PaveState – Further Explanation

DETAILED USE ON A DRAINAGE PROJECT

Contribution from Deflection Testing and Structural Analysis

Understanding the subgrade conditions and characteristics of deflection test results that point to the potential for improving pavement performance through drainage.

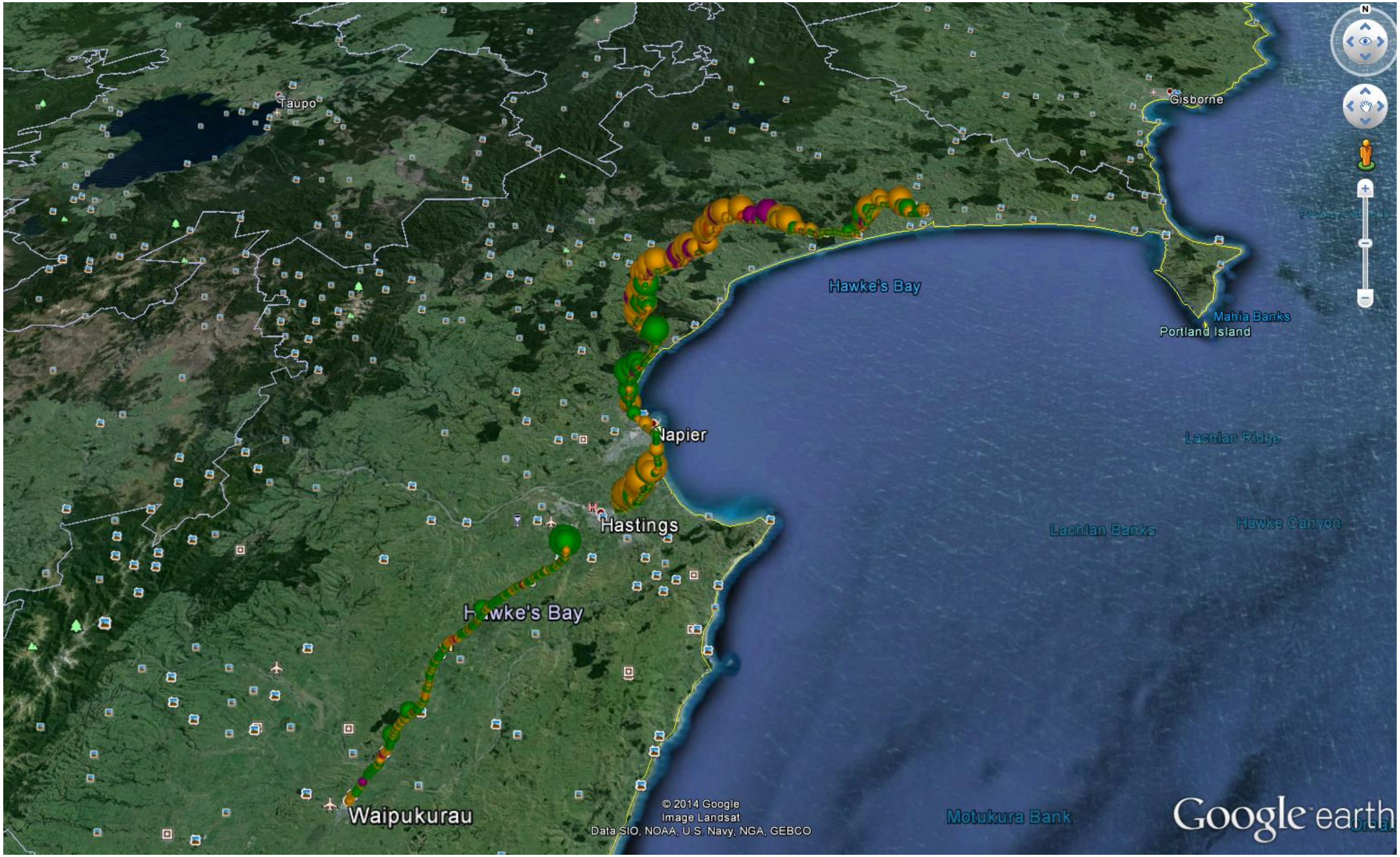
Identification of those locations which will benefit most from drainage, from pavement structural analyses (determining probable stiffness of the subgrade and overlying pavement layers)

either:

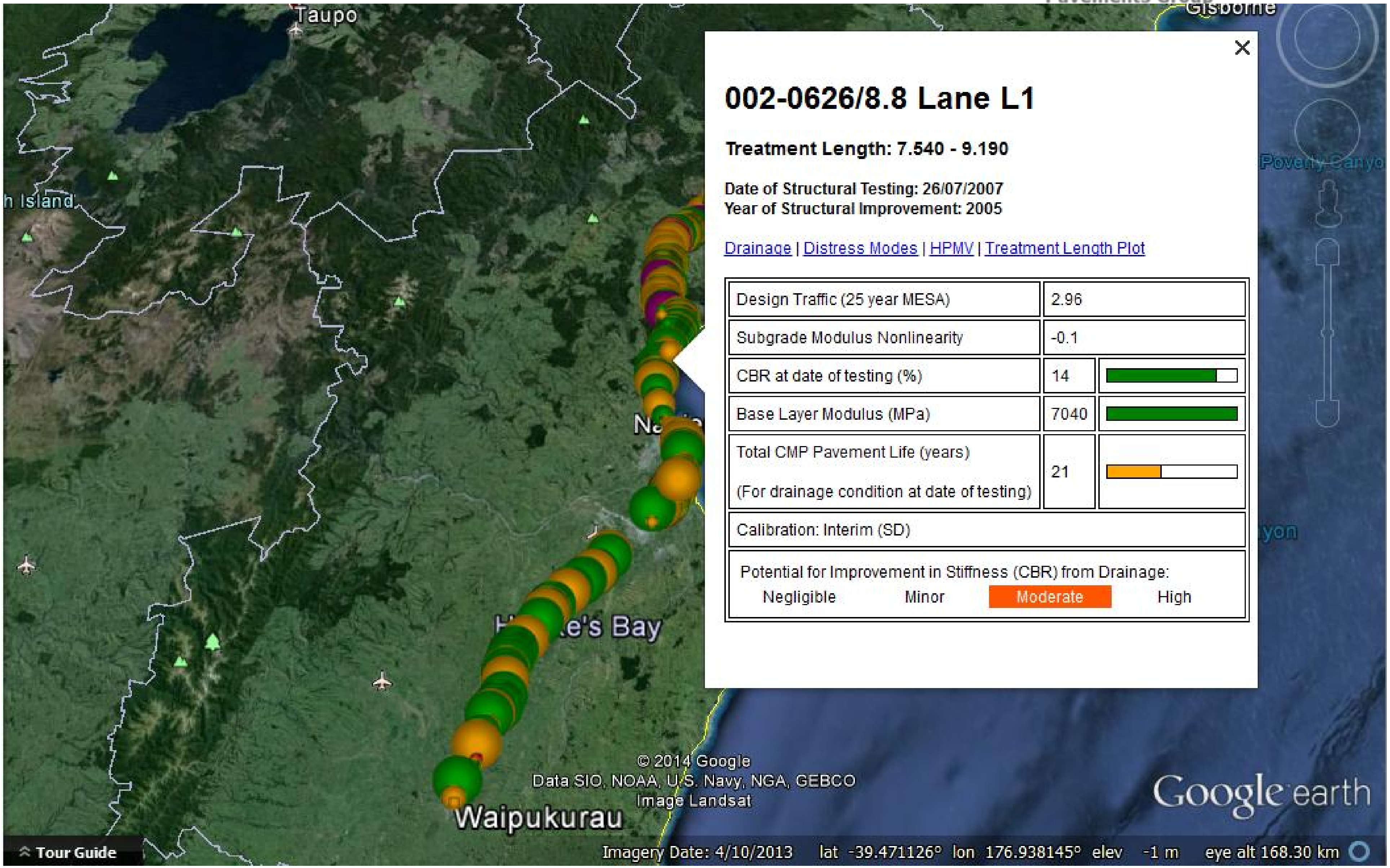
i. In the office, viewing properties of the entire network, or

ii. In the field, at each test position along the road during walkover, using the visual display of a GPS enabled smartphone or tablet.

All data files provided in common format for viewing on Google Earth (.kmz)



Zoom in and click on FWD test point of interest



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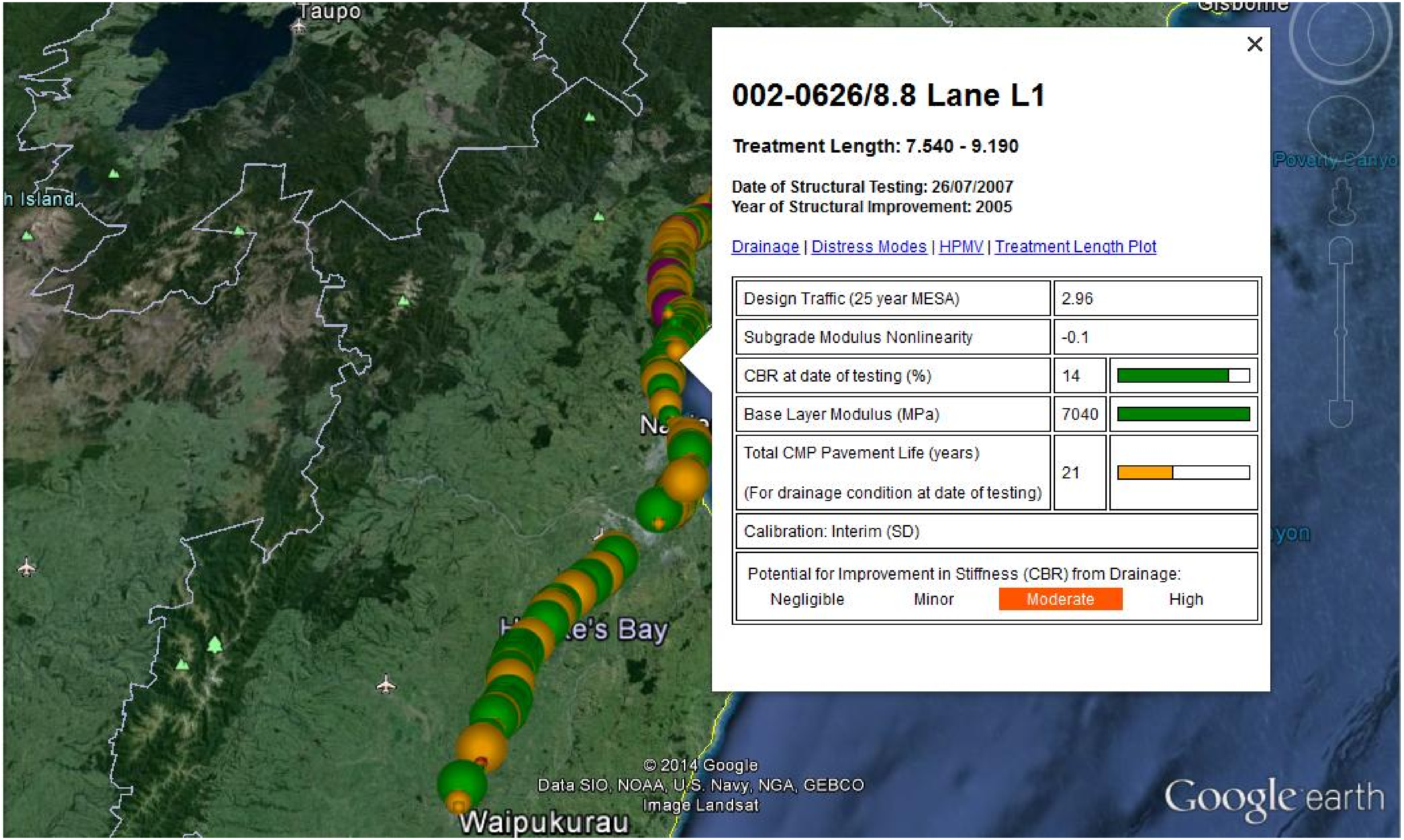
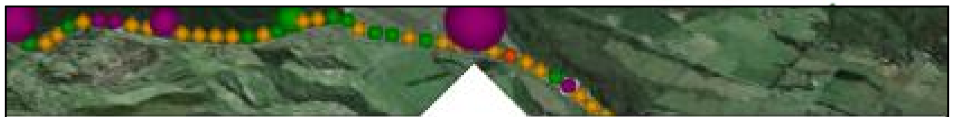


Google Earth: Drainage Tab

When a test point is selected on the map, the first tab that displays is “Drainage”.
In addition to showing the numerical values for a number of parameters related to drainage (seen in the table on the right) a colour code is also used to convey the data visually.

The explanation of the fields that are currently displayed are:

1. State Highway Number and RP, lane and stationing of the deflection test (FWD). All tests are in the left wheelpath unless otherwise stated.
2. Treatment Length – note this is the structural TL, ie as found by the pavement analyst to be structurally uniform, ie not necessarily as recorded in RAMM. Also, if appropriate, individual lanes can be distinguished.
3. The 25 year ESA/lane/year as supplied to the analyst.



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002-0562/11.2 Lane L1

Treatment Length: 11.030 - 12.101

Date of Structural Testing: 31/07/2007
Year of Structural Improvement: 2005

Drainage | Distress Modes | HPMV | Treatment Length Plot

Design Traffic (25 year MESA)	1.7	
Subgrade Modulus Nonlinearity	-0.5	
CBR at date of testing (%)	1	
Base Layer Modulus (MPa)	613	
Total CMP Pavement Life (years) (For drainage condition at date of testing)	2	
Calibration: Interim (SD)		

Potential for Improvement in Stiffness (CBR) from Drainage:
Negligible Minor Moderate High

Google Earth: Drainage Tab

4. Subgrade Modulus Exponent (*n*)

The ELMOD back-analysis package uses the bowl deflections to calculate C and *n* in the non-linear subgrade modulus relationship:

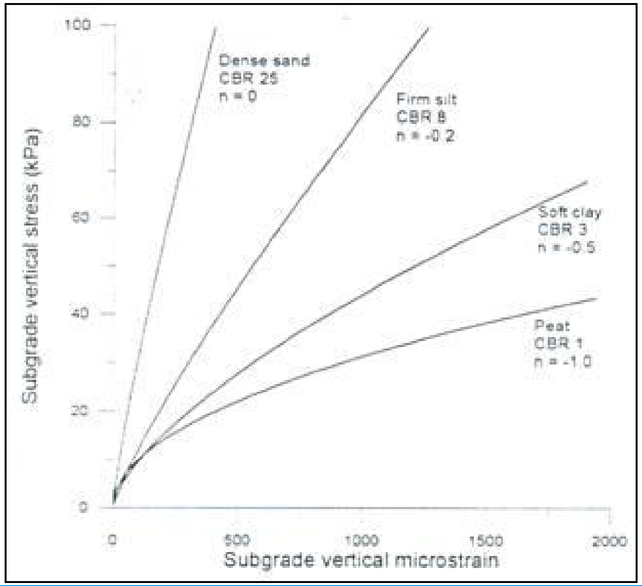
$$E = C\,(\sigma_z/\sigma')^n \text{ where:}$$

C is a constant , *n* is a constant exponent , σ_z is the vertical stress and σ' is a reference stress.

The reference stress is introduced to make the equation correct with respect to dimensions; *E* (modulus of elasticity) and *C* then both take dimensions of stress [Pa]. This approach allows quick and accurate modelling, and has the additional benefit of being able to broadly identify the subgrade soil type.

The exponent *n* is a measure of the subgrade modulus's non-linearity. If *n* is zero, the material is linear elastic (for example hard granular materials).

Soft cohesive soils may be markedly non-linear with *n* being between -0.3 and -0.6 with occasionally lower values.
The exponent *n* therefore defines the departure from Hooke's Law, as shown :

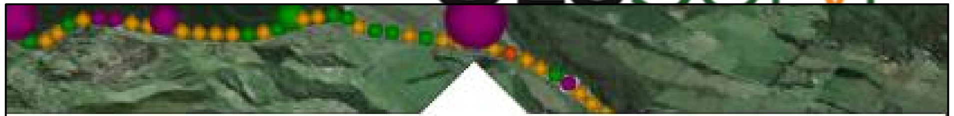


Google Earth: Drainage Tab

4. Subgrade Modulus Exponent (*n*) continued…

Results showing moderate or high subgrade moduli, together with unusually high non-linear response, may represent poor drainage at the top of the subgrade, rather than being caused only by material properties. Very low subgrade moduli, together with strongly non-linear responses, are indicative of soft saturated clays or peat.

Based on verification surveys and feedback from field personnel familiar with their networks, an algorithm has been developed that looks for n values that are "atypical" and flags these as probable candidates for consideration of drainage, ie it is not unequivocal. There are other possible explanations (eg buried topsoil) that cause apparent ultra-low *n* exponents, but staff specialists in analytics are continuing to improve their interpretations of unusual deflection bowls.



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Google Earth: Drainage Tab

5. CBR
California Bearing Ratio for the subgrade, deduced using a conservative approximation from the FWD back-calculated subgrade modulus. Values lower than 7 become increasingly likely to be saturated. Higher values are unlikely to be improved by drainage.

6. Base Layer Modulus

The FWD back-calculated modulus for Layer 1. Color coding is with respect to a typical unbound granular basecourse. A stabilized basecourse or including some proportion of bound material can be inferred for values over about 1500 MPa.

It is not possible to distinguish layers that are thinner than 75 mm (half the radius of the loading plate) therefore thin AC or OGPA surfacing's are usually modelled as a mixed layer.

Characteristics of the recovery phase of the deflection test sometimes indicate unusual response that corresponds to shear instability in an unbound basecourse layer. This is subject to ongoing research and at this stage is presented as a probabilistic parameter, ie indicating that instability is likely to develop sooner rather than later. The color coding is changed to purple if shear instability is indicated, and while subsoil drainage is not likely to give improvement, waterproofing of the seal coat is. It is particularly important to watch for cracking in these cases, ie there may be a case for resurfacing earlier rather than later.

Google Earth: Drainage Tab

7. Total Pavement Life (RPP)
The pavement life is important for drainage decisions because if a pavement has a saturated subgrade yet the pavement is so thick it will last for many decades, then that pavement can be deferred as a lower priority when deciding where to apply a limited budget.
Color coding shows the expected pavement life.

The ideal measure of pavement life for this study is the life based on Regional Precedent Performance (which is a Calibrated Mechanistic Procedure, CMP) which uses an ongoing study of regional networks throughout New Zealand. Several regions now have 40- 50,000 deflection bowls collected historically. Collation of all these structural analyses have been used for ranking pavement life and establishing regionally calibrated deformation criteria rather than the Austroads criteria which are for very different climates and materials.

The total life based on RPP can be regarded as the expected life of the pavement, for the design traffic based on local precedent performance. The rationale uses the same concept as the TNZ Precedent Method for overlay design except that an entire regional network rather than just one treatment length is used for determining parameters from precedent performance. If the FWD predicted RPP life is less than the average expected life of each reseal, then renewal is likely to be more economic than resurfacing. If the RPP life is labelled as “Interim” then the criteria from a NZ region that is considered similar has been used, because calibration has not yet been done for that network.

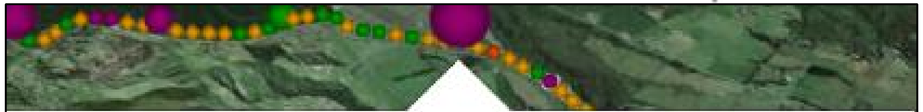
Google Earth: Drainage Tab

8. Potential for Improvement in Subgrade Stiffness with Drainage

The Google Earth overview displays large symbols for FWD test points where the pavement life is limited, and colour coding is used to show where the most drainage improvement can be expected, using the deflection results. The goal is to provide a display that readily identifies drainage priorities and can be used either in the office or in field using a GPS enabled tablet or smartphone.

The numerical value is determined by a formula weighted from the following parameters:

- Subgrade Modulus Exponent
- Subgrade Modulus
- Rut Differential



002-0562/11.2 Lane L1

Treatment Length: 11.030 - 12.101

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Drainage | Distress Modes | HPMV | Treatment Length Plot

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Calibration: Interim (SD)		
Potential for Improvement in Stiffness (CBR) from Drainage: Negligible Minor Moderate **High**		

Google Earth: Drainage Tab

This function gives the drainage potential for improvement as increasing with nonlinearity and decreasing with modulus. Typical results are in the range 0-4 and interpreted as follows:

<=0.2: Negligible potential for improvement
<0.4: Minor potential for improvement
<0.8: Moderate potential for improvement
>=0.8: High potential for improvement

Rut Differential. In addition, to compare both wheelpaths using a similar concept as that promoted in the UK Drainage Project using the Deflectograph, our FWD data have been supplemented with a parameter derived from the HSD for rut depths in LWP vs RWP. If the ratio of LWP/RWP rut is greater than 1.0, progressively more weighting is placed on potential for drainage improvement.
The value is given by the formula:
(LWP / RWP) – 1

002-0562/11.2 Lane L1

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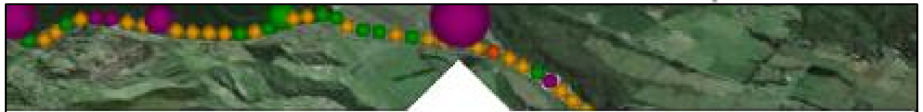
Google Earth: Drainage Tab

9. Prioritising works: Structural Benefit/Cost for Drainage (SBD).

The need for improvement also needs to be considered as well as the potential. If a given test point shows 100 years life (because there is a very thick pavement) then there is little benefit. Similarly, there is less benefit in prioritizing roads with low traffic (ESA). A suitable parameter for ranking of drainage priorities not only within one network, but also for benchmarking between networks is proposed, simply by weighting the Potential for Improvement, taking into account current pavement life, design MESA and the rut differential.



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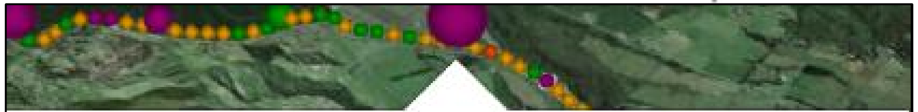
Structural Benefit/Cost for Drainage (Number and colour code)

Google Earth: Drainage Tab

An interim screening parameter to be explored could be:
SBD = Potential * log10 (design MESA) * RutDifferential/(RPP Life)

This structural parameter, could then be used with the surface information to assign an overall rating and priority. In practice it will still be important to use such a parameter with caution, and make the individual components of it accessible to practitioners as there will always be multiple factors used in the final judgment.



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Structural Benefit/Cost for Drainage (Number and colour code)

Google Earth: Drainage Tab

A new technique for detecting saturation in pavement layers.

Background

A pavement with relatively low water content (high air voids) will experience vertical compression beneath an FWD plate loading and minimal lateral deformation because there are high lateral confining pressures provided by the compacted pavement layers. However, a pavement with high water content (no air voids) is composed only of very low compressibility materials, hence rapid vertical loading test such as the FWD impact applied to a fully saturated pavement, induces deformation but with little net change in overall volume, ie vertical compression that reduces the volume of material beneath the plate must be accompanied by a similar volume change causing bulging of material laterally, beyond the plate perimeter. At the same time pore pressures are transmitted by hydraulic shock, far beyond the plate perimeter in the pavement layers, reducing the effective lateral confining stresses and hence reducing layer moduli.

Test setup

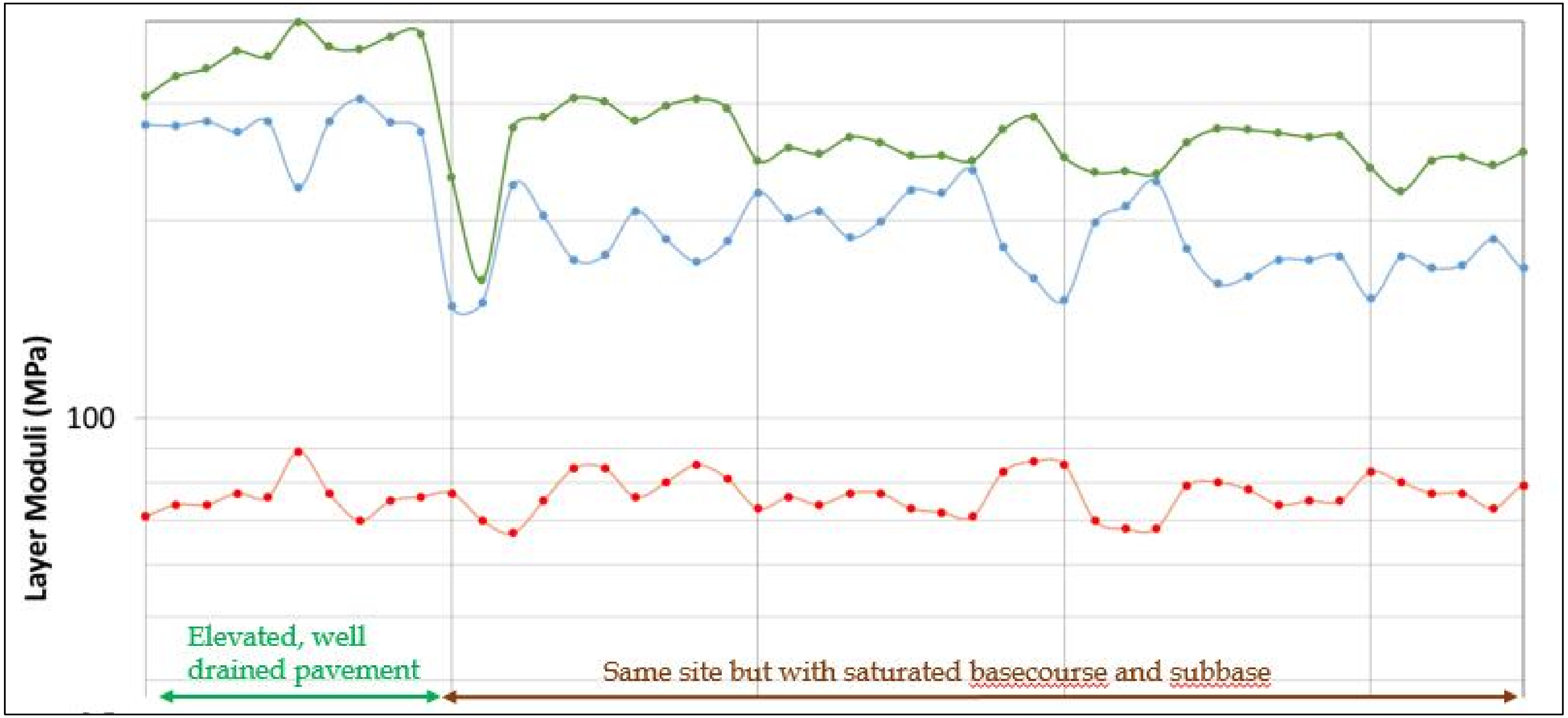
To verify the above, a trial section of chip-seal pavement located in a well drained, elevated location was tested dry with 10 repeated FWD tests applied at the one point. The relative lateral deformation was recorded and very little movement was detected. Then, a ring of holes was drilled through the seal, around the FWD sensors with soakage tubes inserted to saturate the basecourse and subbase layers.

FWD tests numbered 1 to 1.9 on the following diagram were on the dry pavement, 2.0-2.9 after 8 hours of irrigation of the basecourse, then continuing to irrigate before testing again at 3.0-3.9 and 4.0-4.9. After turning off the irrigation, further tests were carried out, numbered from 5.0-5.9

Google Earth: Drainage Tab

Saturation effects.

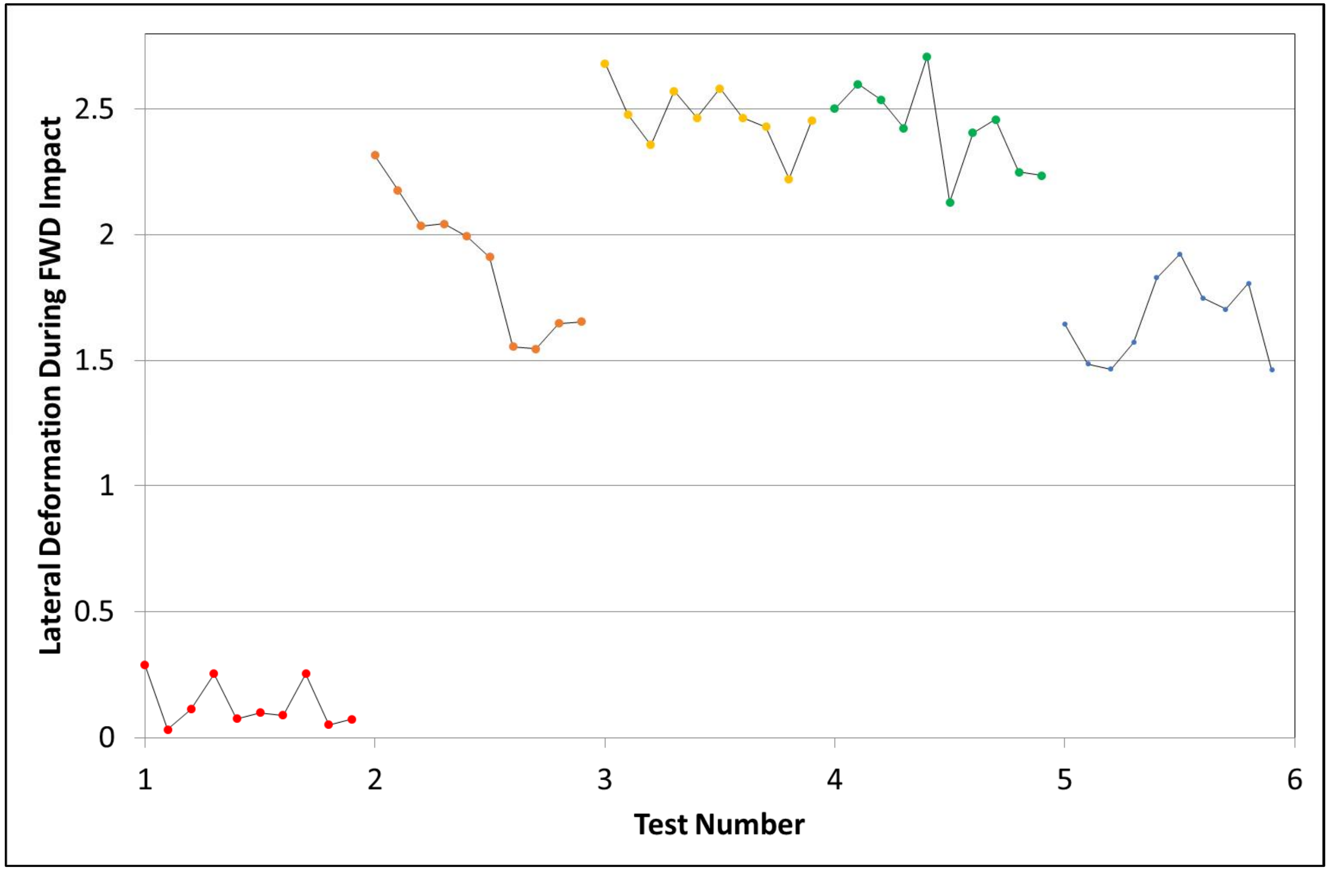
Moduli of the basecourse (green) and subbase (blue) reduced markedly, but the subgrade (red) changed minimally.



Google Earth: Drainage Tab

Saturation effects.

Each set of tests showed that adding water resulted in a marked increase in the amount of lateral deformation that was exhibited during the plate impact.

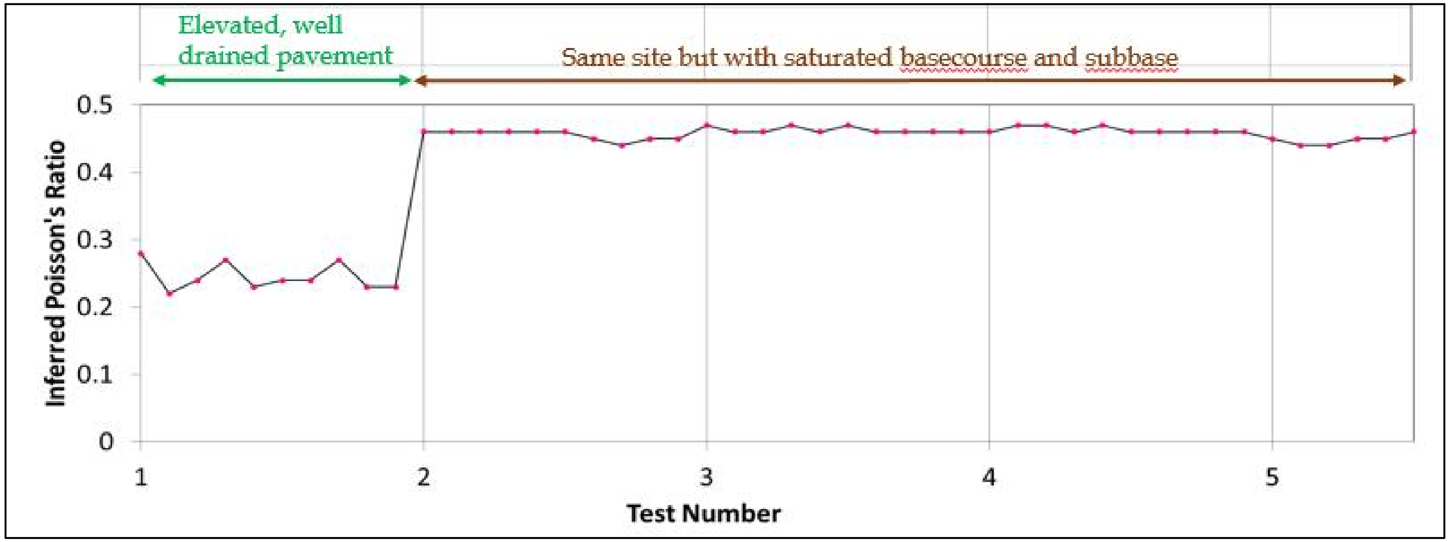


Google Earth: Drainage Tab

Quantifying Saturation:

A tentative correlation has been developed from inspection of the available test data, to provide estimates for degree of saturation and Poissons Ratio. These will require further calibration for refinement of absolute values, but the ability to assess relative saturation for comparisons of pavements with a quantitative, non-destructive test is a significant advance for pavement maintenance

Poisson's Ratio



Google Earth: Drainage Tab

Saturation & Poisson's Ratio

The reason for the ease with which saturation can be detected with the modified FWD test is that the dynamic Poisson's ratio will be high (ie close to the maximum theoretical value of 0.5) when all layers within the influence of the stress bulb are saturated. Conversely if the voids have a low degree of saturation, then Poisson's ratio will tend to be lower, ie about 0.4 for dry cohesive materials, 0.3 for dry granular materials and 0.2 for dry cement bound layers. By observing lateral as well as vertical deformation effects in the full time history of each deflector, any particular type of pavement structure can be evaluated to obtain relative rankings for the Poisson's ratio. At this stage a single value for each test point can be assigned (averaged over all pavement layers). Ongoing studies are in progress to refine this technique, to assess the relative contributions of each layer, and hence identify where the saturation and Poisson's Ratio are highest. Meanwhile the average value for each test point has been added to the FWD parameters used to assess benefits of drainage.

This development, taken in conjunction with the other indicators described, provides a highly effective tool for selecting candidate intervals of each lane that are demonstrably in need of intervention, with the added benefit that focus on priorities will be assured: only those intervals that will definitely benefit from drainage need be targeted, so that reducing budgets can be applied to give increasing levels of service.

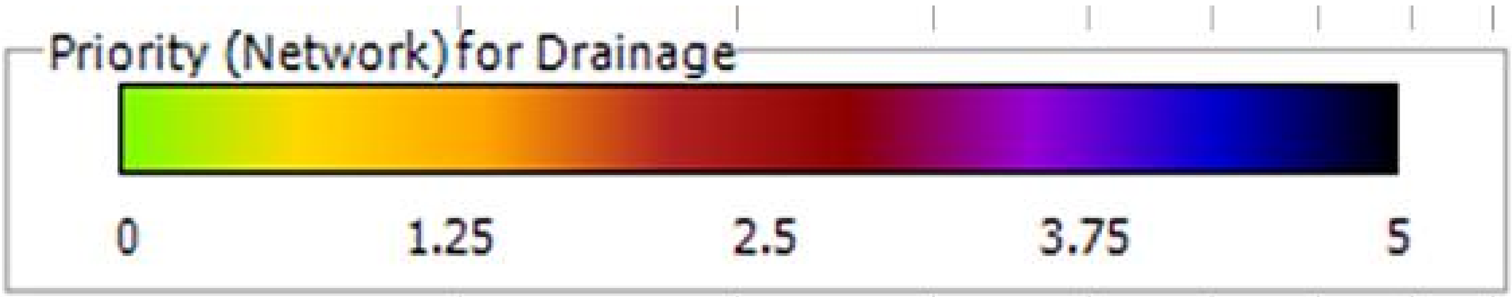
Saturation – combining with other characteristics

A routine has been used to generate a measure (index) of subsurface drainage in terms of both potential for benefit and priority for drainage maintenance. It uses the following indicators which can be deduced from the modified FWD test and supplemented with other RAMM data, finding those points with the most adverse situations. The index is zero for points where drainage would have zero benefit, and increases with:

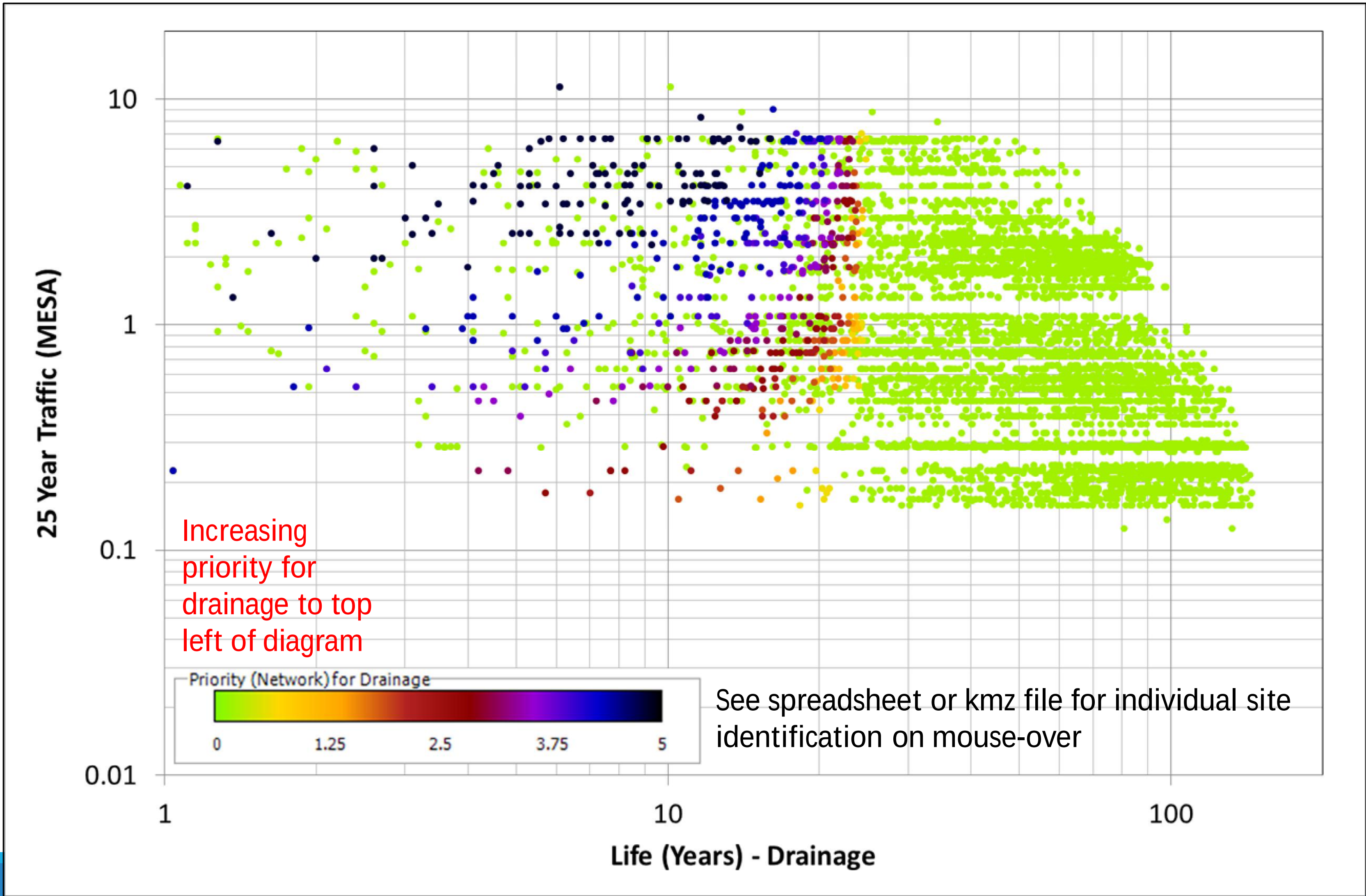
1. Low subgrade modulus (CBR)
2. Marked non-linearity (stress-dependence) of subgrade
3. High lateral deformations under FWD plate impact
4. Rut depth in left wheel path significantly greater than the right.
5. Predicted Life (RPP) less than 25 years (used for priority).
6. Intended design traffic -MESA (used for priority).

The index should of course be used in conjunction with the relevant surface characteristics
Presentation uses colours for ease of implementation –

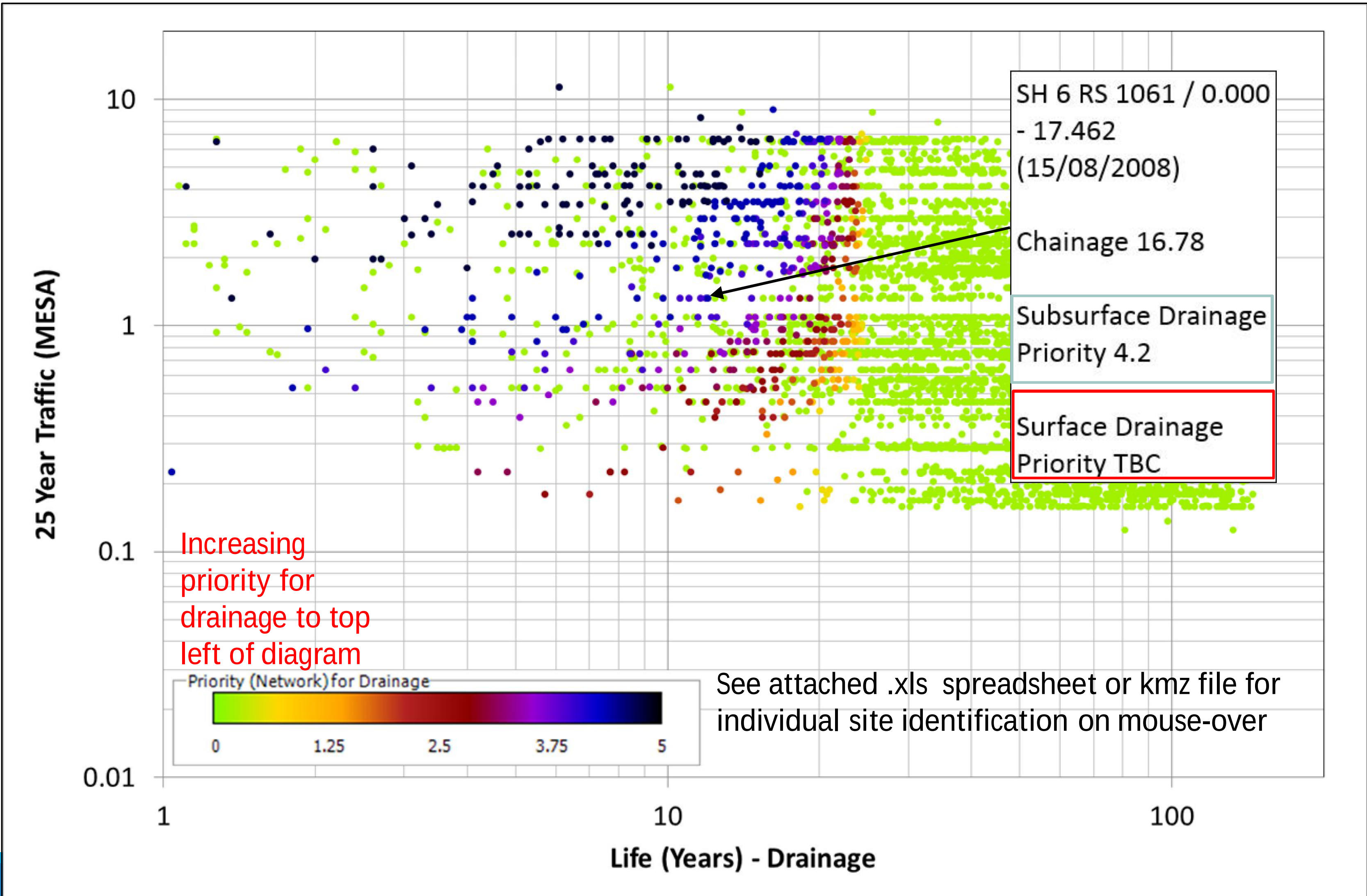
Low High



Presentation of Drainage Priorities -
Traffic versus Predicted Life



Presentation of Drainage Priorities -
Integration of the two systems:
Surface Drainage combined with Subsurface Drainage Priorities



See attached .xls spreadsheet or kmz file for individual site identification on mouse-over

Google Earth: Distress Modes Tab

The second tab is "Distress Modes" and these show visually on a 50 year timescale when each of the six distress types is expected to result in a terminal condition of the pavement at the selected test point. The type which will result in the earliest failure is taken as "Governing Life" parameter, seen at the bottom of the table.

Additionally:
Rutting information for both, the left and right wheel paths, is displayed in the top row.

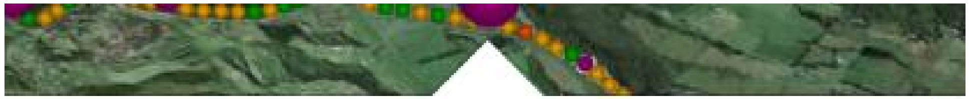
Calibration for each distress mode is required, but the relativity should still give an appreciation of comparative performance of different parts of the network.

Google Earth: HPMV Tab

Recent studies of networks throughout NZ have led to rational means of assessing appropriate values of the load damage exponent for each FWD test point. Regional calibration is required, but relative performance can be used in the interim.

The pavement life (CMP) is presented for the current traffic and an alternative life is indicated in the event that HPMV individual axle loads are increased by 10 percent (CMP+10%).

This provides an immediate appreciation of the risk of disproportionate damage in the event that this order of axle load increment is applied. Proportionate damage can be assessed for other increments.



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002-0562/11.2 Lane L1

Treatment Length: 11.030 - 12.101

Date of Structural Testing: 31/07/2007
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Drainage | Distress Modes | HPMV | Treatment Length Plot

Load Damage Exponent	10
Current Traffic (MESA/Lane/25 Years)	1.7
Pavement Life - Current (years)	2
Pavement Life with x 1.1 Axle Load	1
Cumulative Damage Factor $CDF_{CMP+10\%}$	36
Inferred Pavement Condition	0%

Risk Presented by HPMV Loads:
Low Medium High

Google Earth: Patching Tab

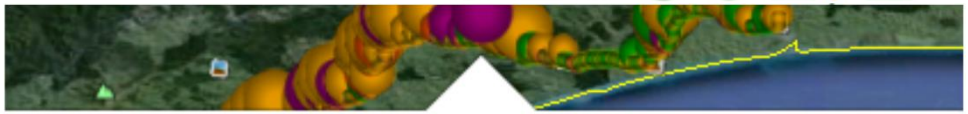
This tab provides relevant parameters for alternative forms of patching or widening with provisional designs for alternative forms of treatment, that will allow the finished surface to be maintained at the same level.

1. Digout/ (or Widening) Depth (II)

The initial minimum depth that excavation should be taken to if full depth unbound granular replacement is planned.

2. CBR Reconstruction (CBR)

The expected in situ CBR at the nominated Digout Depth, that should then be verified by Scala, prior to backfilling. (If Scala is less than expected, then deeper digout is required.)



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002-0562/11.2 Lane L1

Treatment Length: 11.030 - 12.101

Date of Structural Testing: 31/07/2007
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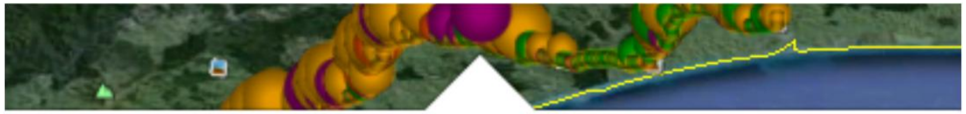
Drainage | Distress Modes | HPMV | Patching | Treatment Length Plot

Digout (or Widening) Depth (mm)	750
CBR (%)	2.7
Cement Stabilised Depth (mm)	350
FBS Depth (mm)	N/A
NOTE: Stabilisation greater than 300mm requires an alternative solution.	

Google Earth: Patching Tab

3. Cement Stabilised Depth (ID)
If this value is less than about 250-300 mm, cement stabilisation should be viable. If not, another option should be selected.

4. FBS Depth (IE)
As above but for foamed bitumen stabilisation. These depth estimates are provisional from the NZ models (NZTA RR461).



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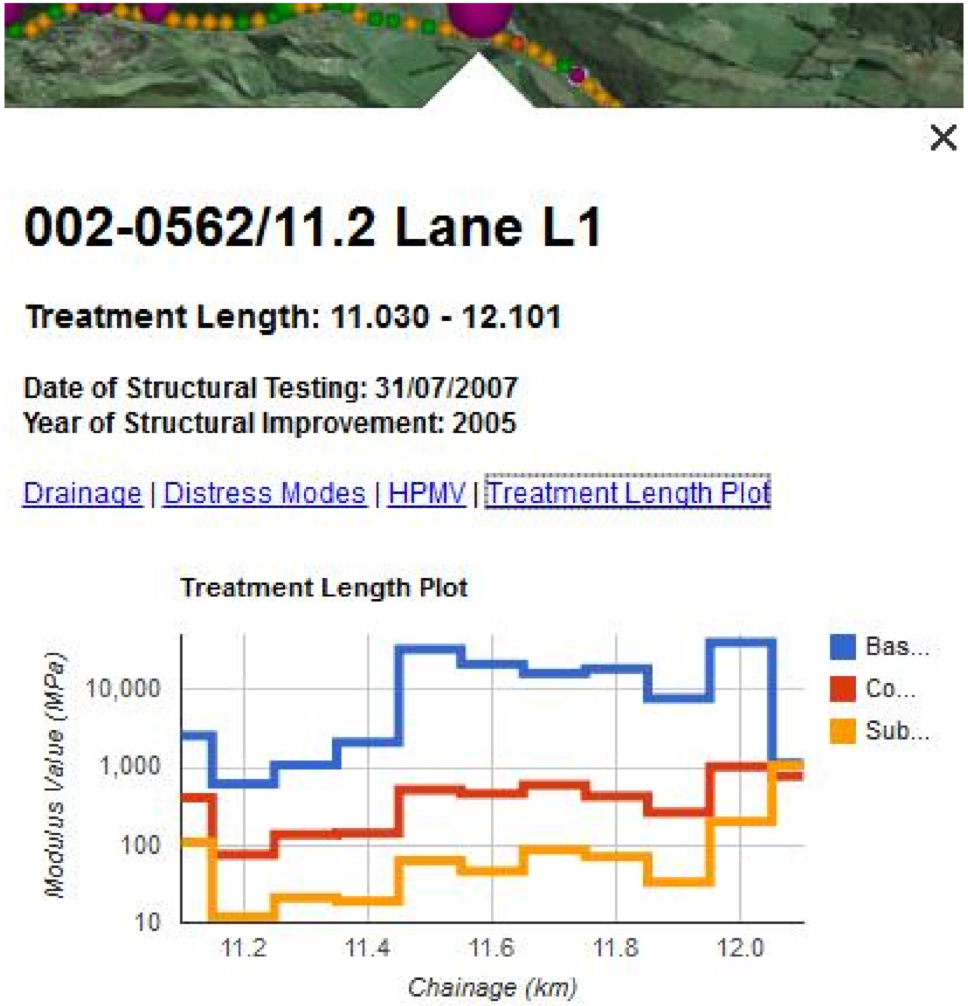
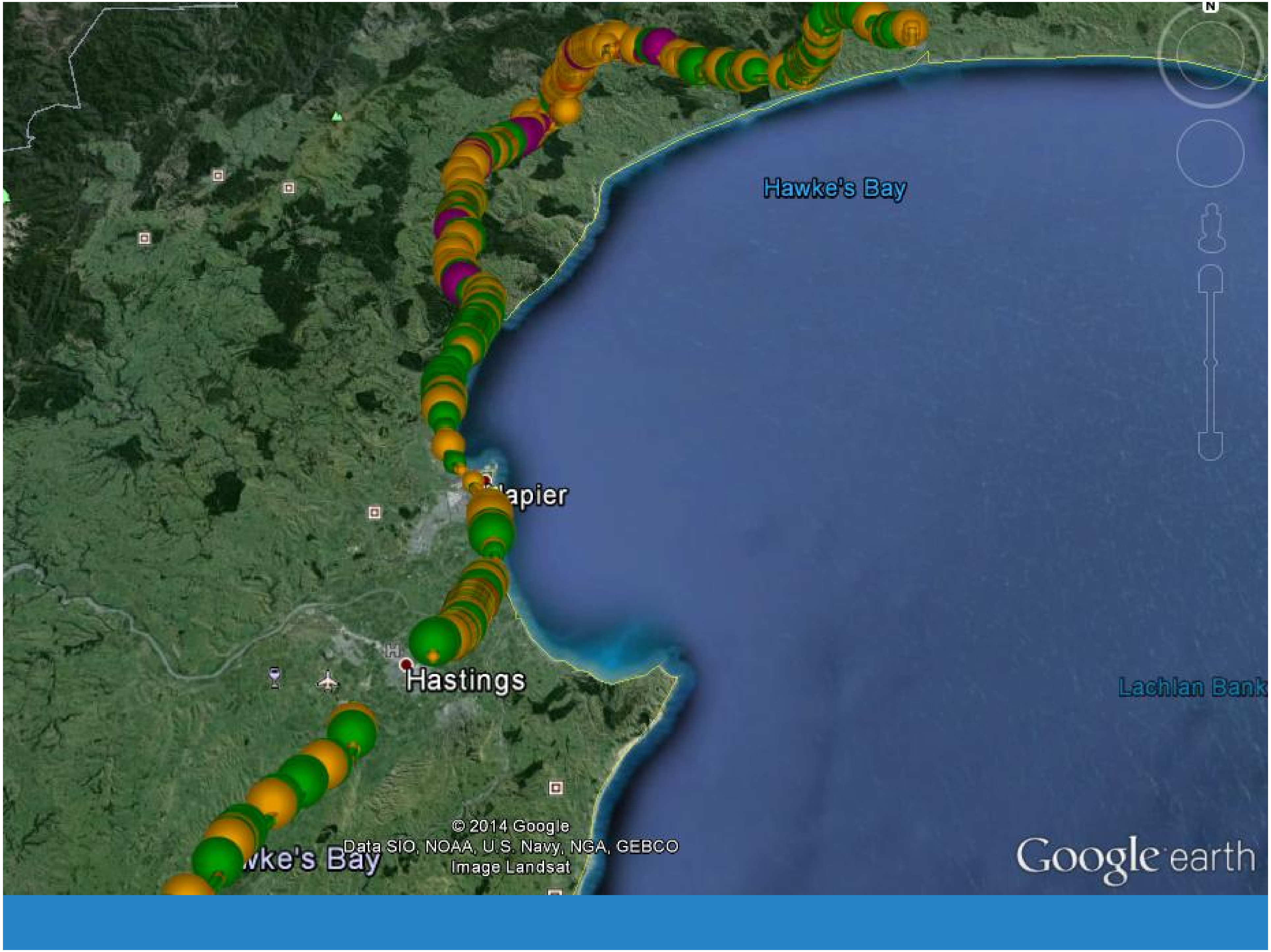
Google Earth: Treatment Length Plot Tab

The final tab shows a plot of the modulus values for the basecourse and subgrade layers – as well as the “composite modulus” – related to chainage over the entire treatment length to which the selected test point belongs.

In order to provide a continuous plot the measured values are shown extending to the halfway point between each test point, resulting in the square wave graph seen on the right.

Additional Tabs can soon be generated to show file data for test pits plus their locations or any other RAMM fields.

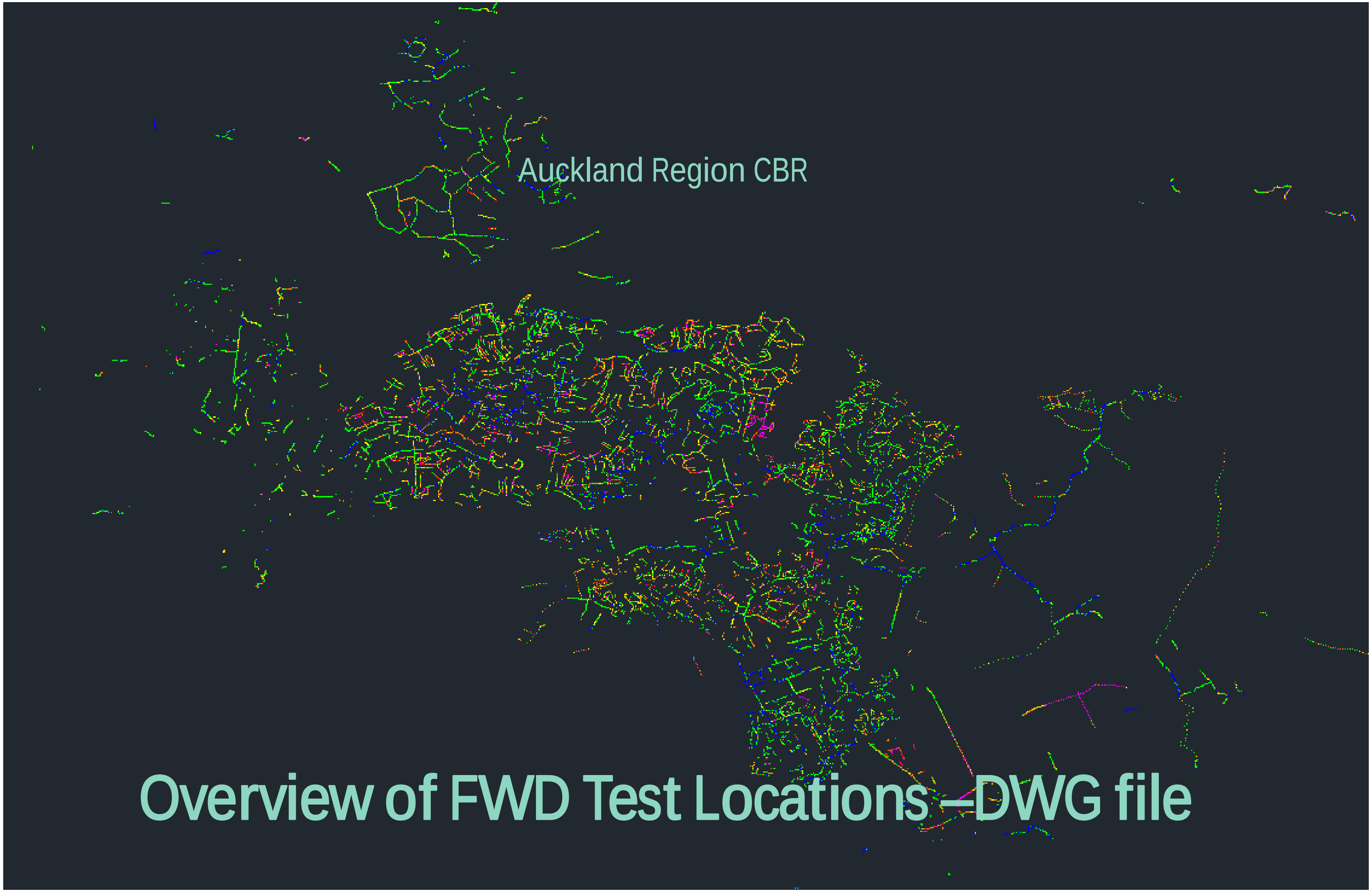


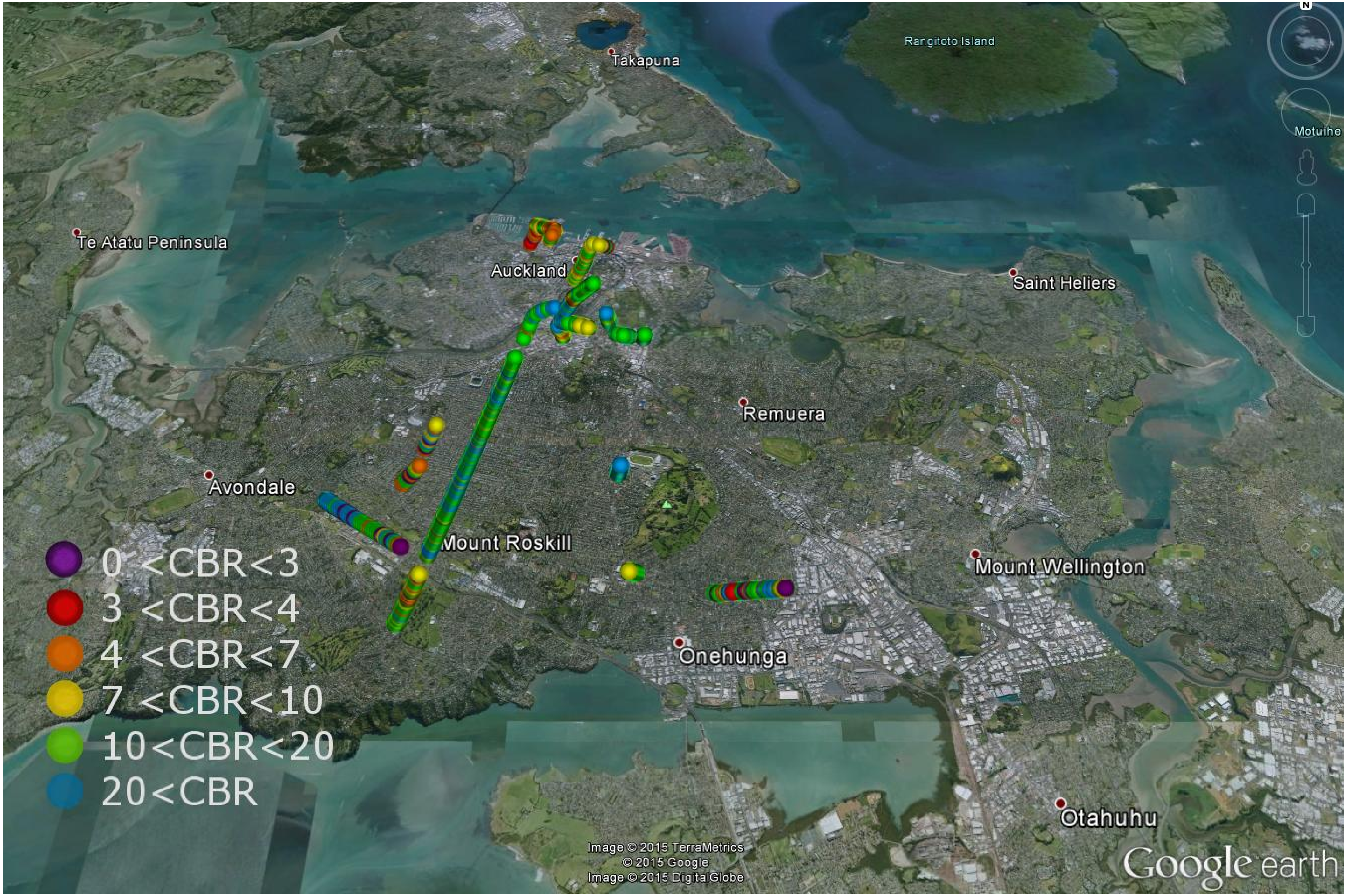

Hawke's Bay
Napier
Hastings
Lachlan Bank
wke's Bay
© 2014 Google
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image Landsat
Google earth

Custom Formats

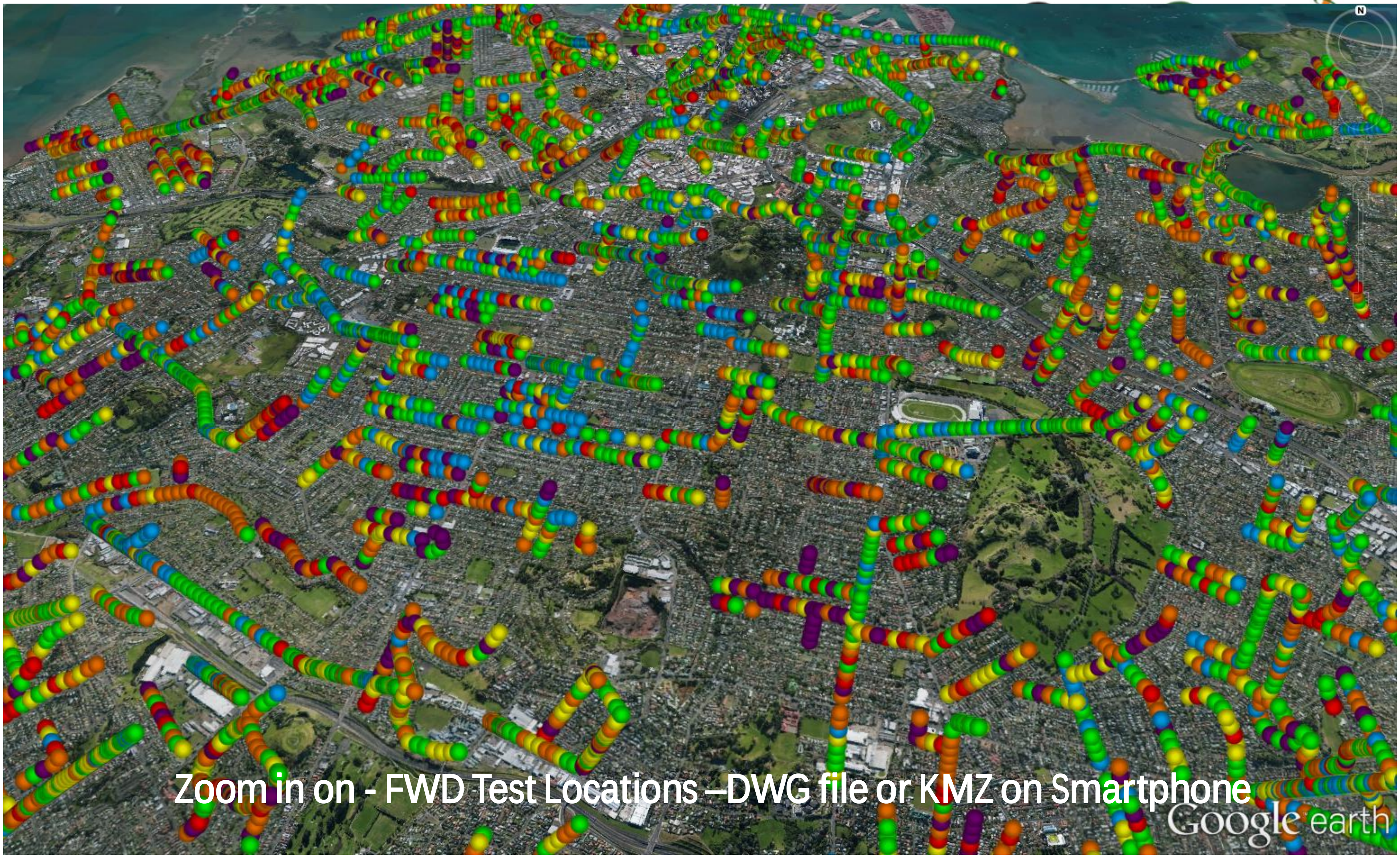
EXAMPLE: CBR

Estimated from 0.1*subgrade modulus (MPa), and can also add the depth at which this is measured by the FWD


Auckland Region CBR
Overview of FWD Test Locations –DWG file



Selected by road - FWD Test Locations –DWG file


Zoom in on - FWD Test Locations –DWG file or KMZ on Smartphone
Google earth

KMZ (Google Earth) format

CBR indicated by colour:

- >=0: Purple
- >=3: Red
- >=4: Orange
- >=7: Yellow
- >=10: Green
- >=20: Light Blue

Additional information by clicking on data point

Customised for a large range of raw or interpreted parameters