ANNUAL SUMMARY REPORT

Implementation of Intelligent Compaction in Queensland
(Year 2 – 2019–20)

ARRB Project No.: 014961

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17/11/2020

AN INITIATIVE BY:

SUMMARY

Intelligent compaction (IC) can provide important and immediate roller operating parameters to the operator (in the form of a visual map) to ensure that pavement layers and earthworks are compacted uniformly and in accordance with appropriate standards. IC data can also be uploaded and stored online for archiving and remote-monitoring purposes. Over the last decade, this technology has gained popularity around the world and has been shown to improve construction quality and productivity.

This project commenced in the 2018–19 financial year to facilitate the implementation of IC technology in Queensland. A comprehensive literature review was undertaken during the first year to evaluate the potential benefits of such technology for the Queensland Department of Transport and Main Roads and the wider road construction industry.

This report is a summary of the activities undertaken during year two (2019–20) . Year 2 focused on the development of a pilot project-specific technical specification for use in demonstration trials. The specification was successfully trialled on the Ipswich Motorway Upgrade Stage 1 (Rocklea to Darra) project. The IC technology was trialled on different materials compacted as part of the project including embankment fill, subgrade, cement modified base and unbound granular base.

It was found that IC technology can readily identify soft areas in a pavement or embankment and can also be used to improve the uniformity of the compacted layers. The study showed that the Compaction Meter Value (CMV) has varying degrees of correlation against the in situ stiffness (measured by a light weight deflectometer) and conventional density results (measured by a nuclear density gauge). It was also noted that the CMV is sensitive to in situ moisture conditions during construction.

It was realised early in the project that there will be significant learning required for the industry to become familiar with IC technology and to incorporate it into construction practices. Towards the end of this year’s project, the team delivered an online webinar to disseminate the results from the demonstration trial. AAPA also delivered a virtual masterclass, providing additional training on the use of the latest IC data management software, Veta 6.0. Finally, the project has funded Veta 6.0 to support the latest GDA2020 system which will soon be the main cadastral grid to be used across different jurisdictions in Australia.

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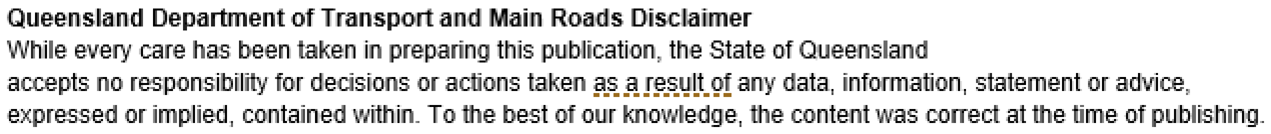

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ACKNOWLEDGEMENTS

The project team appreciates the site support provided by the construction team at the Ipswich Motorway Upgrade Stage 1 (Rocklea to Darra) project.

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1 INTRODUCTION

1.1 BACKGROUND

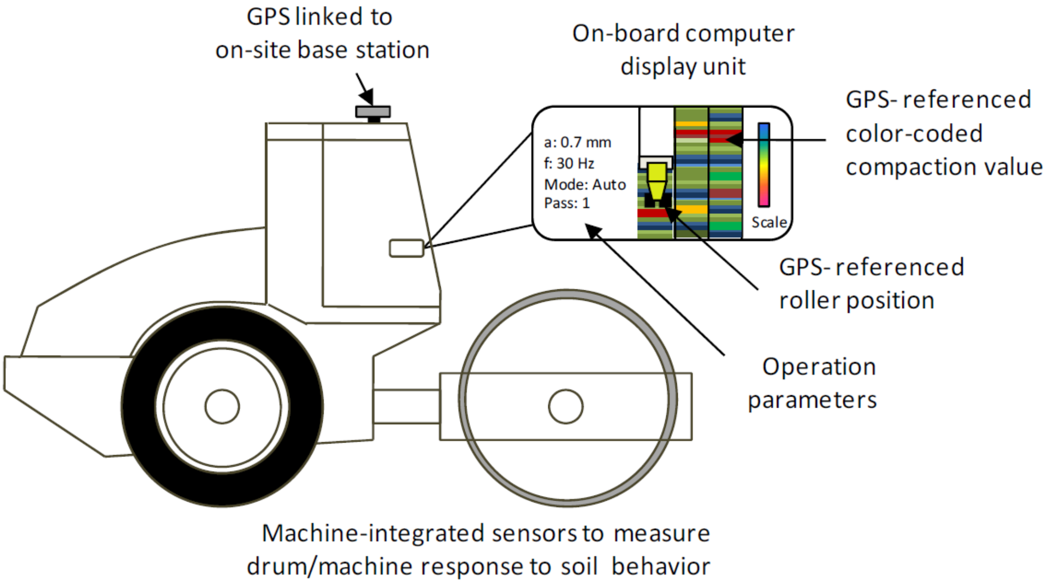
The use of conventional compaction methods and quality control (QC) procedures can result in under-compacted or over-compacted materials, which may result in excessive differential settlement and/or poor long-term pavement performance. To confirm adequate compaction has been achieved, in situ spot tests are generally carried out post-compaction using light weight deflectometer (LWD), dynamic cone penetrometer (DCP), nuclear moisture-density gauge (NG), sand replacement measurement, falling weight deflectometer (FWD), or static plate loading tests (PLT). However, in situ spot tests are limited and take place at random locations. As a result, the tests do not necessarily represent the entire pavement area (Kumar et al. 2016). Furthermore, uniform compaction may not be easily achieved because the operator does not receive live feedback of the material's response or compaction level.

According to Mooney et al. (2010) and Gallivan, Chang, and Horan (2011), the devices currently used for quality control and quality assurance testing (i.e. spot testing) are typically used to assess less than 1% of the actual compacted area. Correia and Parente (2014) also pointed out that the limited in situ testing carried out during conventional QC and quality assurance (QA) processes may be insufficient for the appropriate QC of road construction. This issue can potentially be addressed using intelligent compaction (IC) technology that can provide a more comprehensive assessment of the level of compaction achieved during construction.

It should be noted that there was not a unified definition of intelligent compaction in the literature reviewed. Mooney et al. (2010) defined intelligent soil compaction systems as systems that can continuously assess the mechanical soil properties by monitoring roller vibration, real-time adjustment of roller settings, including a global positioning system (GPS) to provide a complete geographic information-based compaction record of the site. Correia and Parente (2014) stated that IC is a real-time automatic adjustment and continuous compaction control technology for geomaterials or asphalt. However, in other literature, roller-integrated systems that can provide continuous compaction control (CCC) are considered to be IC systems (e.g. Cai et al. 2017; Hossain et al. 2006; Mooney & Adam 2007; White et al. 2009). The latter definition is adopted in this report.

An IC system typically includes a single drum roller, an accelerometer mounted on the drum, an integrated roller measurement system, and a GPS receiver/base station. Figure 1.1 shows a typical IC system.

Figure 1.1 Overview of Intelligent Compaction Measurement Value (CMV) compaction monitoring system



Source: *Chang et al. (2011).*

The number of roller passes, the drum acceleration, velocity, and amplitude can be recorded continuously with the measurement system. The collected information can then be interpreted as intelligent compaction measurement values ICMVs to assess the level of compaction achieved. Based on the modulus reported by the measurement system, optimisation of the compaction process can be achieved by the roller operator by ensuring that the ICMVs achieved are equal to or greater than a predetermined threshold value. This process is recognised as CCC.

Also, there is an automatic feedback control system that uses the information collected by the measurement system to adapt the equipment performance continuously and automatically to optimise the compaction effort and meet the required conditions. This system automatically adjusts the compaction parameters for the roller such as the drum vibration amplitude, frequency and the roller operating speed (impact distance) to optimise compaction.

1.2 SCOPE OF PROJECT

This project commenced in the 2018–19 financial year to explore and facilitate the implementation of IC technology in Queensland. A comprehensive literature review was undertaken during the first year to evaluate the potential benefits of IC technology to TMR. The literature review was documented in the following two separate reports:

- *Implementing Intelligent Compaction Technology for Use in Queensland (Year 1 – 2018–19) for Earth Fill, Granular and Stabilised Materials* (Fatahi et al. 2019).
- *Implementing Intelligent Compaction Technology for Use in Queensland (Year 1 – 2018–19) for Asphalt Applications* (Zargar & Lee 2019).

The above reports present a summary of the background and history of IC, followed by an introduction to IC instrumentation systems, including the benefits and disadvantages of the technology. A summary of existing IC specifications adopted in Europe and the USA is also presented, which may serve as references for the development of Australian specifications on the use of IC.

An Intelligent Compaction Data Management workshop was also undertaken with a recognised international expert in IC technology in year one.

Year two of the project focused on stakeholder engagement and the development of a pilot specification for the use of the technology on TMR projects. The main tasks completed in year two were:

- stakeholder engagement (both internal TMR and external)
- the development of a pilot specification for use on demonstration trials
- a field demonstration trial
- knowledge transfer activities
- the preparation of an annual summary report.

1.3 REPORT STRUCTURE

The Introduction is followed by the discussion in Section 2 of the development of a pilot trial specification for use in a major TMR project. Section 3 presents the results collected during 2019–20 from the Ipswich Motorway Upgrade project. A number of knowledge transfer activities were undertaken in the second half of this project and are outlined in Section 4. In anticipation of the introduction of GDA2020 by TMR, the project has engaged the software developer of Veta to provide the support for the GDA2020 coordinate system and is presented in Section 5. Section 6 presents the conclusions and recommendations.

2 THE DEVELOPMENT OF A TECHNICAL SPECIFICATION FOR IC

2.1 STAKEHOLDER ENGAGEMENT

Improvements in construction processes, which include the placement and compaction of pavement and subgrade materials, will generally lead to a more durable and resilient road infrastructure. IC technology can be used on a range of road-building materials and, to explore the full implications of adopting this technology, the project team has conducted multiple meetings at the start of the project with multiple TMR representatives to discuss the benefits, construction implications, potential roadblocks, and implementation strategy.

The internal stakeholder meetings identified the need to have a draft technical specification that can be used on TMR projects to trial the IC technology. This led to the development of project-specific technical specification 116 *Intelligent Compaction – Earthworks and Pavements* (PSTS116) as discussed in Section 2.2.

Other than discussions with internal TMR stakeholders, it has also been identified that the department needed an appreciation of the availability of the IC equipment in Australia and more specifically in Queensland. Subsequently, informal discussions were held with the following industry representatives:

- roller equipment manufacturers
- equipment hiring companies
- suppliers of GPS surveying equipment and IC retrofit kits.

At this stage, there are a limited number of compaction rollers in Australia that are already fitted with IC technology. However, existing rollers can be retrofitted with IC systems. IC retrofit kits are available directly from suppliers, and there are also a limited number of rollers that have been retrofitted with IC technology available for hire from equipment hiring companies.

2.2 DEVELOPMENT OF PROJECT-SPECIFIC TECHNICAL SPECIFICATION (PSTS116)

As mentioned in Section 2.1, a project-specific technical specification (PSTS116) was developed for the implementation of IC trials in Queensland. This specification is intended to be used for the compaction of earthworks, unbound and stabilised pavement layers, but excludes asphalt layers and sprayed bituminous seals. A copy of PSTS116 is included in Appendix A .

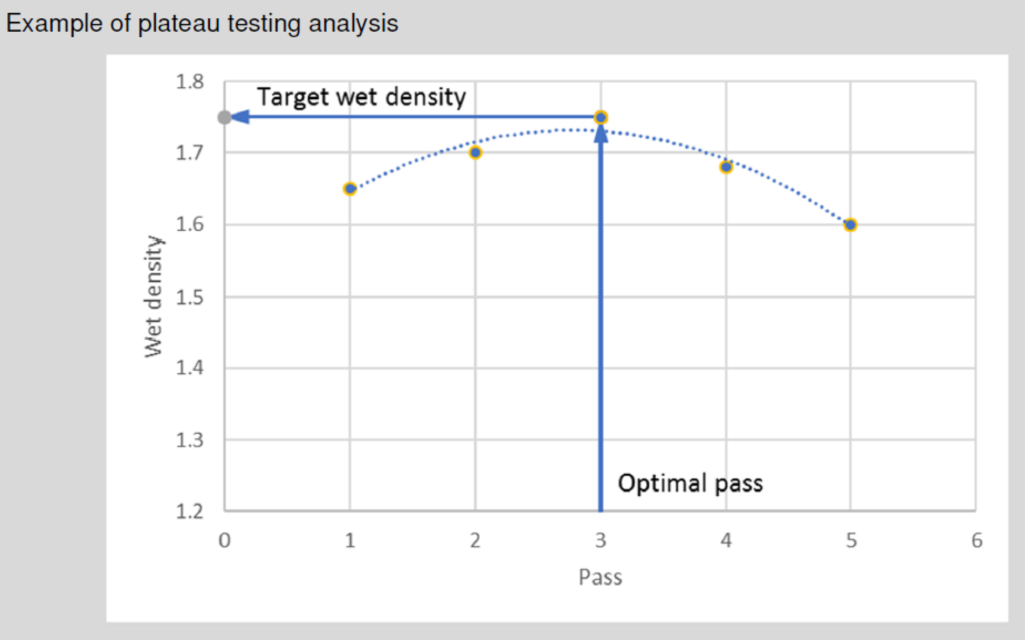
PSTS116 refers to several current standard TMR specifications, and covers the following key aspects:

- definition of terms
- hold points and witness points
- IC equipment requirements
- pre-mapping of underlying layers
- a procedure to determine target ICMVs and reporting of the IC data.

The specification includes two analysis procedures to assist the roller operator to determine the optimum number of roller passes and the target ICMV. The ‘plateau analysis’ procedure shown in Figure 2.1 determines the optimum number of passes to meet the minimum target wet density specified for compaction.

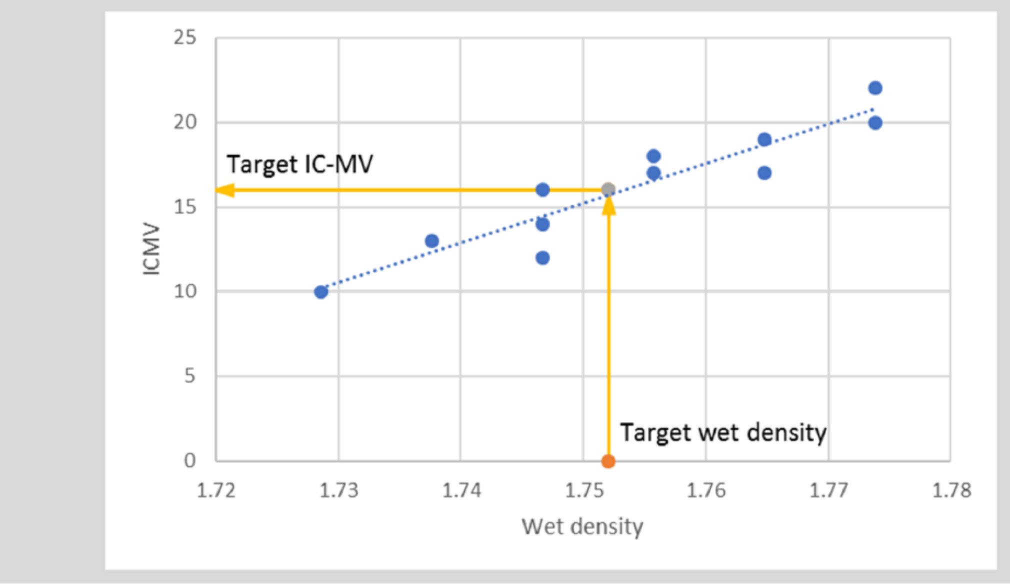
The optimal number of passes is when the target wet density reaches the peak of the stiffness or density results. ‘Over-compaction’ can occur if an excessive number of roller passes were applied, which will be evident through a drop in stiffness or in situ density past the optimal number of passes.

Figure 2.1 Illustration of the plateau testing analysis referenced in PSTS116



The specification also provides a procedure to determine a target ICMV for a particular material type. It should be noted that the construction condition (e.g. moisture condition and layer thickness) used in the trial should reflect the production. The target ICMV can be determined by plotting the in situ stiffness or density values against the ICMV measured from the IC roller. When the coefficient of determination (R^2) value of the linear regression is greater than 0.5, the target ICMV would be the value corresponding to the target wet density on the correlation chart (Figure 2.2).

Figure 2.2 Illustration of the target ICMV analysis referenced in PSTS116



3 DEMONSTRATION TRIAL – IPSWICH MOTORWAY UPGRADE

With the internal release of PSTS116, a demonstration trial was undertaken on the Ipswich Motorway Upgrade: Rocklea to Darra – Stage 1 (R2D) project. The project is an urban highway upgrade located near Oxley in Brisbane and comprised the following:

- a new Granard Road interchange just east of the Oxley Road roundabout
- upgrading the existing motorway to 6 lanes (3 lanes in each direction), widening the road shoulders, and reducing the number of entry/exit ramps
- increasing the flood immunity over Oxley Creek
- construction of new service road connections over Oxley Creek and Boundary Road Connection
- improved cycle and pedestrian facilities.

The objective of the trial was to use IC technology in accordance with PSTS116 on a major TMR project. The experience gained will assist TMR to evaluate the benefit of the technology as well as formulating future implementation strategies. The demonstration trial undertook additional side-by-side compaction testing using IC technology and these additional testing did not change the QA requirements originally nominated in the project contract documents.

3.1 IC RETROFIT VIBRATORY ROLLER

The construction team used a range of rollers and since none of the on-site rollers were fitted with an IC system, several equipment hiring options were explored to implement IC technology on the project. The Trimble IC retrofit kit was selected and the system was fitted onto a Dynapac smooth drum roller (Model CA512D) with an operating mass of 15.6 tonnes. The IC retrofit kit (shown in Figure 3.1), comprised of an onboard display tablet and a GPS antenna which can be easily dismounted daily.

The other part of the IC retrofit kit which is permanently installed on the roller is an accelerometer mounted on a bracket on the drum rotating axle as shown in Figure 3.2. The accelerometer measures the one-dimensional acceleration of the drum and the signal is processed by the onboard tablet and provides instantaneous visual feedbacks (e.g. number of passes, CMV, speed, vibration amplitude, and vibration frequency) to the roller operator.

Figure 3.1 A Trimble intelligent compaction retrofit kit

Figure 3.2 An accelerometer installation on the IC roller used in the compaction auditing trial

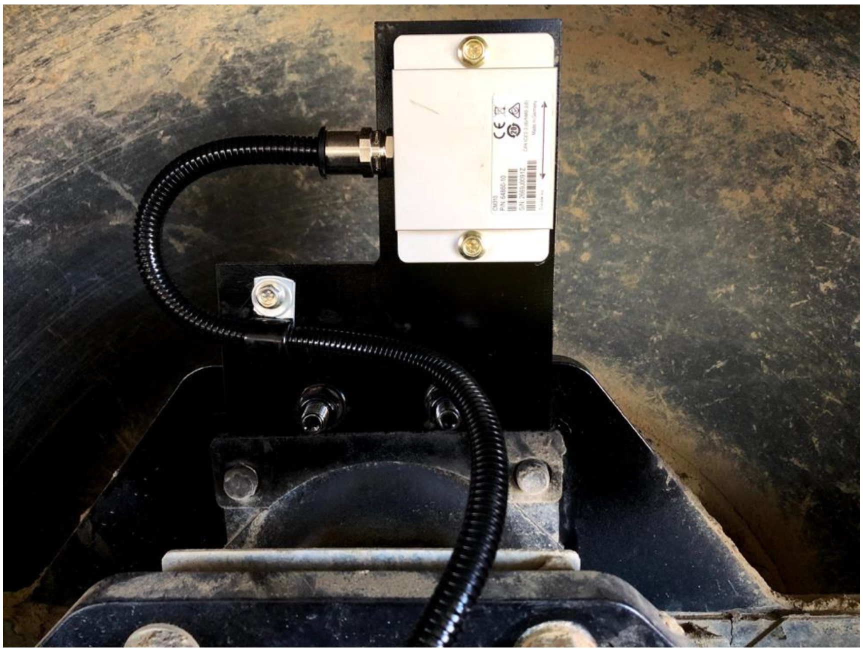


Figure 3.3 shows the Dynapac roller with the Trimble IC retrofit kit undertaking the final roller pass collecting CMV and a typical CMV output screen is shown in Figure 3.4. The data collected from the onboard Trimble tablet are uploaded directly to the Trimble Visionlink server and can be exported to a format suitable for direct import into the VETA software developed by the Transtec Group for the analysis of IC data.

Figure 3.3 A Dynapac smooth drum roller installed with IC technology

Figure 3.4 Operator view of the Trimble tablet showing a CMV map of a recent compacted area

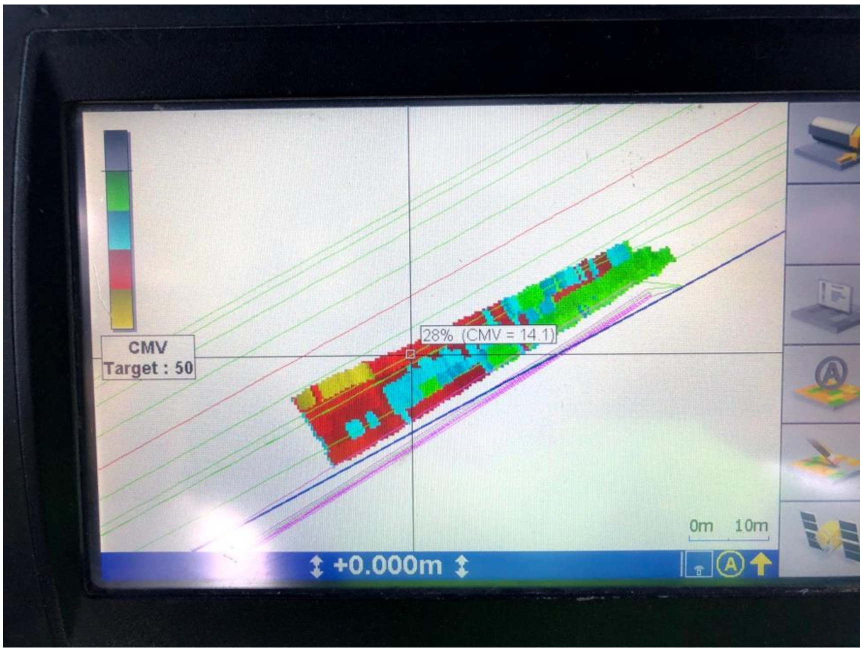
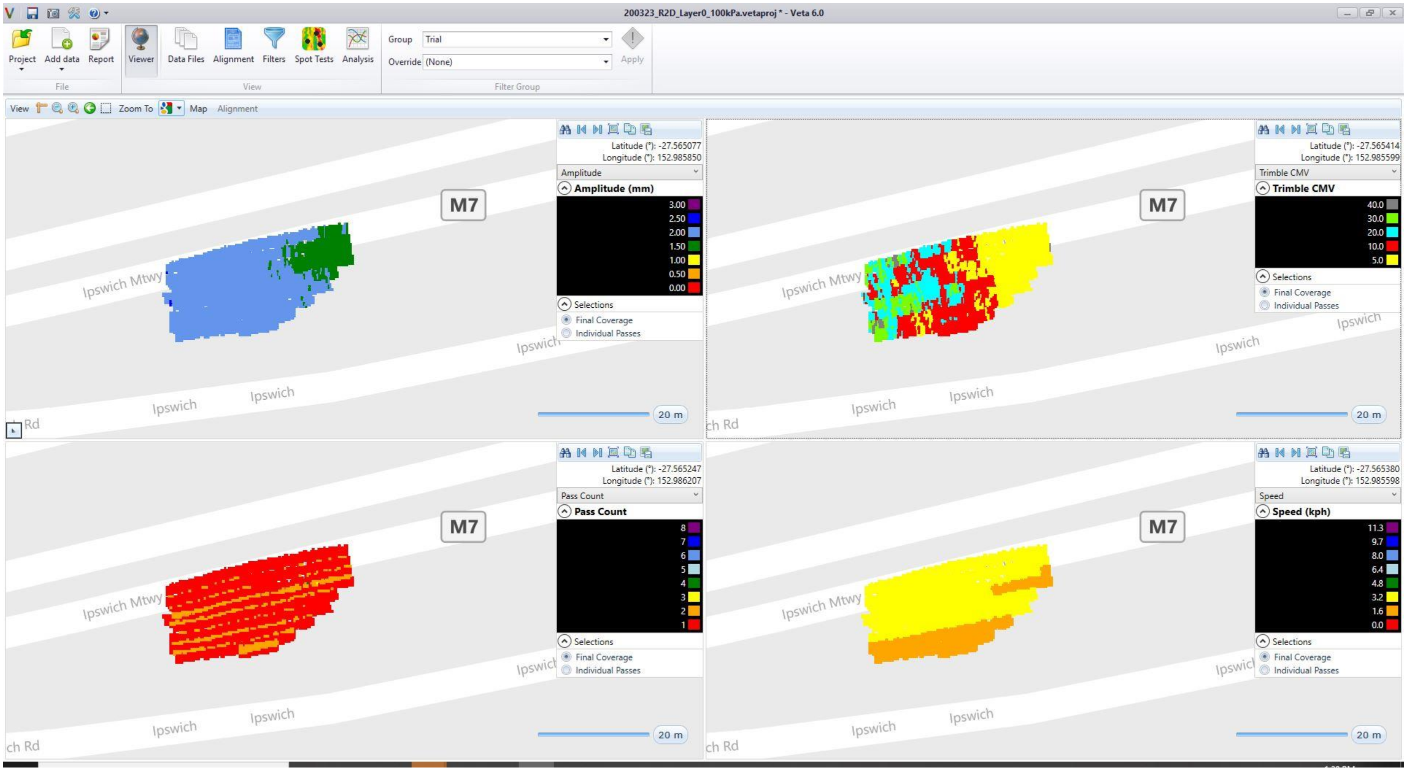


Figure 3.5 is a screenshot from the VETA 6 software used to display and analyse the IC data. This simultaneously shows the amplitude, pass count, ICMV and roller speed.

Figure 3.5 Veta plots for IC pre-mapping of an embankment fill area on 23 March 2020



200323_R2D_Layer0_100kPa.vetaproj * - Veta 6.0

Group: Trial

Override: (None)

3.2 LAYOUT OF TEST SITES AT R2D

In this year of the project, only a limited number of areas were tested as part of the demonstration trial due to limited access as a result of the construction program. Additional data are expected to become available as the project continues throughout 2020–21.

The approximate locations of the test sites evaluated between March and June 2020 are shown in Figure 3.6. In general, the IC evaluation comprised the following material:

- embankment fill
- subgrade
- plant mixed cement modified material
- unbound granular base material.

Figure 3.6 Test site locations

Source: Google Map 2020, ‘Australia, Queensland, Oxley, image, map data: DigitalGlobe, Google, CA, USA, viewed on 11 November 2020, https://goo.gl/maps/EGkg1k3wXSaMA4cw5

3.3 IC RESULTS

3.3.1 IDENTIFICATION OF SOFT AREAS

The longevity of road infrastructure relies on properly compacted materials from the embankment fill, subgrade, and different pavement layers up to the final pavement surface where the wheel load is directly applied. It is therefore essential that unform compaction is achieved and any soft areas (indicative of poor compaction or low-strength materials) are removed before placing the next layer. Soft areas are often identified during construction using proof rolling, whereby a loaded vehicle (typically a water truck) is used to visually assess the stability of the underlying material. However, this process can be subjective and open to different interpretations (and in some instances may lead to disputes on site). IC technology is a very good replacement for traditional proof rolling due to its ability to measure the stiffness of the underlying materials.

Figure 3.7 shows an area of subgrade material being proof rolled using an IC roller in the demonstration trial. The subgrade was first trimmed to level, and the smooth drum roller applied a low amplitude vibration of the trimmed surface. As shown in the figure, a weak area (with a CMV between 5 and 20) was identified which corresponded to a wet area where a water truck just ran over.

This observation also illustrates that the moisture content of the material being compacted can have a significant effect on the measured CMV.

Figure 3.7 Pre-mapping of the subgrade area on 9 April 2020 showing the variation of CMV with moisture

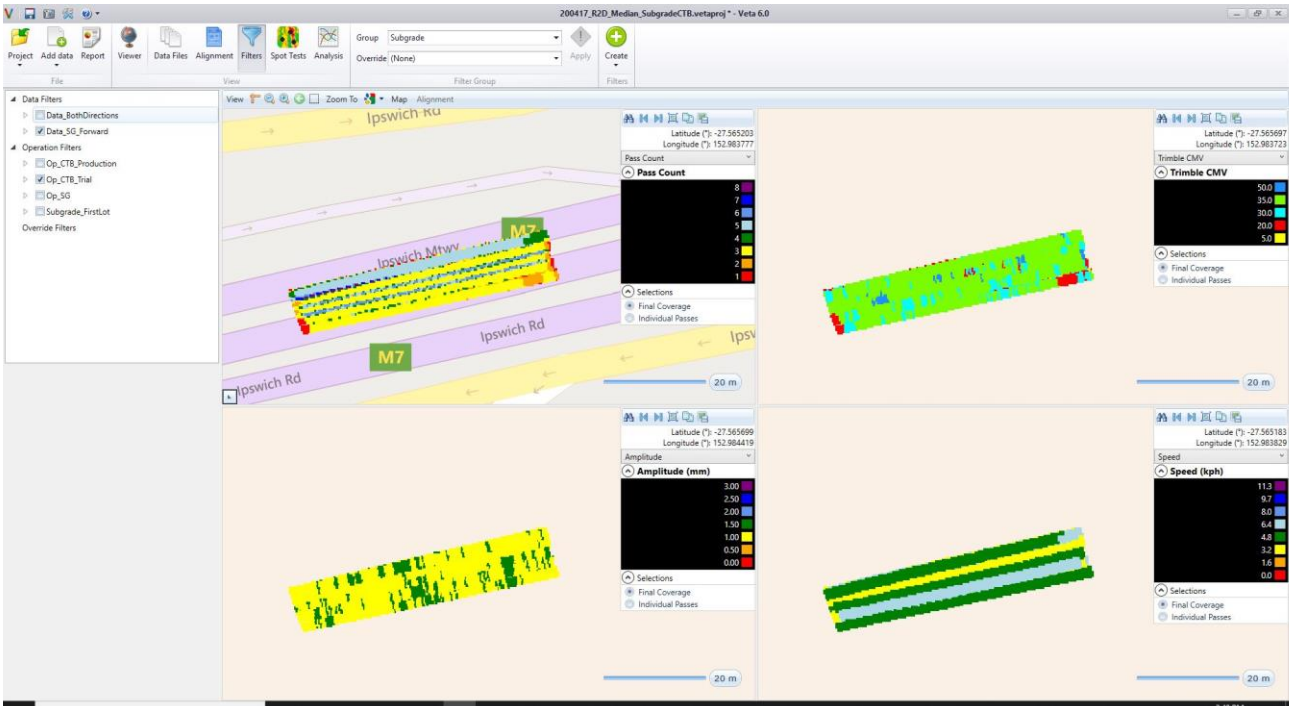
This observation also illustrates that the moisture content of the material being compacted can have a significant effect on the measured CMV.

Figure 3.8 shows another section of the subgrade that was proof rolled with the IC roller along the mainline adjacent to the previous test section. The CMV plot shown in Figure 3.9 confirmed that most of the area has an acceptable CMV over 35 and now soft spots were identified.

It should be noted that the IC roller was operated in the vibratory mode while moving forward to improve the accuracy of the CMV measurements.

Figure 3.8 A subgrade area ready for IC pre-mapping

Figure 3.9 Veta plots for IC pre-mapping of a subgrade area on 16 April 2020


200417_R2D_Median_SubgradeCTB.vetaproj * - Veta 6.0

Group: Subgrade
Override: (None)

- Data Filters
  - ☐ Data_BothDirections
  - ☑ Data_SG_Forward
- Operation Filters
  - ☐ Op_CTB_Production
  - ☑ Op_CTB_Trial
  - ☐ Op_SG
  - ☐ Subgrade_FirstLot
- Override Filters

Latitude (°): -27.565203
Longitude (°): 152.983777
Pass Count

Latitude (°): -27.565697
Longitude (°): 152.983723
Trimble CMV

Latitude (°): -27.565699
Longitude (°): 152.984419
Amplitude

Latitude (°): -27.565183
Longitude (°): 152.983829
Speed

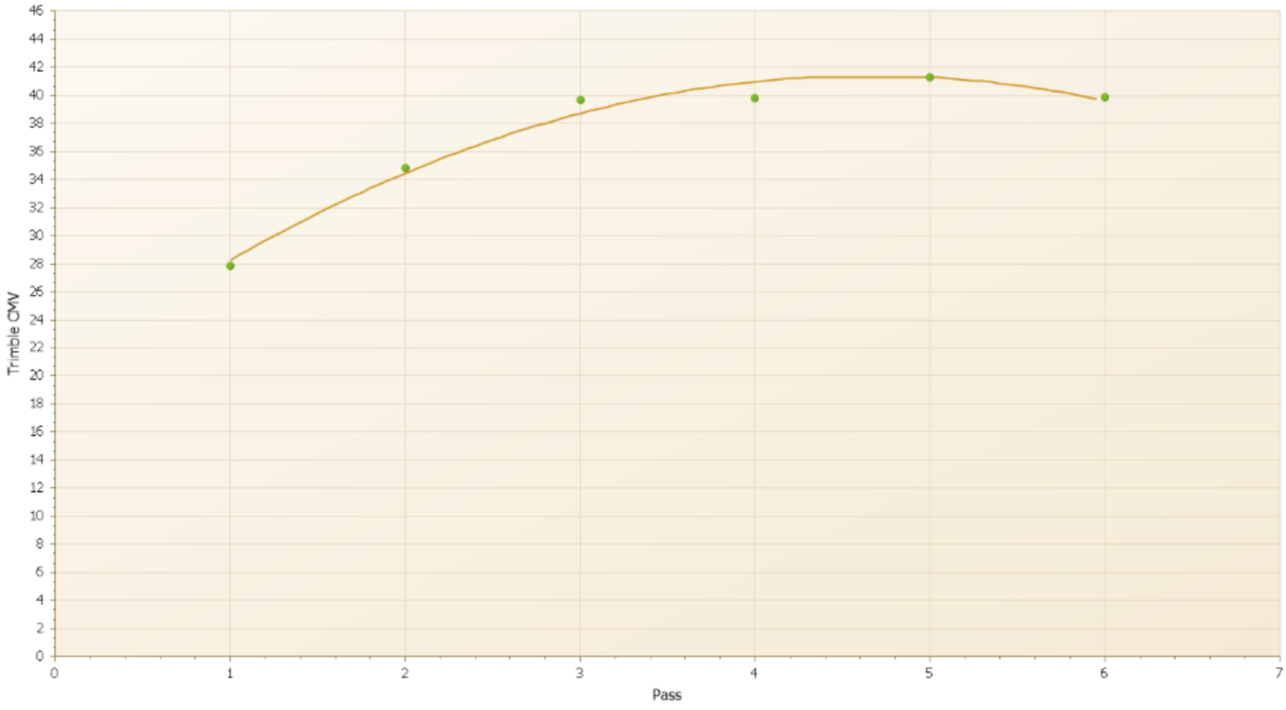
Selections: ● Final Coverage ○ Individual Passes

3.3.2 FIELD COMPACTION CURVES

As mentioned in the previous section, the optimum number of roller passes can be determined using the ‘plateau analysis’ process. This analysis was undertaken for a 150 mm thick cement modified improved (working platform) layer along the westbound carriageway (Figure 3.10). The progression of the CMV against the number of roller passes was tracked as shown in Figure 3.11. The compaction curve shown in Figure 3.11 is typical for the material encountered on site and demonstrated that four roller passes were the optimum number to reach a peak CMV.

Figure 3.10 IC roller compacting a cement modified layer

Figure 3.11 Relationship between the Trimble CMV and the number of vibratory roller passes on the cement modified layer



Compaction curve is valid only for data from the same roller with constant operation settings (speed, amplitudes, frequency).

3.3.3 CORRELATION BETWEEN ICMV AND STIFFNESS/DENSITY TEST RESULTS

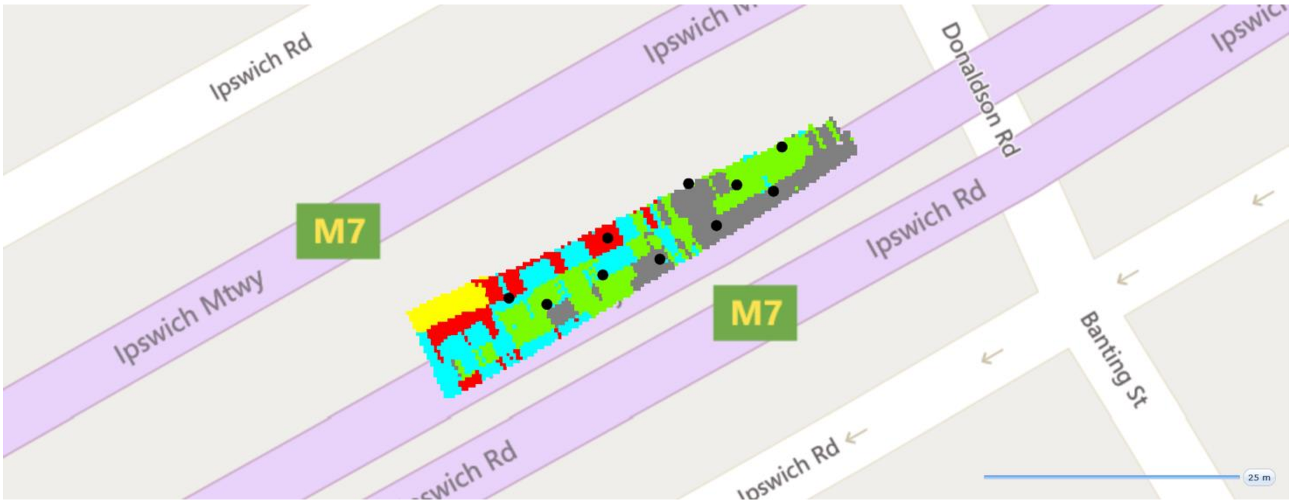
Throughout the demonstration trial, individual density tests (using a nuclear density gauge (NDG)) were undertaken for QA purposes as per the contract requirements (Figure 3.12). Besides, the in situ stiffness of the compacted materials was also measured using an LWD device as part of the demonstration trial (Figure 3.13). Both density and stiffness testing was undertaken on an area of subgrade material as well as cement modified materials. The test locations were selected based on random sampling using TMR Test Method Q050 – *Random Selection of Sampling or Test Locations* (TMR 2020).

The test locations were overlaid on top of the CMV measurement in VETA 6 as shown in Figure 3.14.

Figure 3.12 NDG testing

Figure 3.13 LWD testing

Figure 3.14 An example of a CMV map with individual spot test locations



Typical correlation – subgrade

Figure 3.15 and Figure 3.16 show typical correlations between the CMV, density ratio, and in situ stiffness, respectively.

In this instance, the LWD stiffness correlates well ($0.81 < R^2 < 0.93$) with the CMV measured. However, the density ratio measured using the density measured using the NDG has a very weak correlation ($R^2 < 0.01$) with the CMV measured.

Figure 3.15 Relationship between the Trimble CMV and the density ratio at different contact pressures on the subgrade layer

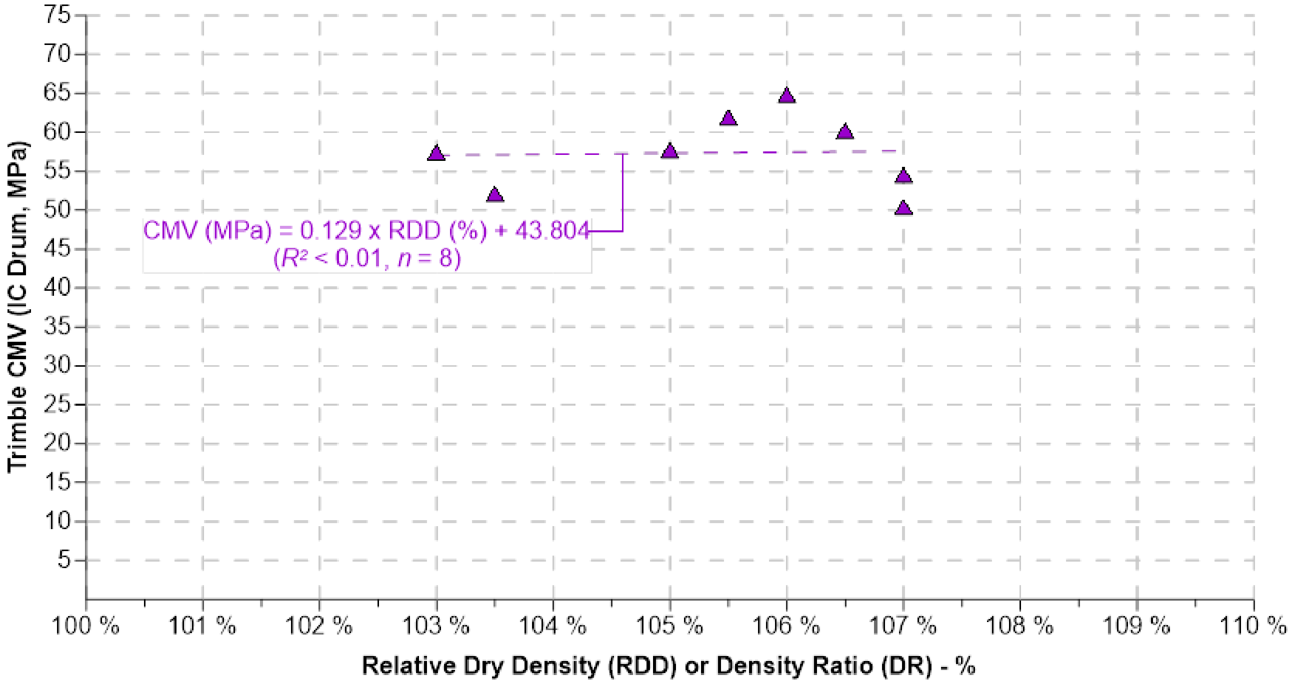
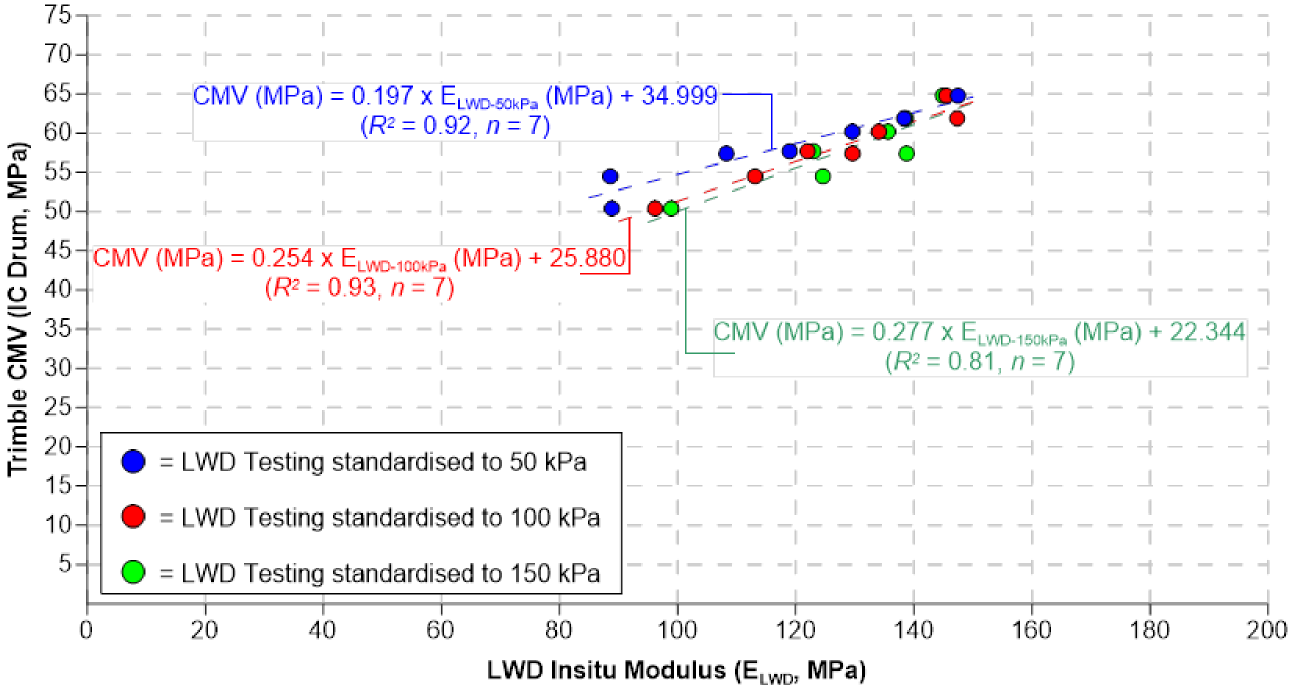


Figure 3.16 Relationship between the Trimble CMV and the LWD modulus at different contact pressures on the subgrade layer

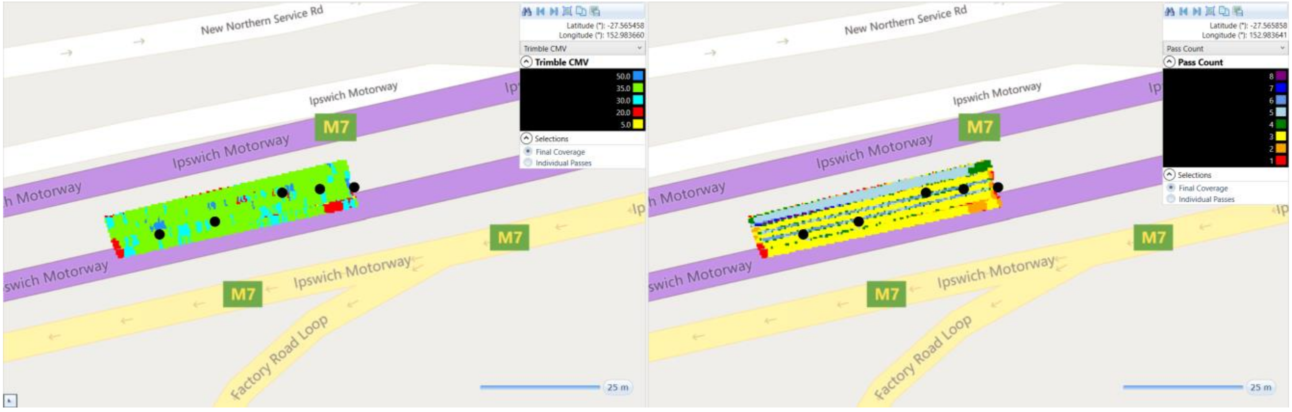


Typical correlation – cement modified material

Figure 3.17 shows the CMV measured for an area where a 150 mm thick layer of cement modified material was placed. Half of the area (left of the CMV area) is the field trial lot where the project team attended the site during the compaction. Additional spot tests were ordered and measured after every roller pass. The remaining half (right of the CMV area) was part of the 'business-as-usual' production. Figure 3.18 shows the five locations where spot tests (i.e. NDG and LWD) were carried out.

Figure 3.17 Veta CMV plot of an IC roller on a CMB layer

Figure 3.18 Veta CMV and roller pass plots of an IC roller on a CMB layer



In this instance, as shown in Figure 3.19, the density ratio measured correlates well with the CMV measurements ($R^2 = 0.76$). The correlation can be further improved by undertaking two separate linear regression analyses for the data collected during the first and second roller passes (refer to Figure 3.20).

Figure 3.19 Relationship between the Trimble CMV and the density ratio on the CMB layer

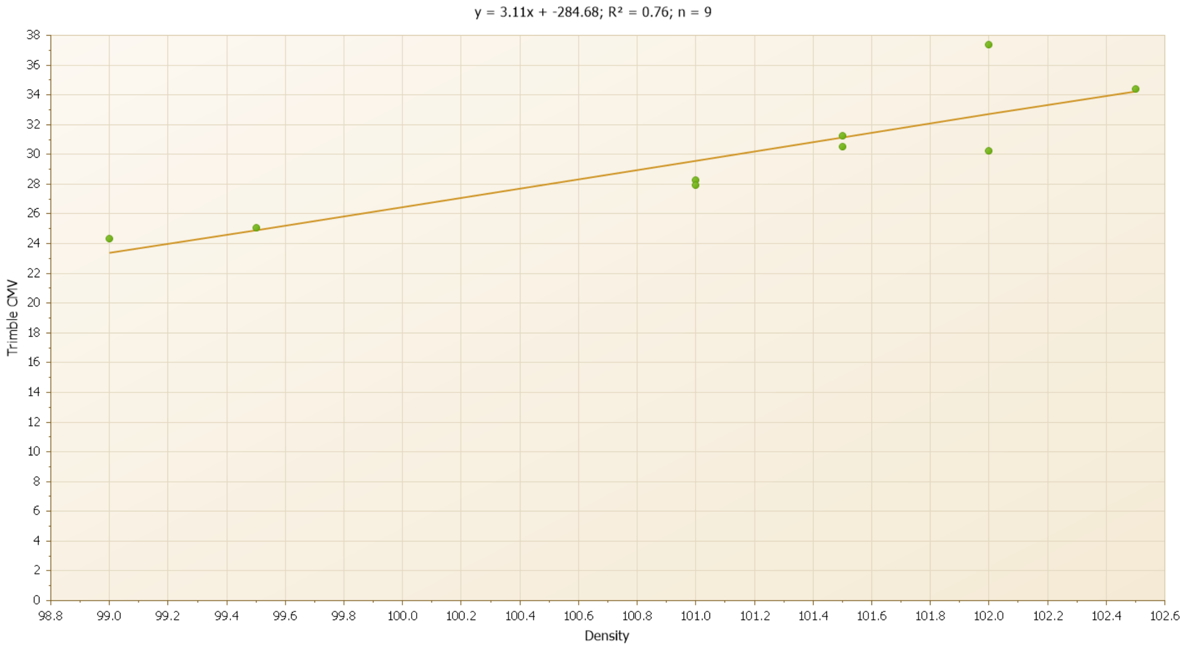
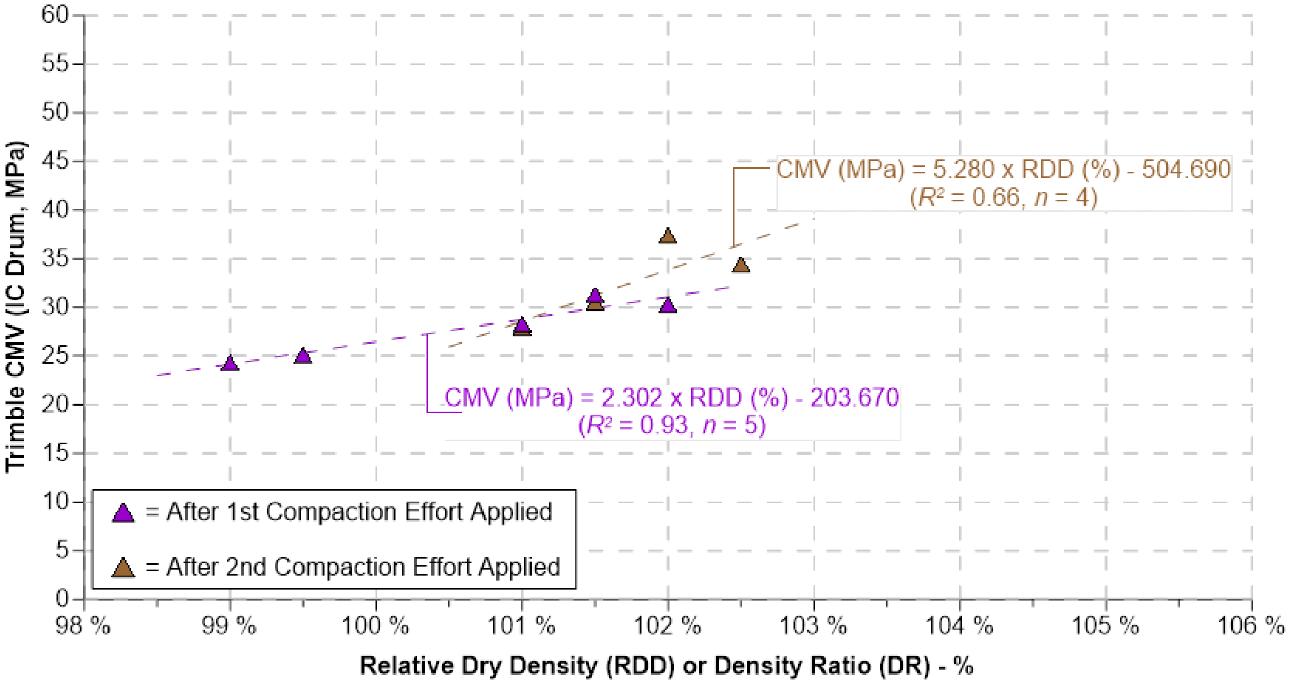


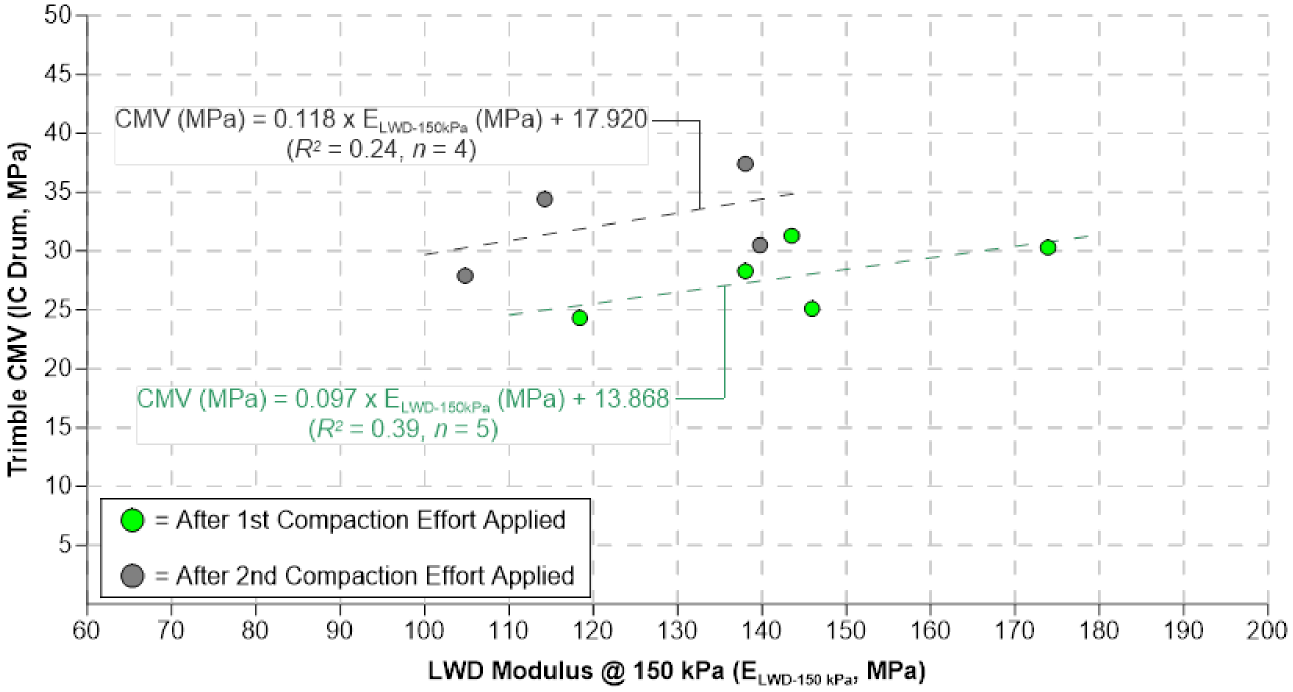
Figure 3.20 Relationship between the Trimble CMV and the density ratio on the CMB layer



However, as shown in Figure 3.21, the LWD has a poor correlation against the CMV measured for this particular site. Even by undertaking a linear regression analysis separately for the data collected after the first and second roller pass, the R^2 remains very low (ranging between 0.24 and 0.39).

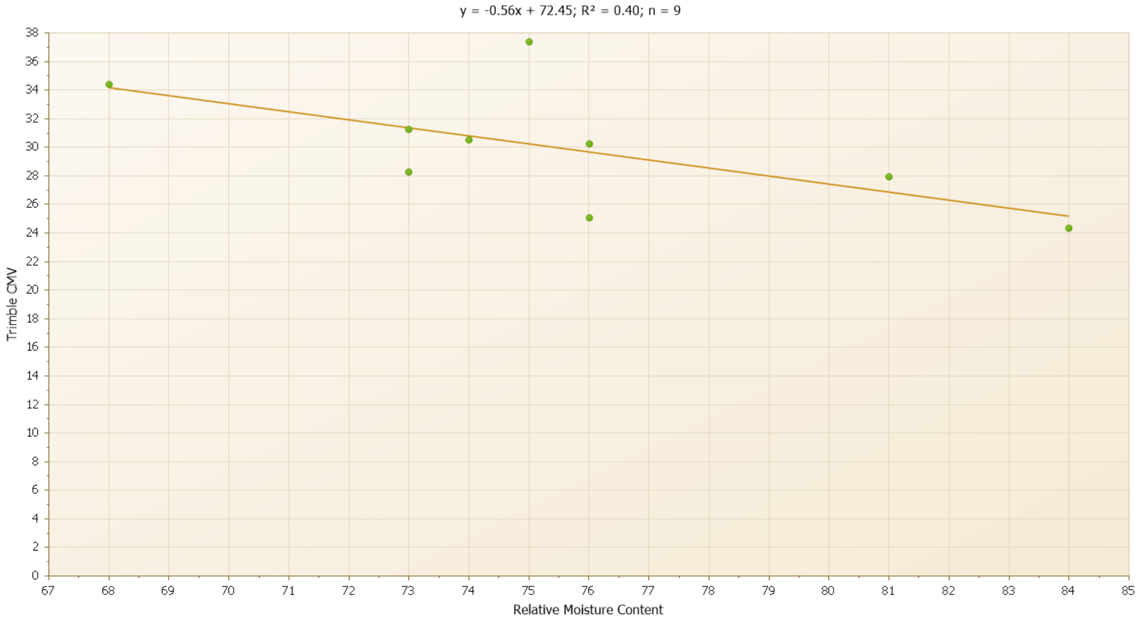
It is possible that one of the reasons for this poor correlation is the complex moisture regime within the cement modified material between each roller pass while the cement in the material is still hydrating. Another reason could be due to insufficient stress levels being applied by the LWD device on the cemented layer.

Figure 3.21 Relationship between the Trimble CMV and the LWD modulus at 150 kPa pressure on the CMB layer



Finally, the CMVs are also plotted against moisture content (Figure 3.22). This shows that the CMV is sensitive to the moisture content within the cement modified material and decreases with an increase in moisture content.

Figure 3.22 Relationship between the Trimble CMV and the relative moisture content on the CMB layer



4 KNOWLEDGE TRANSFER

To assist with industry uptake of IC technology, several knowledge transfer activities were conducted to inform the industry of the technology and promote its benefits. Due to the COVID19 outbreak, most of the knowledge transfer activities conducted this year have been delivered online.

4.1 ONLINE PRESENTATION – R2D

Throughout the compaction auditing work at the Ipswich Motorway Upgrade: Rocklea to Darra – Stage 1, feedback has been provided to the team at the project office.

4.2 NACOE P105 WEBINAR

On 6 July, an online webinar was presented on the project. This presented the essential elements of a PSTS developed by TMR and its use as a compaction auditing tool on a major road project in Queensland – the Ipswich Motorway Upgrade: Rocklea to Darra – Stage 1. The results from this year's work will be incorporated into the future PSTS revisions, and a discussion of the future development of IC technology in Australia was presented. The presentation also highlighted the new features of VETA 6.0 as well as the support of the GDA2020 survey system funded by the NACOE project.

The webinar was accessed by a large audience.

4.3 AAPA INTELLIGENT COMPACTION MASTERCLASS

On 9 and 12 July, the Australian Asphalt Pavement Association (AAPA) organised a two-day online virtual masterclass on intelligent compaction. NACOE provided support in organising the event. On the first day an update on the latest developments in intelligent compaction in the USA and Australia was provided by a panel of IC experts comprising:

- State of the practice – Dr. George Chang (Transtec Group)
- State of the art – Professor Soheil Nazarian (University of Texas at El Paso)
- Importance of intelligent compaction: an agency perspective – Rebecca Embacher (Minnesota Department of Transportation)
- Intelligent compaction in Australia: NACOE update – Dr. Jeffrey Lee (Australian Road Research Board).

The second day was a training session on the Veta sofware. Veta 6 is the latest software release and features many improvements, allowing a more comprehensive viewing and analysis for intelligent construction data and expands on features in previous versions.

5 VETA V6.0 COORDINATE SYSTEM

Currently, Australia uses the GDA94 coordinate system which was established based on the assumption that Australia's continental tectonic plate was fixed. However, due to the tectonic plate moving approximately 7 cm per year, the GDA94 coordinate system is out of position relative to a global reference frame by 1.8 m in 2020.

To improve accuracy, the position reference systems in Australia are changing to the Geocentric Datum of Australia 2020 (GDA2020). GDA2020 is defined in the National Measurement (Recognized-Value Standard of Measurement of Position) Determination 2017 by the coordinates on 109 GNSS Continuously Operating Reference Stations known as the Australian Fiducial Network (AFN). ANZLIC – the Spatial Information Council – announced that 30 June 2020 was to be the date by which ANZLIC member agencies in Australian states and territories were to be ready to deliver and receive national scale foundation spatial data on GDA2020.

Other Queensland government departments, such as the Department of Natural Resources, Mines, and Energy have adopted the GDA2020 system from 1 July 2020.

The key features of GDA2020 include:

- It is a static datum (similar to GDA94).
- A 'static' datum means that the coordinates of features (e.g. roads, buildings and property boundaries) do not change with time.
- The change is to ensure spatial data can be more closely aligned to positions observed using the global navigation satellite system (e.g. GPS).

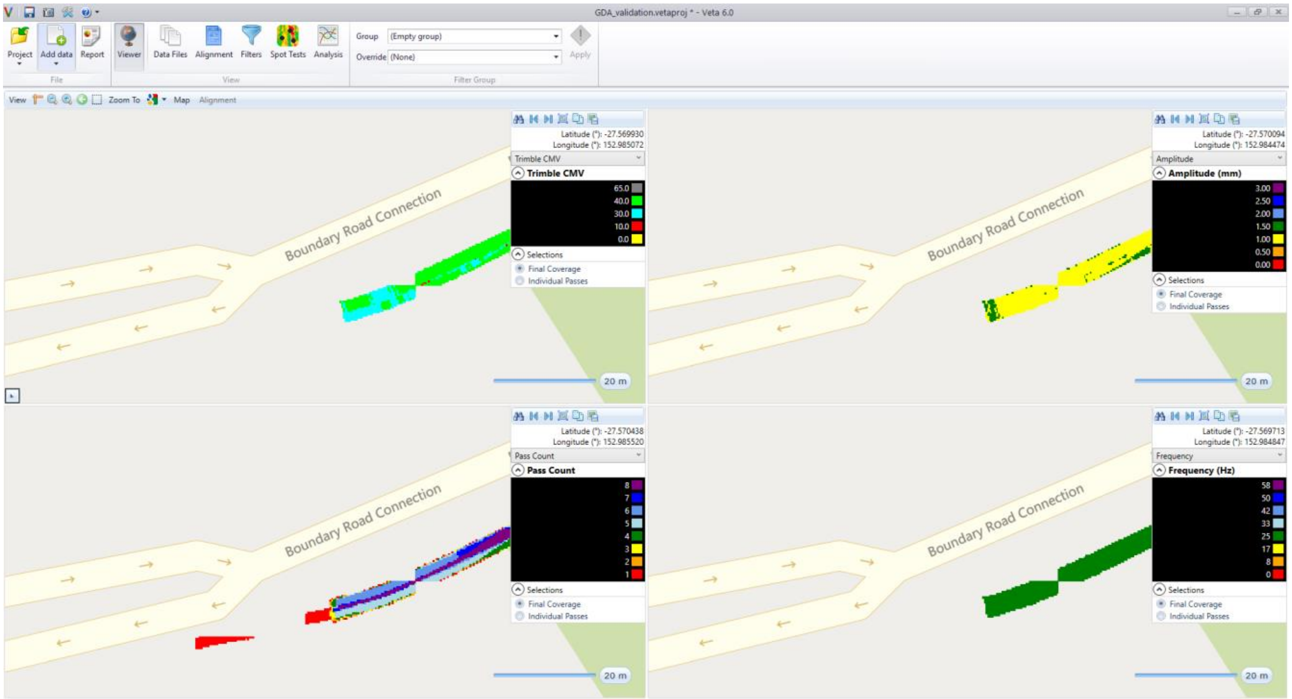
The VETA software was primarily developed to cater to the needs in North America. To facilitate the adoption of IC in Australia, multiple agencies have funded the upgrade of VETA to support the coordinate systems commonly used in Australia, namely:

- AAPA funded to include the MGA94, Map Grid of Australia (1994)
- NACOE funded to include the GDA2020 and the Map Grid of Australia 2020 (MGA2020).

As part of this year's work, VETA v6.0 now supports both GDA2020 and MGA2020. Appendix B details the validation work undertaken to confirm the successful implementation of GDA2020 in VETA v6.0.

As part of the validation process, a short segment of IC data was collected using the GDA2020 coordinate system. The data was successfully imported into VETA v6.0 and a screenshot of the data is shown in Figure 5.1.

Figure 5.1 Veta v6.0 screenshot showing the GDA2020 coordinate system IC data



GDA_validation.vetaproj * - Veta 6.0

Group (Empty group)

Override (None)

Latitude (°): -27.569930
Longitude (°): 152.985072

Latitude (°): -27.570094
Longitude (°): 152.984474

Latitude (°): -27.570438
Longitude (°): 152.985520

Latitude (°): -27.569713
Longitude (°): 152.984847

6 CONCLUSIONS AND RECOMMENDATIONS

This report is a summary of the activities undertaken during year two (2019–20) of the project. The project team (TMR and ARRB) drafted a project-specific technical specification (PSTS 116) and used it in a compaction auditing trial at Ipswich Motorway Upgrade Stage 1 (Rocklea to Darra). IC technology (Trimble CMV) was trialled on different materials including embankment fill, subgrade, cement modified base and unbound granular base.

From the compaction auditing trial, it was found that IC technology can readily identify the soft spot and can be used to improve the uniformity of the final construction work. It was also found that the CMV has a different degree of correlation against the in situ modulus (measured by a lightweight deflectometer) and the conventional density (measured by a nuclear density gauge). It is also noted that the CMV is sensitive to the in situ moisture condition.

It was realised early in the project that there will be significant learning required for the industry to become familiar with the technology and incorporate it into construction practice. Towards the end of this year's project, the project delivered an online webinar to disseminate the findings gained during the compaction auditing exercise. Furthermore, an AAPA-organised virtual masterclass was also delivered, providing additional training on the use of the latest IC data management software, Veta 6.0. Finally, the project has funded Veta 6.0 to support the latest GDA2020 system which will be the main cadastral grid to be used soon across different jurisdictions in Australia.

It is recommended that this technology be further developed and promoted for use on TMR construction projects. It is also proposed to further investigate the use of IC technology for the construction of asphalt pavements and bituminous sprayed seals.

REFERENCES

Cai, H, Kuczek, T, Dunston, PS & Li, S 2017, 'Correlating intelligent compaction data to in situ soil compaction quality measurements', *Journal of Construction Engineering and Management*, vol. 143, no. 8.

Chang, G, Xu, Q, Rutledge, J, Horan, B, Michael, L, White, D & Vennapusa, P 2011, *Accelerated implementation of intelligent compaction technology for embankment subgrade soils, aggregate base, and asphalt pavement materials*, FHWA-IF-12-002, Federal Highway Administration, Washington, DC, USA.

Correia, AG & Parente, M 2014, 'Intelligent compaction technology for geomaterials: a demonstration project', *Transport research arena conference, 5th, 2014*, *Paris, France,* European Commission, Luxembourg City, Luxembourg, 10 pp.

Fatahi, B, Khabbaz, H, Dong, Y & Lee, J 2019, ‘Implementing intelligent compaction technology for use in Queensland (year 1 – 2018/19) for earth fill, granular and stabilised materials’, contract report 014125, ARRB, Port Melbourne, Vic.

Gallivan, VL, Chang, GK & Horan, DR 2011, 'Intelligent compaction for improving roadway construction', in D Chen, J Chang, M Zaman, C Zhao & Z Yao (eds), *Emerging technologies for material, design, rehabilitation, and inspection of roadway pavements*, American Society of Civil Engineers, Reston, VA, USA, pp. 117-24.

Hossain, M, Mulandi, J, Keach, L, Hunt, M & Romanoschi, S 2006, 'Intelligent compaction control', *Airfield and highway pavements specialty conference, 2006, Atlanta, Georgia,* American Society of Civil Engineers, Reston, VA, USA, pp. 304-16.

Kumar, SA, Aldouri, R, Nazarian, S & Si, J 2016, 'Accelerated assessment of quality of compacted geomaterials with intelligent compaction technology', *Construction and Building Materials*, vol. 113, pp. 824-34.

Mooney, M & Adam, D 2007, 'Vibratory roller integrated measurement of earthwork compaction: an overview', *International symposium on field measurements in geomechanics, 7th, 2007, Boston, Massachusetts,* American Society of Civil Engineers, Reston, VA, USA.

Mooney, MA, Rinehart, RV, Facas, NW, White, DJ, Vennapusa, PKR & Musimbi, OM 2010, *Intelligent soil compaction systems*, NCHRP report 676, Transportation Research Board, Washington, DC, USA.

White, DJ, Vennapusa, P, Zhang, J, Gieselman, H & Morris, MD 2009, *Implementation of intelligent compaction performance-based specifications in Minnesota*, MN/RC 2009-14, Iowa State University, Ames, IA, USA.

Zargar, M & Lee, J 2019, ‘Implementation of intelligent compaction technology in Queensland (year 1 – 2018/2019) for asphalt applications’, contract report 014125, ARRB, Port Melbourne, Vic.

Standard

TMR Q050:2020, *Random selection of sampling or test locations.*

APPENDIX A PSTS116 – INTELLIGENT COMPACTION – EARTHWORKS AND PAVEMENTS

Department of Transport and Main Roads

Project Specific Technical Specification

Transport and Main Roads Specifications PSTS116 Intelligent Compaction – Earthworks and Pavements

January 2020

Developed for: Rocklea to Darra – Stage 1 Project

Queensland Government

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Contents

1 Introduction

1.1 General

This Project Specific Technical Specification applies to the use of intelligent compaction (IC) in the construction of pavements and earthworks including stabilised materials but excluding asphalt and sprayed seals.

This Project Specific Technical Specification has been developed for the implementation of IC trials in Queensland. As the knowledge and understanding of IC is developed through these field trials, this document will be updated to reflect best practise.

The requirements of this Project Specific Technical Specification are supplementary to the relevant parent Technical Specifications, as given in Table 1. Where there are any contradictory requirements between this Project Specific Technical Specification and the respective parent Technical Specification, the requirements of this Project Specific Technical Specification shall apply where intelligent compaction is used.

Table 1 – Parent Technical Specifications

Parent Technical Specification	Application
MRTS04	*General Earthworks*
MRTS05	*Unbound Pavements*
MRTS06	*Reinforced Soil Structures*
MRTS07A	*Insitu Stabilised Subgrades using Quicklime or Hydrated Lime*
MRTS07B	*Insitu Stabilised Pavements using Cement or Cementitious Blends*
MRTS07C	*Insitu Stabilised Pavements using Foamed Bitumen*
MRTS08	*Plant-Mixed Heavily Bound (Cemented) Pavements*
MRTS09	*Plant-Mixed Pavement Layers Stabilised using Foamed Bitumen*
MRTS10	*Plant-Mixed Lightly Bound Pavements*
MRTS35	*Recycled Material Blends for Pavements*

This Project Specific Technical Specification shall be read in conjunction with MRTS01 *Introduction to Technical Specifications*, MRTS50 *Specific Quality System Requirements* and other Technical Specifications as appropriate.

IC rollers used on pavement and earthworks construction are fitted with equipment to record roller passes and coverage on a lot, and measure and record the stiffness of the layer being compacted

2 Definition of terms

The terms used in this Project Specific Technical Specification shall be as defined in Clause 2 of MRTS01 *Introduction to Technical Specifications*. Additional terms used in this Technical Specification shall be as defined in Table 2.

Table 2 – Definition of terms

Term	Definition
Geodetic Coordinates	A coordinate system used to describe a position in terms of longitude, latitude, and altitude above an imaginary ellipsoid surface (GRS80) based on a specific geodetic datum. GDA94 is the required datum to be used.
GDA94	A mathematical definition of the earth's shape, with its origin at the earth's centre of mass. GDA94 was fixed against the International Terrestrial Reference Frame 1992 (ITRF92) at epoch 1994.0, hence referred to as GDA94.
GPS	A space-based satellite navigation system that provides location and time information in all weather, anywhere on or near the Earth to determine the location in geodetic coordinates. In this specification, GPS is referring to all GPS-related signals including US GPS, and other Global Navigation Satellite Systems (GNSS).
GPS Base Station	A single ground-based system that consists of a GPS receiver, GPS antenna, radio and radio antenna to provide L1/L2 differential GPS correction signals to other GPS receivers within a range limited by radio signal strength and topography. Typically, 1-5 kms in radius without repeaters.
GPS Correction Service Subscription	A service that can be subscribed to receive a GPS correction in order to achieve higher accuracy GPS positioning normally via cellular wireless data services; that is, without the need for a ground-based GPS Base Station. Examples of GPS Correction Service subscriptions include Trimble VRS NOW, HxGn SmartNet, AllDayRTK, and so on
Grid Coordinate	Grid: Refer also to MGA94 in this Project Specific Technical Specification.
GUI Display	Graphical User Interface Display.
Hand-held GPS rover	A portable GPS radio/receiver for in-situ point measurements.
Intelligent Compaction (IC)	A compaction system that includes assessment of stiffness using vibration monitoring integrated with global positioning system (GPS) and displayed for the plant operator. The data can be exported to provide a complete record of compaction and for further analysis with Veta.
Intelligent Compaction Measurement Value (IC-MV)	Generic term for IC roller-integrated stiffness measurement value. Proprietary products may measure IC-MV using different terminology/units.
Light Weight Deflectometer (LWD)	Portable, non-destructive test device used to measure pavement deflections by applying a dynamic load to the pavement surface.
Network RTK	Network RTK is a system that use multiple bases in real-time to provide high-accuracy GPS positioning within the coverage area that is generally larger than that covered by a single GPS Base Station; for example, Trimble VRS NOW.
RTK-GPS	Real Time Kinematic Global Positioning Systems based on the use of carrier phase measurements of the available GPS signals where a single reference station or a reference station network provides the real-time corrections in order to achieve centimetre-level accuracy.

Term	Definition
UTC	Coordinated Universal Time (UTC) is commonly referred to as Greenwich Mean Time (GMT) and is based on a 24 hours' time scale from the mean solar time at the Earth's prime meridian (zero degrees longitude) located near Greenwich, England.
MGA94	Cartesian coordinates from a universal transverse Mercator projection based on the Geocentric Datum of Australia 1994 (GDA94). Zone Number, Easting and Northing represents a grid coordinate.
Veta	A map-based software tool for Contractors and Administrators to standardise, display, analyse and report data collected by intelligent compaction (IC) and paver-mounted thermal profiling (PMTP) technologies during construction. Veta can import data from various IC machines and PMTP to perform editing, filtering, spot test correlation, and statistical analysis as a post-processing tool.

3 Referenced documents

Table 3 list documents referenced in this Project Specific Technical Specification.

Table 3 – Referenced documents

Reference	Title
MRTS01	*Introduction to Technical Specifications*
MRTS50	*Specific Quality System Requirements*

4 Standard test methods

Testing of all work shall be undertaken in accordance with Clause 4 of MRTS01 *Introduction to Technical Specifications*.

Unless stated elsewhere herein, the standard test methods listed in Table 4 shall be used in this Project Specific Technical Specification.

Table 4 – Standard test methods

Property to be Tested	Method No.
Random selection of sampling or test locations	Q050
Measuring deflections with a Light Weight Deflectometer (LWD)	ASTM D2583
Insitu wet density	Q141A or AS 1289.5.8.1

5 Quality system requirements

5.1 Hold Points, Witness Points and Milestones

General requirements for Hold Points, Witness Points and Milestones are detailed in Clause 5.2 of MRTS01 *Introduction to Technical Specifications*.

The Hold Points, Witness Points and Milestones applicable to this Project Specific Technical Specification are summarised in Table 5.1.

Table 5.1 – Hold Points, Witness Points and Milestones

Clause	Hold Point	Witness Point	Milestone
5.2	1. Acceptance of construction procedures for IC		
7.2	2. Provide training for Contractors and Administrators staff		
7.3	3. Notify Administrator of any weak and/or non-homogeneous areas identified during the pre-mapping of underlying layer.		
7.4.2	4. Determine the target IC-MV prior to continuing IC works.		

5.2 Construction procedures

The Contractor shall prepare documented procedures for all construction processes in accordance with Clause 6 of MRTS50 *Specific Quality System Requirements*.

In addition to the requirements of the relevant parent Technical Specifications, the Contractor shall prepare a Construction Procedure that provides, as a minimum, the following details:

a) The number of rollers to be used in the Works and the number of these rollers equipped with IC technology, and

b) For each roller equipped with IC technology:

   i. the roller make and model, and

   ii. the IC equipment make, model and software version

c) For each roller not equipped with IC technology:

   i. the roller make and model

No works using IC shall commence until the construction procedure described in this clause has been submitted to and accepted by the Administrator. **Hold Point 1**

> Compatibility is important, mixing of IC-MV data from different systems is not currently possible in Veta. There should be only one supplier of IC equipment used in the construction of a single lot.

5.3 Lot sizes

Intelligent compaction shall be undertaken on a lot basis as specified in the relevant parent Technical Specification.

IC results shall be reported for each lot.

6 Equipment

6.1 General

The Contractor will determine the number of IC rollers required to achieve the intent of this Project Specific Technical Specification.

Not all rollers used in a lot need to be IC equipped, however sufficient IC rollers need to be provided to ensure that coverage and stiffness of the entire lot can be measured and recorded.

6.2 Intelligent compaction rollers

The IC rollers shall meet the following requirements:

a) IC rollers for use in pavements and earthworks compaction shall be self-propelled single-drum vibratory rollers equipped to measure the interactions between the rollers and compacted materials and evaluate the applied compactive effort.

b) IC rollers shall be fitted with a smooth drum

c) IC rollers shall be capable of recording and displaying

   i. real-time colour-coded maps of the IC-MV

   ii. location of the roller

   iii. number of roller passes

   iv. roller speeds, and

   v. vibration frequency and amplitude of roller drums.

d) The data output from the IC roller shall be compatible with Veta

e) The positioning system and zone settings shall comply with the requirements of Appendix A.

7 Construction

7.1 Coverage

Where not all rollers used in the Works are fitted with IC equipment, the Contractor shall ensure that the full extent of each lot is mapped with an IC equipped roller at the following points during the Works:

a) for the first lot, at the completion of compaction (final roller pass) in order to determine the target IC-MV (refer to Clause 7.4), and

b) for subsequent lots, at the completion of the compaction process (final roller pass) in order to report the IC data (refer to Clause 8.2).

7.2 On-site training

The Contractor shall coordinate and provide on-site training for their own and the Administrators personnel on the operation of the IC technology, prior to the commencement of the Works.
Hold Point 2

The Contractor's personnel shall include the Contractor's Project Manager, Project Engineer(s), Quality Representative, Works Supervisors(s) and roller operator(s).

The Administrators personnel are to be nominated by the Administrator.

Minimum training topics shall include:

a) Background information for the specific IC system(s) to be used

b) setup and checks for IC system(s), GPS receiver, base-station and hand-held GPS rovers

c) operation of the IC system(s) on the roller; that is, setup data collection, start/stop of data recording, and on-board display options

d) transferring raw IC data from the roller(s), that is, via USB or mobile/wireless connections, and

e) operation of vendor's software to open and view raw IC data files and exporting all passes and final coverage data files in a Veta-compatible format.

~~f) operation of Veta software to import the IC data files, inspect IC maps, input point test data, analyse the data and produce reports.~~

7.3 Pre-mapping of underlying layer

Prior to the construction of each lot of earthworks and/or pavements, the Contractor shall undertake pre-mapping of the underlying layer.

Pre-mapping shall involve making a single pass over the lot area with the IC roller and mapping the IC-MV results.

Where the underlying lot was constructed by the Contractor using IC, the construction records themselves are adequate for pre-mapping.

Where pre-mapping identifies weak and/or non-homogeneous areas, the Administrator shall be notified prior to the commencement of the Works. **Hold Point 3**

> Where the underlying layer has been constructed by the Contractor as part of the Works, the Contractor would typically be responsible for ensuring the overlying layer can be constructed to meet the specified compaction standards, and may need to undertake dry-back and/or rework of the underlying layer accordingly.
>
> Where the underlying layer was not constructed as part of the Contract, the Contractor and Administrator should consider what/if any additional work is required to achieve compaction of the overlying earthworks or pavement. In some circumstances the Contractor and Administrator may undertake additional investigation of the weak and/or non-homogenous underlying area (for example, proof rolling, DCP, test pit and so on).

7.4 Determine the target IC-MV

7.4.1 General

The target IC-MV shall be used by the Contractor as a guide to indicate when the required compaction standard has been achieved, and to report the uniformity of each lot.

Achieving the target IC-MV for a lot does not circumvent nonconformances recorded against the compaction requirements specified in the relevant parent Technical Specification.

The Contractor shall initially determine the target IC-MV on the first lot of the Works. The target IC-MV shall be determined using:

- the compaction equipment nominated in the Contractor's construction procedure, and

- the procedure given in Clause 7.4.2.

The target IC-MV shall be established for each combination of the following and re-established for any change thereafter:

- material type
- layer thickness, and/or
- nominal moisture content.

Regular revisions of the IC-MV shall be undertaken in accordance with Clause 7.5.

Typically, the Contractor would develop a rolling pattern to achieve the specified compaction standard. The use of IC allows the Contractor to assess the compaction of a lot with each roller pass and at completion of compaction. By doing so the rolling pattern can be optimised in real time to help ensure that the specified compaction standard is achieved.

7.4.2 Procedure

The target IC-MV shall be determined using the following procedure.

Where each roller pass during compaction is being undertaken by an IC equipped roller (or non-IC equipped roller of the same make, model and configuration), follow steps 1 – 7.

Where only the final roller passes is being undertaken by an IC equipped roller (for example where a padfoot roller is being used for the primary compaction), follow steps 4 -7.

Table 7.4.2 – Procedure for determining the target IC-MV

Step	Description	Responsibility	Notes
Step 1	Commence compacting the lot using the nominated rollers and rolling pattern. Undertake the first roller pass. Pause the compaction process to allow for the testing specified in Step 2.	Contractor	
Step 2	At a minimum of 10 locations within the lot measure: • The stiffness of the layer using a Light-Weight Deflectometer (LWD), and • The insitu wet density of the layer using a Soil Density / Moisture (nuclear) Gauge.	Transport and Main Roads	Each testing locations shall be determined using Test Method Q050, unless otherwise directed by the Administrator. The location of all stiffness and density tests shall be recorded using a hand-held GPS rover that complies with the positioning requirements given in Appendix A. These test locations shall be input into Veta.

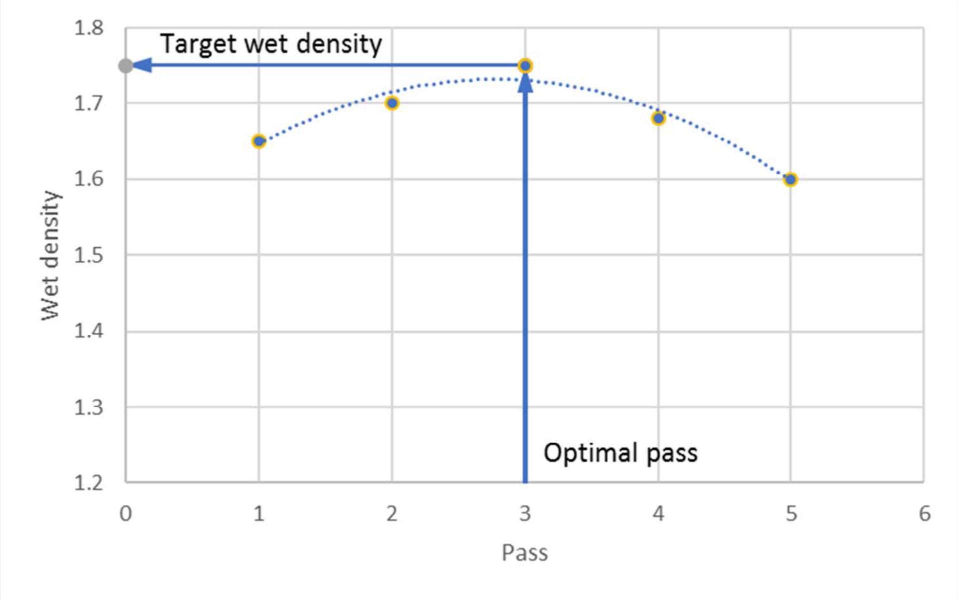
Step	Description	Responsibility	Notes
Step 3	Undertake subsequent roller passes repeating Steps 1 and 2 until it is deemed that the specified compaction standard has been achieved in accordance with the parent Technical Specification.	Contractor for roller passes and coverage (Step 1) Transport and Main Roads for testing (Step 2)	Testing to be undertaken at the same locations determined in Step 2.
Step 4	At the completion of compaction, use the IC equipped roller to map the stiffness of the entire lot (if not already done).	Contractor	
Step 5	After the final pass with the IC equipped roller, undertake a final suite of LWD and insitu wet density testing as per Step 2.	Transport and Main Roads	Testing to be undertaken at the same locations determined in Step 2.
Step 6	**Undertake a plateau analysis of the compaction data.** Analyse the compaction data by plotting the number of roller passes against the stiffness and insitu wet density results.	Contractor and Transport and Main Roads	This process will assess what amount of compactive effort is required to achieve the minimum specified compaction standard. The optimum compactive effort is the number of passes required to reach the peak of the stiffness and/or density results, whichever is the greater.
Step 7	**Determine the target IC-MV. Hold Point 4** Upload all IC data into Veta for analysis. Use Veta to perform a correlation analysis between the IC-MV and stiffness/wet density results using a linear regression. This analysis should include all locations where there is corresponding IC-MV and stiffness/density data (for example, each pass where IC equipped rollers are used throughout compaction of the lot).	Contractor and Transport and Main Roads	Where the coefficient of determination (R^2) of the linear regression is greater than 0.5, the target IC-MV would be the value corresponding to the t target wet density on the correlation chart. The correlation between IC-MV and stiffness should be checked for consistency. If the coefficient of determination (R^2) is less than 0.5, the homogeneity of the materials (for example, gradation, thickness and moisture content) shall be examined to determine its suitability for use and this procedure repeated on the next lot until a target IC-MV can be determined.

This procedure has been developed for the purpose of undertaking trials.

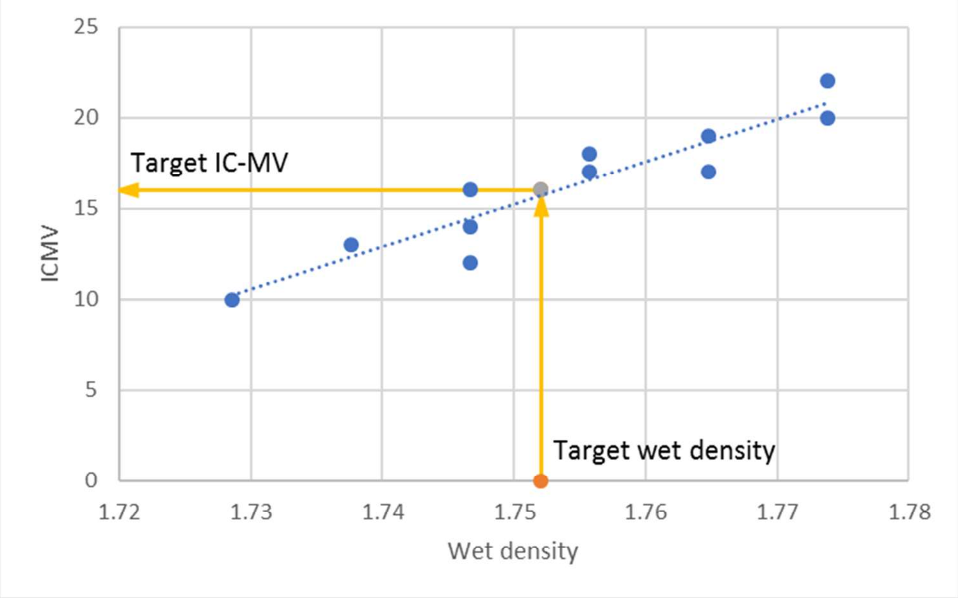
The responsibility for each step may be altered on a case by case basis.

Using the target IC-MV determined from the procedure detailed in Table 7.4.2, the Contractor and Administrator shall use this value for subsequent IC lots and IC data reporting (refer to Clause 8.2).

Example of plateau testing analysis



Example of Target IC-MV analysis



- Similar plots can be drawn up to analyse the LWD data with respect to insitu wet density and IC-MV.

7.5 Revision of the target IC-MV

The target IC-MV shall be checked at the frequencies shown in Table 7.5.

Table 7.5 – Frequencies for the revision of the target IC-MV

Interval	Action
1st Lot	Determine target IC-MV as per the procedure detailed in Clause 7.4.2.
Monthly	Review target IC-MV in accordance with the procedure detailed in Clause 7.4.2.
Intermediate lots	Use the most recently determined target IC-MV to report the IC data of each lot (refer to Clause 8.2).

For the purpose of the initial IC trials, revision of the target IC-MV may need to occur more frequently than shown in Table 7.5 to help develop the trial.

8 IC data reporting requirements

The intent of this specification for compliance and reporting of each IC lot is as follows:

- The Contractor shall be responsible for the compliance of each lot in accordance with its parent Technical Specification.
- The Contractor will record the IC data for each lot and provide it to the Administrator (as per Clause 8.2).
- The Contractor will undertake an analysis of the IC data for each lot using Veta and report the analysis to the Administrator (as per Clause 8.2).
- As the understanding and confidence in the IC process grows, a reduced level of compliance testing (for example, reduced number of relative compaction tests) may be considered by the Administrator in conjunction with the submission of conforming IC analysis.

8.1 Compliance test locations

The Contractor shall record the locations of all compliance testing undertaken in accordance with the parent Technical Specification using a hand-held GPS rover that complies with the positioning requirements given in Appendix A.

These test locations shall be input into Veta and reported with the IC results.

8.2 IC data analysis

In addition to the requirements of the relevant parent Technical Specifications, for each lot where IC is used, the Contractor shall use Veta to analyse the IC data for:

- **Coverage** – the number of roller passes made and coverage of the lot (applicable if the entire compaction effort was completed using IC equipped roller(s)), and
- **Compaction Value** – percent of the lot area meeting or exceeding the target IC-MV determined in accordance with Clause 7.4 and subsequently revised in accordance with 7.5.

The Veta software is freely available on the website www.intelligentconstruction.com

For each lot, the Contractor shall provide to the Administrator all input files necessary to analyse the data in Veta and a report of the Veta analysis (which can be output directly from Veta). The report shall include the locations and values of compliance test results. All data and files must be clearly linked to the construction lot which they relate to.

9 Supplementary requirements

The requirements of this Project Specific Technical Specification are varied by the supplementary requirements given in Clause 1 of Annexure PSTS116.1.

Appendix A – Positioning requirements

A.1 Positioning system

A.1.1 General

The Contractor shall provide a positioning system that meets the following requirements. The goal of the positioning system requirements is to achieve accurate and consistent position measurements among all positioning devices on the same project. Conversions of positioning system data need to be minimised to avoid errors introduced during the process.

All GPS devices for this project shall be set to the same consistent coordinate datum/system no matter whether GPS or Grid data are originally recorded. MGA is the preference and shall be set to zone no. (5x) for this project.

Use of MGA will facilitate GPS data checks onsite. If MGA coordinates are not available, contact the Transport and Main Roads local surveying representative to agree on an acceptable datum. Ad-hoc local coordinate systems are not allowed.

In addition, the positioning system shall be regularly maintained and calibrated in accordance with the manufacturer's / supplier's recommendations and to ensure the requirements of this Project Specific Technical Specification are met. The results of equipment calibration checks shall be recorded and reported to the Administrator as specified in Clause 8.1.1.

A.1.2 GPS requirements

Contractor shall provide the GPS system (including GPS receivers on IC rollers and hand-held GPS rovers) that makes use of the same coordinate reference system. The GPS system should be capable of achieving RTK-GPS accuracies. Examples of valid combinations are:

a) GPS receivers on IC rollers and hand-held GPS rovers referenced to the same ground-based GPS base station, or

b) GPS receiver on IC rollers and hand-held GPS rovers referenced to the same network RTK.

A.1.3 GPS data records and formats

The recorded GPS data, whether from the IC rollers or hand-held GPS rovers, shall be in the following formats:

a) Time: The time stamp shall be in military format, hhmmss.ss in either UTC or local time zone.0.01 second is required to differentiate sequence of IC data points during post process.

b) Geodetic coordinates of latitudes and longitude shall be in decimal degrees, dd.dddddddd (to at least eight decimal places which is approximately equivalent to 1 mm in Queensland). Latitudes are negative south of the equator and longitudes are positive when measuring eastward from the Prime Meridian.

c) GPS Grid coordinates shall be in meters with at least three digits of significance (0.001 m or 1 mm).

When importing IC-MV data into the data analysis management program, the GPS data and associated IC measurements shall be stored with minimum data conversions and minimum loss of precision. Users can then select unit of preference to allow real time unit conversion for the GUI display.

Post-process GPS check. Follow the vendor-specific instructions to export IC-MV data to Veta-compatible formats. The Contractor should import the IC roller data into Veta and enter GPS point measurements from the rover and visually inspect the IC map and point measurements on the Veta display screen for consistency.

A.1.4 Datum

The IC roller shall be able to output geodetic / grid coordinates using GDA94 / MGA94 respectively.

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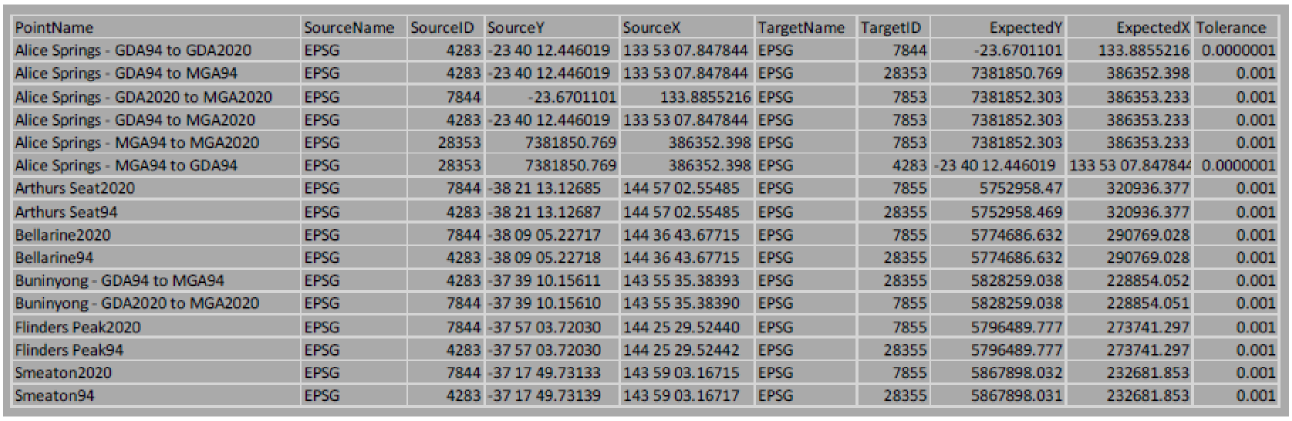
APPENDIX B VALIDATION OF VETA SUPPORT FOR GDA 2020

B.1 VETA SUPPORT FOR GDA 2020 – VALIDATION

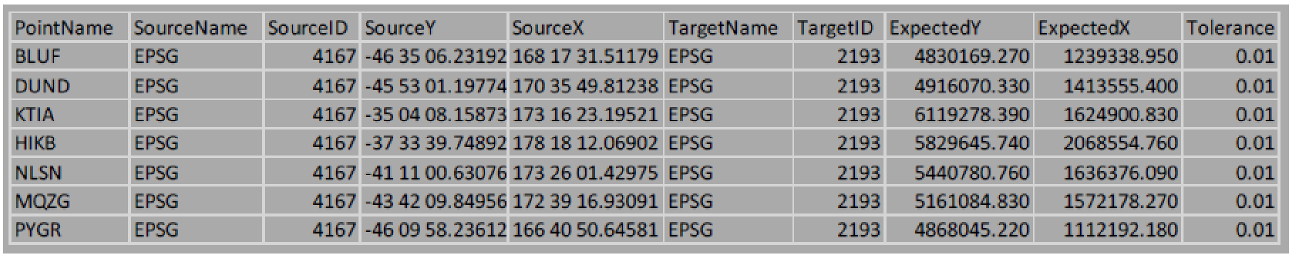
The Veta system has been updated to support GDA 2020. The updated coordinate system has been validated by the Veta development team using the following data points nominated by the GDA2020 validation process.

The data points for the DGA2020 validation in Australia are shown in the chart below.



PointName	SourceName	SourceID	SourceY	SourceX	TargetName	TargetID	ExpectedY	ExpectedX	Tolerance
Alice Springs - GDA94 to GDA2020	EPSG	4283	-23 40 12.446019	133 53 07.847844	EPSG	7844	-23.6701101	133.8855216	0.0000001
Alice Springs - GDA94 to MGA94	EPSG	4283	-23 40 12.446019	133 53 07.847844	EPSG	28353	7381850.769	386352.398	0.001
Alice Springs - GDA2020 to MGA2020	EPSG	7844	-23.6701101	133.8855216	EPSG	7853	7381852.303	386353.233	0.001
Alice Springs - GDA94 to MGA2020	EPSG	4283	-23 40 12.446019	133 53 07.847844	EPSG	7853	7381852.303	386353.233	0.001
Alice Springs - MGA94 to MGA2020	EPSG	28353	7381850.769	386352.398	EPSG	7853	7381852.303	386353.233	0.001
Alice Springs - MGA94 to GDA94	EPSG	28353	7381850.769	386352.398	EPSG	4283	-23 40 12.446019	133 53 07.847844	0.0000001
Arthurs Seat2020	EPSG	7844	-38 21 13.12685	144 57 02.55485	EPSG	7855	5752958.47	320936.377	0.001
Arthurs Seat94	EPSG	4283	-38 21 13.12687	144 57 02.55485	EPSG	28355	5752958.469	320936.377	0.001
Bellarine2020	EPSG	7844	-38 09 05.22717	144 36 43.67715	EPSG	7855	5774686.632	290769.028	0.001
Bellarine94	EPSG	4283	-38 09 05.22718	144 36 43.67715	EPSG	28355	5774686.632	290769.028	0.001
Buninyong - GDA94 to MGA94	EPSG	4283	-37 39 10.15611	143 55 35.38393	EPSG	28355	5828259.038	228854.052	0.001
Buninyong - GDA2020 to MGA2020	EPSG	7844	-37 39 10.15610	143 55 35.38390	EPSG	7855	5828259.038	228854.051	0.001
Flinders Peak2020	EPSG	7844	-37 57 03.72030	144 25 29.52440	EPSG	7855	5796489.777	273741.297	0.001
Flinders Peak94	EPSG	4283	-37 57 03.72030	144 25 29.52442	EPSG	28355	5796489.777	273741.297	0.001
Smeaton2020	EPSG	7844	-37 17 49.73133	143 59 03.16715	EPSG	7855	5867898.032	232681.853	0.001
Smeaton94	EPSG	4283	-37 17 49.73139	143 59 03.16717	EPSG	28355	5867898.031	232681.853	0.001

The data points for the DGA2020 validation in New Zealand are shown in the chart below.



PointName	SourceName	SourceID	SourceY	SourceX	TargetName	TargetID	ExpectedY	ExpectedX	Tolerance
BLUF	EPSG	4167	-46 35 06.23192	168 17 31.51179	EPSG	2193	4830169.270	1239338.950	0.01
DUND	EPSG	4167	-45 53 01.19774	170 35 49.81238	EPSG	2193	4916070.330	1413555.400	0.01
KTIA	EPSG	4167	-35 04 08.15873	173 16 23.19521	EPSG	2193	6119278.390	1624900.830	0.01
HIKB	EPSG	4167	-37 33 39.74892	178 18 12.06902	EPSG	2193	5829645.740	2068554.760	0.01
NLSN	EPSG	4167	-41 11 00.63076	173 26 01.42975	EPSG	2193	5440780.760	1636376.090	0.01
MQZG	EPSG	4167	-43 42 09.84956	172 39 16.93091	EPSG	2193	5161084.830	1572178.270	0.01
PYGR	EPSG	4167	-46 09 58.23612	166 40 50.64581	EPSG	2193	4868045.220	1112192.180	0.01

In the above cases, coordinates with spaces are latitude/longitude. The Veta developers used the source coordinates for the validation tests to compare with the expected values. It has been demonstrated that the tolerance meets the requirement of the GDA2020 coordinate system.