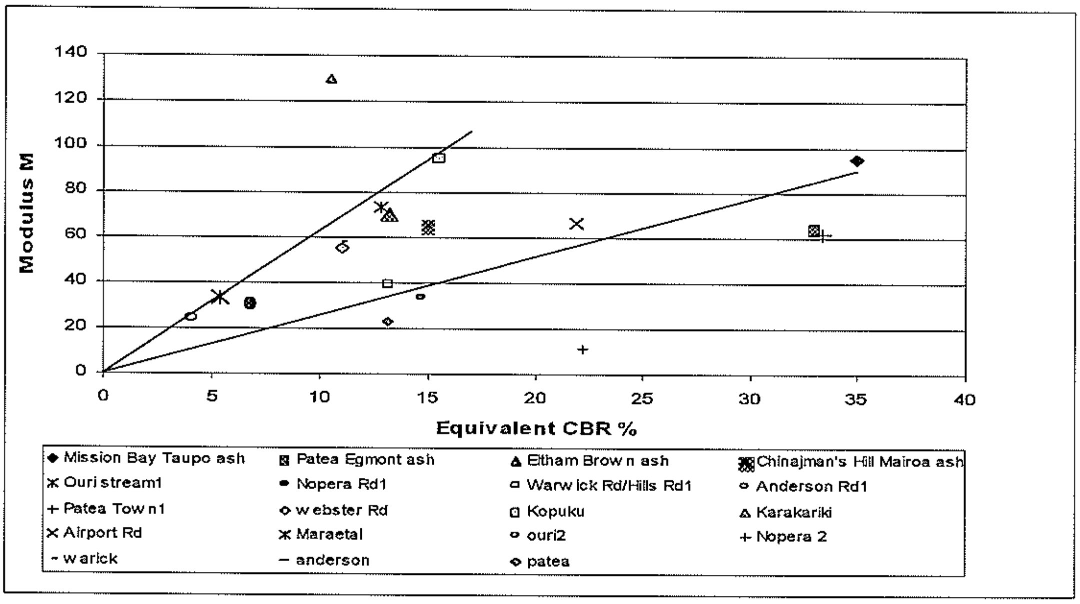

Figure 3.1 Graph of Modulus versus Equivalent CBR value from past work.

In order to obtain results from locations spread throughout the North Island, (so that a broad set of test results, and therefore relationship, could be obtained) the location of the testing from the existing reports were plotted on a map of the North Island. This allowed area's where relatively little information was available, to be identified. These areas were considered a priority to achieve more information so a potentially broad relationship could be obtained for volcanic soils, if there was one. The site selection covered the main volcanic soils in the central North Island.

4 Site Selection

4.1 General

As discussed in section 3, the volcanic ashes grouping was based on their geological description and from the geological map (Rijkse and Hewitt, 1995). The three groupings were the pumiceous soils, the Taranaki brown ashes and the Hamilton ashes. The existing data was plotted on the geological map. So that areas where little information existed could then be identified easily. Sites were selected so that together with the existing data the results would enable a wide spread of sites within the broad groupings to be obtained and so that the testing was not duplicated.

It was found that a relatively large amount of information existed for the Taranaki brown ashes. Little information on the modulus and shear strength of the pumice soils was available for areas tested at the same site. Areas in the Hamilton ashes were shown to have been tested fairly extensively but were wide ranging. It was decided therefore, to select more sites in the pumice soils to achieve a spread of results, to test a few sites on the brown ashes to verify previous data, and to obtain a spread of data throughout the Hamilton ash to identify a possible relationship in their variability.

A detailed site inspection ensured that the sites were not located on fill and were representative of the surrounding area. Fifteen sites in total were selected.

4.2 Site locations

Due to the lack of existing information in the pumice soils, five sites were selected. The location of sites 1 to 5 are shown in Figure 4.1 and a more detailed description of each site is included in Table 1, with a site location plan for each site in appendix A. A relatively large amount of existing test results was available for Taranaki brown ash so it was decided to select only two sites in this area to confirm the existing data, sites 6 and 7. An additional site was also selected on 'brown soil', (Hewitt 1998 classification) site 8. This site was selected to determine the soil's properties and to investigate whether they are similar to the volcanics, due to the sites close proximity to the brown ash and allophanic soils.

Previous testing around the Hamilton area has provided information on volcanic ash within the area, but because of the variability of the ash falls three sites were chosen to try and determine if a pattern to the variability could be found (sites 9, 10 and 11). Two non-volcanic soils were also tested within this area to try and assess their difference between volcanic soils (sites 14 and 15). These sites were also used as a control. South of Auckland low-strength soils can be found, but the main volcanic material is from weathered Basaltic and pyroclastic deposits. One site was located on this 'granular material' (site 12), together with a site located between Hamilton and Pukekohe (site 13).

Description of selected sites; (A detailed site location plan for each site can be found in appendix A)

Site	Location	Soil Grouping
Site 1.	Okere Falls, Okere Road	Pumiceous
Site 2.	Lichfield, Vospers Road	Pumiceous
Site 3.	Murupara, Golf Road	Pumiceous
Site 4.	Waiotapu, Jay Road	Pumiceous
Site 5.	Bennydale, SH30	Pumiceous
Site 6.	Stratford-Inglewood, Tariki Road	Brown ash
Site 7.	Waitara-Urenui, Upper Epiha Road	Brown ash
Site 8.	Whangamomona, SH43	Brown soil
Site 9.	Pio Pio, Mairoa Road	Hamilton ash (south)
Site 10.	Hamilton-Cambridge, Day Road	Hamilton ash
Site 11.	Te Poi, Stopfords Road	Hamilton ash (east)/pumice
Site 12.	Pukekohe, Coles Road	Granular material
Site 13.	Taupiri, Jew Road	Hamilton ash (north, granular)
Site 14.	Te Awamuta, Bowman Road	Non-volcanic
Site 15.	Cambridge, Peake Road	Non-volcanic

Table 4.1 Sites selected for testing

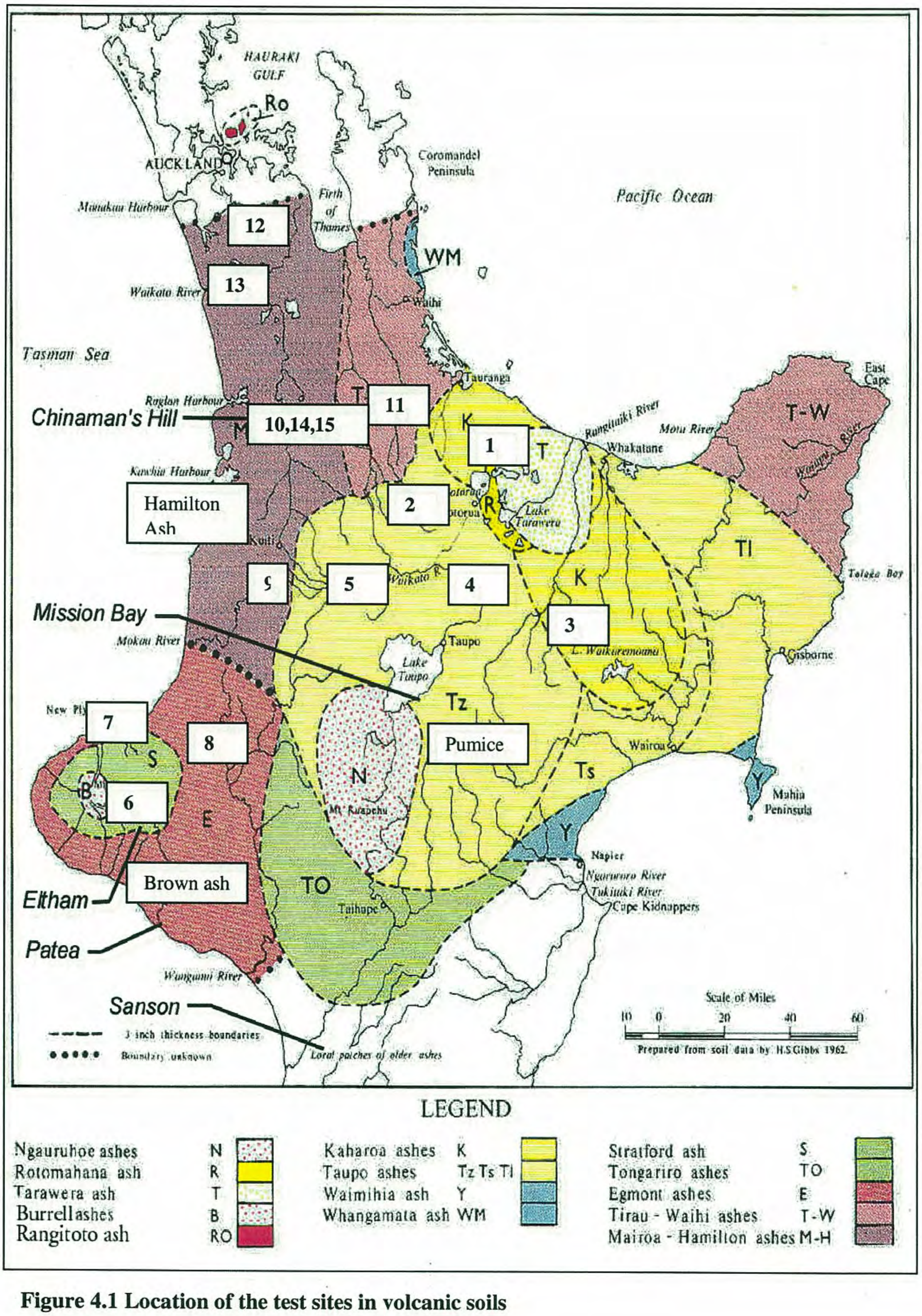

Figure 4.1 Location of the test sites in volcanic soils

5 Testing

5.1 Testing Conducted

After each specific site had been located, ensuring that the sites were not located on fill and were representative of the surrounding area, on-site testing was carried out. Testing at each of the 15 sites included;

- two logged/photographed test pits, for the identification of the pavement layers, the subgrade and the depth;
- *in situ* CBR tests were performed on the subgrade, together with dynamic cone penetrometer tests, moisture contents. Allophane contents were also determined and the subgrade density. Atterburg tests were conducted at the laboratory.

Testing was carried out to NZS 4402 (refer to appendix B for the test results).

Falling weight deflectometer (FWD) tests were also carried out to determine the modulus of the subgrade. FWD tests were conducted and marked out before the test pits were dug so that the two could be located on the same part of pavement. The FWD testing involved testing the section of roadway in one direction at 20m intervals for a length between 100 to 200m. At least two loading levels were used to give a measure of the stress dependency of the subgrade. The modulus results from the FWD testing are included in the summary in Appendix B.

6 Results and Analysis

6.1 General

The results from the on-site and laboratory testing, and the FWD were analysed and relationships between the CBR and the FWD derived modulus determined for volcanic soils.

This relationship was then used to determine factors for the determination of the CBR from the FWD modulus so that the structural number (SN) for pavements could be obtained and also the determination of the vertical modulus from the CBR for use in Austroads pavement design.

The indirect method of determining the SNP (the SNC for thin pavements) from the deflection results without knowledge of the pavement structure [developed by Tonkin & Taylor (Salt and Stevens, 2001)] was also examined, and a factor for modifying the relationship for the different subgrade types determined.

6.2 Results from the Trial Pits

Two test pits were dug at each site with measurements of *in situ* CBR and scala penetrometer values obtained. Laboratory testing of samples was also conducted.

Results from the Allophane testing showed variable amounts of the clay mineral Allophane throughout the sites tested. In general the highest concentrations were found to be located south of Hamilton. Medium levels were obtained near Tauranga and Taranaki. The soils near Taranaki and Tauranga have been historically sensitive to remoulding and able to change their psd (Jacquet 1987), initially reported to be due to the Allophane mineral present: however from the testing, this may not be the only reason. As suggested in section 3, the sensitivity may also be due to the break-down of the soil matrix due to the oxidation of iron within the soil.

The Allophane test results are summarised in Table 6.1 with the test pit results summarised and presented at the beginning of appendix B.

6.3 FWD Analysis

6.3.1 General

Transfund Research Report No. 117 describes the procedure for the detailed structural analysis of the pavement from the shape of the deflection bowl. Basically, the outer deflections define the stiffness of the subgrade while the bowl shape close to the loading plate allows analysis of the stiffness of the near-surface layers. A broad bowl with little curvature indicates that the upper layers of the pavement are stiff in relation to the subgrade. A bowl with the same maximum deflection but high curvature around the loading plate indicates that the upper layers are weak in relation to the subgrade.

A back-analysis procedure is generally adopted to find moduli from an observed deflection bowl. Once the pavement profile model is established, a forward-analysis can be carried out to determine the strains for say, a modelled rehabilitation treatment such as overlay.

Site Number	Location	Allophane >7% (High)	Allophane 5-7% (Medium)	Allophane<5% (Low)
1	Okere Falls		PP1,PP2	
2	Lichfield	PP1,PP2		
3	Murupara			PP1,PP2
4	Waiotapu			PP1,PP2
5	Bennydale	PP2	PP1	
6	Stratford -Ingle		PP1,PP2	
7	Waitara - Urenui		PP1,PP2	
8	Whangamonoma			PP1,PP2
9	Pio Pio	PP1,PP2		
10	Hamilton - Cam	PP1	PP2	
11	Te Poi		PP1,PP2	
12	Pukekohe			PP1,PP2
13	Taupiri		PP1	PP2
14	Te Awamutu		PP2	PP1
15	Cambridge			PP1,PP2

PP1 =test pit 1, PP2 =test pit 2

Table 6.1 Results from the Allophane testing

6.4 ELMOD

Back-analysis to determine the subgrade modulus from the FWD data was carried out using the ELMOD (Evaluation of Layer Moduli and Overlay Design) programme. ELMOD (Dynatest 1989) is based on the Odemark-Boussinesq transformed section approach (Ullidtz 1987), and can combine both the back and forward analysis.

ELMOD has the capacity to analyse non-linear subgrade moduli as stress dependent (rather then depth dependent from sublayering). It will only analyse isotropic materials. The package only requires one subgrade layer because it uses the deflections to calculate C and n in the non-linear subgrade modulus relationship:

$$E = C\,(\sigma_z/\sigma')^n \qquad (6.1)$$

where:

E modulus of elasticity,

C and n are constants,

σ_z is the vertical stress and,

σ' is a reference stress.

The reference stress is introduced to make the equation dimensionally correct, with E and C then both having the dimensions of stress. The exponent 'n' is a measure of the non-linearity of the subgrade modulus. If 'n' is zero the material is linear elastic. Soft cohesive soils may have an 'n' value between –0.3 and –1, indicating the amount of non-linearity in the soil.

ELMOD analysis can be carried out either with or without knowing the thickness of the pavement; in this case the depth of the pavement to the subgrade was found from the test pits and inputted into the analysis.

ELMOD calculates the isotropic modulus of the pavement materials. The Tonkin and Taylor (1998) report infers that, if the calculated FWD ELMOD subgrade moduli are to be used in CIRCLY for Austroads pavement design (for anisotropic granular materials), then the moduli would have to be multiplied by 1.5 to model the vertical modulus for the subgrade with an anisotropic modulus, $E_v \div E_h$ of 2. The horizontal modulus would then be calculated from $0.5 \times E_v$.

Relevant results for this project found from the FWD analysis include the modulus of the subgrade and basecourse, C, subgrade modulus exponent 'n', deflection and stress level.

The results for the subgrade modulus show some variations in value at each site, but in general are small, so it can be assumed that they are a natural variation along the length of the pavement. These variations may also be due to volcanic soils within the basecourse layer clouding the indicated modulus for the subgrade.

Results of the subgrade modulus are plotted in Figure 6.1 together with the results of the *in situ* CBR.

6.5 FWD Modulus CBR Relationship

It has been documented (Tonkin &Taylor 1998) that the modulus CBR relationship may vary by a factor of two. Austroads pavement design for granular roads have suggested using 10 times the CBR for all soils to obtain the vertical anisotropic modulus, and 6.7 times the CBR value for isotropic modulus. It has been found from previous reports, Sutherland et al. (1997), that this may not be the case for volcanic soils.

Traditional pavement design charts and the structural number have been determined from the measured CBR value. Because of time and money constraints, non-destructive testing to obtain the modulus of the pavement is now used. However, the basis of the CBR value is still used to obtain the design and life of the pavement. Therefore the relationship $10 \times$ CBR, and thus the pavement design, may be correct for tested CBR values: however, the determination of the CBR from the measured *in situ* modulus may not be correct, especially for volcanic soils.

The results from the *in situ* testing are shown in Figure 6.1. Both the FWD subgrade modulus and *in situ* CBR of the subgrade have been plotted. It is apparent that two relationships can be seen, with a possible third in between.

It was found that, in general, the sandy pumiceous soils lay near the bottom of the graph, with the clayey volcanic materials forming the steeper relationship. A linear regression was carried out and the following correlations found:

Isotropic modulus = 10 × CBR, for clayey volcanic soils (6.2)

Isotropic modulus = 1 × CBR, for pumiceous sandy soils (6.3)

These relationships are very different from each other and may account for the reason for the many discrepancies occur in the testing of volcanic soils.

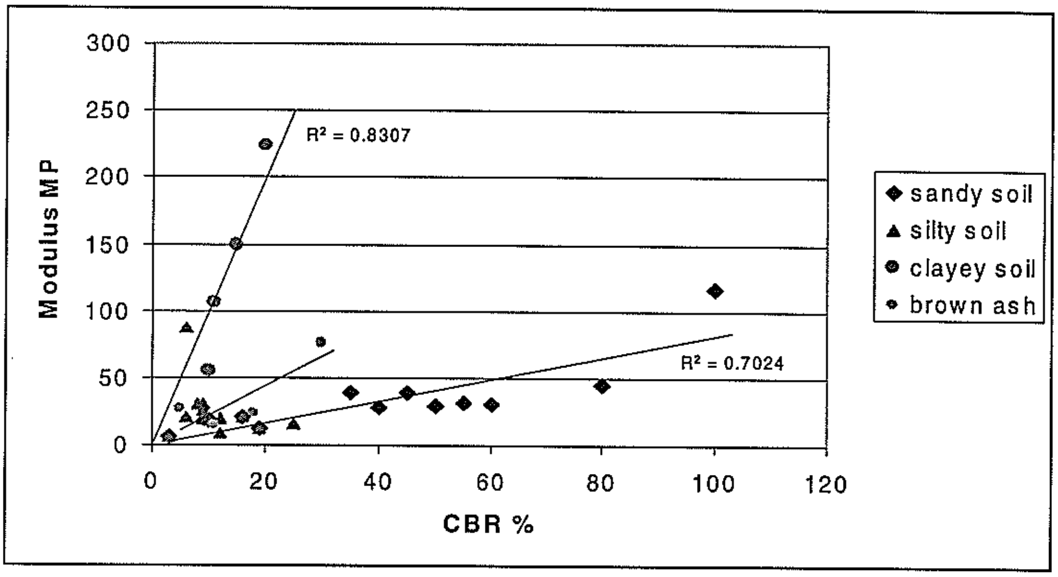

Figure 6.1 Graph of FWD Isotropic Modulus versus *in situ* CBR for tests.

The R^2 for the correlations shown on Fig 6.1 are reasonable for a network study. However for localised areas the relationships may vary somewhat, and therefore the use in project level tools requires some caution, Patrick and Dongol (2001).

The data obtained from previous projects was also added and plotted on the same graph, Fig 6.2.

The possible third relationship can now also be seen although not well defined. Variations with the test data made it difficult to make precise judgements regarding the relationship. Largely the two main constituents of soil type that could be found producing this relationship were Silty soil and Brown ash.

Therefore an additional relationship, which will need additional data to define, for volcanic Brown ash and silty soils is:

Isotropic modulus = 3 × CBR (6.4)

Transfund Research Report No. 128 also recommended a relationship of 3 × CBR for brown ashes.

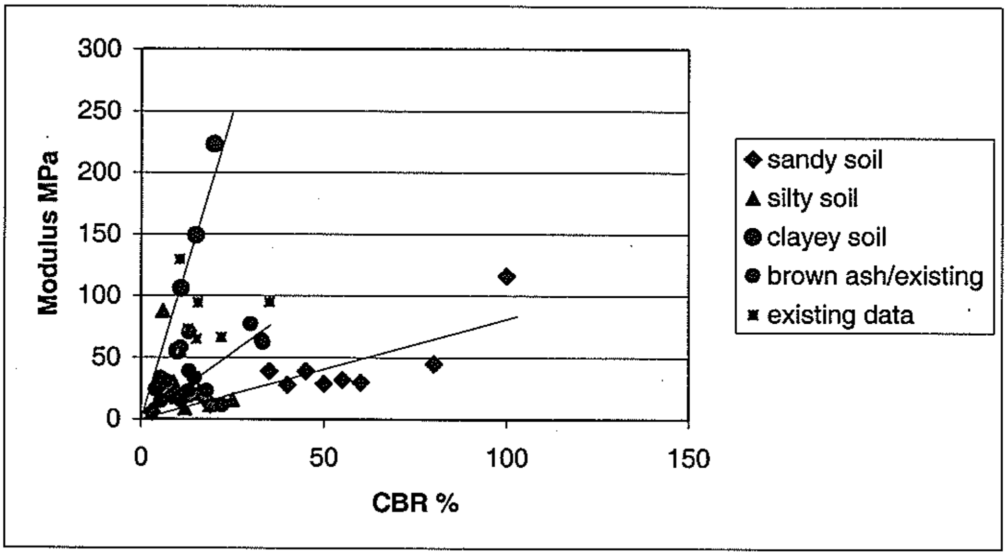

Figure 6.2 Graph of Isotropic Modulus versus CBR for current data and previous data.

A possible reason why this relationship may not be well defined, is that when remoulded the clayey materials containing the Allophane mineral tend to alter their particle size distribution into more like a silt, and may therefore lie below the 10 × CBR, and obscures the third relationship.

The possible explanation for relationships in Fig 6.2, may lie in the structure and grain shape of the volcanic soils. Pumice soils tend to be sandy and have sharp angular grains which would indicate a high CBR value; however, due to their structure, under the FWD loading the pumice soils exhibit a high elastic deformation and therefore low modulus when back-analysis of the FWD results are carried out. This type of behaviour can be seen in Fig. 6.2. The clayey soils on the other hand are finer grained and usually exhibit higher water contents, which may lead to lower CBR values and higher modulus values when dynamically loaded by the FWD. This relationship can also be seen in Fig 6.2.

Consequently silty soils tend to lie in-between the two relationships owing to being neither clays or sandy, as would be expected. The brown ash is slightly different in that is shows a low modulus and a low CBR value. This maybe due to: the Allophane content, as discussed above, the *in situ* structure of the soils as pumice, and the fined grained nature of the soil producing a low CBR. The degree of saturation, an unknown variable in the *in situ* CBR test, may affect the results slightly.

The above correlations are not dissimilar to the groups used to select the various site locations for testing (section 3.3). The pumiceous were mainly sandy soils, and the Hamilton ashes mostly clayey soils. The Taranaki soils however, which were also classified in the test pits as clayey, lay closer to the middle correlation together with the silty soils. Again, this may be due to the behaviour of Allophane, as suggested above.

The above relationships are also similar to those presented on Figure 3.1, with the brown ash largely forming the 3 times relationship. However, the 6 times CBR relationship (equation 3.1), is different – this may be due to the presence of the Allophane changing the psd of the soil as discussed above. In general the presence of the Allophane material tended to affect the results, in that some variation was found which affected the correlations – but the content of the mineral did not seem to affect the results too much.

6.5.1 Summary of the FWD, *in situ* CBR relationship

The relationships discussed above can be summarised into three subgrades types A, B, and C:

A: Typically pumice/sandy soils, isotropic modulus = 1 × CBR (eqn. 6.3)
B: Mixture of silty soils and brown ash, isotropic modulus = 3 × CBR (However, the relationship is not well defined.) (eqn. 6.4)
C: Typically includes clayey ash soils, isotropic modulus = 10 × CBR (eqn.6.2)

6.6 Calculation of Modified Structural Number (SNC)

The modified structural number (SNC) is an indication of the pavement strength and has been adopted in a number of empirically based pavement design and deterioration models of organisations such as AASHTO (1986), the Transport and Road Research Laboratory (1977), and the World Bank (Paterson, 1987).

Structural numbers can be determined using direct or indirect methods. Direct methods use measurements of the strengths of each of the layers in a pavement and indirect methods are generally based on deflections of the entire pavement (Patrick and Dongol 2001).

A number of different ways have been developed, to calculate the structural number. Some indirect methods however, are based on correlations obtained from back-calculations (against more direct methods); and have limitations that need to be understood (Patrick and Dongol 2001).

To determine the SNC using non-destructive methods an indication of the relationship between CBR and modulus needs to be known.

During a FWD test the deflection of the pavement is back-analysed to obtain a measurement of modulus of the various pavement layers. The calculated modulus of the basecourse and subsequent layers can be inputted into the structural number equation directly, but the subgrade contribution to the strength of the pavement cannot as it is based on the CBR. The calculated modulus therefore requires to be converted into a CBR value. As discussed in section 6.5 this relationship for volcanic soils indicates that it is different to the standard modulus = 10 × CBR usually used for soils. Factors presented below allow the structural number to be determined for volcanic subgrades, based on the relationships indicated in section 6.5.

The structural number, including the additional variable for subgrade strength, is defined as follows:

$$SNC = (1/25.4)\sum_{i=1}^{n} a_i h_i + SN_{sg} \qquad (6.5)$$

where a_i = layer coefficient
h_i = thickness of layer, mm
SN_{sg} = structural number contribution from the subgrade

$$a_i = a_g(E_i/E_g)^{1/3} \qquad (6.6)$$

where a_g = layer coefficient of standard materials (AASHTO road test as listed in Table 6.2)
E_i = layer modulus (in this case, from FWD)
E_g = modulus of standard materials (AASHTO road test as listed in Table 6.2)

LAYER TYPE	**LAYER Coe a_g**	**RESILIENT MODULUS E_g (MPa)**
Asphalt concrete surface coarse	0.44	3100
Untreated and stabilised base course	0.14	207
Granular Subbase	0.11	104

Table 6.2 Layer coefficients and resilient modulus of standard materials in AASHTO road test.

The contribution to the structural number from the subgrade was derived by Hodges et al. (1975).

$$SN_{sg} = -0.85\,(\log CBR)^2 + 3.51\,(\log CBR) - 1.43 \qquad (6.7)$$

where CBR = California Bearing Ratio of the subgrade (percent).

Traditionally, when determining the structural number of pavements, the CBR for the subgrade has been obtained from the *in situ* CBR testing. However, faster non-destructive testing is now being used, such as the FWD test. As the FWD only gives the modulus of the pavement materials, a relationship between the CBR and FWD modulus must be obtained to allow equation 6.7 to be calculated. But while $10 \times$ CBR has been used by Austroads, for some volcanic soils this is not applicable. Patrick and Dongal (2001) also state that care must also be taken when determining the structural number on volcanic subgrades, in that due to the 'bouncy' nature of the soils cracking may be an issue. They suggest that a second SNP [SNC for thin pavements] should be derived which may give a better prediction of cracking.

6.6.1 Factors which the isotropic modulus should be divided by to obtain CBR for determination of SNC

From the FWD, *in situ* CBR relationship, summarised in section 6.5.1., the table below gives a factor which the FWD isotropic modulus should be *divided* by to obtain a value for CBR which can then be inputted into eqn 6.7.

Volcanic Soil Type	A (pumice)	B (mixture Silty)	C (Clayey)
Factor	1	≅ 3	10

Table 6.3 Factor for the determination of CBR for SNC calculations

These factors should only be used for the determination of the SNC, as the isotropic modulus is used.

6.6.2 Steps to obtain the SNC from FWD measurements

Once the FWD testing has been carried out by the back-analysis of the deflection bowl, the isotropic modulus for each layer can be calculated and subsequently the CBR of the subgrade can be obtained. Depending on the subgrade type, the factor from Table 6.3 can be used to obtain the CBR value from the isotropic FWD modulus. An example is shown in Table 6.4.

Volcanic Soil Type, section 6.5.1	FWD isotropic Modulus MPa *(obtained from testing)*	Factor from Table 6.3 *(Modulus divided by)*	CBR
A	50	1	50
B	50	3	16.7
C	50	10	5

Table 6.4 Example of using factors in Table 6.3

Using equation 6.7 the contribution to the pavement strength from the subgrade can be obtained. Inputting the modulus of the pavement layers into equation 6.6 together with Table 6.2 the contribution to the strength of the pavement obtained from the pavement layers can be obtained. The various contributions to the strength are then summed (equation 6.5) which gives the SNC for that particular pavement.

6.7 Determination of the Anisotropic and Isotropic Modulus for input into Austroads Pavement Design

For the Austroads pavement design on granular pavements; traditionally the anisotropic vertical modulus is calculated from 10 × CBR. The isotropic modulus is calculated from 6.7 × CBR. If these relationships were to be used for pavement design on volcanic subgrades, due to the 'bouncy' nature of volcanic soils that leads to low FWD modulus, a low CBR would be obtained, and the road may therefore be over designed. For volcanic soils the following is recommended: that the factor in

Table 6.5, be *multiplied* by the *CBR* to obtain the vertical modulus and isotopic modulus respectively, which can then be inputted into Austroads pavement design.

Volcanic Soil Type	A (pumice)	B (mixture Silty)	C (Clayey)
Factor Vertical Modulus	1.5	≅ 4.5	15
Factor for Isotropic Modulus	1	≅ 3	10

Table 6.5 Factor to be applied to the CBR to determine the vertical/isotropic modulus for input into Austroads pavement design.

6.7.1 Example using Factors for Pavement Design

An example of using the factors in Table 6.5 is presented below for determination of the vertical modulus for the input into Austroads design.

Volcanic Soil Type, section 6.5.1	CBR	Factor from Table 6.5 (*CBR multiplied by*)	Anisotropic vertical modulus MPa
A	50	1.5	75
B	16.7	4.5	75
C	5	15	75

Table 6.6 Example of using the factors in Table 6.5 to determine the anisotopic vertical modulus.

6.8 Modification to T&T deflection based assessment of structural number

To estimate indirectly the SNC or (SNP for thin pavements) Patrick and Dongal (2001) recommended that the T&T method (Salt and Stevens, 2001) be used for network surveys, as it was derived using typical New Zealand pavements. The method requires no information regarding the thickness of the pavement or the soils properties; only the deflection bowl measurements. The equation used is

$$SNP = 112\,(D_0)^{-0.5} + 47(D_0-D_{900})^{-0.5} - 56(D_0-D_{1500})^{-0.5} - 0.4 \qquad (6.8)$$

However, to derive this equation equation 6.7 was used together with the standard relationship for the Modulus CBR, defined by Emery and used in the AASHTO method 1 (1986) where equation 6.9 was used which may not be applicable to volcanic soils.

$$E_{sg} = 41.19\ CBR^{0.385} \qquad (6.9)$$

The different relationships for the CBR modulus presented for the different volcanic subgrade types will affect the CBR calculated for equation 6.7, and therefore will also affect the T&T equation 6.8.

To try and obtain an approximate solution to this problem so that equation 6.8 could be used on volcanic soils, the SNsg [calculated from equation 6.7] difference between using Emery's equation (6.9), and the relationships for volcanic soils, was plotted, Fig.6.3.

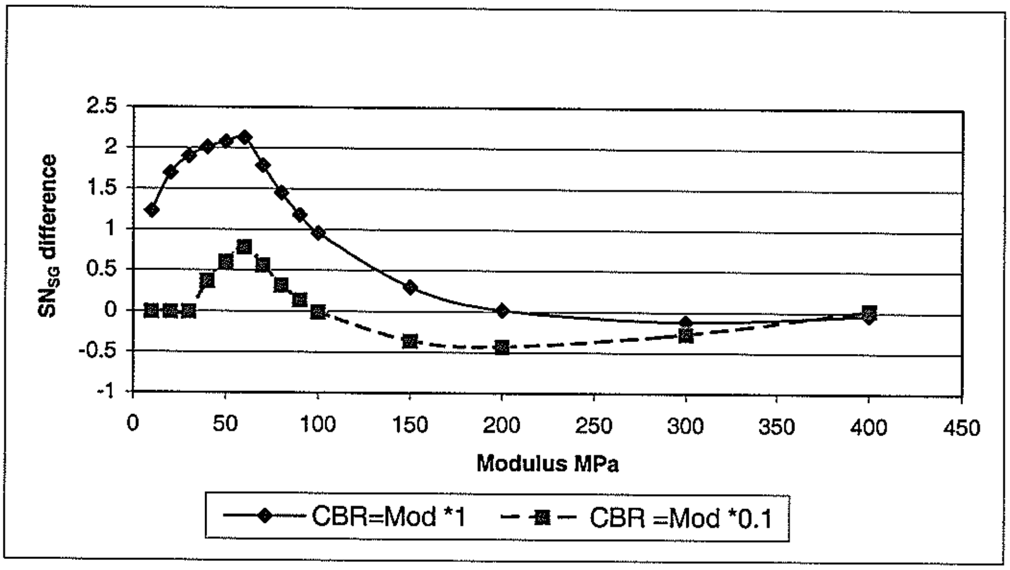

Fig 6.3 Comparison with the T&T method

Fig 6.3 shows two relationships for volcanic soils (the third was not used as it was not well defined). The difference between the CBR = Mod × 0.1 (clayey) and Emery (equation 6.9) is small, and with the T&T equation (6.8) the error is of a similar magnitude and therefore within its limits.

However, for the CBR = Mod × 1 relationship (pumice) the difference is larger, between 1 and 2. To enable equation 6.8 to be used on pumiceous soils on a network level this difference will have to be taken into account. It is proposed to use the average 1.5 difference and add this to equation 6.8, giving equation 6.10:

$$SNP = 112\,(D_0)^{-0.5} + 47(D_0\text{-}D_{900})^{-0.5} - 56(D_0\text{-}D_{1500})^{-0.5} + 1.1 \qquad (6.10)$$

This relationship is not an exact fit but should be sufficient for network surveys. If a more exact fit is required the fundamental equations should be used, using *in situ* CBR.

7 Summary and Conclusions

Volcanic soils tend to produce larger elastic deformations when a dynamic load is applied compared to non-volcanic soils. At present the CBR is calculated from the vertical modulus by dividing by ten, or 6.7 in the case of isotropic modulus or using Emery's equation. However, past studies have indicated that this may not be applicable to volcanic soils. By using the relationship above, a low value for subgrade CBR is produced, giving a low structural number resulting in an under-prediction of the life of the pavement in dTIMS. Conversely, if that low subgrade CBR were used for pavement design, the pavement would be over-designed. In order to determine a relationship for volcanic soils, between the FWD modulus and *in situ* CBR, 15 test sites were located and tested.

It has been found that deposits of volcanic soils are extensive over the North Island. Past work has indicated that some volcanic soils are sensitive to remoulding due to the oxidation of iron, which forms a matrix within the soil. During remoulding this matrix breaks down causing a drop in strength of the soil. Volcanic soils containing the mineral Allophane also expel water when remoulded and the soil particles form aggregations, and effectively change the psd of the soil to one more silty.

The different behaviour of volcanic soils to non-volcanic soils therefore depends largely on the minerals present within the soil.

The engineering properties of volcanic soils are variable due to their amount of weathering, minerals and remoulding. A classification of volcanic soils based on their geological description was presented and 15 sites were selected based on the location of past work. Testing at each site included two test pits with measurements of scala and *in situ* CBR. FWD testing was also carried out.

The subgrade modulus, obtained from the FWD tests (via ELMOD), was plotted on a graph with *in situ* CBR. The following relationships were obtained for volcanic soils.

- A: Typically pumice/sandy soils, Isotropic Modulus = 1 × CBR
- B: Mixture of silty soils and brown ashes, Isotropic Modulus = 3 × CBR (However the relationship is not well defined)
- C: Typically includes clayey ash soils, Isotropic Modulus = 10 × CBR

These relationships can then be to be used in pavement deterioration modelling and pavement design. Factors were presented which related the modulus to CBR for structural number modelling, and CBR to vertical modulus for pavement design, Table 6.3 and 6.5.

The procedure for determining the Structural Number of pavements on volcanic subgrades using the presented CBR, modulus relationships was presented. A modification to the deflection bowl based on the T&T method was also proposed, (equation 6.10), which allowed the structural number to be estimated on pumice volcanic subgrades.

8 Recommendations

It is recommended that on volcanic soils a *possible* correlation between the FWD modulus and *in situ* CBR for volcanic soils on a network basis maybe:

- Isotropic Modulus = 1 × CBR, typically for pumice/sandy soils,
- Isotropic Modulus = 3 × CBR, mixture of silty soils and brown ash, (However, the relationship is not well defined)
- Isotropic Modulus = 10 × CBR, typically includes clayey ash soils,
- That the above correlations be used to determine the CBR, which can be then used to calculate the SNC.
- That within the above relationship the modulus should be *multiplied* by 1.5 to obtain the vertical anisotropic modulus for use in Austroads design.
- That the T&T method for network surveys should be modified by the *addition* of 1.5, when using on pumice subgrades.
- That further research be performed to define the relationship between the FWD modulus and *in situ* CBR for volcanic silty soils.

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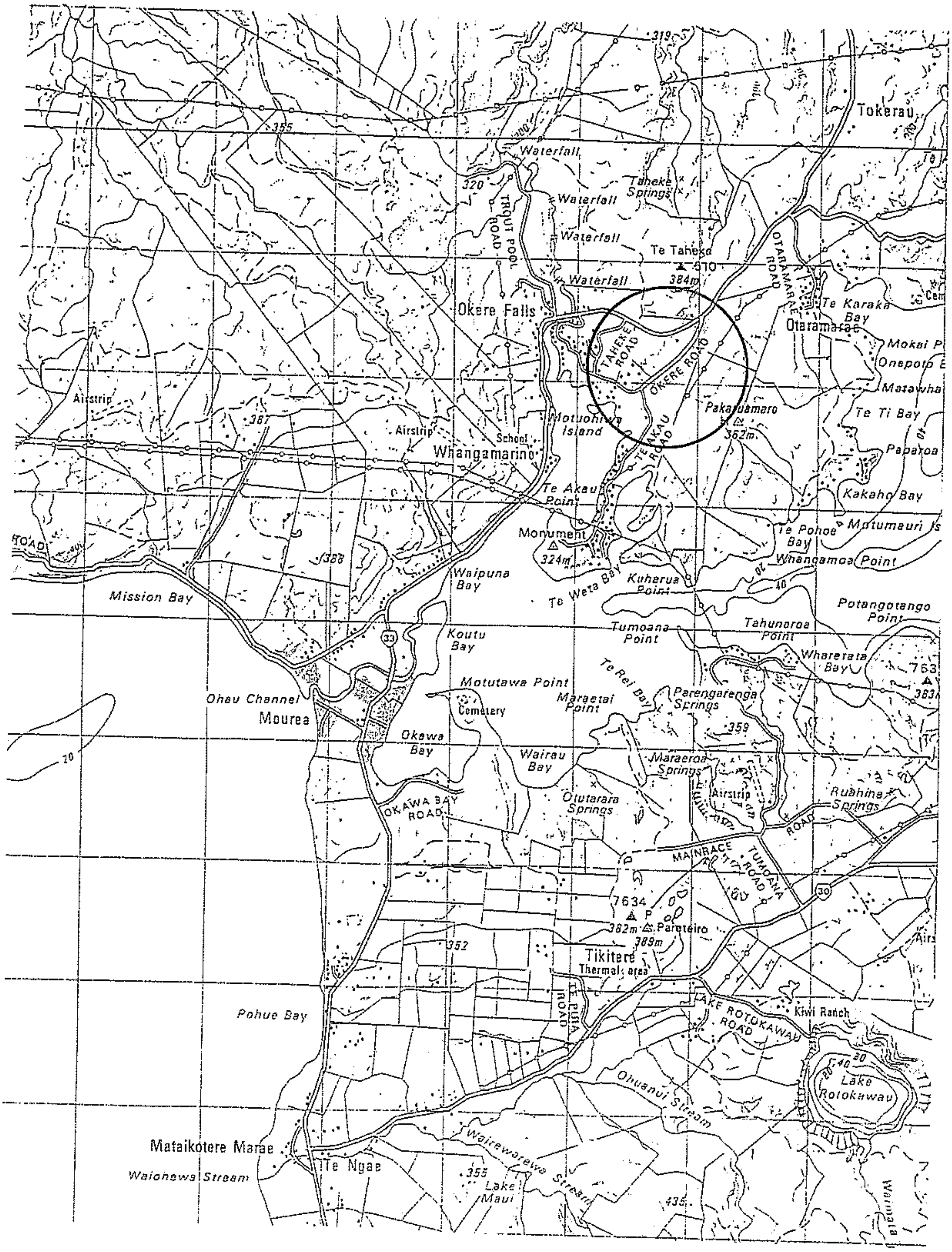
Appendix A

VOLCANIC SOILS PROJECT

LOCATION MAP

SITE: 1 OKERE FALLS

(Okere Road)

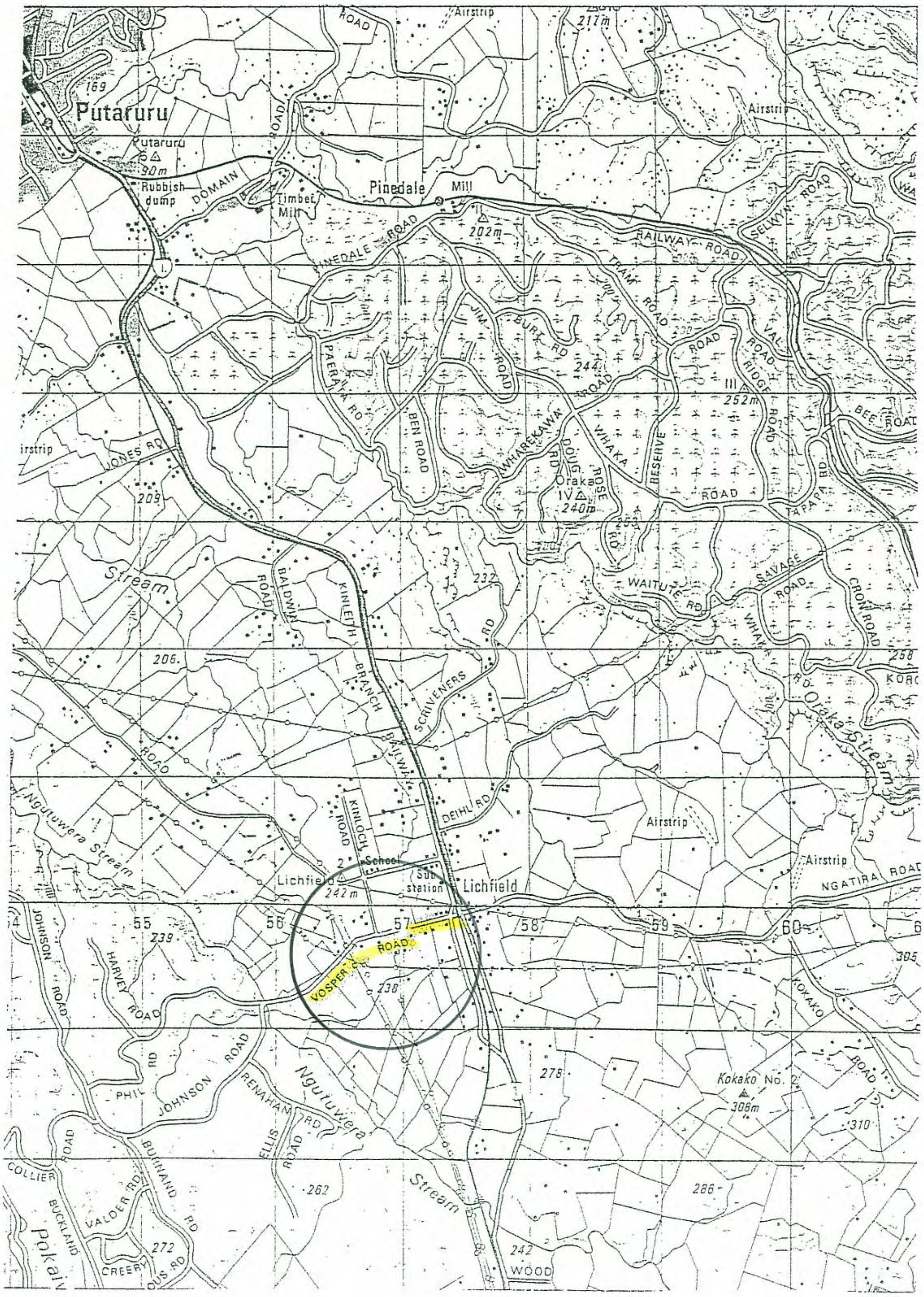


VOLCANIC SOILS PROJECT

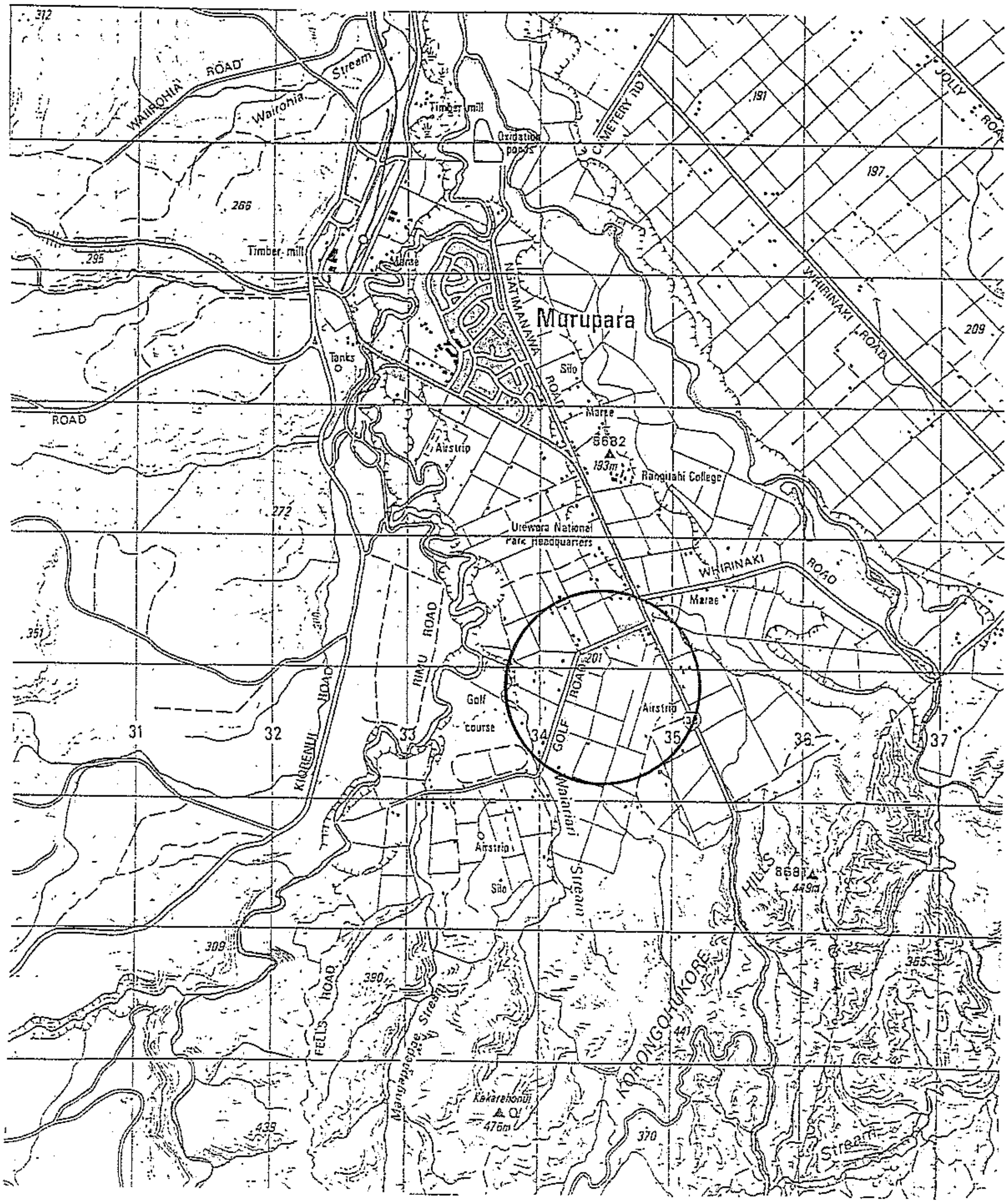
LOCATION MAP

SITE: 2 LICHFIELD

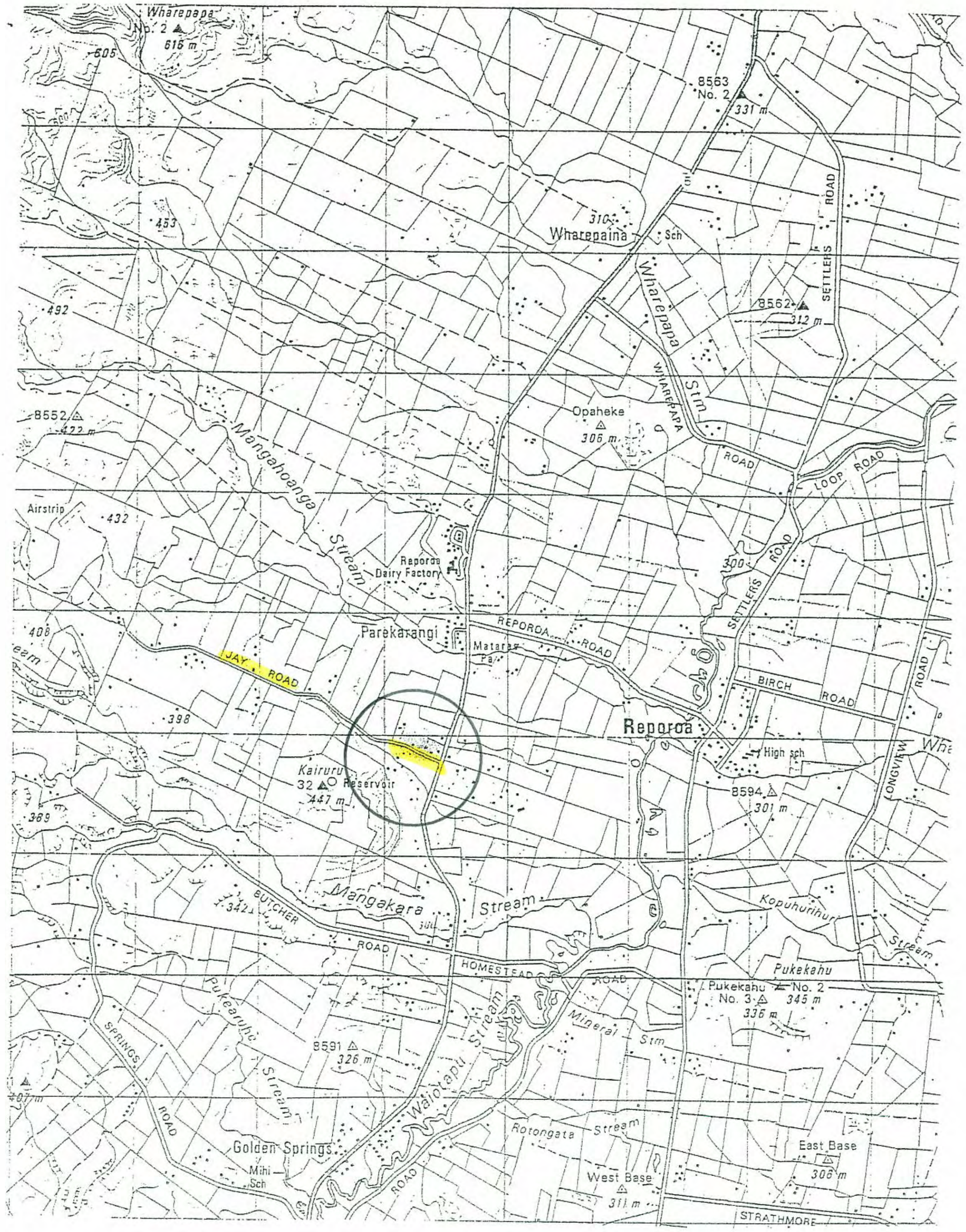
(Vospers Road)



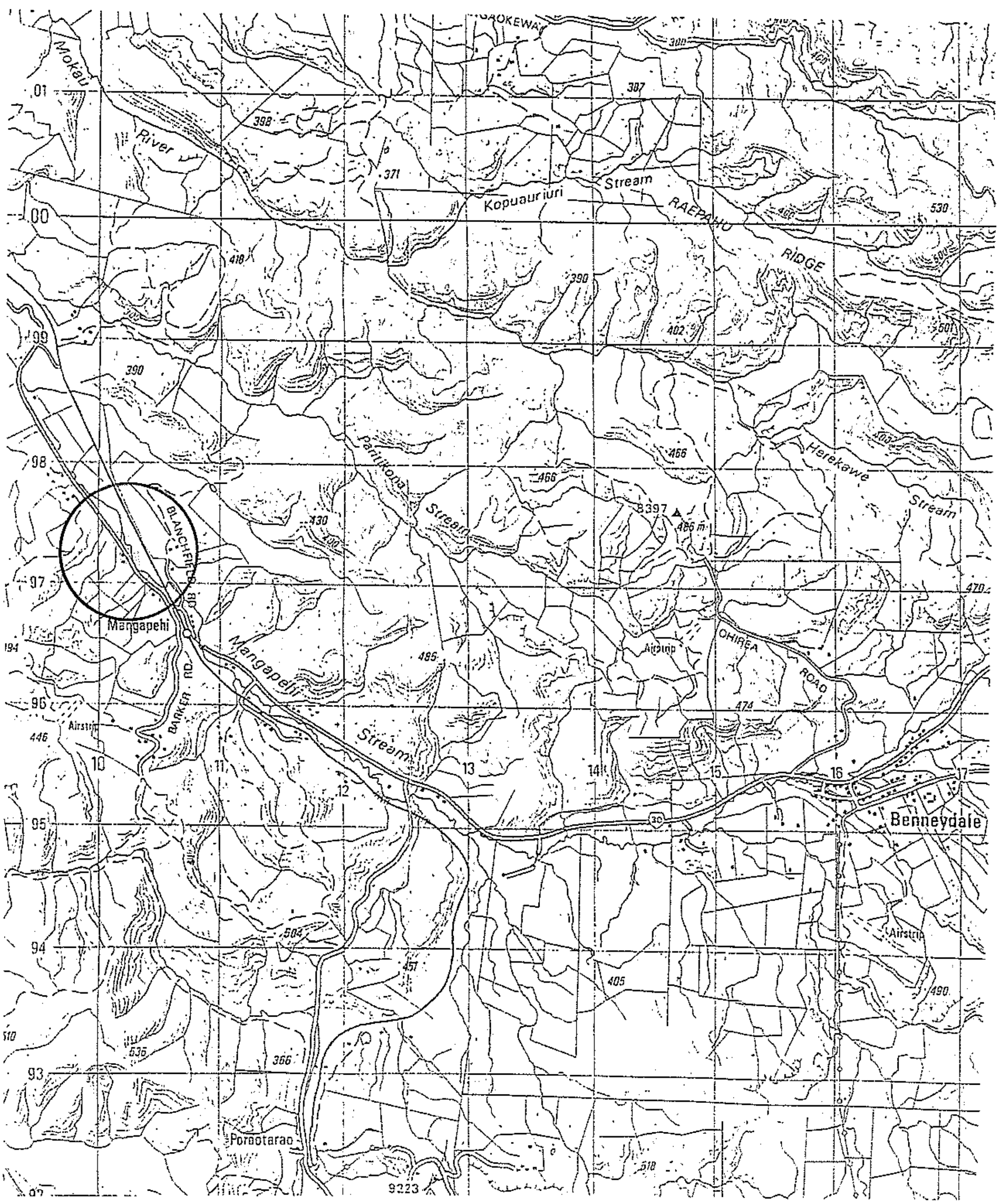
VOLCANIC SOILS PROJECT
LOCATION MAP
SITE: 3 MURUPARA
(Golf Road)



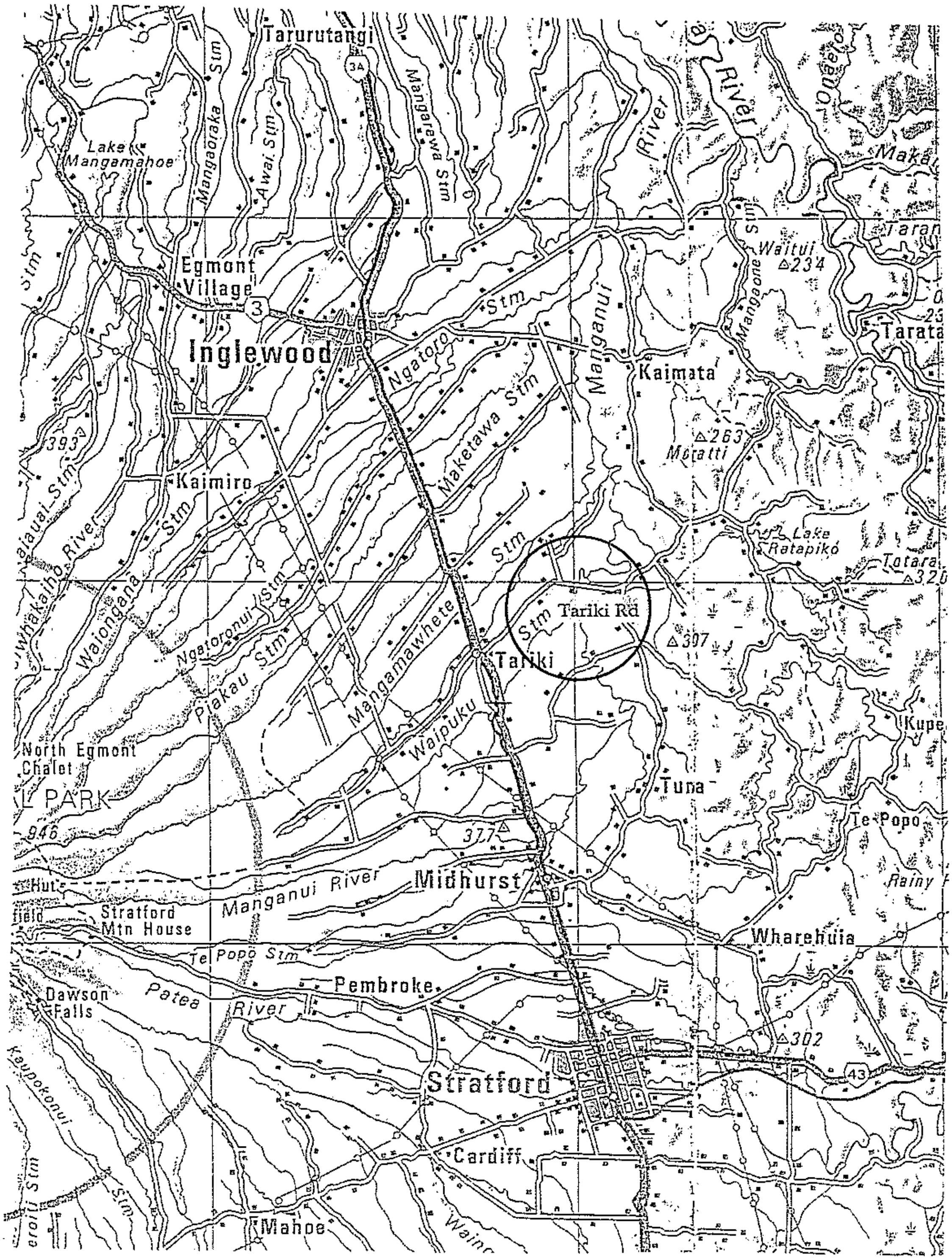
VOLCANIC SOILS PROJECT
LOCATION MAP
SITE: 4 WAIOTAPU
(Jay Road)



VOLCANIC SOILS PROJECT
LOCATION MAP
SITE: 5 BENNYDALE
(SH 30)



VOLCANIC SOILS PROJECT
LOCATION MAP
SITE: 6 STRATFORD-INGLEWOOD
(Tariki Road)

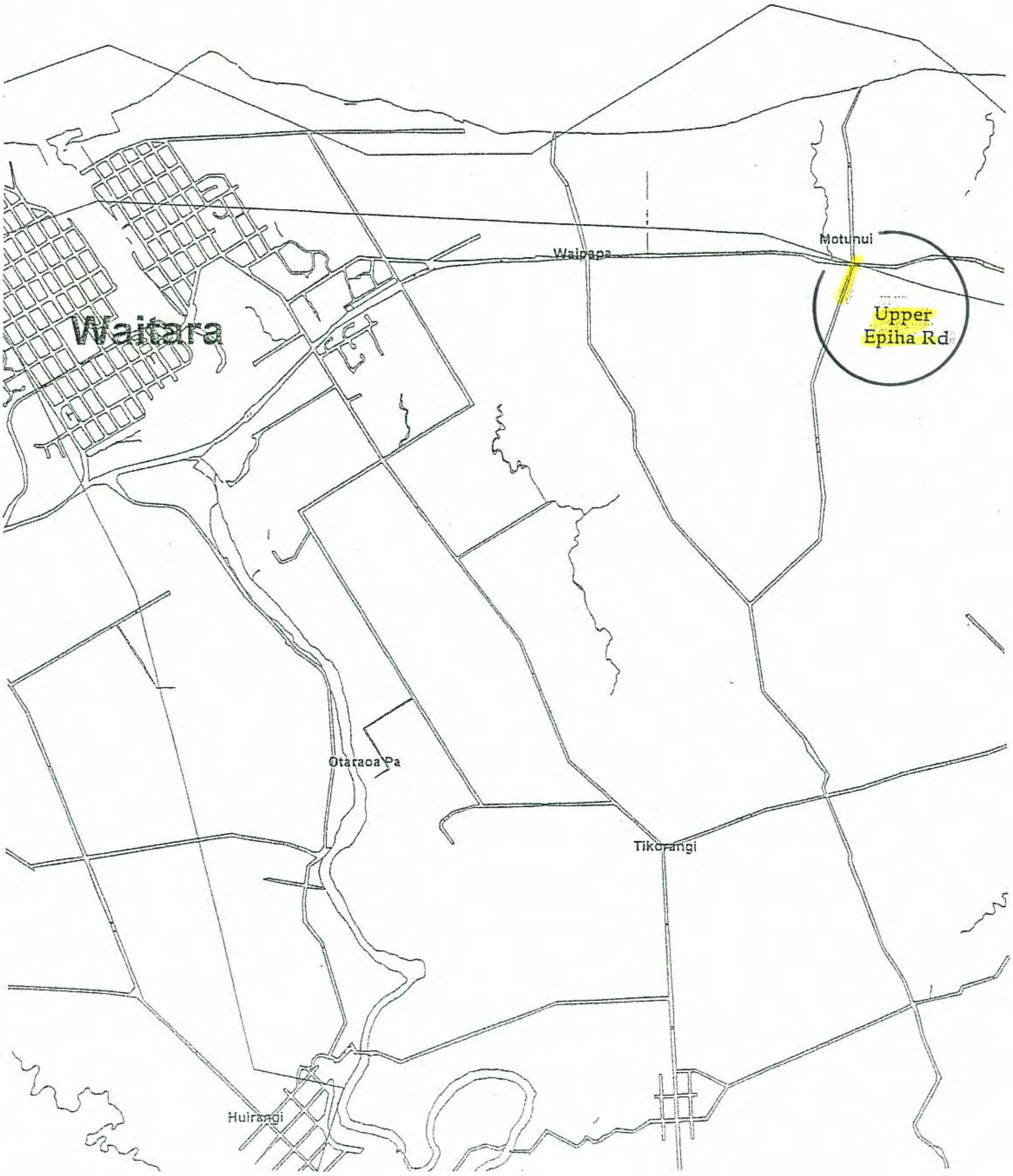


VOLCANIC SOILS PROJECT

LOCATION MAP

SITE: 7 WAITARA-URENUI

(Upper Epiha Road)

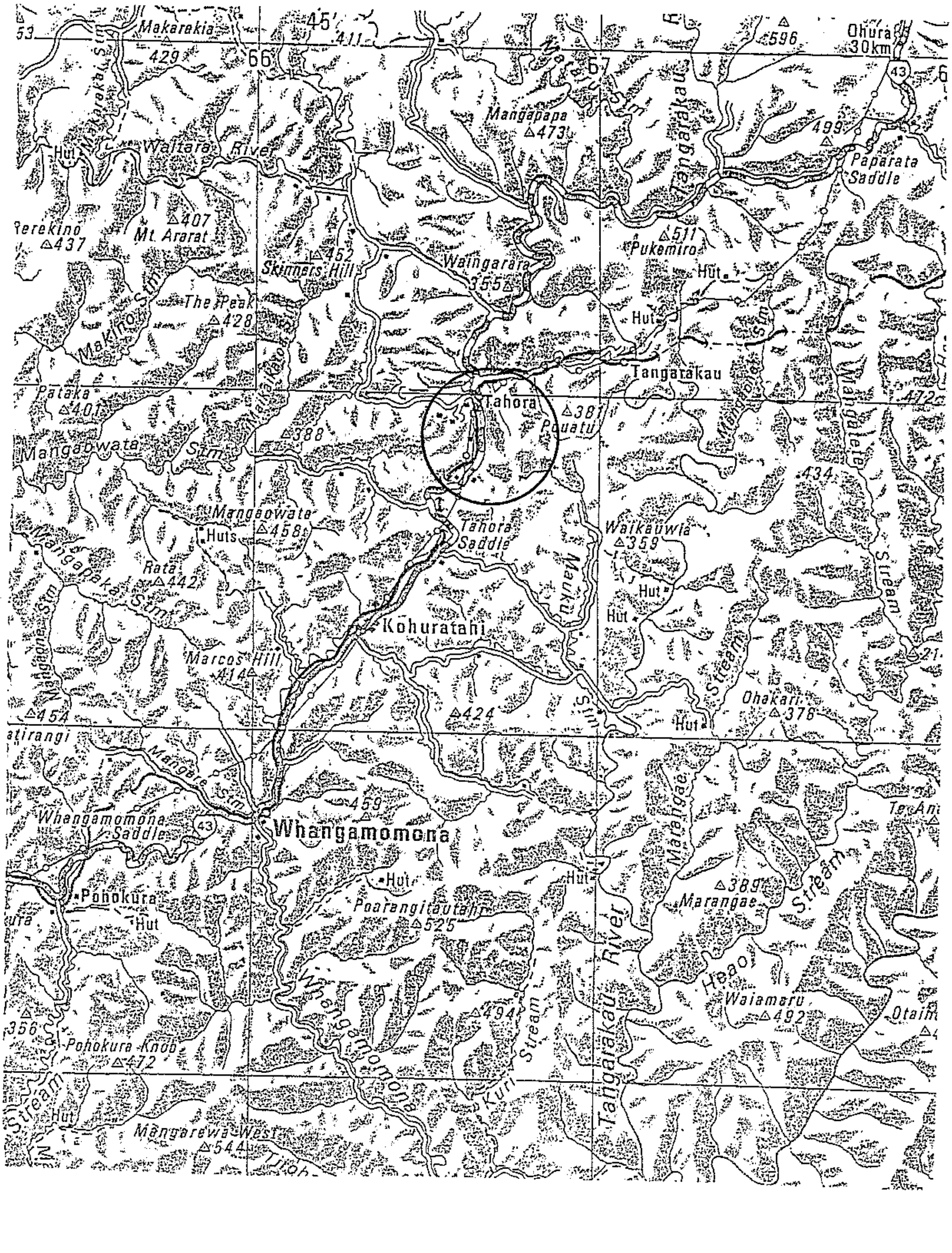


VOLCANIC SOILS PROJECT

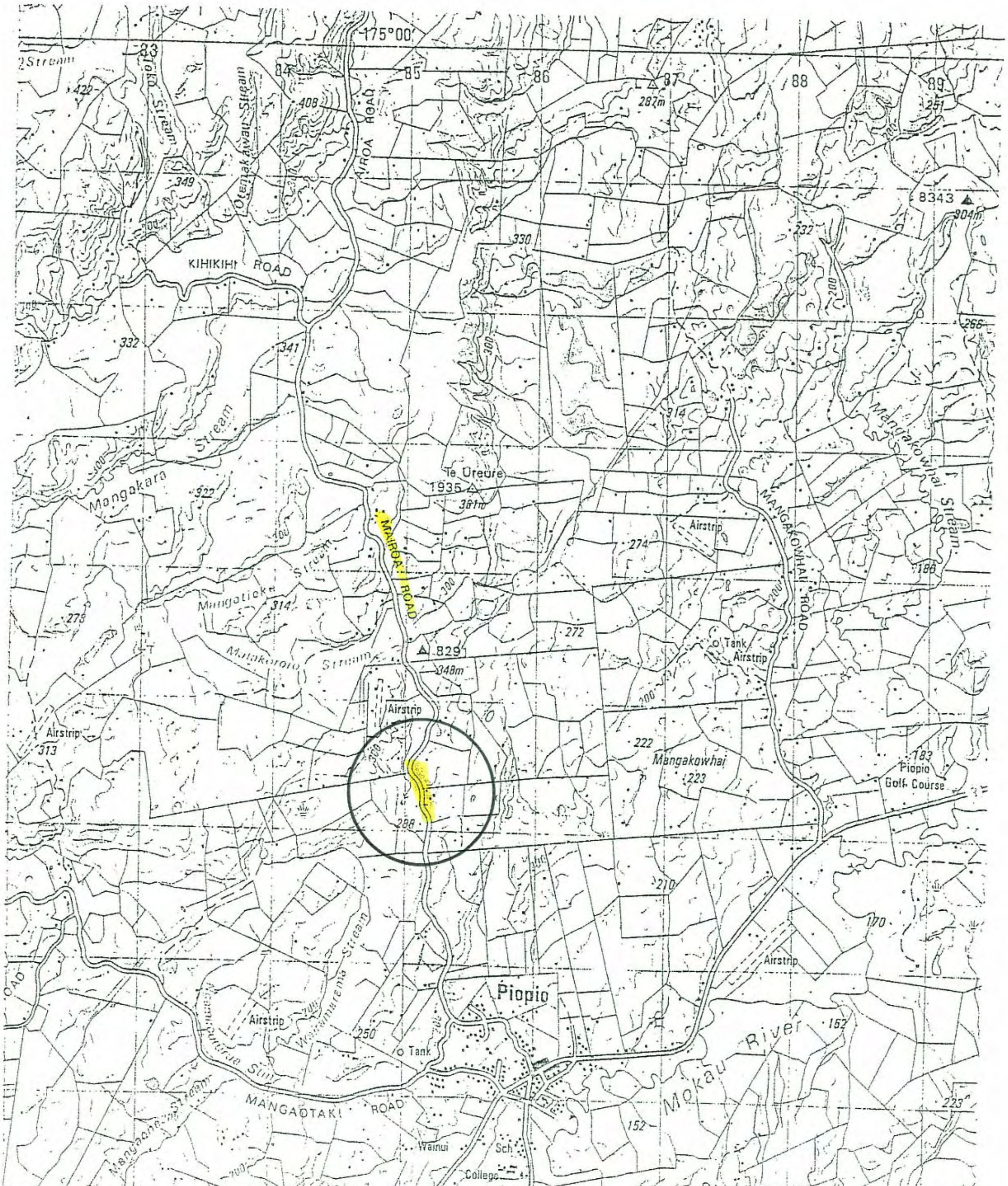
LOCATION MAP

SITE: 8 WHANGAMOMONA

(SH 43)

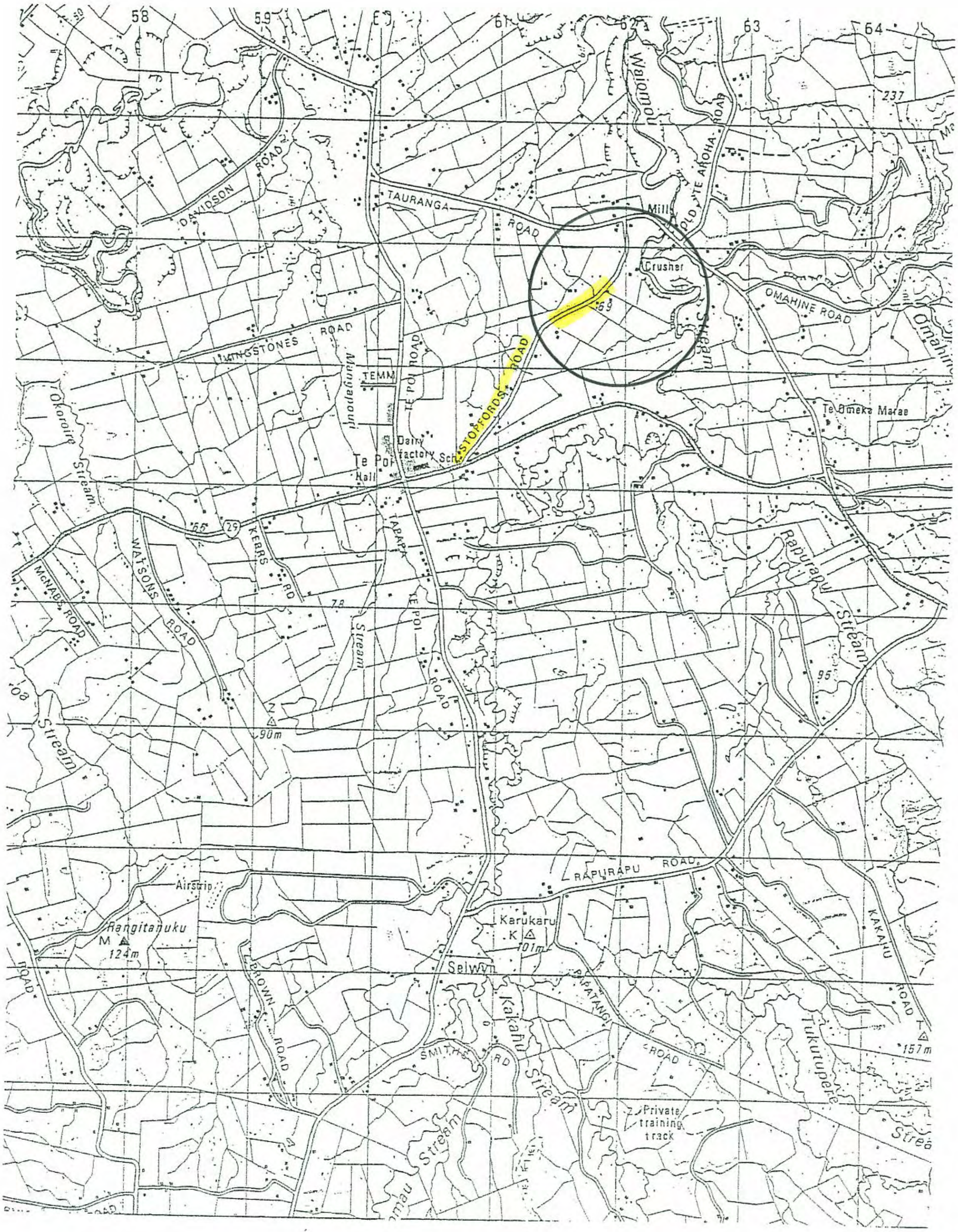


VOLCANIC SOILS PROJECT
LOCATION MAP
SITE: 9 PIO PIO
(Mairoa Road)



VOLCANIC SOILS PROJECT
LOCATION MAP
SITE: 10 HAMILTON-CAMBRIDGE
(Day Road)

VOLCANIC SOILS PROJECT
LOCATION MAP
SITE: 11 TE POI
(Stopfords Road)

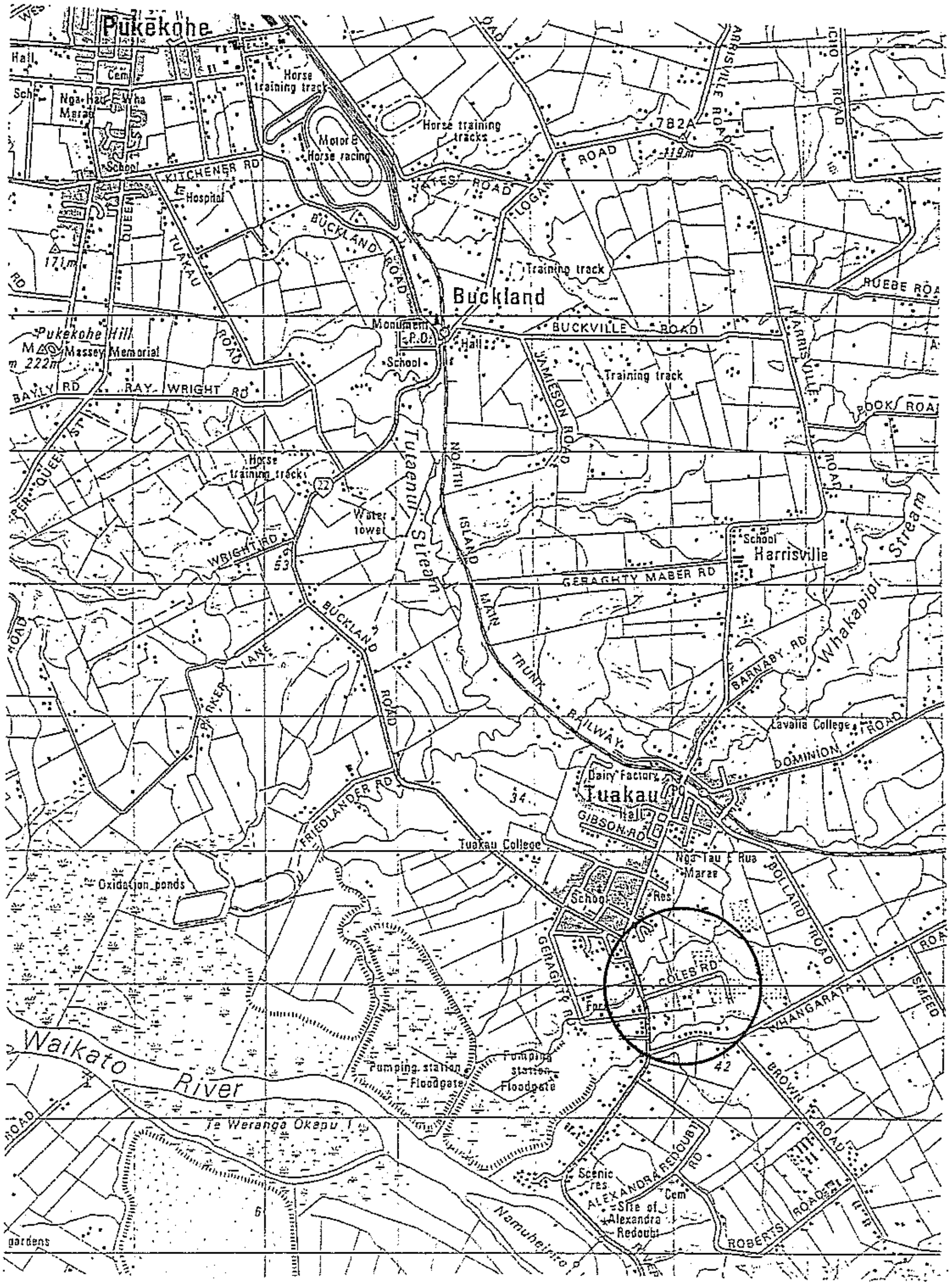


VOLCANIC SOILS PROJECT

LOCATION MAP

SITE: 12 PUKEKOHE

(Coles Road)

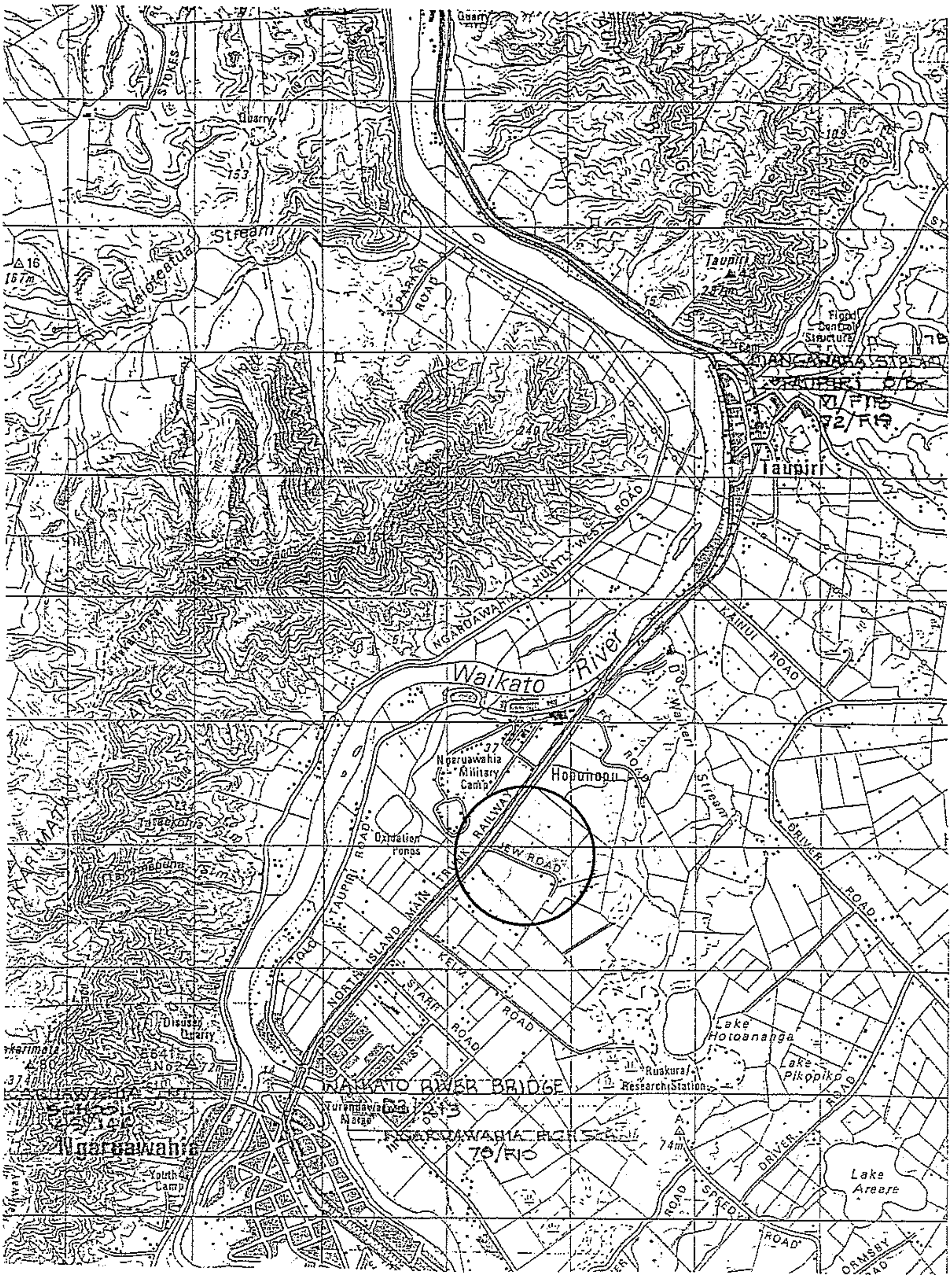


VOLCANIC SOILS PROJECT

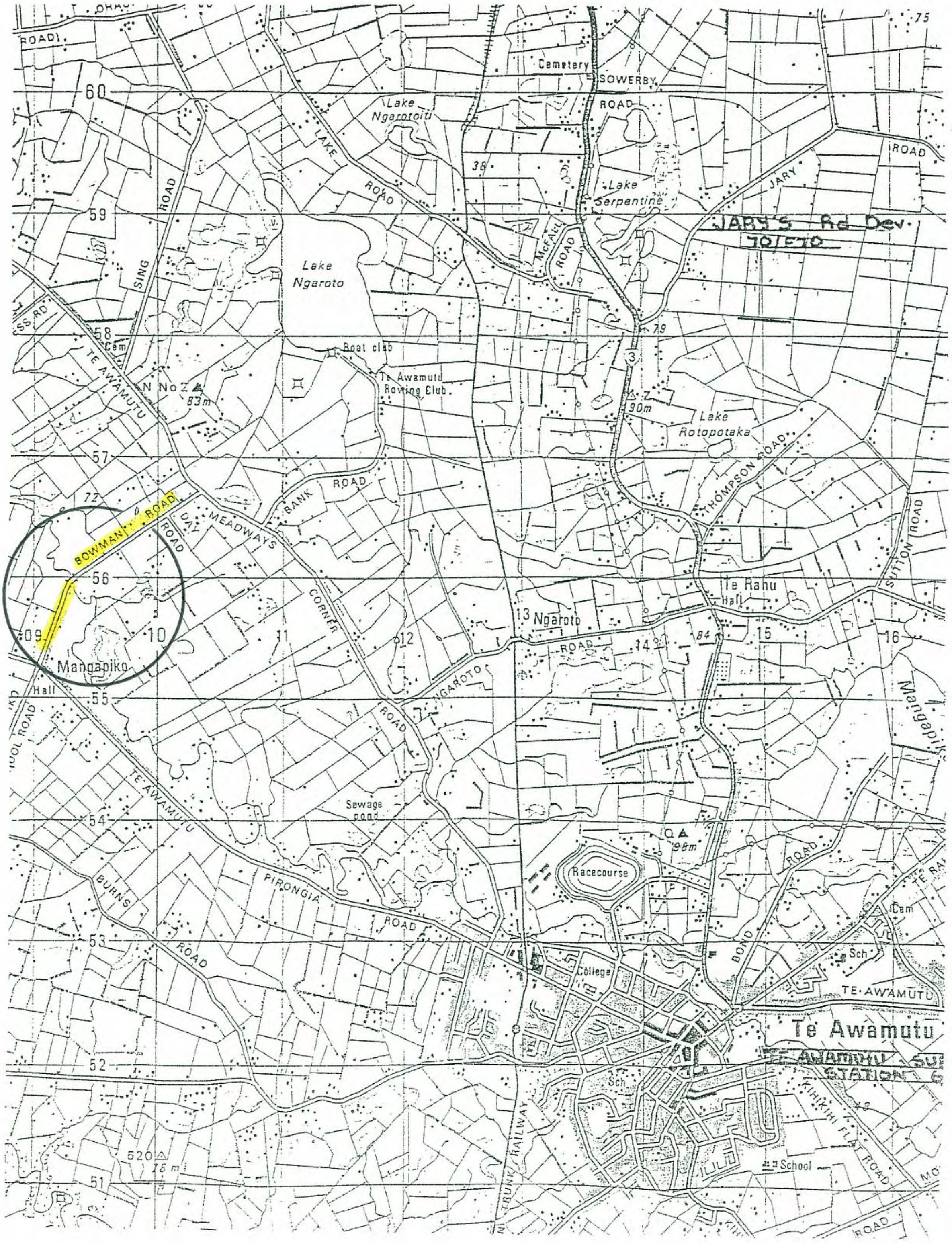
LOCATION MAP

SITE: 13 TAUPIRI

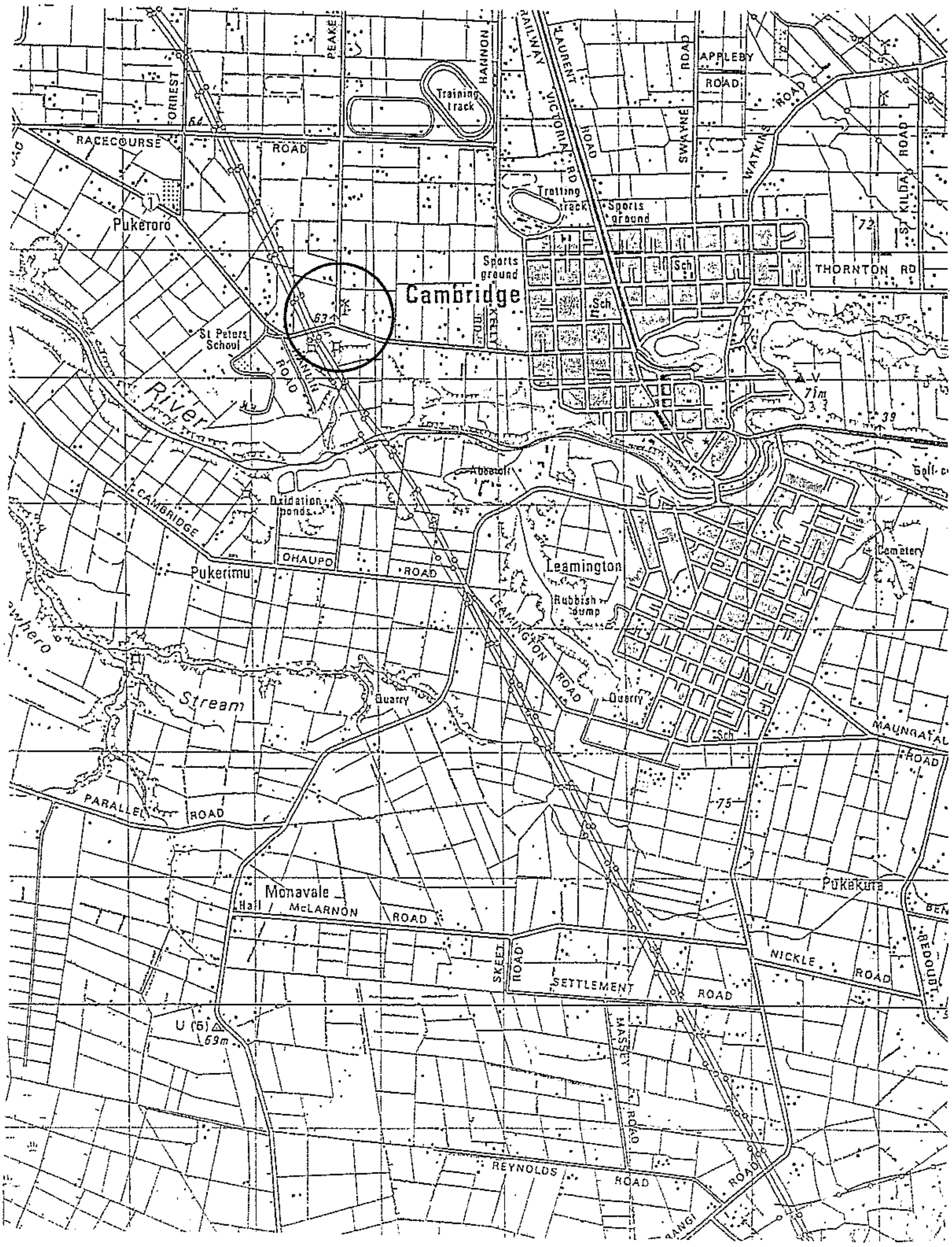
(Jew Road)



VOLCANIC SOILS PROJECT
LOCATION MAP
SITE: 14 TE AWAMUTU
(Bowman Road)



VOLCANIC SOILS PROJECT
LOCATION MAP
SITE: 15 CAMBRIDGE
(Peake Road)



Appendix B

Site Number	Location	Subgrade Description	In-Situ CBR		CBR (from Scala)		Modulus from the FWD		Water Content %		Dry Density t/m3	
Test Pit			1	2	1	2	1	2	1	2	1	2
1	Okere Falls	Pumice SAND	35	45	2	2	39	39	17.5	20.9	1.27	1.16
2	Lichfield	SILT/fine SAND	16	10	4	10	21	18	66.9	61.5	0.78	0.85
3	Murupara	Pumice SAND	50	40	8	7	29	28	18.6	15.2	1.09	1.09
4	Waiotapu	Pumice SAND	60	55	18	20	30	32	42.8	38.9	0.9	0.88
5	Bennydale	1SILT, rare CLAY2Pum SAND	3	19	2	4	6	12	93.4	60.4	0.69	0.66
6	Stratford -Ingle	CLAY	5	11	2	2	27	15	65.9	58.1	0.91	1
7	Waitara - Urenui	CLAY	30	18	16	5	77	23	33.6	79.4	1.42	0.85
8	Whangamonoma	SILT	12	25	8	9	19	16	24.8	23.4	1.69	1.63
9	Pio Pio	SILT	9	6	5	5	30	88	112.5	70.9	0.51	0.79
10	Hamilton - Cam	SILT	8	9	4	5	30	21	68.1	58.8	0.89	0.99
11	Te Poi	SILT, rare CLAY	9	6	5	4	19	21	61	63.5	0.83	0.78
12	Pukekohe	CLAY, some silt	10	15	7	5	55	149	68	46.5	0.94	0.73
13	Taupiri	CLAY	11	20	10	12	106	223	40.5	26.2	1.03	1.37
14	Te Awamutu	SAND	80	100	45	45	45	116	9.2	10.6	-	-
15	Cambridge	SILT, rare CLAY	9	12	5	5	25	9	29.1	54.1	1.15	1

Appendix B Summary of in-situ test results

PLASTICITY INDEX FOR SOILS
TEST REPORT

Project :	Volcanic Soils Project
Location :	As shown
Client :	OPUS International Consultants Ltd.
Contractor :	N/A
Sampled by :	OPUS Laboratory Staff
Date sampled :	April/May 2001
Sampling method :	NZS 4407: 1991, Test 2.4.8.2
Sample condition :	Natural
Date received :	April/May 2001

OPUS
INTERNATIONAL CONSULTANTS

Project No	5-22480.00
Lab Ref N	01/310/001/1 -15
Client Ref No :	03AHL

Test Results

Site:	1. Okere Falls		2. Lichfield		3. Murupara		4. Waiotapu	
Location:	Okere Road		Vospers Road		Golf Road		Jay Raod	
Sample ID:	PP1	PP2	PP1	PP2	PP1	PP2	PP1	PP2
Liquid Limit	Non	Non	84	88	Non	Non	Non	Non
Plastic Limit	Plastic	Plastic	See Note 1	See Note 1	Plastic	Plastic	Plastic	Plastic
Plasticity Index	(Sand)	(Sand)	NP	NP	(Sand)	(Sand)	(Sand)	(Sand)

Site:	5. Bennydale		6. Strat - Inglewood		7. Waitara - Urenui		8. Whangamomona	
Location:	SH30		Tariki Road		Upper Epiha Road		SH43	
Sample ID:	PP1	PP2	PP1	PP2	PP1	PP2	PP1	PP2
Liquid Limit	109	Non	Non	84	53	112	48	31
Plastic Limit	56	Plastic	Plastic	55	See Note 1	68	32	24
Plasticity Index	53	(Sand)	(Sand)	29	NP	44	16	7

Site:	9. Pio Pio		10. Ham - Cambridge		11. Te Poi		12. Pukekohe	
Location:	Mairoa Road		Day Road		Stopfords Road		Coles Road	
Sample ID:	PP1	PP2	PP1	PP2	PP1	PP2	PP1	PP2
Liquid Limit	182	129	92	82	93	96	111	105
Plastic Limit	107	98	67	60	57	57	60	41
Plasticity Index	75	31	25	22	36	39	51	64

Site:	13. Taupiri		14. Te Awamutu		15. Cambridge			
Location:	Jew Road		Bowman Road		Peake Road			
Sample ID:	PP1	PP2	PP1	PP2	PP1	PP2		
Liquid Limit	72	48	Non	Non	49	77		
Plastic Limit	35	23	Plastic	Plastic	28	60		
Plasticity Index	37	25	(Sand)	(Sand)	21	17		

Test Methods	Notes
Liquid Limit, NZS 4402 : 1986, Test 2.2	1. Unable to roll to specified dimensions.
Plastic Limit, NZS 4402 : 1986, Test 2.3	2. NP=Non Plastic
Plasticity Index, NZS 4402 : 1986, Test 2.4	

Date tested : June 2001

Date reported : 05/07/01

IANZ Approved Signatory

20 new zealand accredited laboratory

All tests reported herein have been performed in accordance with the laboratory's scope of accreditation

Designation *Senior Civil Engineering Technician*

Date : 05/07/01

CSF 2101 (12/98)

Opus International Consultants Limited
Hamilton Laboratory
Quality Management Systems Certified to ISO 9001

Fox Street
Private Bag 3057
Hamilton, New Zealand

Telephone +64 7 856 2870
Facsimile +64 7 856 2873
Website www.opus.co.nz

PAVEMENT INVESTIGATION LOG
TEST REPORT

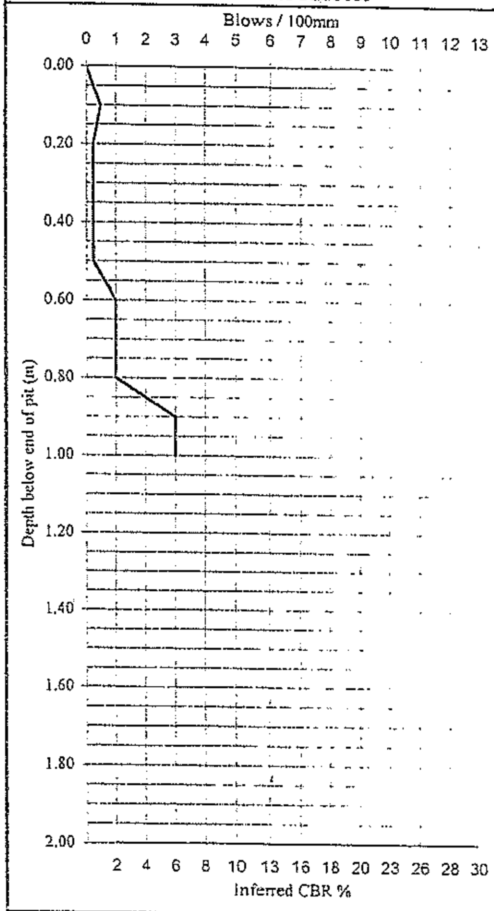
Project :	Volcanic Soils Project (Site 1, Okere)
Location :	Okere Rd @ 60m LHS OWT
Client :	Opus International Consultants Ltd
Contractor :	N/A
Sampled by :	A Ingoe. (Opus Laboratory, Hamilton)
Date Sampled :	23/04/01
Sampling method :	NZS 4407 : 1991 Test 2.4.8.2
Sample condition :	Natural
Pavement pit number :	1

OPUS INTERNATIONAL CONSULTANTS

Project No :	5-22480.00
Lab Ref No :	01/310/001/1
Client Ref No :	Okere PP1

Depth (mm)	Pavement Description
0	CHIPSEAL Grade 3. Worn, slightly flushed.
50	BASECOURSE Greyish brown Gravelly fine to medium grained pumice SAND, gravels subrounded/fine to medium grained, dense, moist, non plastic.
300	SUBGRADE Brown Silty fine to medium SAND, quartz/pumice intermixed, loose, moist, non plastic.
450	END OF PIT

Scala Penetrometer



Insitu CBR Test Results		
	Test Depth	350mm
	CBR %	35
	Penetration	2.5mm
	Water Content %	17.5

Basecourse sample not recovered.
Subbase sample not recovered.
Subgrade sample recovered at : 350 - 450mm.
Depth at scala penetrometer started : 350mm.

Subgrade Density

Push tube results at :	350mm
Wet density (t/m^3) :	1.49
Dry density (t/m^3) :	1.27
W / C % :	17.5

Test Methods

Determination of Penetration Resistance of a Soil, NZS 4402 : 1988, Test 6.5.2
Insitu Density, sampling tube method, NZS 4402 : 1986, Test 5.1.3
California Bearing Ratio (insitu), NZS 4402: 1988, Test 6.1.3
Inferred CBR values taken from Austroads pavement design manual 1992

Notes

IANZ Accreditation does not apply to inferred CBR values or pavement descriptions

Date tested : 23/04/01
Date reported : 27/04/01

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IANZ Approved Signatory

Designation : Laboratory Manager
Date : 27/04/01

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Opus International Consultants Limited
Hamilton Laboratory
Quality Management Systems Certified to ISO 9001

Fox Street
Private Bag 3057
Hamilton, New Zealand

Telephone +64 7 856 2870
Facsimile +64 7 856 2873
Website www.opus.co.nz

PAVEMENT INVESTIGATION LOG
TEST REPORT

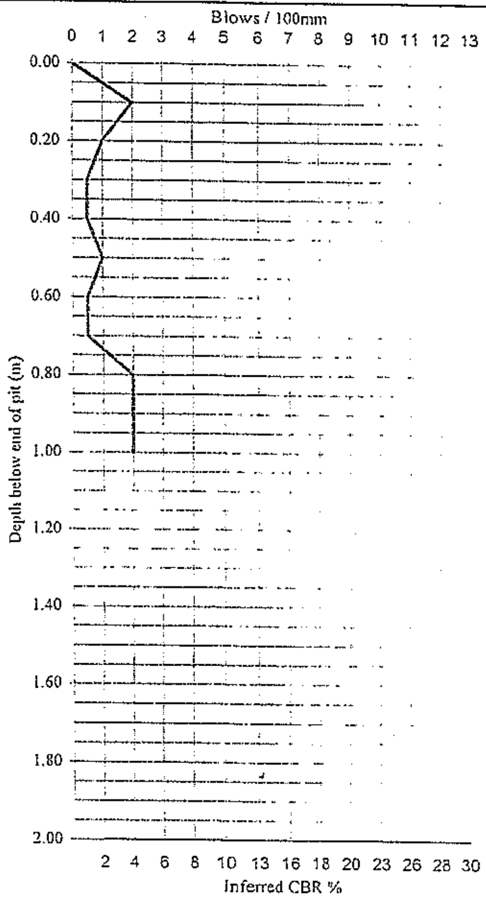
OPUS INTERNATIONAL CONSULTANTS

Project :	Volcanic Soils Project (Site 1, Okere)
Location :	Okere Rd @ 180m LHS OWT
Client :	Opus International Consultants Ltd
Contractor :	N/A
Sampled by :	A Ingoe. (Opus Laboratory, Hamilton)
Date Sampled :	23/04/01
Sampling method :	NZS 4407 : 1991 Test 2.4.8.2
Sample condition :	Natural
Pavement pit number :	2

Project No :	5-22480.00
Lab Ref No :	01/310/001/1
Client Ref No :	Okere PP2

Depth (mm)	Pavement Description
0	CHIPSEAL Grade 3. Worn, slightly flushed.
55	BASECOURSE Greyish brown Gravelly fine to medium grained pumice SAND, gravels subrounded/fine to medium grained, some clasts of brown Silty Sand intermixed, dense, moist, non plastic.
400	SUBGRADE Brown Gravelly fine to medium pumice SAND, abundant fine rounded pumice gravels, loose, moist, non plastic
550	END OF PIT

Scala Penetrometer



Insitu CBR Test Results		
	Test Depth	440mm
	CBR %	45
	Penetration	2.5mm
	Water Content %	20.9

Basecourse sample not recovered.
Subbase sample not recovered.
Subgrade sample recovered at : 440 - 550mm.
Depth at which scala penetrometer started : 440mm.

Subgrade Density	
Push Tube result at :	440mm
Wet density (t/m^3) :	1.41
Dry density (t/m^3) :	1.16
W / C % :	20.9

Test Methods

Determination of Penetration Resistance of a Soil, NZS 4402 : 1988, Test 6.5.2
Insitu Density, sampling tube method, NZS 4402 : 1986, Test 5.1.3
California Bearing Ratio (insitu), NZS 4402: 1988, Test 6.1.3
Inferred CBR values taken from Austroads pavement design manual 1992

Notes

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Date tested : 23/04/01
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Designation : Laboratory Manager
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Opus International Consultants Limited
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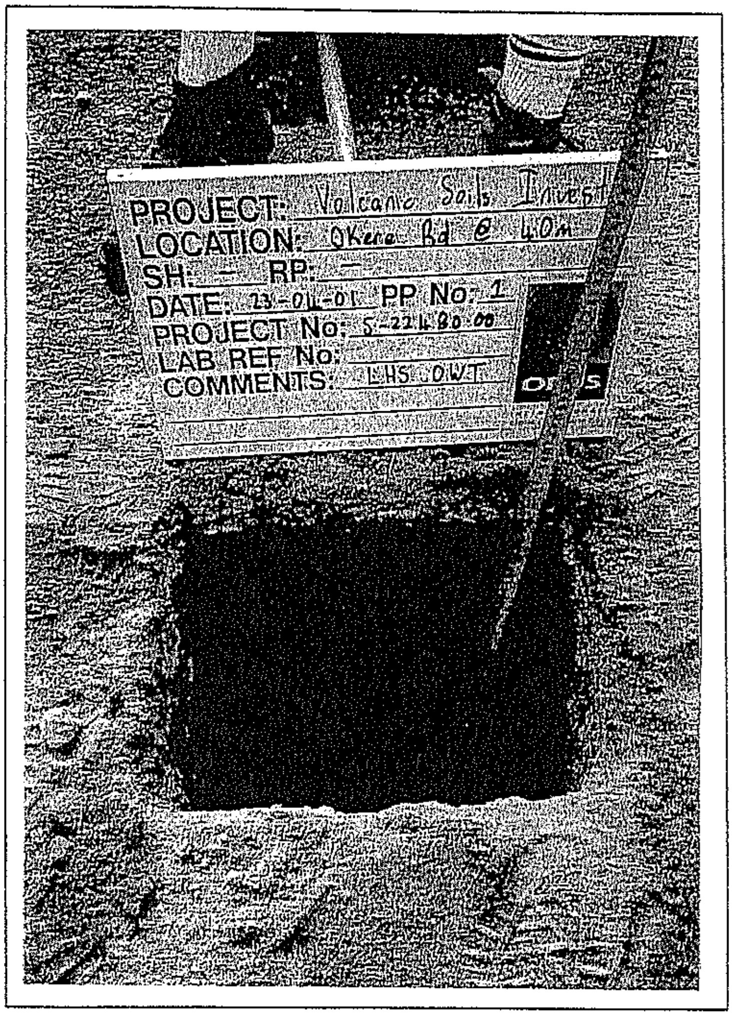
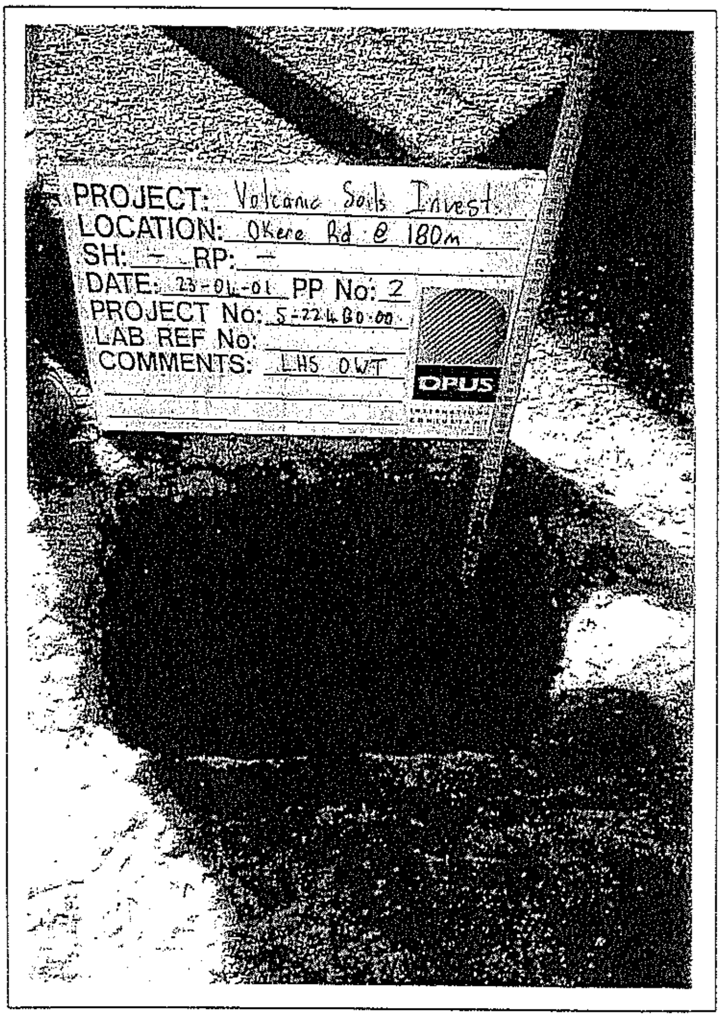
Hamilton, New Zealand
Telephone +64 7 856 2870
Facsimile +64 7 856 2873
Website www.opus.co.nz

Volcanic Soil Project Site 1: Okere Falls

Project No: 5-22480.00
Lab Ref No: 01/310/001/1



Okere Road
Pavement Pit 1
@ 60m LHS, OWT



Okere Road
Pavement Pit 2
@ 180m LHS, OWT

PAVEMENT INVESTIGATION LOG
TEST REPORT

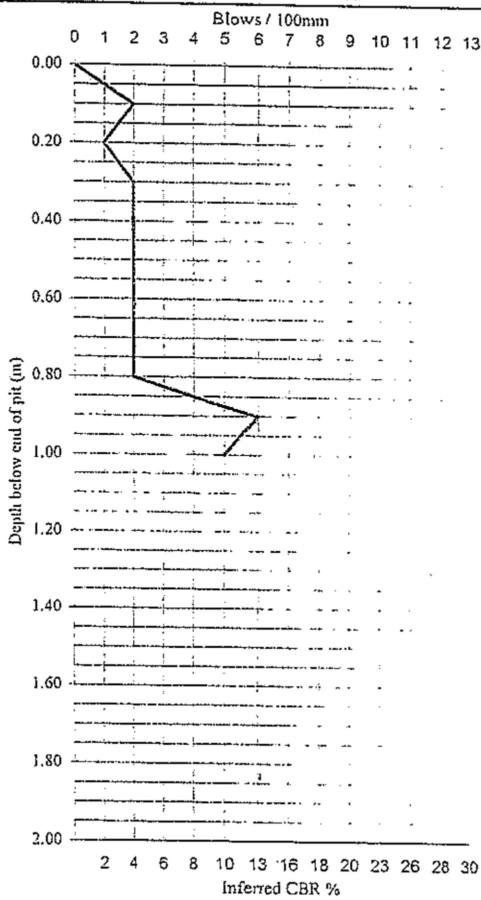
OPUS INTERNATIONAL CONSULTANTS

Project :	Volcanic Soils Project (Site 2, Lichfield)
Location :	Vospers Rd @ 60m LHS OWT
Client :	Opus International Consultants Ltd
Contractor :	N/A
Sampled by :	A Ingoe. (Opus Laboratory, Hamilton)
Date Sampled :	24/04/01
Sampling method :	NZS 4407 : 1991 Test 2.4.8.2
Sample condition :	Natural
Pavement pit number :	1

Project No :	5-22480.00
Lab Ref No :	01/310/001/2
Client Ref No :	Lichfield PP1

Depth (mm)	Pavement Description
0	CHIPSEAL Grade 4. Sound.
25	BASECOURSE I AP 40. Fresh to slightly weathered angular GREYWACKE, well graded, medium dense, moist, non plastic.
100	SUBBASE Light greyish brown Gravelly fine SAND, some Silt, Gravels sub-rounded/fine to medium grained, medium dense, dry, non plastic.
220	OLD CHIPSEAL LAYER
250	BASECOURSE II GAP 40. Moderately to highly weathered GREYWACKE/Silty SAND conglomerate, medium dense, moist, slighly plastic
390	SUBGRADE Light brown SILT/fine SAND mixture, some black organic Silt intermixed in top 100mm, soft, slightly moist, non plastic.
600	END OF PIT

Scala Penetrometer



Insitu CBR Test Results		
	Test Depth	440mm
	CBR %	16
	Penetration	2.5mm
	Water Content %	66.9

Basecourse sample not recovered.
Subbase sample not recovered.
Subgrade sample recovered at : 440 - 600mm.
Depth at which scala penetrometer started : 440mm.

Subgrade Density

Push Tube result at :	440mm
Wet density (t/m^3) :	1.30
Dry density (t/m^3) :	0.78
W / C % :	66.9

Test Methods

Determination of Penetration Resistance of a Soil, NZS 4402 : 1988, Test 6.5.2
Insitu Density, sampling tube method, NZS 4402 : 1986, Test 5.1.3
California Bearing Ratio (insitu), NZS 4402: 1988, Test 6.1.3
Inferred CBR values taken from Austroads pavement design manual 1992

Notes

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Date tested : 24/04/01
Date reported : 27/04/01

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IANZ Approved Signatory

Designation : Laboratory Manager
Date : 27/04/01

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Opus International Consultants Limited
Hamilton Laboratory
Quality Management Systems Certified to ISO 9001

Fox Street
Private Bag 3057
Hamilton, New Zealand

Telephone +64 7 856 2870
Facsimile +64 7 856 2873
Website www.opus.co.nz

PAVEMENT INVESTIGATION LOG
TEST REPORT

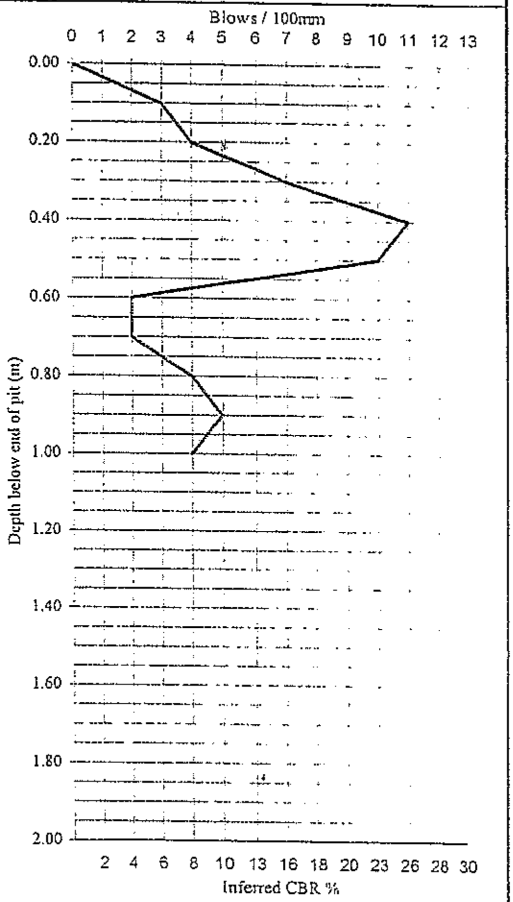
Project :	Volcanic Soils Project (Site 2, Lichfield)
Location :	Vospers Rd @ 120m LHS OWT
Client :	Opus International Consultants Ltd
Contractor :	N/A
Sampled by :	A Ingoe. (Opus Laboratory, Hamilton)
Date Sampled :	24/04/01
Sampling method :	NZS 4407 : 1991 Test 2.4.8.2
Sample condition :	Natural
Pavement pit number :	2

OPUS INTERNATIONAL CONSULTANTS

Project No :	5-22480.00
Lab Ref No :	01/310/001/2
Client Ref No. :	Lichfield PP2

Depth (mm)	Pavement Description
0	CHIPSEAL Grade 4. Sound.
30	BASECOURSE AP 40. Fresh to slightly weathered angular GREYWACKE, well graded, medium dense, moist, non plastic.
90	SUBBASE Light pinkish greyish Gravelly fine SAND, some Silt, Gravels sub-rounded/fine to medium grained, chipseal intermixed from 140mm, medium dense, dry, non plastic.
390	SUBGRADE Yellow brown homogeneous fine Sandy SILT, firm, moist, non plastic.
490	END OF PIT

Scala Penetrometer



Insitu CBR Test Results		
	Test Depth	340mm
	CBR %	10
	Penetration	2.5mm
	Water Content %	61.5

Basecourse sample not recovered.
Subbase sample not recovered.
Subgrade sample recovered at : 340 - 490mm.
Depth at which scala penetrometer started : 340mm.

Subgrade Density

Push Tube result at :	340mm
Wet density (t/m^3) :	1.38
Dry density (t/m^3) :	0.85
W / C % :	61.5

Test Methods
Determination of Penetration Resistance of a Soil, NZS 4402 : 1988, Test 6.5.2
Insitu Density, sampling tube method, NZS 4402 : 1986, Test 5.1.3
California Bearing Ratio (insitu), NZS 4402: 1988, Test 6.1.3
Inferred CBR values taken from Austroads pavement design manual 1992

Notes
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Date tested : 24/04/01
Date reported : 27/04/01

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IANZ Approved Signatory
Designation : Laboratory Manager
Date : 27/04/01

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Hamilton Laboratory
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Fox Street
Private Bag 3057
Hamilton, New Zealand
Telephone +64 7 856 2870
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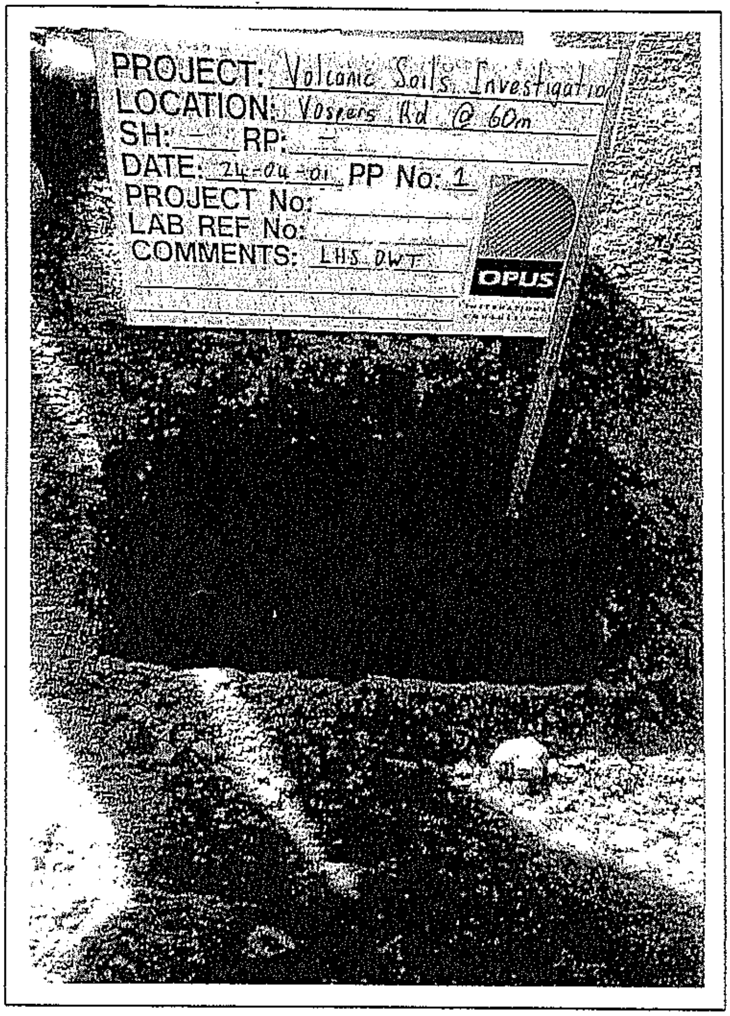
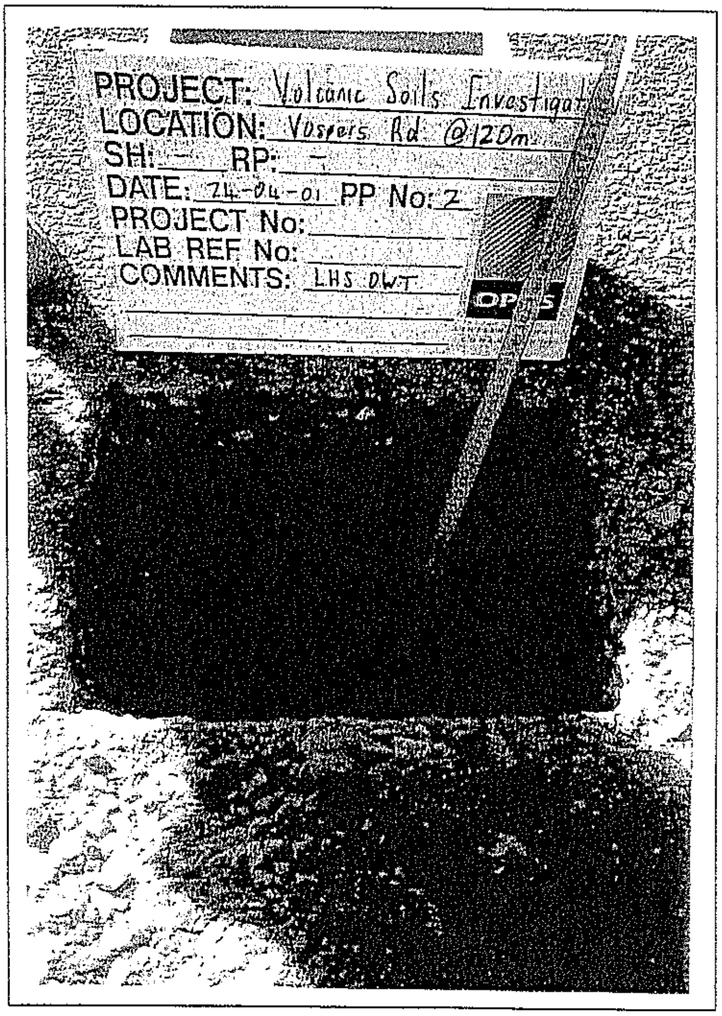
Website www.opus.co.nz

Volcanic Soil Project Site 2: Lichfield

Project No: 5-22480.00
Lab Ref No: 01/310/001/2



Vospers Road
Pavement Pit 1
@ 60m LHS, OWT



Vospers Road
Pavement Pit 2
@ 120m LHS, OWT

PAVEMENT INVESTIGATION LOG
TEST REPORT

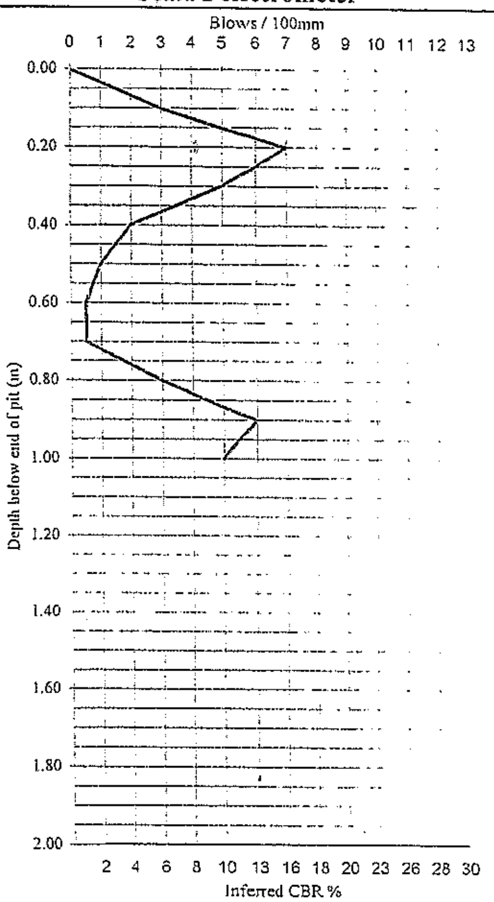
Project :	Volcanic Soils Project (Site 3, Murupara)
Location :	Golf Rd @ 20m LHS OWT
Client :	Opus International Consultants Ltd
Contractor :	N/A
Sampled by :	B. Lorcet (Opus Laboratory, Rotorua)
Date Sampled :	10/04/01
Sampling method :	NZS 4407 : 1991 Test 2.4.8.2
Sample condition :	Natural
Pavement pit number :	1

OPUS INTERNATIONAL CONSULTANTS

Project No :	5-22480.00
Lab Ref No :	01/310/001/3
Client Ref No :	Murupara PP1

Depth (mm)	Pavement Description
0	CHIPSEAL Grade 3, flushed
40	BASECOURSE AP 40. Rounded, poorly graded, excess SAND, some Gravel, moderately dense, dry, non plastic.
150	SUBGRADE Light brown fine to medium pumice SAND, loose, moist, non plastic.
350	END OF PIT

Scala Penetrometer



Insitu CBR Test Results		
	Test Depth	150mm
	CBR %	50
	Penetration	2.5mm
	Water Content %	18.6

Basecourse sample not recovered.
Subbase sample not recovered.
Subgrade sample recovered at : 350 - 450mm.
Depth at scala penetrometer started : 350mm.

Subgrade Density

Push Tube result at :	150mm
Wet density (t/m^3) :	1.29
Dry density (t/m^3) :	1.09
W / C % :	18.6

Test Methods

Determination of Penetration Resistance of a Soil, NZS 4402 : 1988, Test 6.5.2
Insitu Density, sampling tube method, NZS 4402 : 1986, Test 5.1.3
California Bearing Ratio (insitu), NZS 4402: 1988, Test 6.1.3
Inferred CBR values taken from Austroads pavement design manual 1992

Notes

IANZ Accreditation does not apply to inferred CBR values or pavement descriptions

Date tested : 10/04/01
Date reported : 01/05/01

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IANZ Approved Signatory

Designation : Laboratory Manager
Date : 01/05/01

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Opus International Consultants Limited
Hamilton Laboratory
Quality Management Systems Certified to ISO 9001

Fox Street
Private Bag 3057
Hamilton, New Zealand

Telephone +64 7 856 2870
Facsimile +64 7 856 2873
Website www.opus.co.nz

PAVEMENT INVESTIGATION LOG
TEST REPORT

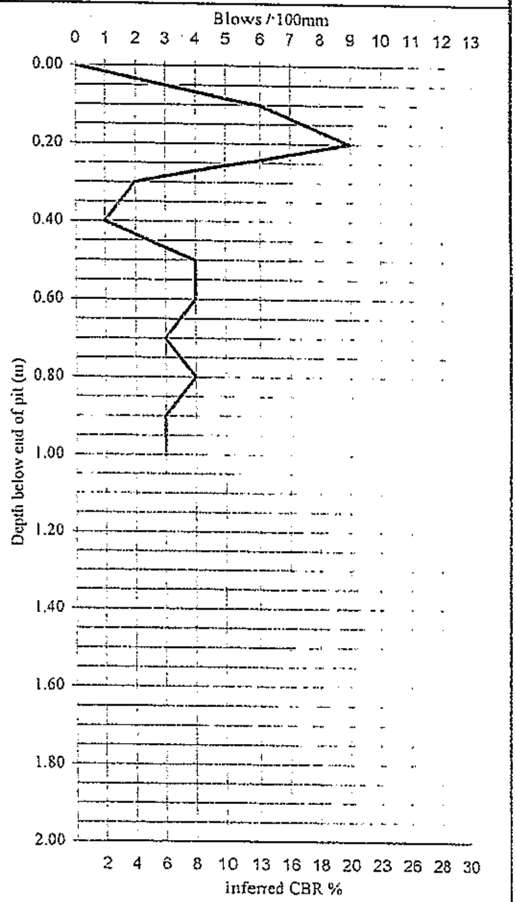
Project :	Volcanic Soils Project (Site 3, Murupara)
Location :	Golf Rd @ 160m LHS OWT
Client :	Opus International Consultants Ltd
Contractor :	N/A
Sampled by :	B. Lorcet (Opus Laboratory, Rotorua)
Date Sampled :	10/04/01
Sampling method :	NZS 4407 : 1991 Test 2.4.8.2
Sample condition :	Natural
Pavement pit number :	2

OPUS INTERNATIONAL CONSULTANTS

Project No :	5-22480.00
Lab Ref No :	01/310/001/3
Client Ref No :	Murupara PP2

Depth (mm)	Pavement Description
0	CHIPSEAL Grade 3, flushed
40	BASECOURSE AP 40. Rounded, poorly graded, excess SAND, some Gravel, moderately dense, dry, non plastic.
190	SUBBASE Dark grey medium to fine Silty SAND, moderately dense, moist, non plastic.
230	SUBGRADE Light brown fine to medium pumice SAND, loose, moist, non plastic.
320	END OF PIT

Scala Penetrometer



Insitu CBR Test Results		
	Test Depth	230mm
	CBR %	40
	Penetration	2.5mm
	Water Content %	15.2

Basecourse sample not recovered.
Subbase sample not recovered.
Subgrade sample recovered at : 230 - 320mm.
Depth at which scala penetrometer started : 230mm.

Subgrade Density

Push Tube result at :	230mm
Wet density (t/m^3) :	1.29
Dry density (t/m^3) :	1.09
W / C % :	15.2

Test Methods

Determination of Penetration Resistance of a Soil, NZS 4402 : 1988, Test 6.5.2
Insitu Density, sampling tube method, NZS 4402 : 1986, Test 5.1.3
California Bearing Ratio (insitu), NZS 4402: 1988, Test 6.1.3
Inferred CBR values taken from Austroads pavement design manual 1992

Notes

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Date tested : 10/04/01
Date reported : 01/05/01

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IANZ Approved Signatory

Designation : Laboratory Manager
Date : 01/05/01

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Private Bag 3057
Hamilton, New Zealand

Telephone +64 7 856 2870
Facsimile +64 7 856 2873
Website www.opus.co.nz

PAVEMENT INVESTIGATION LOG
TEST REPORT

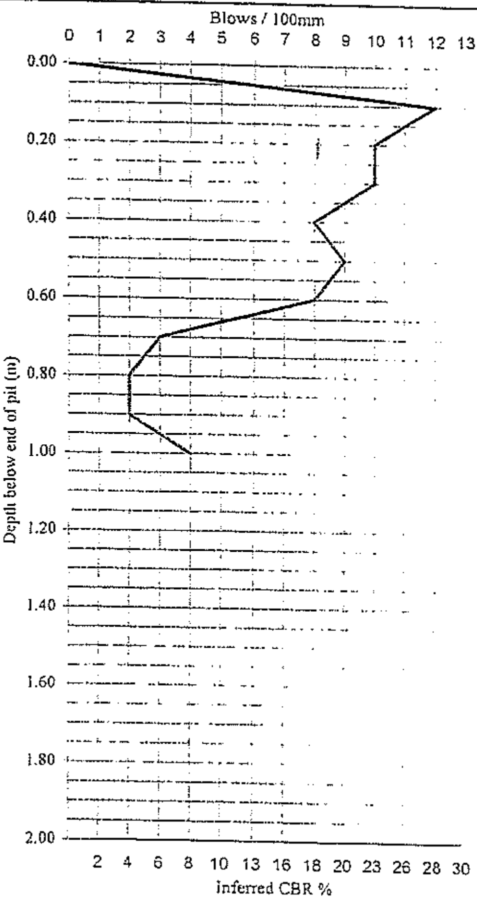
Project :	Volcanic Soils Project (Site 4, Waiotapu)
Location :	Jay Road @ 60m LHS OWT
Client :	Opus International Consultants Ltd
Contractor :	N/A
Sampled by :	A Ingoe. (Opus Laboratory, Hamilton)
Date Sampled :	23/04/01
Sampling method :	NZS 4407 : 1991 Test 2.4.8.2
Sample condition :	Natural
Pavement pit number :	1

OPUS INTERNATIONAL CONSULTANTS

Project No :	5-22480.00
Lab Ref No :	01/310/001/4
Client Ref No :	Waiotapu PP1

Depth (mm)	Pavement Description
0	CHIPSEAL Grade 4/5. Slightly flushed, generally sound.
20	BASECOURSE AP 40. Slightly weathered, subrounded river run GREYWACKE, excess Silty SAND, medium dense, moist, non plastic.
200	SUBGRADE Light brown Gravelly fine pumice SAND, Gravels rounded/fine to medium grained, dense, dry, non plastic.
390	END OF PIT

Scala Penetrometer



Insitu CBR Test Results		
	Test Depth	200mm
	CBR %	60
	Penetration	2.5mm
	Water Content %	42.8

Basecourse sample not recovered.
Subbase sample not recovered.
Subgrade sample recovered at : 200 - 390mm.
Depth at which scala penetrometer started : 200mm.

Subgrade Density

Push Tube result at :	200mm
Wet density (t/m^3) :	1.28
Dry density (t/m^3) :	0.90
W / C % :	42.8

Test Methods

Determination of Penetration Resistance of a Soil, NZS 4402 : 1988, Test 6.5.2
Insitu Density, sampling tube method, NZS 4402 : 1986, Test 5.1.3
California Bearing Ratio (insitu), NZS 4402: 1988, Test 6.1.3
Inferred CBR values taken from Austroads pavement design manual 1992

Notes

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Date tested : 23/04/01
Date reported : 27/04/01

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IANZ Approved Signatory
Designation : *Laboratory Manager*
Date : 27/04/01

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Hamilton Laboratory
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Fox Street
Private Bag 3057
Hamilton, New Zealand
Telephone +64 7 856 2870
Facsimile +64 7 856 2873
Website www.opus.co.nz

PAVEMENT INVESTIGATION LOG
TEST REPORT

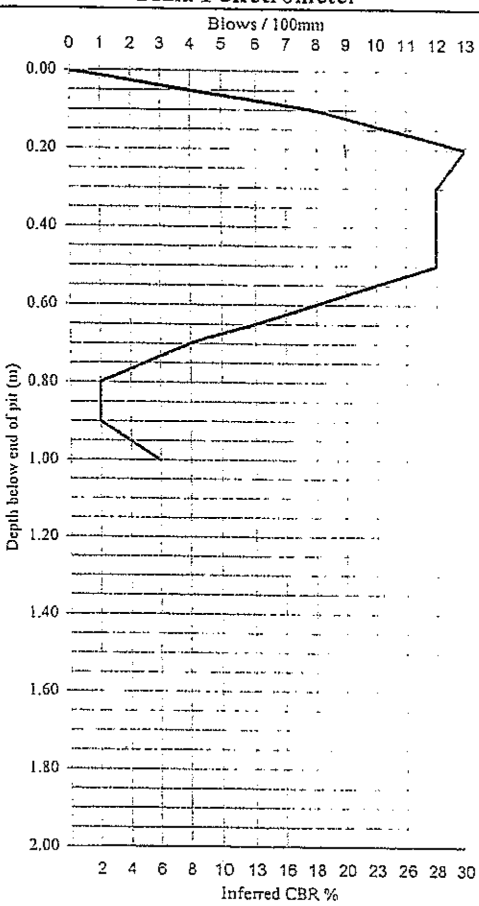
INTERNATIONAL CONSULTANTS

Project :	Volcanic Soils Project (Site 4, Waiotapu)
Location :	Jay Road @ 160m LHS OWT
Client :	Opus International Consultants Ltd
Contractor :	N/A
Sampled by :	A Ingoe. (Opus Laboratory, Hamilton)
Date Sampled :	23/04/01
Sampling method :	NZS 4407 : 1991 Test 2.4.8.2
Sample condition :	Natural
Pavement pit number :	2

Project No :	5-22480.00
Lab Ref No :	01/310/001/4
Client Ref No :	Waiotapu PP2

Depth (mm)	Pavement Description
0	CHIPSEAL Grade 4/5. Slightly flushed, generally sound.
25	BASECOURSE AP 40. Slightly weathered, subrounded river run GREYWACKE, excess Silty SAND, medium dense, moist, non plastic.
170	SUBGRADE Dark brown grading to light brown Gravelly fine pumice SAND, Gravels rounded/fine to medium grained, dense, dry, non plastic.
390	END OF PIT

Scala Penetrometer



Insitu CBR Test Results		
	Test Depth	175mm
	CBR %	55
	Penetration	2.5mm
	Water Content %	38.9

Basecourse sample not recovered.
Subbase sample not recovered.
Subgrade sample recovered at : 175 - 390mm.
Depth at which scala penetrometer started : 175mm.

Subgrade Density

Push Tube result at :	175mm
Wet density (t/m^3) :	1.22
Dry density (t/m^3) :	0.88
W / C % :	38.9

Test Methods

Determination of Penetration Resistance of a Soil, NZS 4402 : 1988, Test 6.5.2
Insitu Density, sampling tube method, NZS 4402 : 1986, Test 5.1.3
California Bearing Ratio (insitu), NZS 4402: 1988, Test 6.1.3
Inferred CBR values taken from Austroads pavement design manual 1992

Notes

IANZ Accreditation does not apply to inferred CBR values or pavement descriptions

Date tested : 23/04/01
Date reported : 27/04/01

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IANZ Approved Signatory

Designation : Laboratory Manager
Date : 27/04/01

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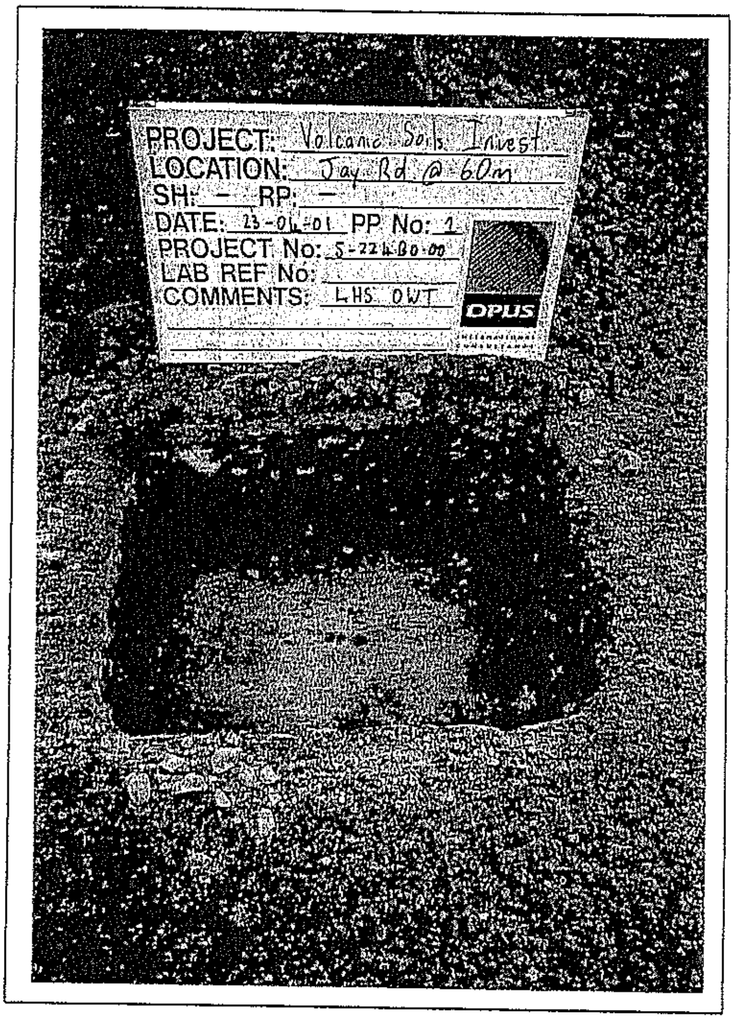
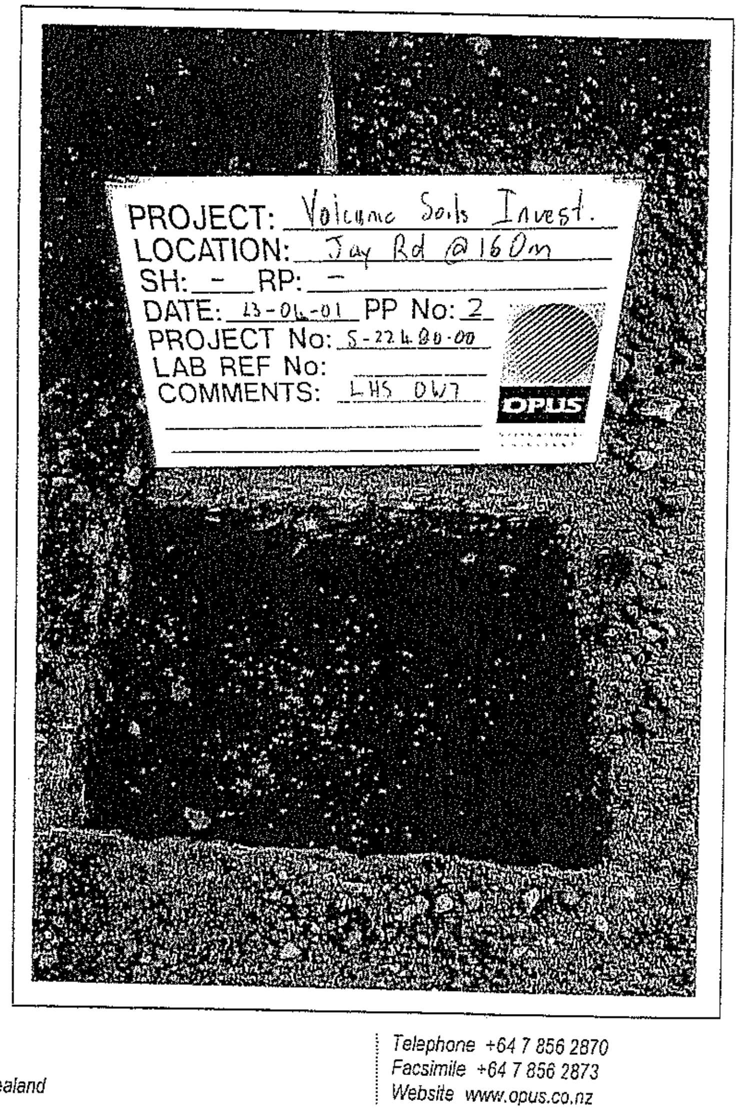
Opus International Consultants Limited
Hamilton Laboratory
Quality Management Systems Certified to ISO 9001
Fox Street
Private Bag 3057
Hamilton, New Zealand
Telephone +64 7 856 2870
Facsimile +64 7 856 2873
Website www.opus.co.nz

<u>Volcanic Soil Project Site 4: Waiotapu</u>

Project No: 5-22480.00
Lab Ref No: 01/310/001/4



Jay Road
Pavement Pit 1
@ 60m LHS, OWT



Jay Road
Pavement Pit 2
@ 160m LHS, OWT

PAVEMENT INVESTIGATION LOG
TEST REPORT

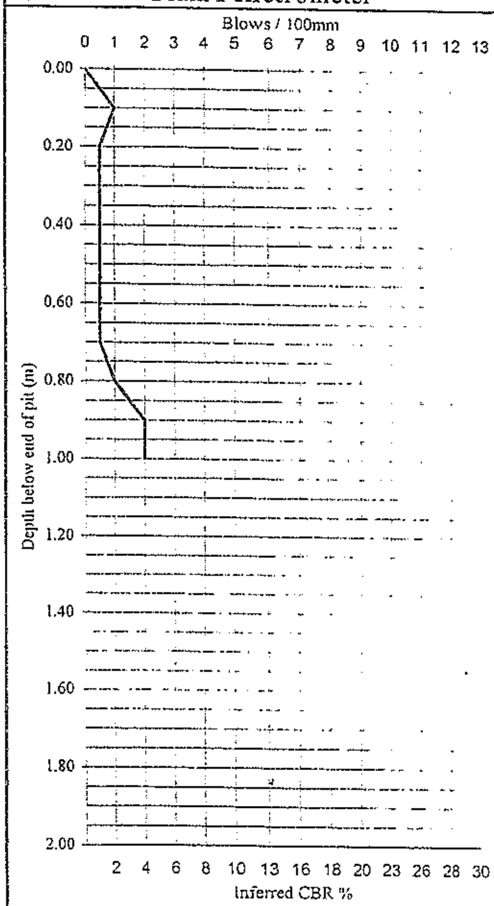
Project :	Volcanic Soils Project (Site 5, Bennydale)
Location :	SH30 @ 60m RHS OWT
Client :	Opus International Consultants Ltd
Contractor :	N/A
Sampled by :	A Ingoe. (Opus Laboratory, Hamilton)
Date Sampled :	26/04/01
Sampling method :	NZS 4407 : 1991 Test 2.4.8.2
Sample condition :	Natural
Pavement pit number :	1

OPUS INTERNATIONAL CONSULTANTS

Project No :	5-22480.00
Lab Ref No :	01/310/001/5
Client Ref No :	Bennydale PP1

Depth (mm)	Pavement Description
0	CHIPSEAL Grade 3/4. Worn, flushed, some rutting.
30	BASECOURSE GAP 40. Slightly weathered angular GREYWACKE. excess Sandy SILT, some Clay & old chipseal intermixed, medium dense, moist, slightly plastic.
300	SUBBASE Brown Clayey SILT, stiff, moist, slightly plastic.
360	SUBGRADE Yellow brown homogeneous SILT, rare Clay, soft, wet, very slightly plastic.
630	END OF PIT

Scala Penetrometer



Insitu CBR Test Results		
	Test Depth	490mm
	CBR %	3
	Penetration	5.0mm
	Water Content %	93.4

Basecourse sample not recovered.
Subbase sample not recovered.
Subgrade sample recovered at : 490 - 630mm.
Depth at which scala penetrometer started : 490mm.

Subgrade Density

Push Tube result at :	490mm
Wet density (t/m^3) :	1.34
Dry density (t/m^3) :	0.69
W / C % :	93.4

Test Methods

Determination of Penetration Resistance of a Soil, NZS 4402 : 1988, Test 6.5.2
Insitu Density, sampling tube method, NZS 4402 : 1986, Test 5.1.3
California Bearing Ratio (insitu), NZS 4402: 1988, Test 6.1.3
Inferred CBR values taken from Austroads pavement design manual 1992

Notes

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Date tested : 26/04/01
Date reported : 27/04/01

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Hamilton, New Zealand

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Facsimile +64 7 856 2873
Website www.opus.co.nz

PAVEMENT INVESTIGATION LOG
TEST REPORT

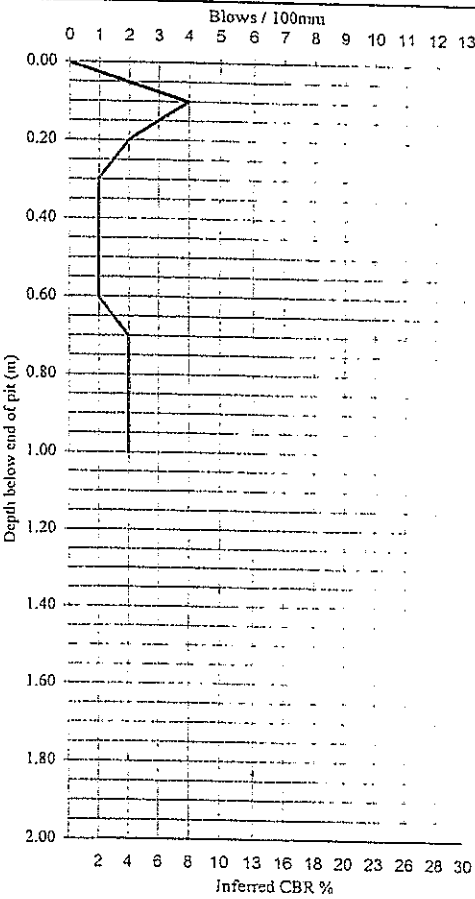
Project :	Volcanic Soils Project (Site 5, Bennydale)
Location :	SH30 @ 140m RHS OWT
Client :	Opus International Consultants Ltd
Contractor :	N/A
Sampled by :	A Ingoe. (Opus Laboratory, Hamilton)
Date Sampled :	26/04/01
Sampling method :	NZS 4407 : 1991 Test 2.4.8.2
Sample condition :	Natural
Pavement pit number :	2

OPUS INTERNATIONAL CONSULTANTS

Project No :	5-22480.00
Lab Ref No :	01/310/001/5
Client Ref No :	Bennydale PP2

Depth (mm)	Pavement Description
0	CHIPSEAL Grade 3/4. Worn, flushed, some rutting.
35	BASECOURSE GAP 40. Slightly weathered angular GREYWACKE, excess Sandy SILT, some Clay & old chipseal intermixed, medium dense, moist, slightly plastic.
180	SUBBASE I Dark Yellow brown Silty CLAY, some aggregates intermixed, Stiff, dry, highly plastic.
260	SUBBASE II Brown / black Gravelly SILT, Gravels angular/ medium grained, stiff, moist, non plastic.
410	SUBGRADE Light brown Gravelly fine to medium pumice SAND loose, dry, non plastic.
590	END OF PIT

Scala Penetrometer



Insitu CBR Test Results		
	Test Depth	420mm
	CBR %	19
	Penetration	2.5mm
	Water Content %	60.4

Basecourse sample not recovered.
Subbase sample not recovered.
Subgrade sample recovered at : 420 - 590mm.
Depth at which scala penetrometer started : 420mm.

Subgrade Density

Push Tube result at :	420mm
Wet density (t/m^3) :	1.05
Dry density (t/m^3) :	0.66
W / C % :	60.4

Test Methods

Determination of Penetration Resistance of a Soil, NZS 4402 : 1988, Test 6.5.2
Insitu Density, sampling tube method, NZS 4402 : 1986, Test 5.1.3
California Bearing Ratio (insitu), NZS 4402: 1988, Test 6.1.3
Inferred CBR values taken from Austroads pavement design manual 1992

Notes

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Date tested : 26/04/01
Date reported : 27/04/01

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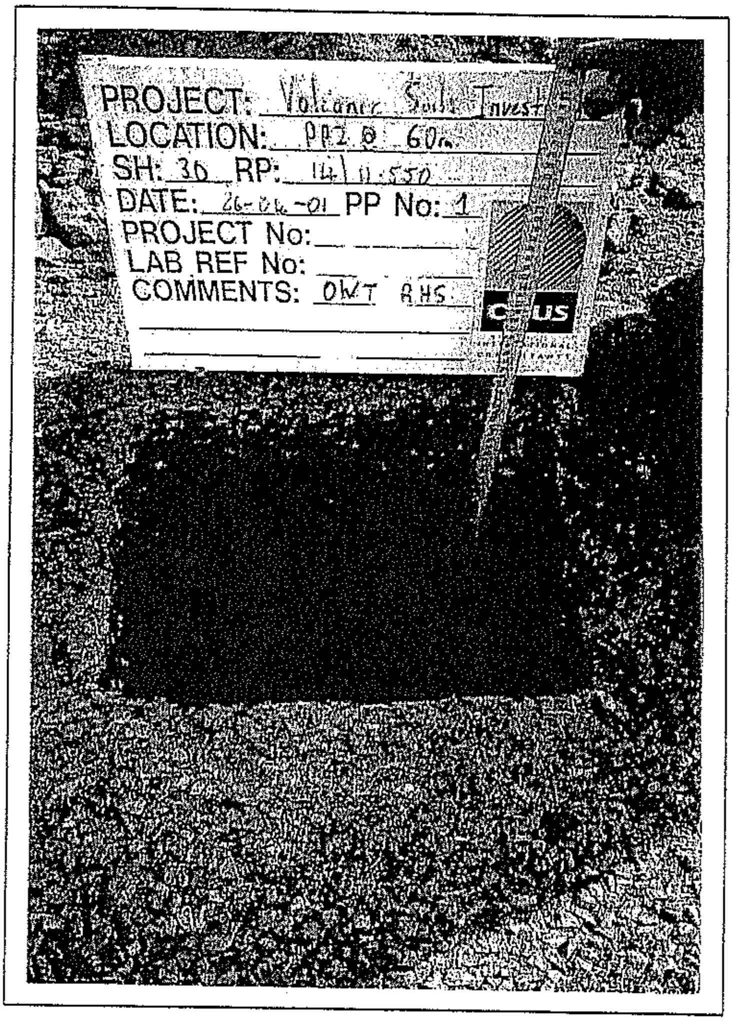
Opus International Consultants Limited
Hamilton Laboratory
Quality Management Systems Certified to ISO 9001

Fox Street
Private Bag 3057
Hamilton, New Zealand

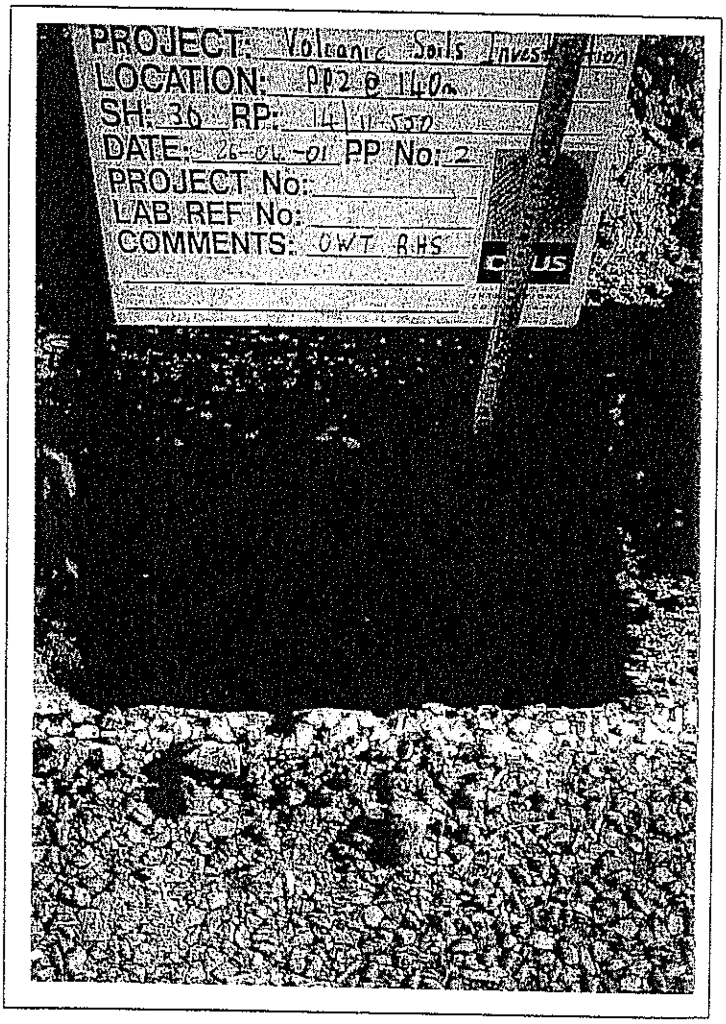
Telephone +64 7 856 2870
Facsimile +64 7 856 2873
Website www.opus.co.nz

Volcanic Soil Project Site 5: Bennydale

Project No: 5-22480.00
Lab Ref No: 01/310/001/5



SH 30
Pavement Pit 1
@ 60m RHS, OWT



SH 30
Pavement Pit 2
@ 140m RHS, OWT

PAVEMENT INVESTIGATION LOG
TEST REPORT

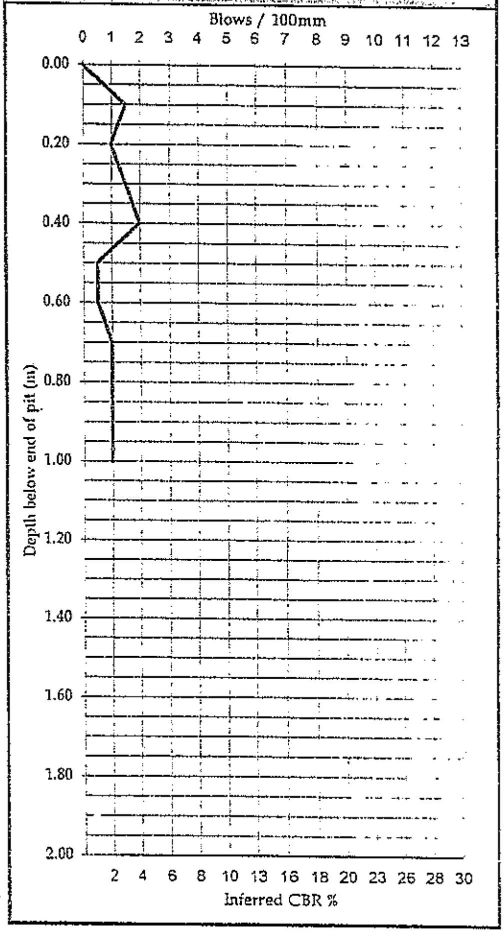
Project : Volcanic Soils Project (Site 6, Stratford - Inglewood)
Location : Tariki Rd @ 80m RHS OWT
Client : Opus International Consultants Ltd
Contractor : N/A
Sampled by : V Rowe. (Opus Laboratory, New Plymouth)
Date Sampled : 04/04/01
Sampling method : NZS 4407 : 1991 Test 2.4.8.2
Sample condition : Natural
Pavement pit number : 1

OPUS INTERNATIONAL CONSULTANTS

Project No. :	5-22480.00
Lab Ref No. :	01/310/001/6
Client Ref No. :	Strat - Ingle PP1

Depth (mm)	Pavement Description
0	CHIPSEAL Grade 3.
25	BASECOURSE AP 40. Well graded, very firm, stabilised.
100	SUBBASE AP 40. Finely graded, contaminated, firm.
190	SUBBASE II AP 65. Well graded, firm.
430	SUBGRADE (Natural) Light brown Silty CLAY, soft, moist, moderately plastic.
530	END OF PIT

Scala Penetrometer



Insitu CBR Test Results		
	Test Depth	430mm
	CBR %	5
	Penetration	5.0
	Water Content %	65.9

Basecourse sample not recovered.
Subbase sample not recovered.
Subgrade sample recovered at : 430 - 530mm.
Depth at scala penetrometer started : 430mm.

Subgrade Density

Push tube results at :	430mm
Wet density (t/m^3) :	1.51
Dry density (t/m^3) :	0.91
W / C % :	65.9

Test Methods

Determination of Penetration Resistance of a Soil, NZS 4402 : 1988, Test 6.5.2
Insitu Density, sampling tube method, NZS 4402 : 1986, Test 5.1.3
California Bearing Ratio (insitu), NZS 4402: 1988, Test 6.1.3
Inferred CBR values taken from Austroads pavement design manual 1992

Notes:

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Date tested : 04/04/01
Date reported : 18/04/01

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Hamilton, New Zealand

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PAVEMENT INVESTIGATION LOG
TEST REPORT

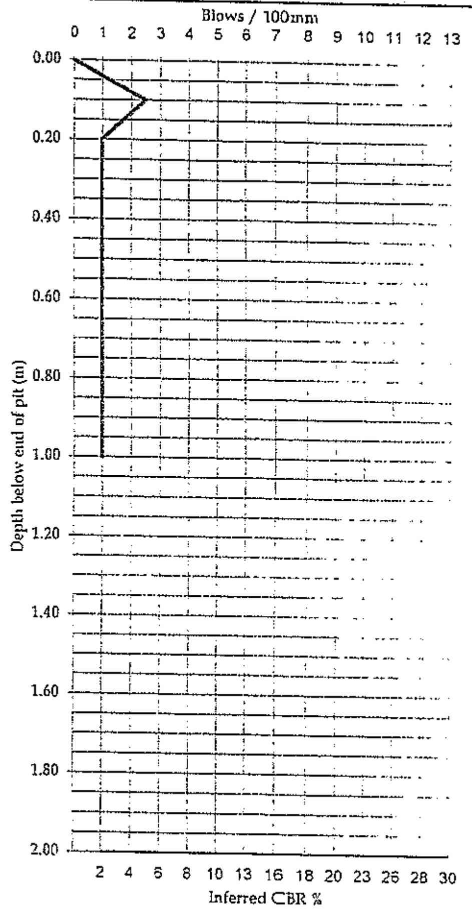
Project :	Volcanic Soils Project (Site 6, Stratford - Inglewood)
Location :	Tariki Rd @ 160m RHS OWT
Client :	Opus International Consultants Ltd
Contractor :	N/A
Sampled by :	V Rowe. (Opus Laboratory, New Plymouth)
Date Sampled :	04/04/01
Sampling method :	NZS 4407 : 1991 Test 2.4.8.2
Sample condition :	Natural
Pavement pit number :	2

OPUS INTERNATIONAL CONSULTANTS

Project No.:	5-22480.00
Lab Ref No.:	01/310/001/6
Client Ref No.:	Strat - Ingle PP2

Depth (mm)	Pavement Description
0	CHIPSEAL Grade 3.
25	BASECOURSE AP 40. Well graded, very firm, stabilised.
110	OLD CHIPSEAL
130	BASECOURSE II AP 40. Pit metal, finely graded, loose.
330	SUBGRADE (Natural) Dark brown Silty CLAY, firm to soft, moist, moderately plastic.
430	END OF PIT

Scala Penetrometer



Insitu CBR Test Results		
	Test Depth	330mm
	CBR %	11
	Penetration	5.0
	Water Content %	58.1

Basecourse sample not recovered.
Subbase sample not recovered.
Subgrade sample recovered at : 330 - 430mm.
Depth at scala penetrometer started : 330mm.

Subgrade Density

Push tube results at :	330mm
Wet density (t/m^3) :	1.59
Dry density (t/m^3) :	1.00
W / C % :	58.1

Test Methods

Determination of Penetration Resistance of a Soil, NZS 4402 : 1988, Test 6.5.2
Insitu Density, sampling tube method, NZS 4402 : 1986, Test 5.1.3
California Bearing Ratio (insitu), NZS 4402: 1988, Test 6.1.3
Inferred CBR values taken from Austroads pavement design manual 1992

Notes

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Date reported : 18/04/01

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Designation : Laboratory Manager
Date : 01/05/01

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Fox Street
Private Bag 3057
Hamilton, New Zealand

Telephone +64 7 856 2870
Facsimile +64 7 856 2873
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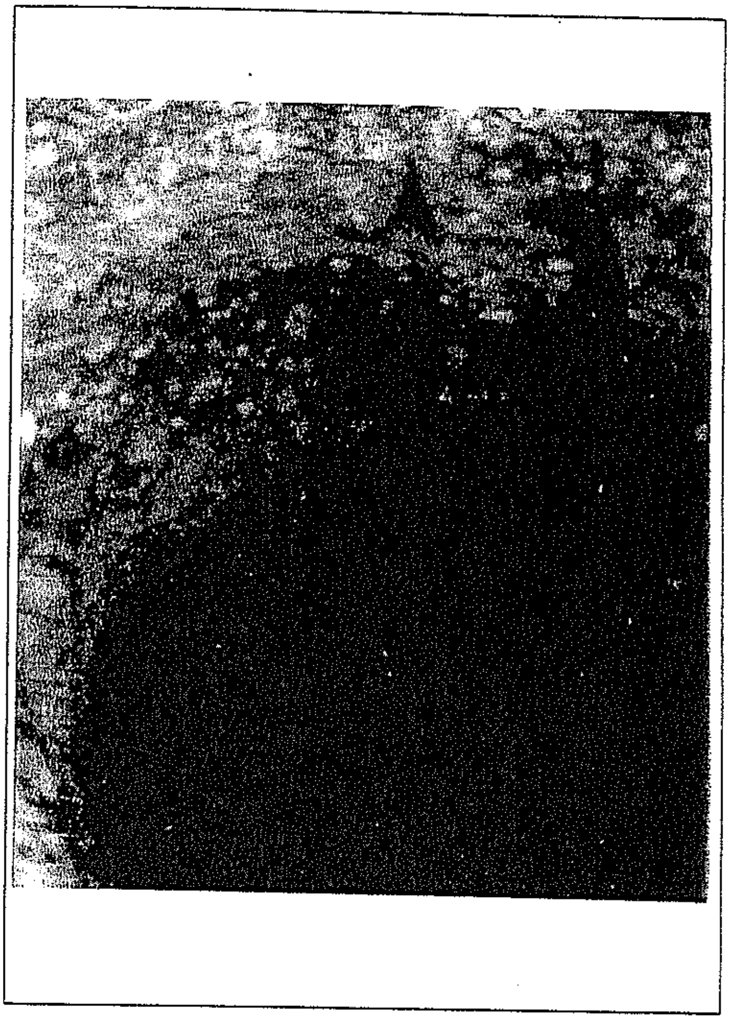
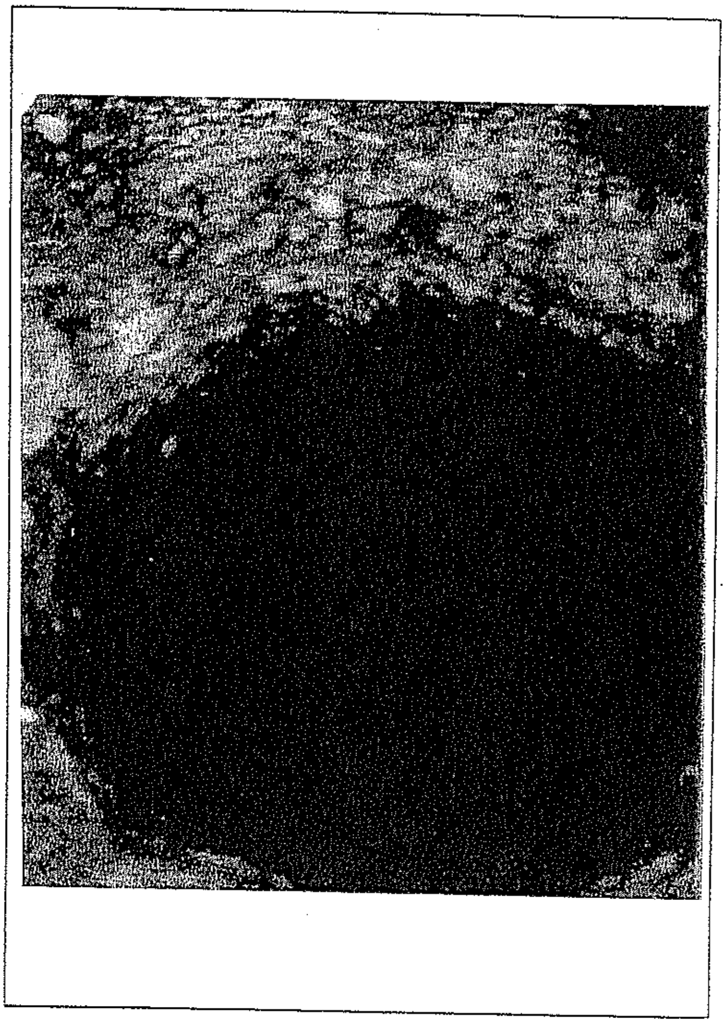
Volcanic Soil Project Site 6: Stratford to Inglewood

Project No: 5-22480.00
Lab Ref No: 01/310/001/6



Tariki Road
Pavement Pit 1
@ 80m RHS, OWT



Tariki Road
Pavement Pit 2
@ 160m RHS, OWT

PAVEMENT INVESTIGATION LOG
TEST REPORT

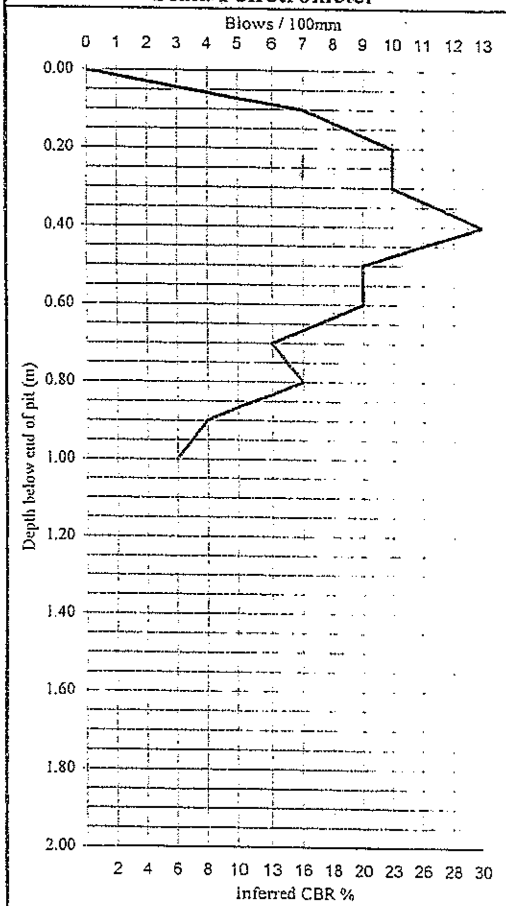
Project :	Volcanic Soils Project (Site 7, Waitara - Urenui)
Location :	Upper Epiha Rd @ 80m LHS OWT
Client :	Opus International Consultants Ltd
Contractor :	N/A
Sampled by :	V Rowe. (Opus Laboratory, New Plymouth)
Date Sampled :	04/04/01
Sampling method :	NZS 4407 : 1991 Test 2.4.8.2
Sample condition :	Natural
Pavement pit number :	1

OPUS INTERNATIONAL CONSULTANTS

Project No :	5-22480.00
Lab Ref No :	01/310/001/7
Client Ref No :	Waitara - Urenui PP1

Depth (mm)	Pavement Description
0	CHIPSEAL Grade 3.
30	BASECOURSE AP 65. Finely graded, contaminated, loose.
200	SUBGRADE (Natural) Dark brown Sandy CLAY, some Silt, stiff, dry, slightly plastic.
300	END OF PIT

Scala Penetrometer



Insitu CBR Test Results		
	Test Depth	200mm
	CBR %	30
	Penetration	5.0mm
	Water Content %	33.6

Basecourse sample not recovered.
Subbase sample not recovered.
Subgrade sample recovered at : 200 - 300mm.
Depth at scala penetrometer started : 200mm.

Subgrade Density

Push tube results at :	200mm
Wet density (t/m^3) :	1.90
Dry density (t/m^3) :	1.42
W / C % :	33.6

Test Methods

Determination of Penetration Resistance of a Soil, NZS 4402 : 1988, Test 6.5.2
Insitu Density, sampling tube method, NZS 4402 : 1986, Test 5.1.3
California Bearing Ratio (insitu), NZS 4402: 1988, Test 6.1.3
Inferred CBR values taken from Austroads pavement design manual 1992

Notes

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Date tested : 04/04/01
Date reported : 18/04/01

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Designation : Laboratory Manager
Date : 01/05/01

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Facsimile +64 7 856 2873
Website www.opus.co.nz

PAVEMENT INVESTIGATION LOG
TEST REPORT

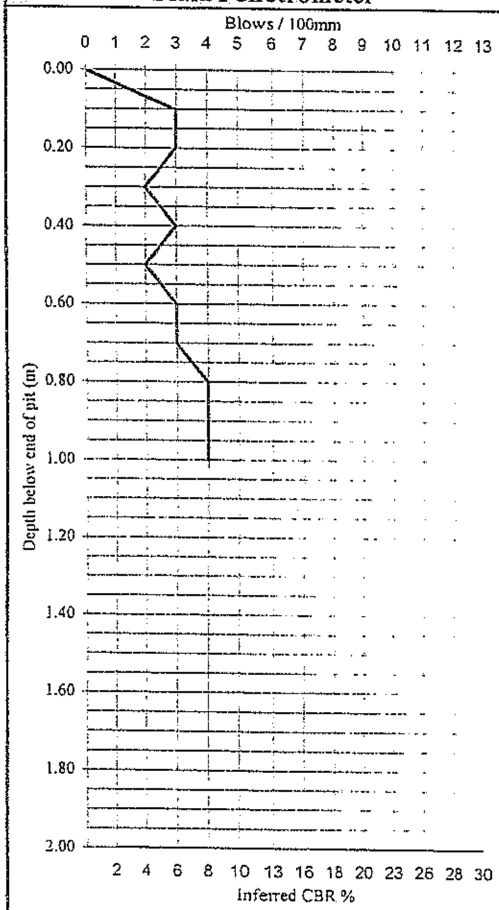
Project :	Volcanic Soils Project (Site 7, Waitara - Urenui)
Location :	Upper Epiha Rd @ 160m LHS OWT
Client :	Opus International Consultants Ltd
Contractor :	N/A
Sampled by :	V Rowe. (Opus Laboratory, New Plymouth)
Date Sampled :	04/04/01
Sampling method :	NZS 4407 : 1991 Test 2.4.8.2
Sample condition :	Natural
Pavement pit number :	2

OPUS INTERNATIONAL CONSULTANTS

Project No :	5-22480.00
Lab Ref No :	01/310/001/7
Client Ref No :	Waitara - Urenui PP2

Depth (mm)	Pavement Description
0	CHIPSEAL Grade 3.
45	BASECOURSE AP 65. Finely graded, contaminated, loose.
210	SUBGRADE (Natural) Light brown silty CLAY, firm, moist, moderately plastic.
310	END OF PIT

Scala Penetrometer



Insitu CBR Test Results		
	Test Depth	210mm
	CBR %	18
	Penetration	5.0mm
	Water Content %	79.4

Basecourse sample not recovered.
Subbase sample not recovered.
Subgrade sample recovered at : 210 - 300mm.
Depth at scala penetrometer started : 210mm.

Subgrade Density

Push tube results at :	210mm
Wet density (t/m^3) :	1.52
Dry density (t/m^3) :	0.85
W / C % :	79.4

Test Methods

Determination of Penetration Resistance of a Soil, NZS 4402 : 1988, Test 6.5.2
Insitu Density, sampling tube method, NZS 4402 : 1986, Test 5.1.3
California Bearing Ratio (insitu), NZS 4402: 1988, Test 6.1.3
Inferred CBR values taken from Austroads pavement design manual 1992

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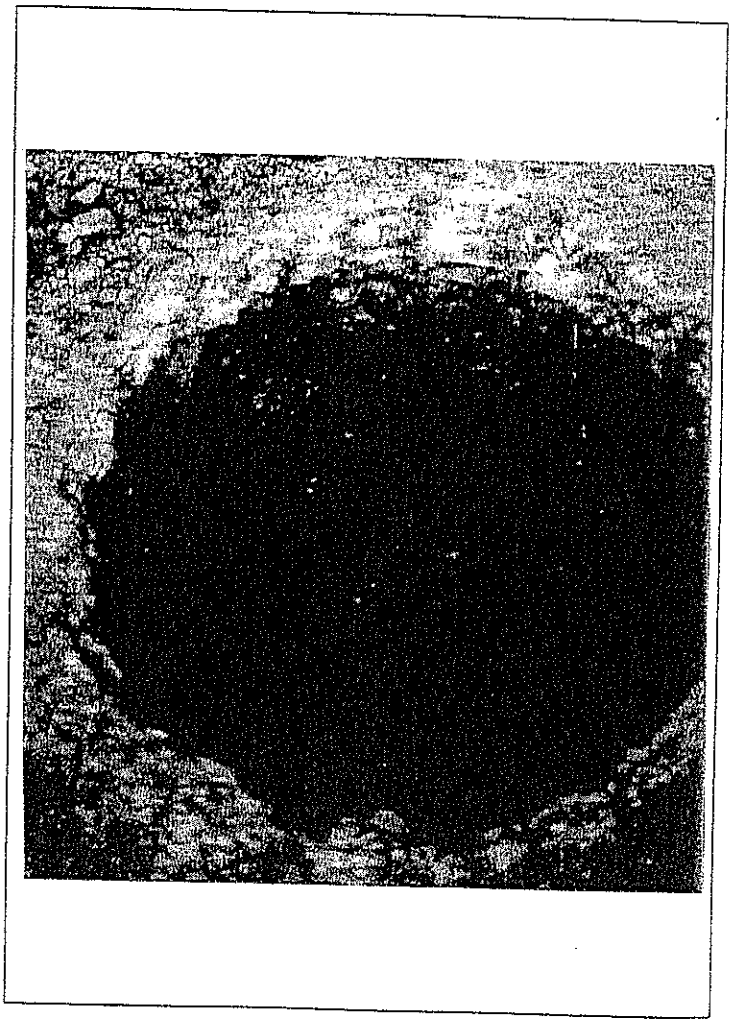
Volcanic Soil Project Site 7: Waitara to Urenui

Project No: 5-22480.00
Lab Ref No: 01/310/001/7

Upper Epihia Road
Pavement Pit 1
@ 80m LHS, OWT



Upper Epihia Road
Pavement Pit 2
@ 160m LHS, OWT

PAVEMENT INVESTIGATION LOG
TEST REPORT

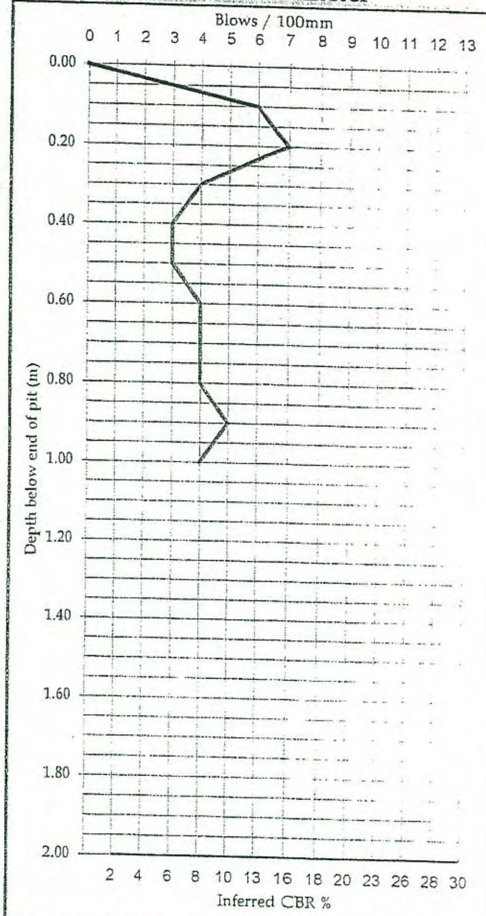
Project :	Volcanic Soils Project (Site 8, Whangamomona)
Location :	SH43 @ 20 RHS OWT
Client :	Opus International Consultants Ltd
Contractor :	N/A
Sampled by :	V Rowe. (Opus Laboratory, New Plymouth)
Date Sampled :	10/04/01
Sampling method :	NZS 4407 : 1991 Test 2.4.8.2
Sample condition :	Natural
Pavement pit number :	1

OPUS
INTERNATIONAL CONSULTANTS

Project No :	5-22480.00
Lab Ref No :	01/310/001/8
Client Ref No :	Whangamomona PP1

Depth (mm)	Pavement Description
0	CHIPSEAL Grade 3.
20	BASECOURSE AP 40. Well graded, firm.
180	SUBBASE AP65. Finely graded, firm.
340	SUBGRADE (Natural) Brown/grey Clayey SILT, firm, moist, moderately plastic.
440	END OF PIT

Scala Penetrometer



Insitu CBR Test Results		
	Test Depth	340mm
	CBR %	12
	Penetration	5.0mm
	Water Content %	24.8

Basecourse sample not recovered.
Subbase sample not recovered.
Subgrade sample recovered at : 340 - 440mm.
Depth at scala penetrometer started : 340mm.

Subgrade Density

Push tube results at :	340mm
Wet density (t/m^3) :	2.11
Dry density (t/m^3) :	1.69
W / C % :	24.8

Test Methods

Determination of Penetration Resistance of a Soil, NZS 4402 : 1988, Test 6.5.2
Insitu Density, sampling tube method, NZS 4402 : 1986, Test 5.1.3
California Bearing Ratio (insitu), NZS 4402: 1988, Test 6.1.3
Inferred CBR values taken from Austroads pavement design manual 1992

Notes

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Date tested : 10/04/01
Date reported : 18/04/01

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IANZ Approved Signatory

Designation : Laboratory Manager
Date : 01/05/01

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PAVEMENT INVESTIGATION LOG
TEST REPORT

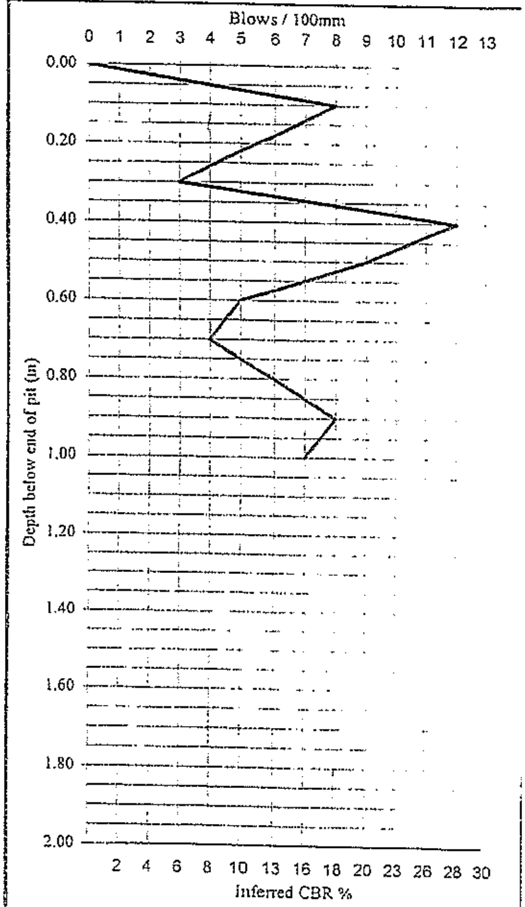
OPUS INTERNATIONAL CONSULTANTS

Project :	Volcanic Soils Project (Site 8, Whangamomona)
Location :	SH43 @ 100 RHS OWT
Client :	Opus International Consultants Ltd
Contractor :	N/A
Sampled by :	V Rowe. (Opus Laboratory, New Plymouth)
Date Sampled :	10/04/01
Sampling method :	NZS 4407 : 1991 Test 2.4.8.2
Sample condition :	Natural
Pavement pit number :	2

Project No :	5-22480.00
Lab Ref No :	01/310/001/8
Client Ref No :	Whangamomona PP2

Depth (mm)	Pavement Description
0	CHIPSEAL Grade 3.
20	BASECOURSE AP 40. Well graded, firm.
100	SUBBASE AP 65. Finely graded, firm.
310	SUBGRADE (Natural) Brown/grey Clayey SILT, firm, moist, moderately plastic.
410	END OF PIT

Scala Penetrometer



Insitu CBR Test Results		
	Test Depth	310mm
	CBR %	25
	Penetration	5.0mm
	Water Content %	23.4

Basecourse sample not recovered.
Subbase sample not recovered.
Subgrade sample recovered at : 310 - 410mm.
Depth at scala penetrometer started : 310mm.

Subgrade Density

Push tube results at :	310mm
Wet density (t/m^3) :	2.02
Dry density (t/m^3) :	1.63
W / C % :	23.4

Test Methods

Determination of Penetration Resistance of a Soil, NZS 4402 : 1988, Test 6.5.2
Insitu Density, sampling tube method, NZS 4402 : 1986, Test 5.1.3
California Bearing Ratio (insitu), NZS 4402: 1988, Test 6.1.3
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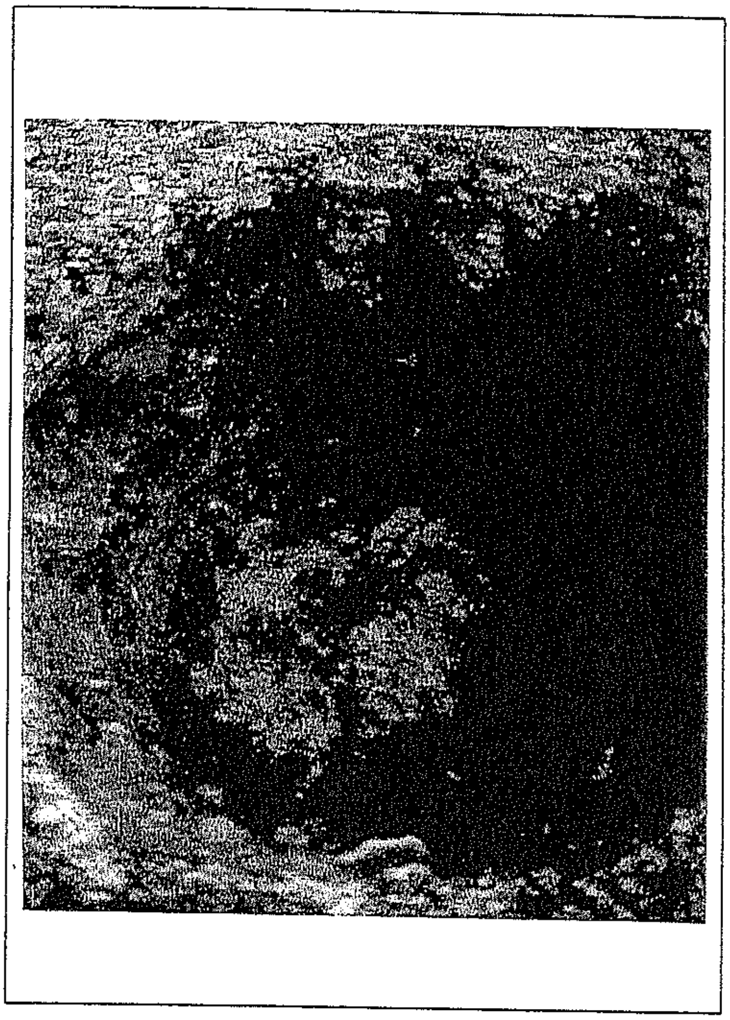
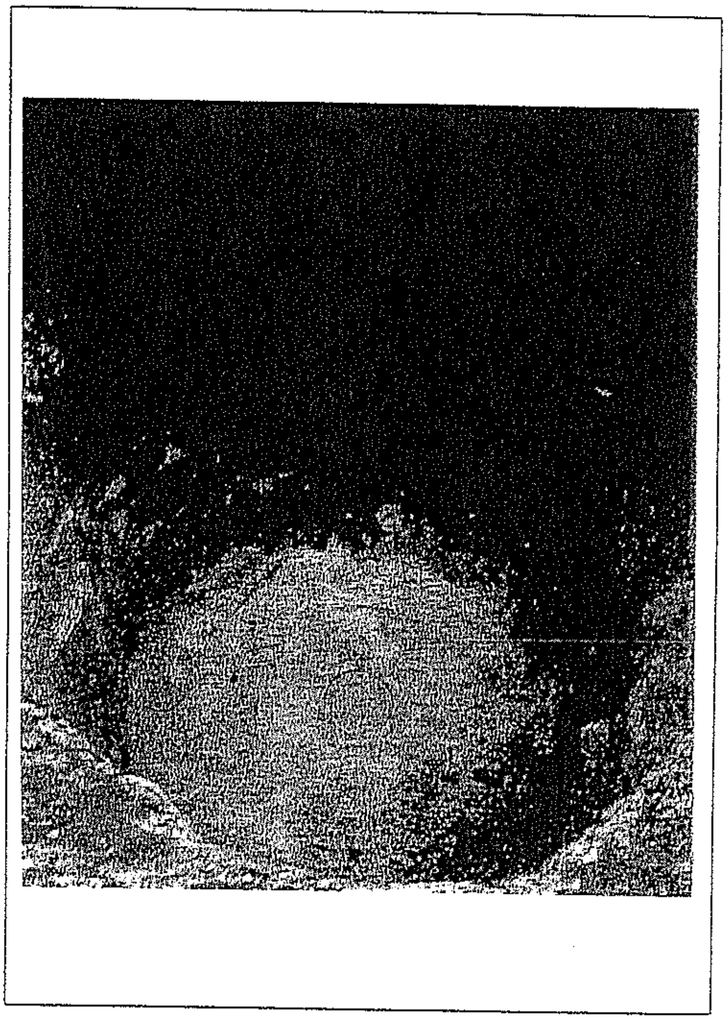
Volcanic Soil Project Site 8: Whangamomona

Project No: 5-22480.00
Lab Ref No: 01/310/001/8



SH 43
Pavement Pit 1
@ 20m RHS, OWT

SH 43
Pavement Pit 2
@ 100m RHS, OWT



PAVEMENT INVESTIGATION LOG
TEST REPORT

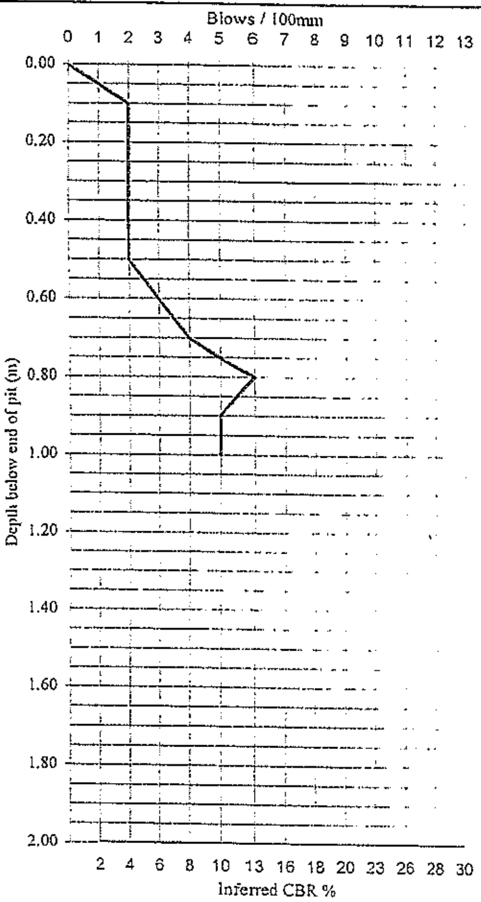
Project :	Volcanic Soils Project (Site 9, Pio Pio)
Location :	Mairoa Rd @ 100m RHS OWT
Client :	Opus International Consultants Ltd
Contractor :	N/A
Sampled by :	A Ingoe. (Opus Laboratory, Hamilton)
Date Sampled :	26/04/01
Sampling method :	NZS 4407 : 1991 Test 2.4.8.2
Sample condition :	Natural
Pavement pit number :	1

OPUS INTERNATIONAL CONSULTANTS

Project No :	5-22480.00
Lab Ref No :	01/310/001/9
Client Ref No :	Pio Pio PP1

Depth (mm)	Pavement Description
0	CHIPSEAL Grade 4. Worn, some flushing.
20	BASECOURSE AP 40. Slightly weathered angular GREYWACKE. Dense, moist, well graded.
140	SUBBASE GAP65. Moderately weathered angular GREYWACKE excess Clayey SILT, some old chipseal intermixed (80 - 260mm), rare 80mm subangular cobbles, dense, moist, non plastic.
360	SUBGRADE Dark orange brown homogeneous Clayey SILT, firm, moist, slightly plastic.
510	END OF PIT

Scala Penetrometer



Insitu CBR Test Results		
	Test Depth	400mm
	CBR %	9
	Penetration	2.5mm
	Water Content %	112.5

Basecourse sample not recovered.
Subbase sample not recovered.
Subgrade sample recovered at : 400 - 510mm.
Depth at which scala penetrometer started : 400mm.

Subgrade Density

Push Tube result at :	400mm
Wet density (t/m^3) :	1.08
Dry density (t/m^3) :	0.51
W / C % :	112.5

Test Methods

Determination of Penetration Resistance of a Soil, NZS 4402 : 1988, Test 6.5.2
Insitu Density, sampling tube method, NZS 4402 : 1986, Test 5.1.3
California Bearing Ratio (insitu), NZS 4402: 1988, Test 6.1.3
Inferred CBR values taken from Austroads pavement design manual 1992

Notes

IANZ Accreditation does not apply to inferred CBR values or pavement descriptions

Date tested : 26/04/01
Date reported : 27/04/01

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IANZ Approved Signatory
Designation : *Laboratory Manager*
Date : 27/04/01

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Opus International Consultants Limited
Hamilton Laboratory
Quality Management Systems Certified to ISO 9001

Fox Street
Private Bag 3057
Hamilton, New Zealand

Telephone +64 7 856 2870
Facsimile +64 7 856 2873
Website www.opus.co.nz

PAVEMENT INVESTIGATION LOG
TEST REPORT

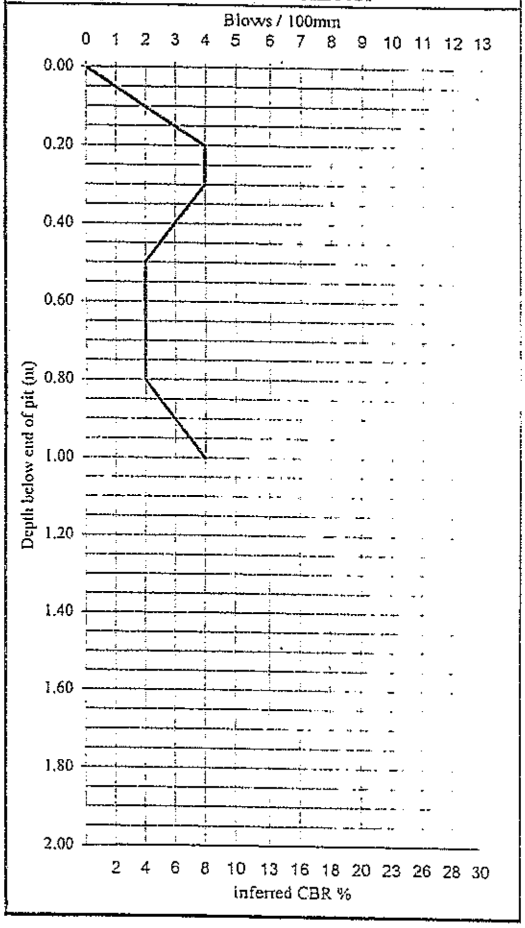
Project :	Volcanic Soils Project (Site 9, Pio Pio)
Location :	Mairoa Rd @ 180m RHS OWT
Client :	Opus International Consultants Ltd
Contractor :	N/A
Sampled by :	A Ingoe. (Opus Laboratory, Hamilton)
Date Sampled :	26/04/01
Sampling method :	NZS 4407 : 1991 Test 2.4.8.2
Sample condition :	Natural
Pavement pit number :	2

OPUS INTERNATIONAL CONSULTANTS

Project No :	5-22480.00
Lab Ref No :	01/310/001/9
Client Ref No :	Pio Pio PP2

Depth (mm)	Pavement Description
0	CHIPSEAL Grade 4. Worn, flushed.
20	BASECOURSE GAP65. Moderately weathered angular GREYWACKE, excess Clayey SILT, some old chipseal, dense, moist, non plastic.
300	SUBGRADE Yellow brown homogeneous SILT, firm, moist, non plastic.
430	END OF PIT

Scala Penetrometer



Insitu CBR Test Results		
	Test Depth	270mm
	CBR %	6
	Penetration	5.0mm
	Water Content %	70.9

Basecourse sample not recovered.
Subbase sample not recovered.
Subgrade sample recovered at : 270 - 430mm.
Depth at which scala penetrometer started : 270mm.

Subgrade Density

Push Tube result at :	270mm
Wet density (t/m^3) :	1.35
Dry density (t/m^3) :	0.79
W / C % :	70.9

Test Methods

Determination of Penetration Resistance of a Soil, NZS 4402 : 1988, Test 6.5.2
Insitu Density, sampling tube method, NZS 4402 : 1986, Test 5.1.3
California Bearing Ratio (insitu), NZS 4402: 1988, Test 6.1.3
Inferred CBR values taken from Austroads pavement design manual 1992

Notes

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Date tested : 26/04/01
Date reported : 27/04/01

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Private Bag 3057
Hamilton, New Zealand

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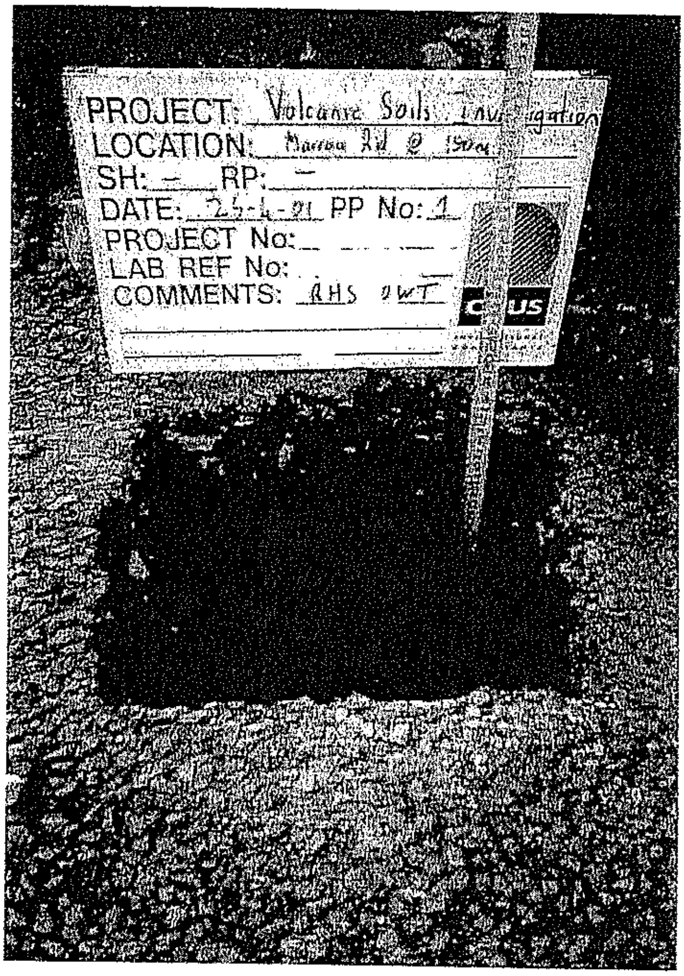
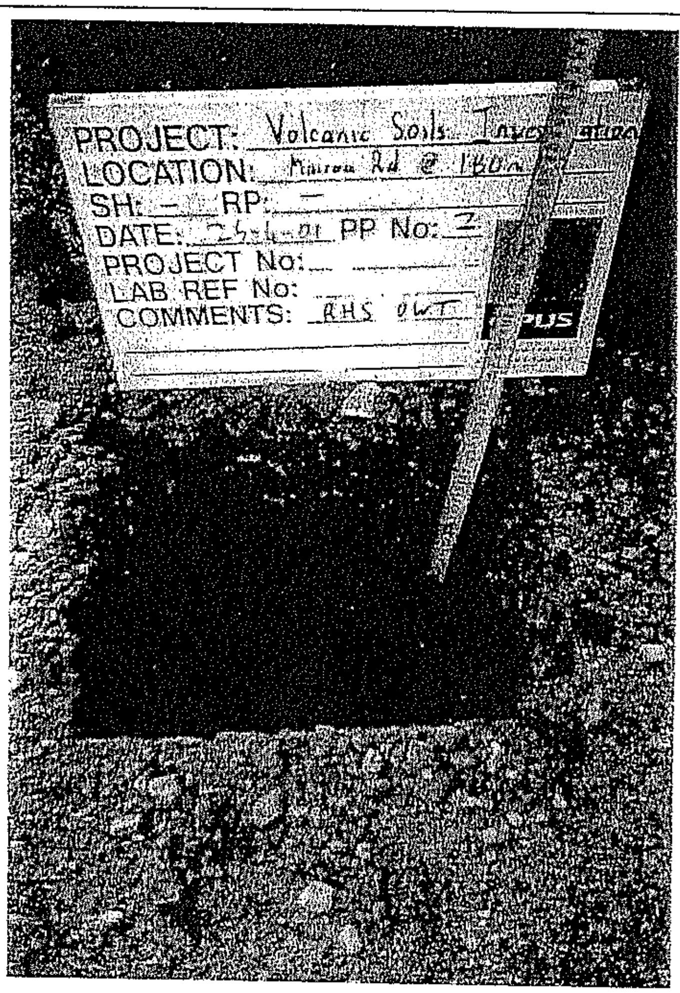


Mairoa Road
Pavement Pit 1
@ 100m RHS, OWT



Mairoa Road
Pavement Pit 2
@ 180m RHS, OWT

PAVEMENT INVESTIGATION LOG
TEST REPORT

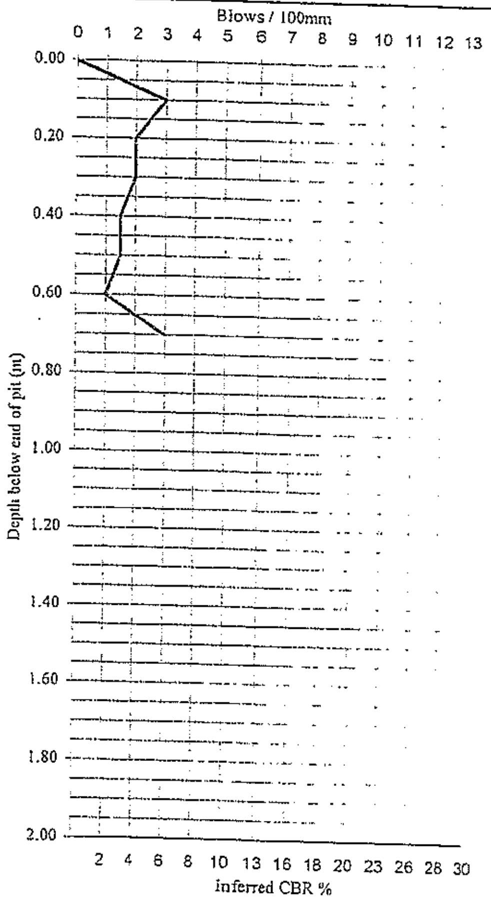
Project :	Volcanic Soils Project (Site 10, Hamilton - Cambridge)
Location :	Day Road @ 20m LHS OWT
Client :	Opus International Consultants Ltd
Contractor :	N/A
Sampled by :	R.S.Warner. (Opus Laboratory, Hamilton)
Date Sampled :	05/04/01
Sampling method :	NZS 4407 : 1991 Test 2.4.8.2
Sample condition :	Natural
Pavement pit number :	1

OPUS INTERNATIONAL CONSULTANTS

Project No :	5-22480.00
Lab Ref No :	01/310/001/10
Client Ref No. :	Ham-Cam PP1

Depth (mm)	Pavement Description
0	CHIPSEAL Grade 3/ 6. Worn, sound.
20	BASECOURSE GAP 40. Fresh, angular GREYWACKE, well graded Silty SAND, moderately dense, slightly moist, non plastic.
250	SUBBASE GAP 65. Fresh to slightly weathered, angular GREYWACKE, slight excess SAND, some Silt, moderately dense, moist, non plastic.
480	SUBGRADE Orange Clayey SILT, soft to firm, moist, slightly plastic.
600	END OF PIT

Scala Penetrometer



Insitu CBR Test Results		
	Test Depth	500mm
	CBR %	8
	Penetration	5.0mm
	Water Content %	68.1

Basecourse sample not recovered.
Subbase sample not recovered.
Subgrade sample recovered at : 500 - 600mm.
Depth at which scala penetrometer started : 500mm.

Subgrade Density

Push Tube result at :	500mm
Wet density (t/m^3) :	1.49
Dry density (t/m^3) :	0.89
W / C % :	68.1

Test Methods

Determination of Penetration Resistance of a Soil, NZS 4402 : 1988, Test 6.5.2
Insitu Density, sampling tube method, NZS 4402 : 1986, Test 5.1.3
California Bearing Ratio (insitu), NZS 4402: 1988, Test 6.1.3
Inferred CBR values taken from Austroads pavement design manual 1992

Notes

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Date tested : 05/04/01
Date reported : 06/04/01

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Designation : Laboratory Manager
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Private Bag 3057
Hamilton, New Zealand

Telephone +64 7 856 2870
Facsimile +64 7 856 2873
Website www.opus.co.nz

PAVEMENT INVESTIGATION LOG
TEST REPORT

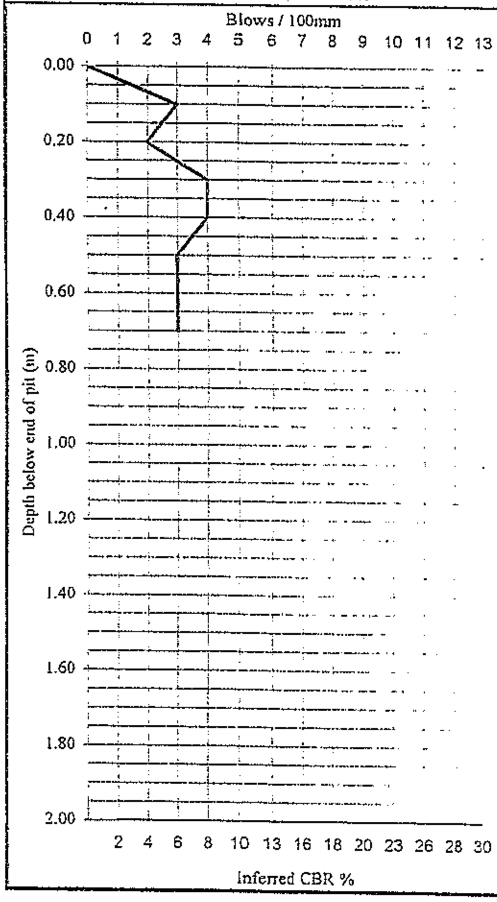
Project :	Volcanic Soils Project (Site 10, Hamilton - Cambridge)
Location :	Day Road @ 80m LHS OWT
Client :	Opus International Consultants Ltd
Contractor :	N/A
Sampled by :	R.S.Warner. (Opus Laboratory, Hamilton)
Date Sampled :	05/04/01
Sampling method :	NZS 4407 : 1991 Test 2.4.8.2
Sample condition :	Natural
Pavement pit number :	2

OPUS INTERNATIONAL CONSULTANTS

Project No :	5-22480.00
Lab Ref No :	01/310/001/10
Client Ref No :	Ham - Cam PP2

Depth (mm)	Pavement Description
0	CHIPSEAL Grade 3/ 6. Worn, sound.
20	BASECOURSE GAP 40. Fresh, angular GREYWACKE, well graded Silty SAND, moderately dense, slightly moist, non plastic.
240	SUBBASE GAP 65. Fresh to slightly weathered, angular GREYWACKE, slight excess SAND, some Silt, moderately dense, moist, non plastic.
400	SUBGRADE Orange clayey SILT, soft to firm, moist, slightly plastic.
560	END OF PIT

Scala Penetrometer



Insitu CBR Test Results		
	Test Depth	420mm
	CBR %	9
	Penetration	2.5mm
	Water Content %	58.8

Basecourse sample not recovered.
Subbase sample not recovered.
Subgrade sample recovered at : 420 - 560mm..
Depth at which scala penetrometer started : 420mm.

Subgrade Density

Push Tube result at :	420mm
Wet density (t/m^3) :	1.57
Dry density (t/m^3) :	0.99
W / C % :	58.8

Test Methods

Determination of Penetration Resistance of a Soil, NZS 4402 : 1988, Test 6.5.2
Insitu Density, sampling tube method, NZS 4402 : 1986, Test 5.1.3
California Bearing Ratio (insitu), NZS 4402: 1988, Test 6.1.3
Inferred CBR values taken from Austroads pavement design manual 1992

Notes

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Date tested : 05/04/01
Date reported : 06/04/01

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Fox Street
Private Bag 3057
Hamilton, New Zealand

Telephone +64 7 856 2870
Facsimile +64 7 856 2873
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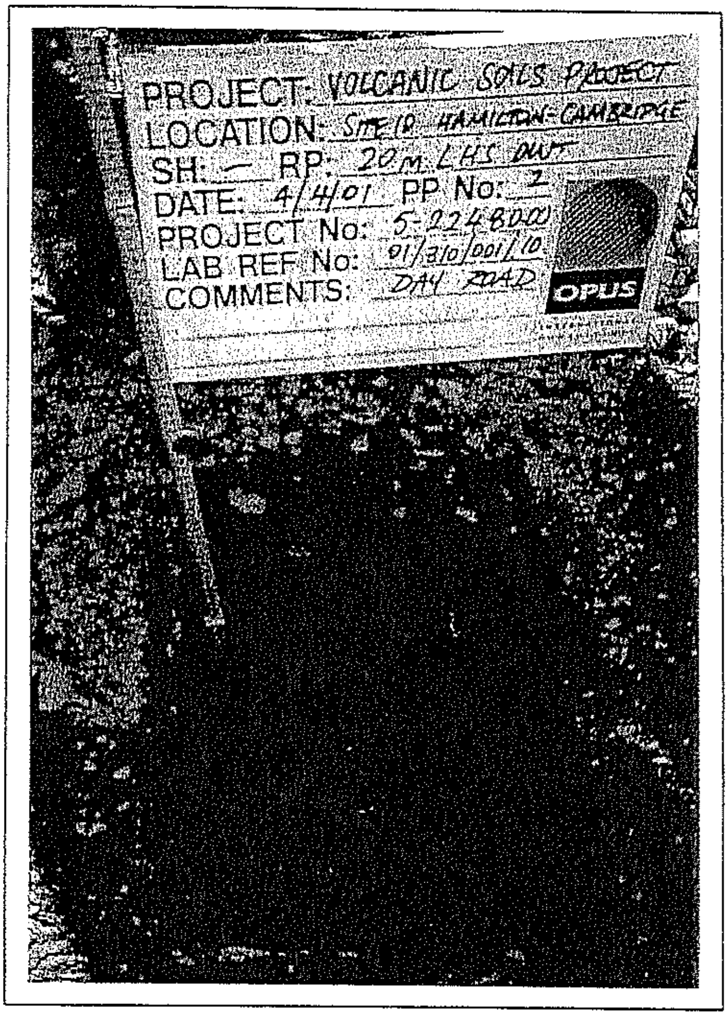
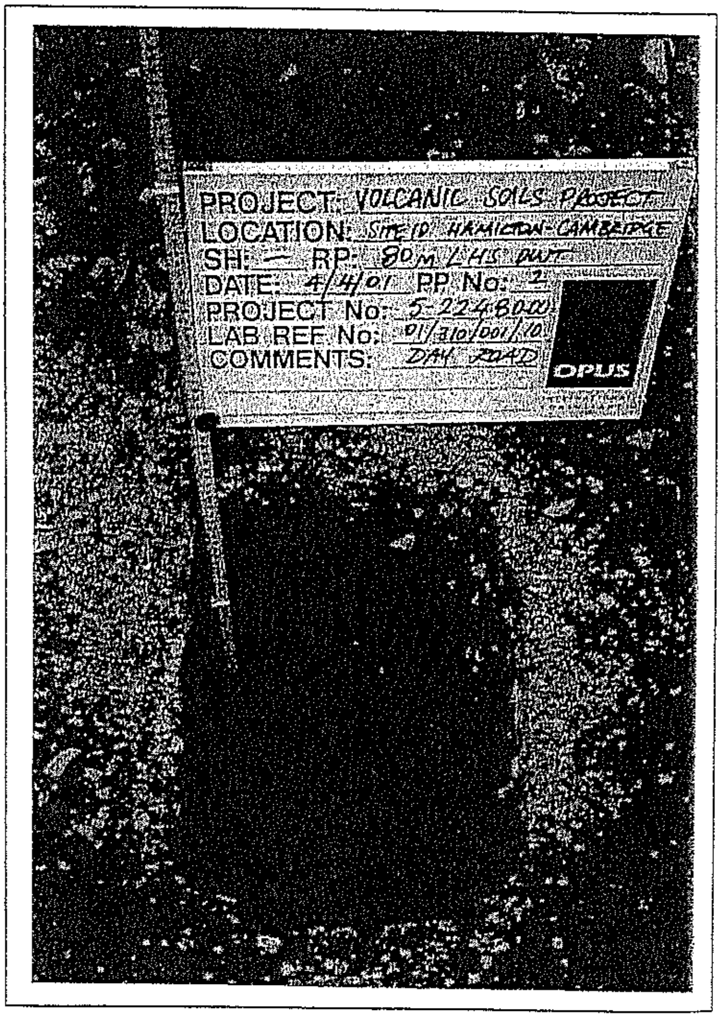
Volcanic Soil Project Site 10: Hamilton-Cambridge

Project No: 5-22480.00
Lab Ref No: 01/310/001/10



Day Road
Pavement Pit 1
@ 20m RHS, OWT



Day Road
Pavement Pit 2
@ 80m RHS, OWT

PAVEMENT INVESTIGATION LOG
TEST REPORT

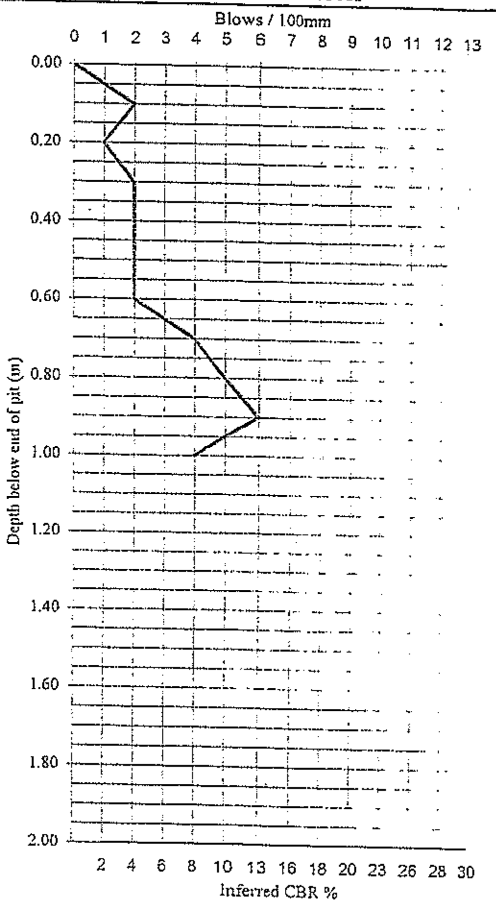
Project :	Volcanic Soils Project (Site 11, Te Poi)
Location :	Stopfords Rd @ 60m RHS OWT
Client :	Opus International Consultants Ltd
Contractor :	N/A
Sampled by :	A Ingoe. (Opus Laboratory, Hamilton)
Date Sampled :	24/04/01
Sampling method :	NZS 4407 : 1991 Test 2.4.8.2
Sample condition :	Natural
Pavement pit number :	1

OPUS INTERNATIONAL CONSULTANTS

Project No :	5-22480.00
Lab Ref No :	01/310/001/11
Client Ref No :	Te Poi PP1

Depth (mm)	Pavement Description
0	CHIPSEAL Grade 2. Worn, slightly flushed.
25	BASECOURSE I GAP40. Moderately weathered angular GREYWACKE excess Silty SAND (cement Stabilised), dense, moist, non plastic.
80	OLD CHIPSEAL LAYER
100	BASECOURSE II Ungraded up to 80mm. Dark reddish brown subrounded Quarry strippings/ Silty SAND conglomerate, dense, moist, non plastic.
230	SUBGRADE Yellow brown homogeneous SILT, rare Clay, firm, moist, very slightly plastic.
450	END OF PIT

Scala Penetrometer



Insitu CBR Test Results		
	Test Depth	280mm
	CBR %	9
	Penetration	2.5mm
	Water Content %	61.0

Basecourse sample not recovered.
Subbase sample not recovered.
Subgrade sample recovered at : 280 - 450mm.
Depth at which scala penetrometer started : 280mm.

Subgrade Density

Push Tube result at :	280mm
Wet density (t/m^3) :	1.34
Dry density (t/m^3) :	0.83
W / C % :	61.0

Test Methods

Determination of Penetration Resistance of a Soil, NZS 4402 : 1988, Test 6.5.2
Insitu Density, sampling tube method, NZS 4402 : 1986, Test 5.1.3
California Bearing Ratio (insitu), NZS 4402: 1988, Test 6.1.3
Inferred CBR values taken from Austroads pavement design manual 1992

Notes

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Date tested : 24/04/01
Date reported : 27/04/01

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Hamilton Laboratory
Quality Management Systems Certified to ISO 9001

Fox Street
Private Bag 3057
Hamilton, New Zealand

Telephone +64 7 856 2870
Facsimile +64 7 856 2873
Website www.opus.co.nz

PAVEMENT INVESTIGATION LOG
TEST REPORT

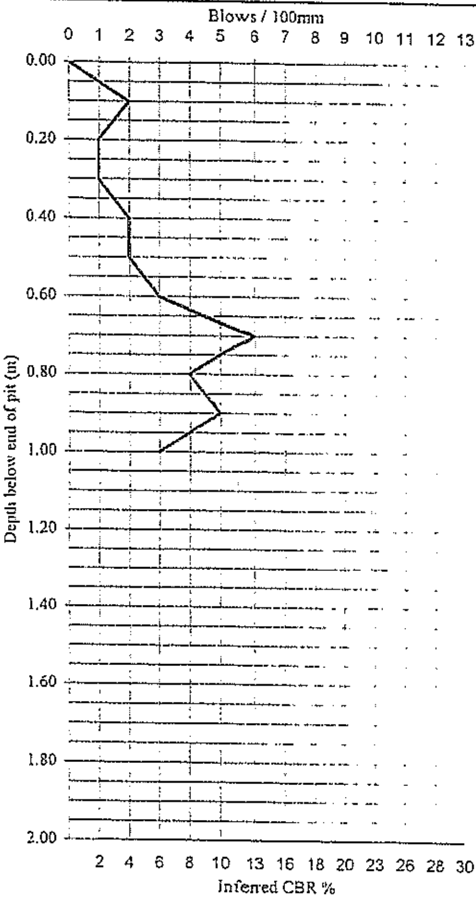
Project :	Volcanic Soils Project (Site 11, Te Poi)
Location :	Stopfords Rd @ 160m RHS OWT
Client :	Opus International Consultants Ltd
Contractor :	N/A
Sampled by :	A Ingoe. (Opus Laboratory, Hamilton)
Date Sampled :	24/04/01
Sampling method :	NZS 4407 : 1991 Test 2.4.8.2
Sample condition :	Natural
Pavement pit number :	2

OPUS INTERNATIONAL CONSULTANTS

Project No :	5-22480.00
Lab Ref No :	01/310/001/11
Client Ref No :	Te Poi PP2

Depth (mm)	Pavement Description
0	CHIPSEAL Grade 2. Worn, slightly flushed.
30	BASECOURSE I GAP40. Moderately weathered angular GREYWACKE excess Silty SAND (cement Stabilised), dense, moist, non plastic.
110	OLD CHIPSEAL LAYER
130	BASECOURSE II Ungraded up to 80mm. Dark reddish brown subrounded Quarry strippings/Silty SAND conglomerate, dense, moist, non plastic.
310	SUBGRADE Yellow brown homogeneous SILT, rare Clay, firm, moist, very slightly plastic.
550	END OF PIT

Scala Penetrometer



Insitu CBR Test Results		
	Test Depth	370mm
	CBR %	6
	Penetration	2.5mm
	Water Content %	63.5

Basecourse sample not recovered.
Subbase sample not recovered.
Subgrade sample recovered at : 370 - 550mm.
Depth at which scala penetrometer started : 370mm.

Subgrade Density

Push Tube result at :	370mm
Wet density (t/m^3) :	1.27
Dry density (t/m^3) :	0.78
W / C % :	63.5

Test Methods

Determination of Penetration Resistance of a Soil, NZS 4402 : 1988, Test 6.5.2
Insitu Density, sampling tube method, NZS 4402 : 1986, Test 5.1.3
California Bearing Ratio (insitu), NZS 4402: 1988, Test 6.1.3
Inferred CBR values taken from Austroads pavement design manual 1992

Notes

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Date tested : 24/04/01
Date reported : 27/04/01

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IANZ Approved Signatory

Designation : *Laboratory Manager*
Date : 27/04/01

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Fox Street
Private Bag 3057
Hamilton, New Zealand

Telephone +64 7 856 2870
Facsimile +64 7 856 2873
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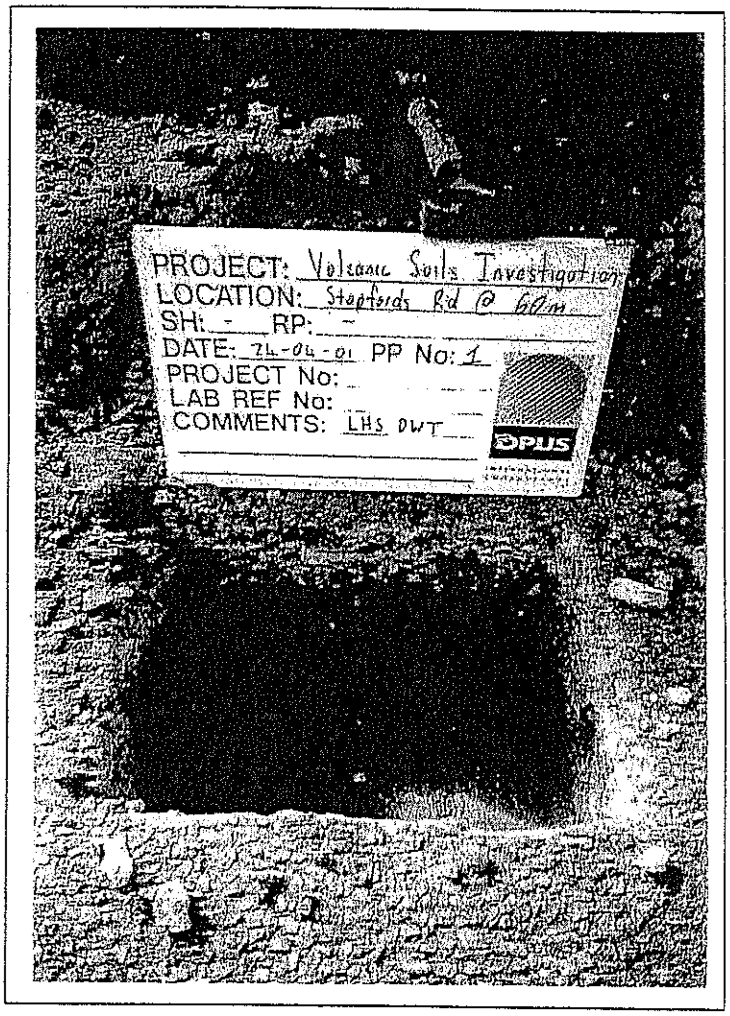
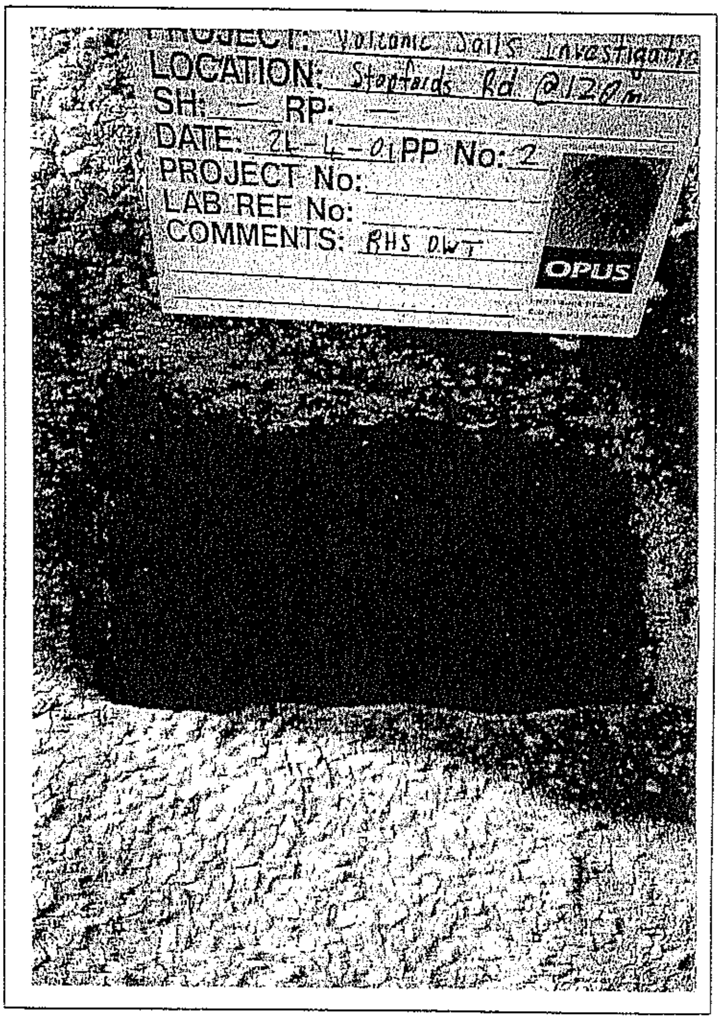
Volcanic Soil Project Site 11: Te Poi

Project No: 5-22480.00
Lab Ref No: 01/310/001/11



Stopfords Road
Pavement Pit 1
@ 60m RHS, OWT



Stopfords Road
Pavement Pit 2
@ 160m RHS, OWT

Opus International Consultants Limited
Hamilton Laboratory
Quality Management Systems Certified to ISO 9001

Fox Street
Private Bag 3057
Hamilton, New Zealand

Telephone +64 7 856 2870
Facsimile +64 7 856 2873
Website www.opus.co.nz

PAVEMENT INVESTIGATION LOG TEST REPORT

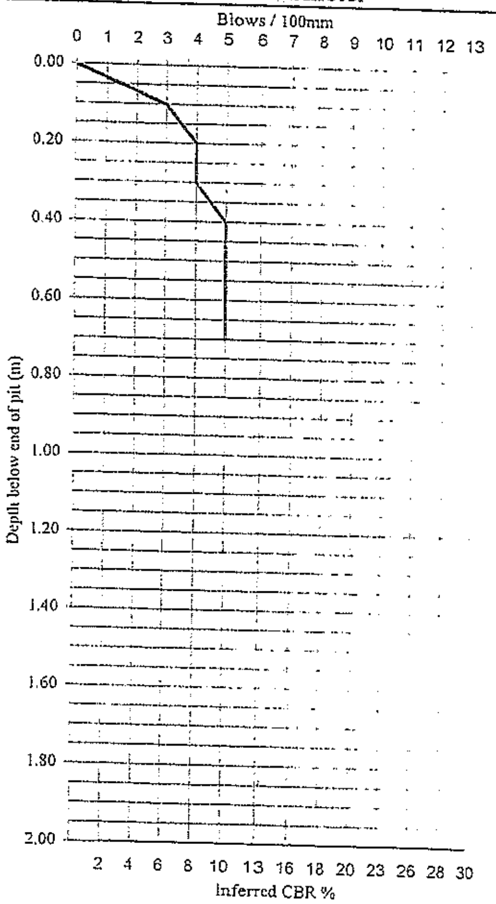
Project : Volcanic Soils Project (Site 12, Pukekohe)
Location : Coles Road, @ 40m RHS OWT
Client : Opus International Consultants Ltd
Contractor : N/A
Sampled by : R.S.Warner (Opus Laboratory, Hamilton)
Date Sampled : 04/04/01
Sampling method : NZS 4407 : 1991 Test 2.4.8.2
Sample condition : Natural
Pavement pit number : 1

OPUS INTERNATIONAL CONSULTANTS

Project No :	5-22480.00
Lab Ref No :	01/310/001/12
Client Ref No :	Pukekohe PP1

Depth (mm)	Pavement Description
0	CHIPSEAL Grade 4. Worn.
20	BASECOURSE GAP 40. Slightly weathered, angular to subangular GREYWACKE, slight excess Sand, some Silt, moderately dense to loose, moist, non plastic.
220	SUBBASE I GAP 65. Slightly weathered, angular to subangular GREYWACKE / Sandy SILT Mixture, moderately dense, moist, non plastic.
380	SUBBASE II Dark brown Silty CLAY, some Aggregates intermixed, soft to firm, moist, moderately plastic.
460	SUBGRADE Orange CLAY, some Silt, firm, moist, moderately plastic.
600	END OF PIT

Scala Penetrometer



Insitu CBR Test Results		
	Test Depth	480mm
	CBR %	10
	Penetration	2.5mm
	Water Content %	68.0

Basecourse sample not recovered.
Subbase sample not recovered.
Subgrade sample recovered at : 480 - 600mm.
Depth at which scala penetrometer started : 480mm.

Subgrade Density

Push tube results at :	480mm
Wet density (t/m^3) :	1.58
Dry density (t/m^3) :	0.94
W / C % :	68.0

Test Methods

Determination of Penetration Resistance of a Soil, NZS 4402 : 1988, Test 6.5.2
Insitu Density, sampling tube method, NZS 4402 : 1986, Test 5.1.3
California Bearing Ratio (insitu), NZS 4402: 1988, Test 6.1.3
Inferred CBR values taken from Austroads pavement design manual 1992

Notes

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Date tested : 04/04/01
Date reported : 05/04/01

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IANZ Approved Signatory

Designation : Laboratory Manager
Date : 05/04/01

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Opus International Consultants Limited
Hamilton Laboratory
Quality Management Systems Certified to ISO 9001

Fox Street
Private Bag 3057
Hamilton, New Zealand

Telephone +64 7 856 2870
Facsimile +64 7 856 2873
Website www.opus.co.nz

PAVEMENT INVESTIGATION LOG
TEST REPORT

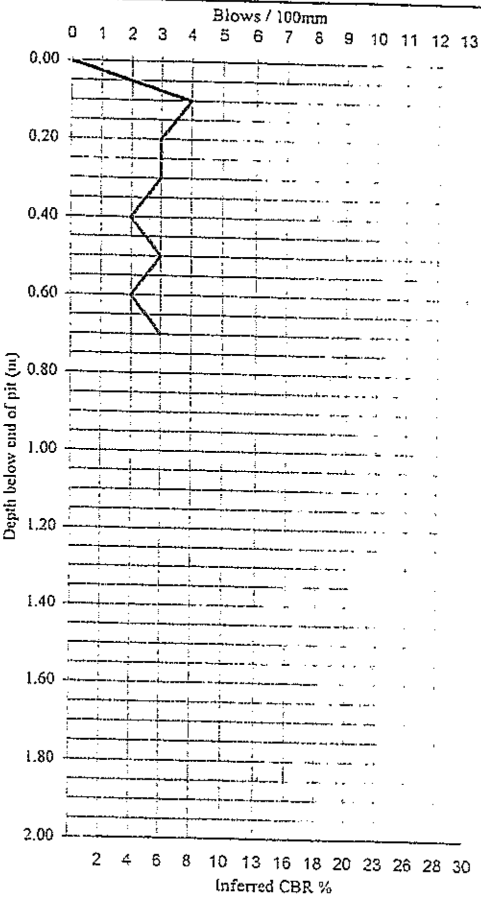
Project :	Volcanic Soils Project (Site 12, Pukekohe)
Location :	Coles Road @ 160m RHS OWT
Client :	Opus International Consultants Ltd
Contractor :	N/A
Sampled by :	R.S.Warner. (Opus Laboratory, Hamilton)
Date Sampled :	04/04/01
Sampling method :	NZS 4407 : 1991 Test 2.4.8.2
Sample condition :	Natural
Pavement pit number :	2

OPUS INTERNATIONAL CONSULTANTS

Project No :	5-22480.00
Lab Ref No :	01/310/001/12
Client Ref No :	Pukekohe PP2

Depth (mm)	Pavement Description
0	CHIPSEAL Grade 4. Worn.
20	BASECOURSE GAP 40. Slightly weathered, angular to subangular GREYWACKE, slightly excess Sand, some Silt, moderately dense to loose, moist, non plastic.
130	SUBBASE Dark brown / grey Silty SAND, occasional AP 65 Aggregate, moderately dense, moist, non plastic.
250	SUBGRADE Orange CLAY, some Silt, firm, moist, moderately plastic.
380	END OF PIT

Scala Penetrometer



Insitu CBR Test Results		
	Test Depth	260mm
	CBR %	15
	Penetration	5.0mm
	Water Content %	46.5

Basecourse sample not recovered.
Subbase sample not recovered.
Subgrade sample recovered at : 260 - 380mm.
Depth at which scala penetrometer started : 260mm.

Subgrade Density

Push tube results at :	260mm
Wet density (t/m^3) :	1.08
Dry density (t/m^3) :	0.73
W / C % :	46.5

Test Methods

Determination of Penetration Resistance of a Soil, NZS 4402 : 1988, Test 6.5.2
Insitu Density, sampling tube method, NZS 4402 : 1986, Test 5.1.3
California Bearing Ratio (insitu), NZS 4402: 1988, Test 6.1.3
Inferred CBR values taken from Austroads pavement design manual 1992

Notes

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Date tested : 04/04/01
Date reported : 05/04/01

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Designation : Laboratory Manager
Date : 05/04/01

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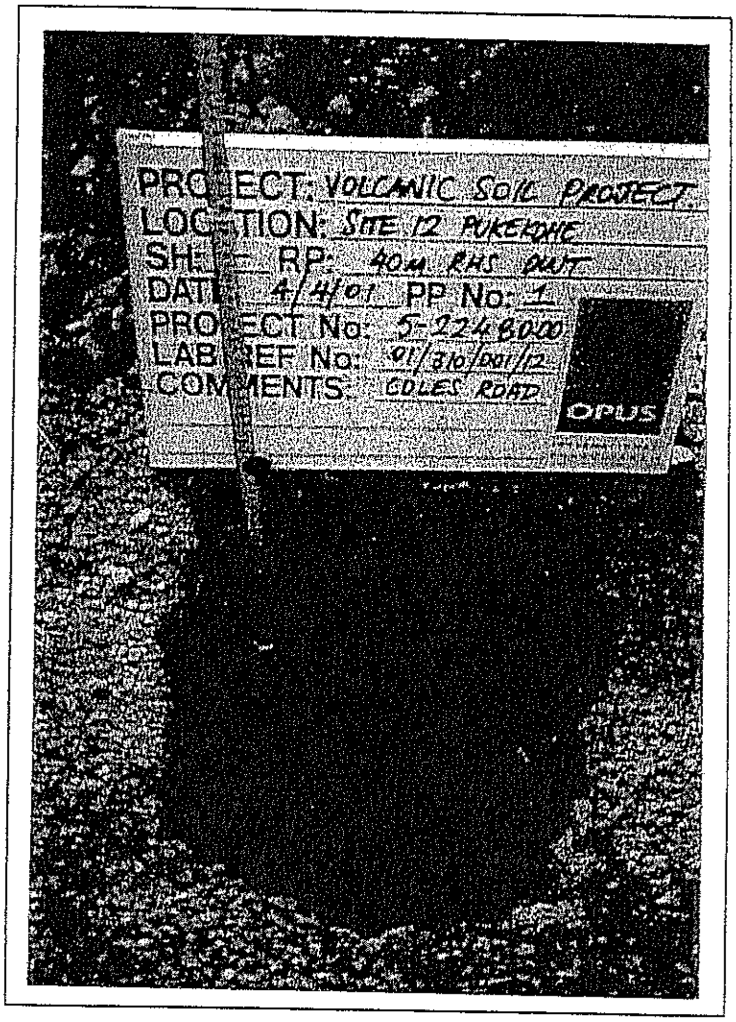
Opus International Consultants Limited
Hamilton Laboratory
Quality Management Systems Certified to ISO 9001

Fox Street
Private Bag 3057
Hamilton, New Zealand

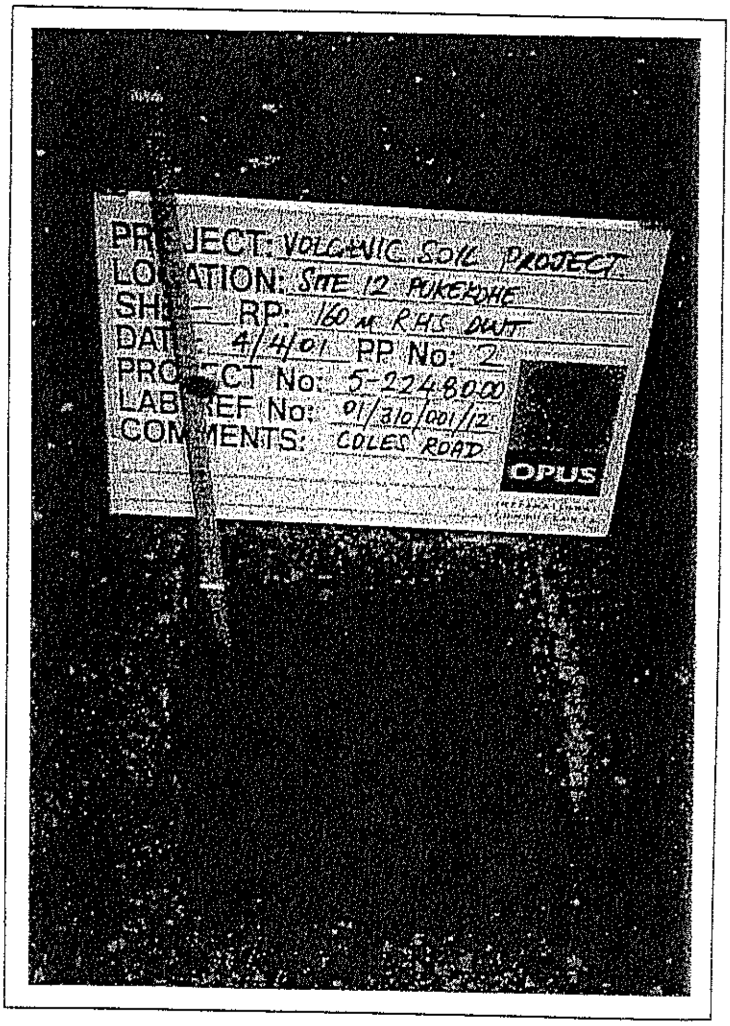
Telephone +64 7 856 2870
Facsimile +64 7 856 2873
Website www.opus.co.nz

Volcanic Soil Project Site 12: Pukekohe

Project No: 5-22480.00
Lab Ref No: 01/310/001/12



Coles Road
Pavement Pit 1
@ 40m RHS, OWT



Coles Road
Pavement Pit 2
@ 160m RHS, OWT

PAVEMENT INVESTIGATION LOG
TEST REPORT

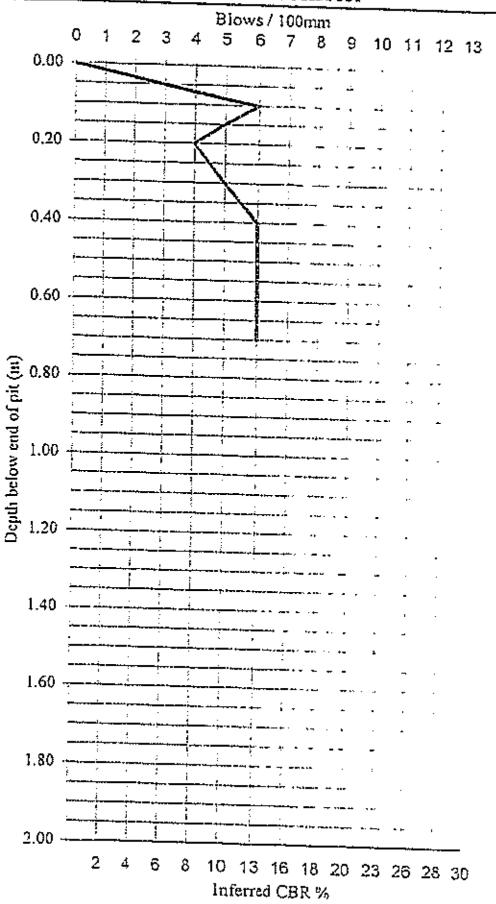
Project :	Volcanic Soils Project (Site 13, Taupiri)
Location :	Jew Road @ 20m LHS OWT
Client :	Opus International Consultants Ltd
Contractor :	N/A
Sampled by :	R.S.Warner (Opus Laboratory, Hamilton)
Date Sampled :	04/04/01
Sampling method :	NZS 4407 : 1991 Test 2.4.8.2
Sample condition :	Natural
Pavement pit number :	1

OPUS INTERNATIONAL CONSULTANTS

Project No :	5-22480.00
Lab Ref No :	01/310/001/13
Client Ref No :	Taupiri PP1

Depth (mm)	Pavement Description
0	CHIPSEAL Grade 6. Worn, sound.
20	BASECOURSE GAP 40. Fresh, angular GREYWACKE, well graded SAND, some Silt, moderately dense, moist, non plastic.
190	SUBBASE Orange / brown SILT, occasional Topsoil claste and aggregates, firm, moist, non plastic.
290	SUBGRADE Orange / brown Silty CLAY, firm to stiff, slightly moist, moderately plastic.
500	END OF PIT

Scala Penetrometer



Insitu CBR Test Results		
	Test Depth	340mm
	CBR %	11
	Penetration	5.0mm
	Water Content %	40.5

Basecourse sample not recovered.
Subbase sample not recovered.
Subgrade sample recovered at : 340 - 500mm.
Depth at which scala penetrometer started : 340mm.

Subgrade Density

Push tube results at :	340mm
Wet density (t/m^3) :	1.44
Dry density (t/m^3) :	1.03
W / C % :	40.5

Test Methods

Determination of Penetration Resistance of a Soil, NZS 4402 : 1988, Test 6.5.2
Insitu Density, sampling tube method, NZS 4402 : 1986, Test 5.1.3
California Bearing Ratio (insitu), NZS 4402: 1988, Test 6.1.3
Inferred CBR values taken from Austroads pavement design manual 1992

Notes

IANZ Accreditation does not apply to inferred CBR values or pavement descriptions

Date tested : 04/04/01
Date reported : 05/04/01

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Private Bag 3057
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PAVEMENT INVESTIGATION LOG
TEST REPORT

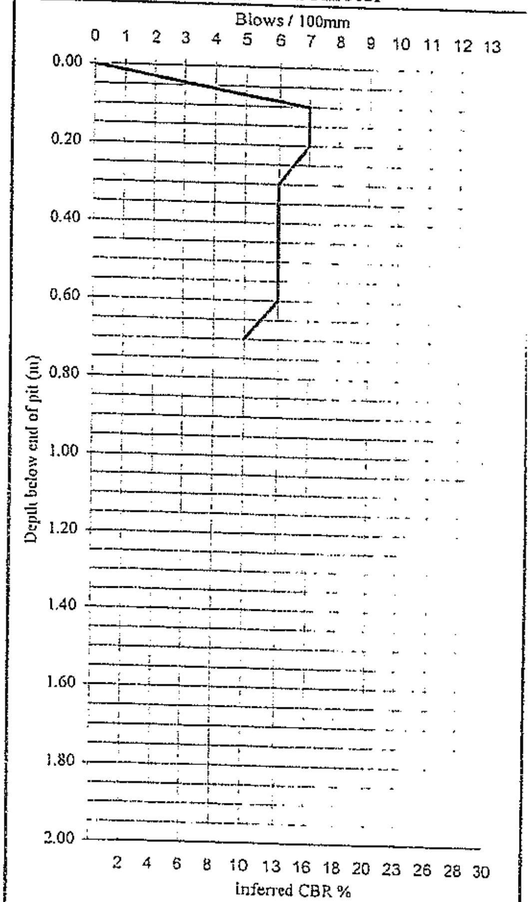
Project :	Volcanic Soils Project (Site 13, Taupiri)
Location :	Jew Road @ 200m LHS OWT
Client :	Opus International Consultants Ltd
Contractor :	N/A
Sampled by :	R.S.Warner. (Opus Laboratory, Hamilton)
Date Sampled :	04/04/01
Sampling method :	NZS 4407 : 1991 Test 2.4.8.2
Sample condition :	Natural
Pavement pit number :	2

OPUS INTERNATIONAL CONSULTANTS

Project No :	5-22480.00
Lab Ref No :	01/310/001/13
Client Ref No :	Taupiri PP2

Depth (mm)	Pavement Description
0	CHIPSEAL Grade 6. Worn, sound.
20	BASECOURSE GAP 40. Fresh, angular GREYWACKE, well graded SAND, some Silt, moderately dense, moist, non plastic.
150	SUBBASE I Orange / brown highly weathered GREYWACKE (ROTTEN ROCK), some Clayey Silt, moderately dense to dense, slightly moist, non plastic.
240	SUBBASE II GAP 65. Slightly weathered, angular to subangular GREYWACKE, some Silty Sand, dry, dense, non plastic.
330	SUBGRADE Orange / brown Silty CLAY, some clayey pockets, stiff, slightly moist, moderately plastic.
500	END OF PIT

Scala Penetrometer



Insitu CBR Test Results		
	Test Depth	350mm
	CBR %	20
	Penetration	5.0mm
	Water Content %	26.2

Basecourse sample not recovered.
Subbase sample not recovered.
Subgrade sample recovered at : 350 - 500mm.
Depth at which scala penetrometer started : 350mm.

Subgrade Density

Push tube results at :	350mm
Wet density (t/m^3) :	1.76
Dry density (t/m^3) :	1.37
W / C % :	26.2

Test Methods

Determination of Penetration Resistance of a Soil, NZS 4402 : 1988, Test 6.5.2
Insitu Density, sampling tube method, NZS 4402 : 1986, Test 5.1.3
California Bearing Ratio (insitu), NZS 4402: 1988, Test 6.1.3
Inferred CBR values taken from Austroads pavement design manual 1992

Notes

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Date tested : 04/04/01
Date reported : 05/04/01

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Quality Management Systems Certified to ISO 9001

Fox Street
Private Bag 3057
Hamilton, New Zealand

Telephone +64 7 856 2870
Facsimile +64 7 856 2873
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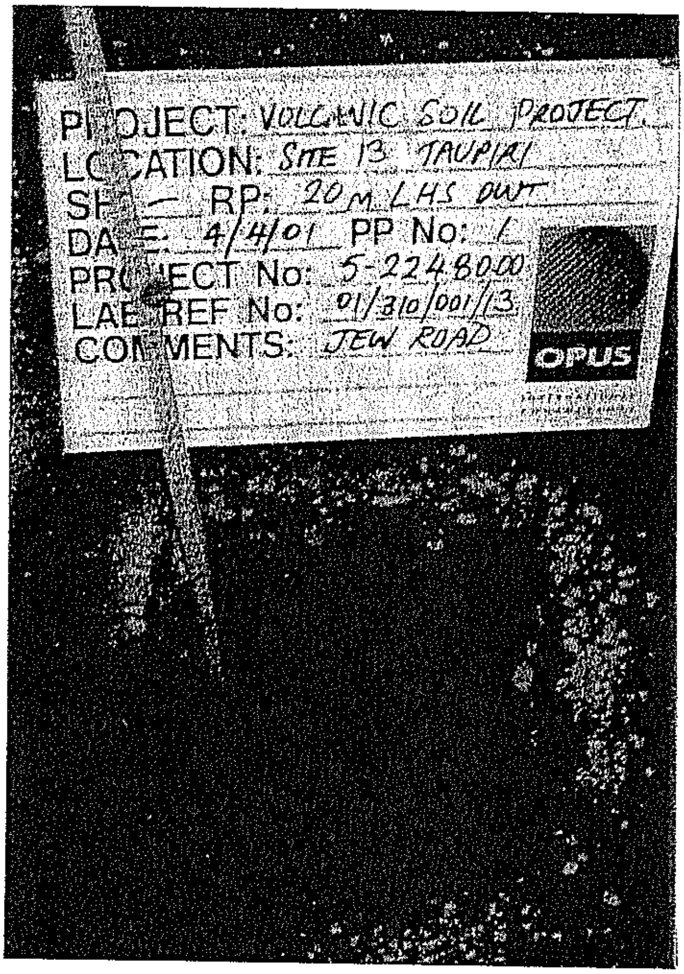
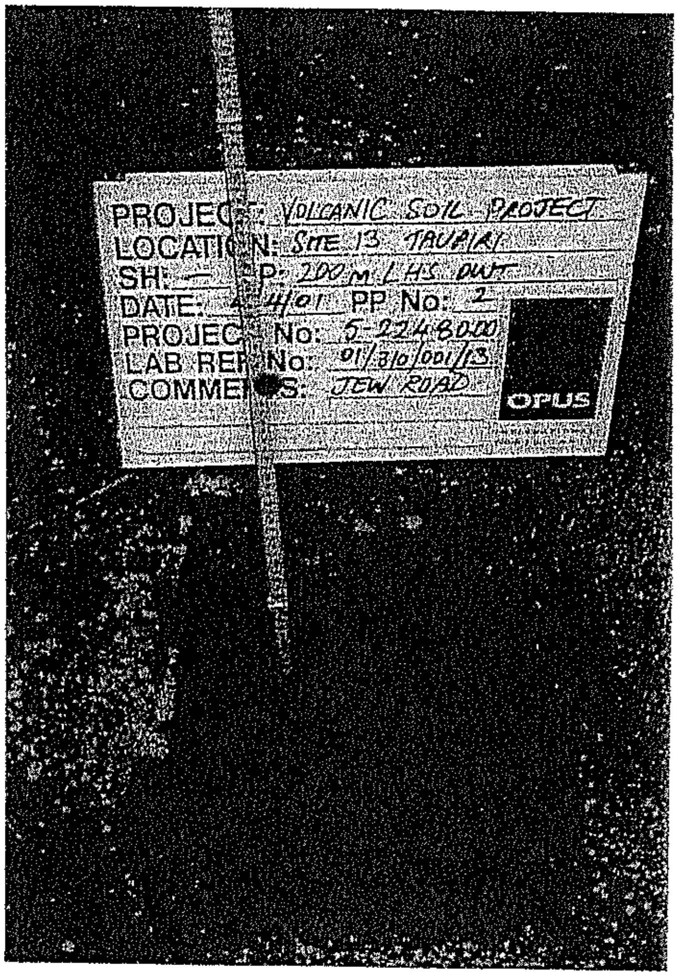
Volcanic Soil Project Site 13: Taupiri

Project No: 5-22480.00
Lab Ref No: 01/310/001/13



Jew Road
Pavement Pit 1
@ 20m LHS, OWT



Jew Road
Pavement Pit 2
@ 200m LHS, OWT

PAVEMENT INVESTIGATION LOG
TEST REPORT

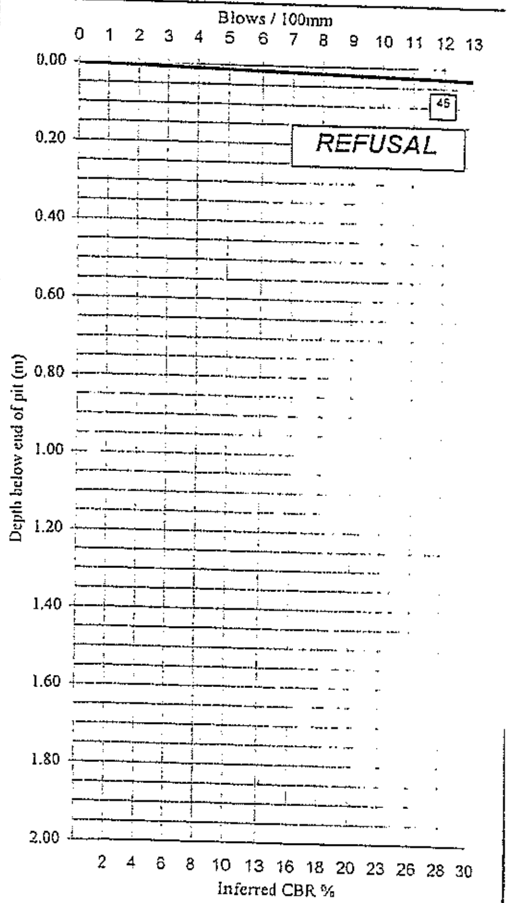
Project :	Volcanic Soils Project (Site 14, Te Awamutu)
Location :	Bowman Road @ 20m LHS OWT
Client :	Opus International Consultants Ltd
Contractor :	N/A
Sampled by :	R.S.Warner (Opus Laboratory, Hamilton)
Date Sampled :	05/04/01
Sampling method :	NZS 4407 : 1991 Test 2.4.8.2
Sample condition :	Natural
Pavement pit number :	1

OPUS INTERNATIONAL CONSULTANTS

Project No :	5-22480.00
Lab Ref No :	01/310/001/14
Client Ref No :	Te Awamutu PP1

Depth (mm)	Pavement Description
0	CHIPSEAL Grade 3/5. Sound.
20	BASECOURSE GAP 40. Fresh, angular GREYWACKE, well graded Sandy SILT, moderately dense, moist, non plastic.
120	OLD CHIPSEAL
140	OLD BASECOURSE GAP 40. Slightly weathered, angular to subangular GREYWACKE/ Sandy SILT mixture, moderately dense, moist, non plastic.
200	SUBGRADE Orange / brown medium to coarse SAND, dense to very dense, moist, non plastic.
460	END OF PIT

Scala Penetrometer



Insitu CBR Test Results		
	Test Depth	300mm
	CBR %	80
	Penetration	5.0mm
	Water Content %	9.2

Basecourse sample not recovered.
Subbase sample not recovered.
Subgrade sample recovered at : 300 - 460mm.
Depth at which scala penetrometer started : 300mm.

Subgrade Density

Push tube results at : Wet density (t/m^3) : Dry density (t/m^3) : W / C % :	Unable to test by Push tube

Test Methods

Determination of Penetration Resistance of a Soil, NZS 4402 : 1988, Test 6.5.2
Insitu Density, sampling tube method, NZS 4402 : 1986, Test 5.1.3
California Bearing Ratio (insitu), NZS 4402: 1988, Test 6.1.3
Inferred CBR values taken from Austroads pavement design manual 1992

Notes

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Date tested : 05/04/01
Date reported : 06/04/01

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Designation : *Laboratory Manager*
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Opus International Consultants Limited
Hamilton Laboratory
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Fox Street
Private Bag 3057
Hamilton, New Zealand

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Facsimile +64 7 856 2873
Website www.opus.co.nz

PAVEMENT INVESTIGATION LOG
TEST REPORT

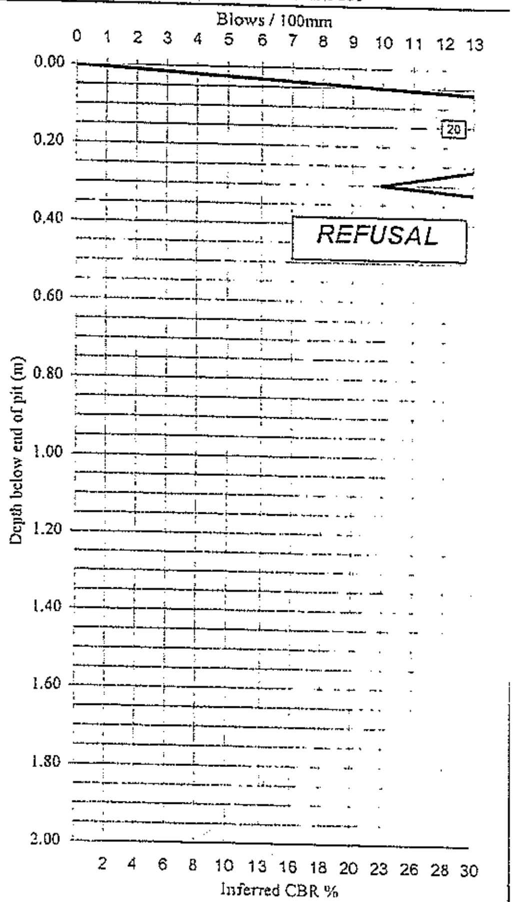
Project :	Volcanic Soils Project (Site 14, Te Awamutu)
Location :	Bowman Road @ 100m LHS OWT
Client :	Opus International Consultants Ltd
Contractor :	N/A
Sampled by :	R.S.Warner. (Opus Laboratory, Hamilton)
Date Sampled :	05/04/01
Sampling method :	NZS 4407 : 1991 Test 2.4.8.2
Sample condition :	Natural
Pavement pit number :	2

OPUS INTERNATIONAL CONSULTANTS

Project No :	5-22480.00
Lab Ref No :	01/310/001/14
Client Ref No :	Te Awamutu PP2

Depth (mm)	Pavement Description
0	CHIPSEAL Grade 3/5. Sound.
20	BASECOURSE GAP 40. Fresh, angular GREYWACKE, well graded Sandy SILT, moderately dense, moist, non plastic.
120	OLD CHIPSEAL
140	OLD BASECOURSE GAP 40. Slightly weathered, angular to subangular GREYWACKE/ Sandy SILT mixture, moderately dense, moist, non plastic.
200	SUBGRADE Orange / brown medium to coarse SAND, dense to very dense, moist, non plastic.
400	END OF PIT

Scala Penetrometer



Insitu CBR Test Results		
	Test Depth	300mm
	CBR %	100
	Penetration	2.5mm
	Water Content %	10.6

Basecourse sample not recovered.
Subbase sample not recovered.
Subgrade sample recovered at : 300 - 400mm.
Depth at which scala penetrometer started : 300mm.

Subgrade Density

Push tube results at :
Wet density (t/m³) :
Dry density (t/m³) :
W / C % :

Unable to test by Push tube

Test Methods

Determination of Penetration Resistance of a Soil, NZS 4402 : 1988, Test 6.5.2
Insitu Density, sampling tube method, NZS 4402 : 1986, Test 5.1.3
California Bearing Ratio (insitu), NZS 4402: 1988, Test 6.1.3
Inferred CBR values taken from Austroads pavement design manual 1992

Notes

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Date tested : 05/04/01
Date reported : 06/04/01

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Designation : *Laboratory Manager*
Date : 06/04/01

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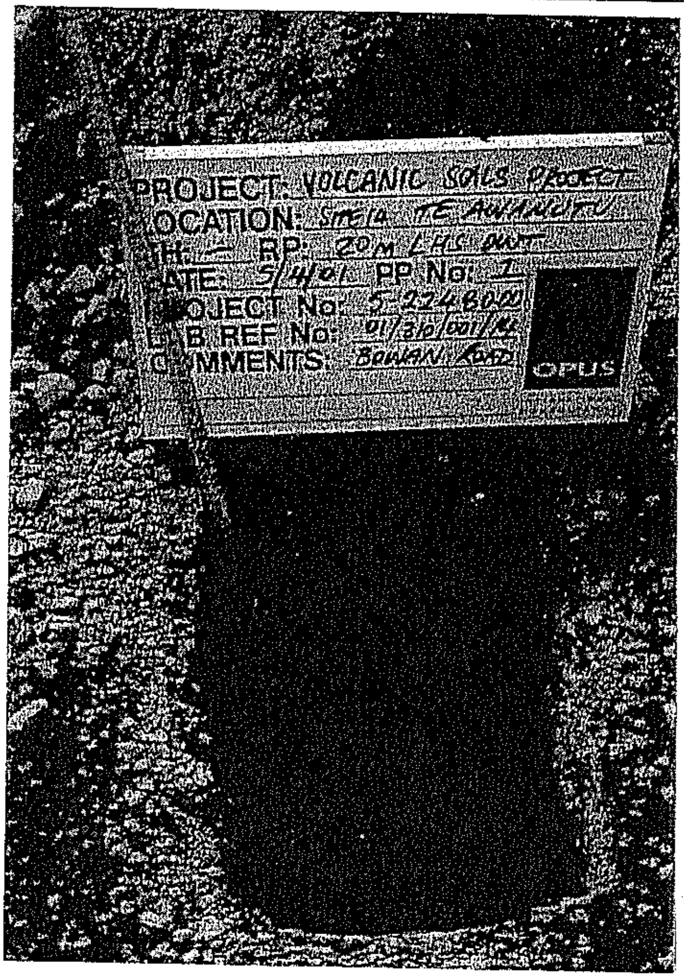
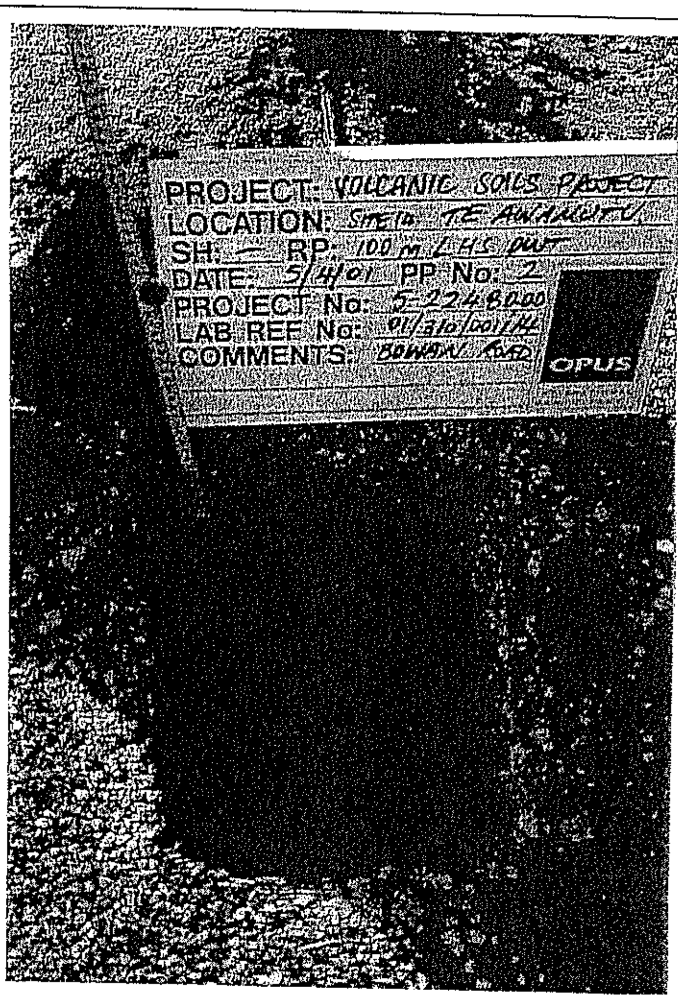


Bowman Road
Pavement Pit 1
@ 20m LHS, OWT



Bowman Road
Pavement Pit 2
@ 100m LHS, OWT

PAVEMENT INVESTIGATION LOG
TEST REPORT

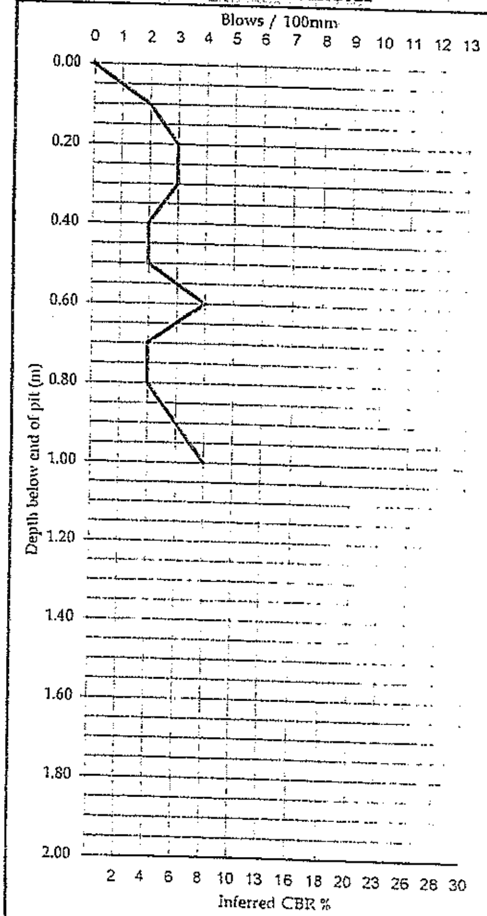
Project :	Volcanic Soils Project (Site 15, Cambridge)
Location :	Peake Rd @ 20m LHS OWT
Client :	Opus International Consultants Ltd
Contractor :	N/A
Sampled by :	R. S. Warner (Opus Laboratory, Hamilton)
Date Sampled :	16/05/01
Sampling method :	NZS 4407 : 1991 Test 2.4.8.2
Sample condition :	Natural
Pavement pit number :	1

OPUS INTERNATIONAL CONSULTANTS

Project No.:	5-22480.00
Lab Ref No.:	01/310/001/15
Client Ref No.:	Cambridge PP1

Depth (mm)	Pavement Description
0	CHIPSEAL Grade 3. Worn, flushed.
40	BASECOURSE GAP 40. Slightly weathered, subangular GREYWACKE/Medium SAND mixture, moderately desne, moist, non plastic
240	SUBBASE Yellow/browm medium SAND, some Gravels, moderately dense, moist, non plastic.
360	SUBGRADE (Natural) Mid to dark brown Sandy SILT, rare Clay, soft, moist, very slightly plastic.
370	END OF PIT

Scala Penetrometer



Insitu CBR Test Results		
	Test Depth	370mm
	CBR %	9
	Penetration	2.5
	Water Content %	29.1

Basecourse sample not recovered.
Subbase sample not recovered.
Subgrade sample recovered at : 370 - 470mm.
Depth at scala penetrometer started : 370mm.

Subgrade Density

Push tube results at :	370mm
Wet density (t/m^3) :	1.48
Dry density (t/m^3) :	1.15
W / C % :	29.1

Test Methods

Determination of Penetration Resistance of a Soil, NZS 4402 : 1988, Test 6.5.2
Insitu Density, sampling tube method, NZS 4402 : 1986, Test 5.1.3
California Bearing Ratio (insitu), NZS 4402: 1988, Test 6.1.3
Inferred CBR values taken from Austroads pavement design manual 1992

Notes

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Date tested : 16/05/01
Date reported : 18/05/01

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Designation : Labbratory Manager
Date : 18/~~05/01~~

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Facsimile +64 7 856 2873
Website www.opus.co.nz

PAVEMENT INVESTIGATION LOG TEST REPORT

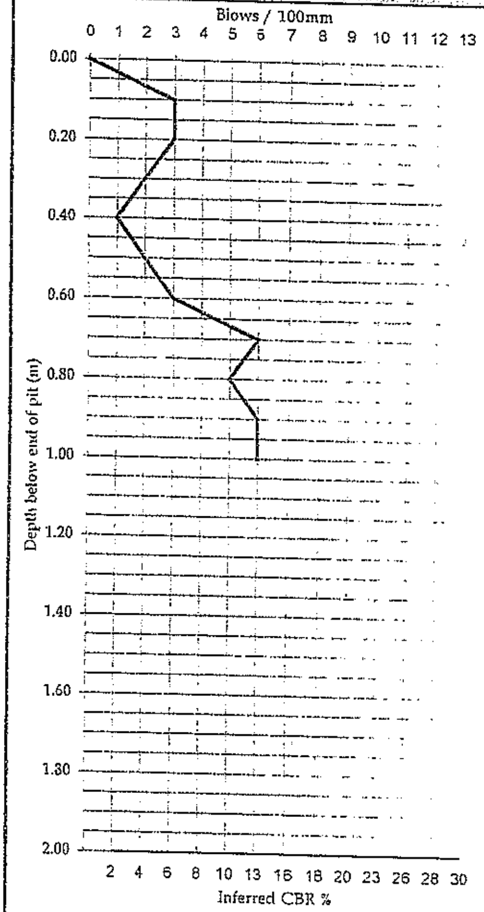
Project :	Volcanic Soils Project (Site 15, Cambridge)
Location :	Peake Rd @ 180m LHS OWT
Client :	Opus International Consultants Ltd
Contractor :	N/A
Sampled by :	R. S. Warner (Opus Laboratory, Hamilton)
Date Sampled :	16/05/01
Sampling method :	NZS 4407 : 1991 Test 2.4.8.2
Sample condition :	Natural
Pavement pit number :	2

OPUS INTERNATIONAL CONSULTANTS

Project No :	5-22480.00
Lab Ref No :	01/310/001/15
Client Ref No :	Cambridge PP2

Depth (mm)	Pavement Description
0	CHIPSEAL Grade 3/5. Worn, flushed.
40	BASECOURSE GAP 40. Slightly weathered, subangular GREYWACKE/Medium SAND mixture, moderatelv desne, moist, non plastic
120	SUBBASE Yellow/browm medium SAND, some Gravels, moderately dense, moist, non plastic.
240	SUBGRADE (Natural) Dark brown Sandy SILT, some Clay, soft to firm, moist, slightly plastic.
250	END OF PIT

Scala Penetrometer



Insitu CBR Test Results		
	Test Depth	250mm
	CBR %	12
	Penetration	2.5
	Water Content %	54.1

Basecourse sample not recovered.
Subbase sample not recovered.
Subgrade sample recovered at : 250 - 350mm.
Depth at scala penetrometer started : 250mm.

Subgrade Density

Push tube results at :	250mm
Wet density (t/m^3) :	1.54
Dry density (t/m^3) :	1.00
W / C % :	54.1

Test Methods

Determination of Penetration Resistance of a Soil, NZS 4402 : 1988, Test 6.5.2
Insitu Density, sampling tube method, NZS 4402 : 1986, Test 5.1.3
California Bearing Ratio (insitu), NZS 4402: 1988, Test 6.1.3
Inferred CBR values taken from Austroads pavement design manual 1992

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Designation : Laboratory Manager
Date : 18/05/01

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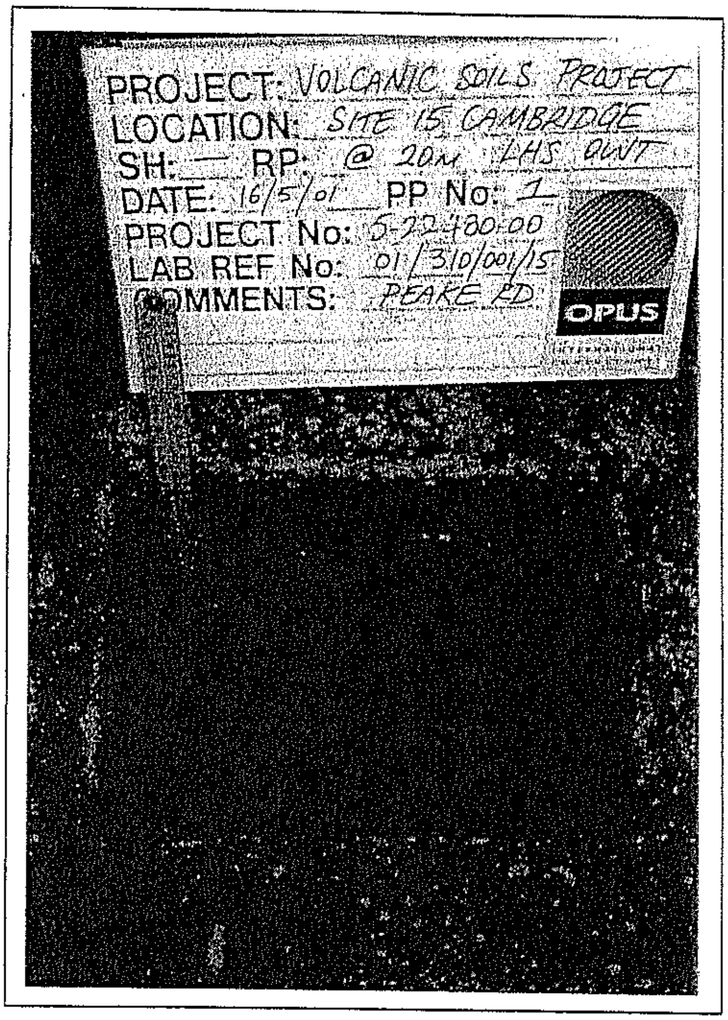
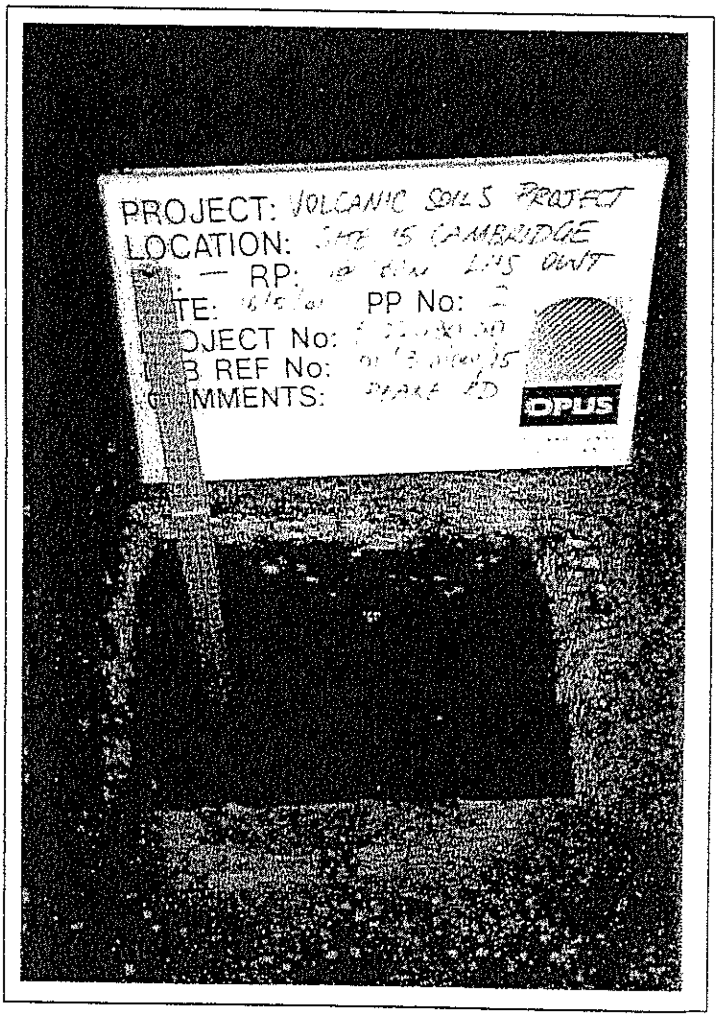
Volcanic Soil Project Site 15: Te Awamutu

Project No: 5-22480.00
Lab Ref No: 01/310/001/15



Peake Road
Pavement Pit 1
@ 20m LHS, OWT



Peake Road
Pavement Pit 2
@ 180m LHS, OWT