

PROCEEDINGS
2018 AUSTRALIAN GEOMECHANICS SOCIETY
VICTORIAN SYMPOSIUM
**Geotechnics and
transport infrastructure**

Wednesday, 24 October 2018, 8:00am – 6:00pm
Rydges Hotel, 186 Exhibition Street, Melbourne



AUSTRALIAN GEOMECHANICS SOCIETY
VICTORIA CHAPTER



Global Synthetics



PREFACE

The Victorian chapter of the Australian Geomechanics Society invited academics and practitioners in the field of geotechnical and ground engineering to attend the 2018 Australian Geomechanics Society Victorian Symposium on 'Geotechnics and transport infrastructure' held on 24 October 2018.

In recent years Victoria has seen significant investment in transport infrastructure as part of a plan to manage the demands of a growing population and expanding urban fringe. The construction of Melbourne Metro, a second crossing of the Yarra River, rail and freeway upgrades as well as numerous level crossing removal projects are just some of the major transport projects currently underway in Melbourne and regional Victoria. Many of these projects carry numerous complex geotechnical challenges.

The 2018 Australian Geomechanics Society Victorian Symposium covers a variety of geotechnical challenges associated with transport geotechnics and present overviews of current infrastructure challenges, state of-the-art practices, innovation, new research results and case studies demonstrating applications of advanced techniques and cost effective solutions in the construction and design of local transport infrastructure. The Symposium brought together professional engineers, researchers, specialist contractors, regulators, educators and students to share and discuss their experiences on the topic of transport infrastructure and associated geotechnical challenges and applications.

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Highways, water, ground investigation and data – a cautionary tale

T. Creighton¹ and B. Waite²

¹Geotechnical Engineer, Asset Services, ²Asset Management Engineer, Metropolitan South East Region, VicRoads, 60 Denmark Street Kew VIC 3101, emails: toby.creighton@roads.vic.gov.au and bill.waite@roads.vic.gov.au

ABSTRACT

VicRoads had an ongoing problem with a section of an important arterial road in the south-east suburbs of Melbourne. The road was duplicated during 2003-2004 and had experienced over 400 mm pavement settlement and associated drainage issues, causing potential road management safety implications. Preconstruction ground investigation data provided no indication as to the likely cause. To design a solution, a conceptual engineering geological model was developed, initially using regional data and then a series of targeted ground investigations to refine the model. The provision of various types of data from a number of sources allowed the iterative development of the model and testing of a number of potential scenarios before identification of a probable cause. This paper describes the problem at the site, the model development & the eventual solution selected, as well as some learnings that were identified during the process.

Keywords: roads, soft ground, settlement, engineering geological models

1 SITE LOCATION AND HISTORY

Cranbourne - Narre Warren Road is an important arterial road in the expanding outer south eastern suburbs of the Melbourne conurbation (see Figure 1). It runs in a north-south direction, to link the local centres of Narre Warren and Cranbourne, in the City of Casey. It is a major feeder route from these population centres to two principal State east – west arterial roads, the Princes Highway and the Monash Freeway. The road currently (2018 data) carries an average of 39000 vehicles per day in both directions, of which about 6% are freight vehicles.

The original single carriageway Narre Warren – Cranbourne Road was constructed prior to 1958, extending from the Princes Highway to the South Gippsland Highway. Eastwards expansion of the Melbourne suburban area in the 1990s has seen increased traffic volumes that prompted duplication of the road in 2003 to 2004, between the Princes Highway and Pound Road.

The land on either side of the road remained generally unaltered until the 1990s, with development of primarily domestic properties occurring between 1994 and the early 2000s, almost exclusively on the eastern side of Narre Warren – Cranbourne Road. On the western side of the road, between Fullard Road, 200m south of the railway line, and the Hallam Main Drain bridge,

approximately 1.4km to the south of this location, there has been minimal development, due to the presence of a flood plain overlay, with much of the land being part of the areal stormwater drainage scheme. Associated with this, a retarding basin was constructed on the western side of the road in the period between 1974 and 1988. This was converted to an artificial wetland by Melbourne Water in the period from 2001 to about 2004.

2 GEOLOGY AND TERRAIN

An overall view of the regional geology, determined from Geological Survey of Victoria indicated the higher ground to be composed of Palaeozoic sedimentary lithologies (Murrindindi Supergroup and Werribee formation), and the valley to be infilled with a cover of Holocene swamp deposits overlying Quaternary lake deposits (Figure 2). The terrain across much of the area traversed by Narre Warren - Cranbourne Road is generally flat lying, with areas of high ground located to the west, east and north (see Figure 3). The overall topographic profile is one of an incised valley, through which flows one of the local main water courses, the Hallam Main Drain. This water course is part of the Dandenong catchment and directs flow westwards into the Patterson River system.

Due to the flat topography of the site there is very limited gradient available for gravity drainage systems, such as a storm and foul water sewers.

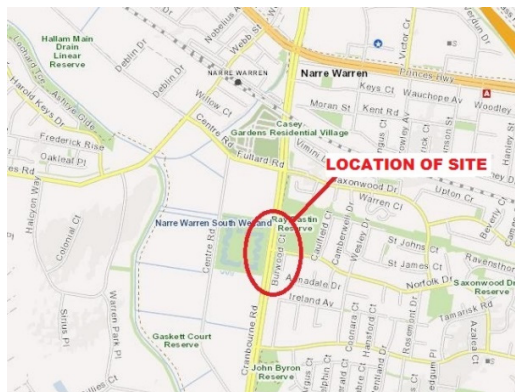


Figure 1. Location Plan

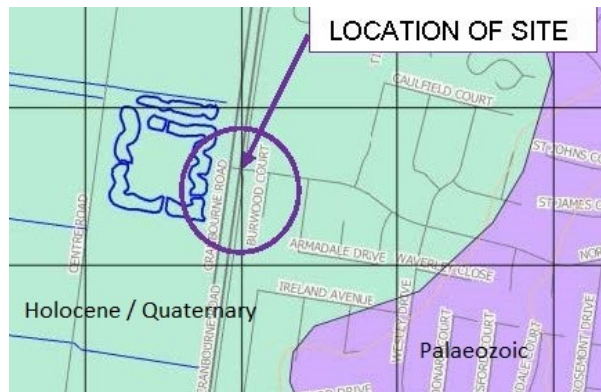


Figure 2. Geological Map Extract (source – GeoVic information)



Fig 3 – contour plan

3 NATURE OF THE PROBLEM

The new southbound carriageway, immediately south of the intersection with a local road (Norfolk Drive), suffered severe shape loss & subsidence / settlement first recognised in 2008. Settlement affected both the longitudinal and transverse elevation of the carriageway and had led to road safety concerns requiring interventions and regulatory speed controls

The problem was first attended to in 2009, by placing asphalt regulation over a 20m section of the right-hand lane in the southbound carriageway, to correct more than 100mm of settlement. In 2010, additional surface correction was required and asphalt regulation was placed over a portion of both lanes. However, by 2013, the shape of the pavement had further degraded, to the extent of requiring asphalt regulation over 100m long on both lanes to correct settlement in excess of 100mm. In addition, an advisory maximum speed of 60km/h had been posted on roadside signs. Some on site modification to the constructed kerb and channel drainage of the road had also been found necessary, to restore a degree of surface drainage in the outside lane through the affected section.

In 2015, the continuing settlement and road pavement deformation problem had spread to cover an approximately 200m length of road. This led to an inability of the road surface to drain after rainfall events, causing significant ponding of water and deteriorating rideability characteristics, prompted reduction of the regulatory speed limit to 60km/h. The same observed settlement and water ponding issues were also affecting the shared user path adjacent to the southbound carriageway. The site was placed on VicRoads register of roads in poor condition, and a bid for funding of a long-term solution to the settlement issue had been submitted. At that time the adjacent northbound carriageway was unaffected.

In 2016, localised deformation of the road pavement became apparent in the adjacent north bound carriageway, although this was not affected by the same settlement problems which affected the southbound carriageway.

4 SITE INVESTIGATIONS AND RESULTS

The first investigation of geotechnical problems at the site focussed on the investigation of the subsurface

conditions in close proximity to the affected section of road.

In 2013, a limited investigation, including borehole excavation and Cone Penetration Tests (CPTs), was undertaken to investigate the ground conditions beneath the southbound carriageway. This indicated the existence of an organic clay within the upper 4m below ground level, with a soft to very soft consistency. A groundwater monitoring standpipe was constructed in one borehole. The high measured static water level in it indicated pressurised groundwater conditions at this location.

During the data review process, it became obvious that an improved way of visualising the information would greatly assist in understanding the overall problem. The need to understand the mechanism and look for a possible link to wider issues suggested that the use of an engineering geological approach might be the most suitable way of determining a probable cause for the on-going settlement problem, rather than treating it as a simple soft pavement subgrade situation. It could also be used to inform further investigation phases as well as design of solutions. Accordingly, a conceptual engineering geological model was developed via an iterative process, and continually updated as more investigation data was forthcoming.

5 DEVELOPMENT OF THE ENGINEERING GEOLOGICAL MODEL

The use of engineering geological models, as described by Fookes (1997) and developed by Fookes *et al.* (2000 & 2001) and others (e.g. Parry *et al.* 2014), has gained acceptance throughout the profession as a best practice means of synthesising regional data and site investigation information. Such models enable better understanding of geological and geotechnical settings, and improve the selection of suitable designs or treatments for geotechnical problems.

5.1 Initial Iteration – pre-construction information

Geological survey records for the location indicated the near surface geology to be composed of unconsolidated alluvium and lacustrine deposits, as previously noted. This appeared to be confirmed by records from the preconstruction investigation (2002 – 2003), for which the nearest investigation points (two test pits, the nearest

of which was 100m from the area undergoing settlement) showed silty clay and clayey silt of stiff consistency. This material was underlain by yellow and grey mottled silty clay, of firm to stiff consistency. Field records indicated this material to have an in-situ moisture content that exceeded its plastic limit, and to contain localised lenses containing free water. Anecdotal information from the time of the construction of the duplication indicated that, during the construction of the southbound carriageway, a number of areas of soft material had been noted in the affected area. Although treatment with more suitable material had been attempted, the extent of these areas had proved difficult to manage. The construction records also confirmed that the duplicated carriageway had been constructed directly above the former southbound verge and table drain at this site.

5.2 Second iteration – first investigation

The first investigation (2013) to specifically investigate the settlement problem included three boreholes and twelve CPTs. The locations were specifically targeted along and adjacent to the section of the southbound carriageway (see Fig. 4) where settlement most affected the road.

Investigation information confirmed a transition in material consistency at around 5m bgl, from soft to generally firm to stiff. CPT information confirmed the existence of organic clays to a similar depth. Wet material had been recovered from each of the three boreholes at a depth of 8.7m bgl. The single groundwater monitoring borehole revealed groundwater at or slightly above the top of the monitoring standpipe, at ground level. Comparison of field assessment of hydraulic conductivity (by recovery test in the standpipe) with laboratory consolidation test permeability results suggested anisotropic permeability within the alluvial material, probably due to intercalations of coarser material. Laboratory consolidation test data for an undisturbed tube sample of clay from 3m below ground level also confirmed a high susceptibility for consolidation.

5.3 Third iteration – second investigation and historical timeline

During 2015 and 2016, the on-going settlement at the site was causing road management safety concerns which required a solution to the issues. This prompted further desktop review including obtaining historical records from various sources. The review included land mapping, aerial photography, Council archives, services information and meteorological information. It also included additional archival information that had become available since the first investigation, relating to vegetation, land use and services construction. This was added to the information set obtained from pre-construction investigations (2002-2003), records during the construction phase (2003-2004), the recent site investigations (2013 & 2016), utility service installations, drainage works, and weather event records. It included a re-evaluation of all information and consideration of other potential mechanisms for the settlement and high groundwater level encountered at the site. The recently obtained historical information included photographic evidence of the degree of settlement since construction, and information indicating that the construction of nearby services (base level 4.7m bgl) prior to the road duplication had been undertaken by trenching. One of

the key requirements was to compile a detailed timeline of land use changes and developments at the site.

The site also required review of its setting in a more regional context, and a detailed topographic survey was commissioned, as was a review of the location and influence of local vegetation. The condition of the local drainage infrastructure was considered to be influencing the condition of the road, and a drainage survey was commissioned. At that time, deterioration of the pavement on an adjacent section of the northbound carriageway also became apparent, and the potential for seepage from the wetland located on the western side of the northbound carriageway was further considered.

The influence of the pavement construction causing consolidation of the underlying materials and its effect on reducing lateral groundwater flows from the high ground towards the lowland was identified as a factor for consideration, due to potential adverse effects on the subgrade condition.

The single groundwater monitoring standpipe installed as part of the 2013 investigation indicated the groundwater table was approximately 8.5m below ground level. The borehole log indicated this was within the alluvial clay formation, and at the base depth of the standpipe installation, 9.45m below ground level, the measured head of water was at or above ground level. A wider monitoring network was required to assess the groundwater conditions laterally and vertically within the local geology. Examination of lateral variability within the near surface geology and fill had also been limited by the scope of previous investigation work.

Expert reviews were undertaken of the potential for vegetation located nearby to influence the ground settlement, and of the chemistry and source of the water found in the 2013 monitoring borehole.

The fieldwork part of the second investigation included the drilling of another eight boreholes at various locations, and the installation of groundwater monitoring standpipes in some of them. A further twelve CPTs were also undertaken.

The results of the review of historical and archival information confirmed the construction of services parallel to the road in the early 1980s, prior to the duplication, and provided anecdotal information that this construction had been undertaken by trenching to a depth of approximately 4.7m bgl. Information also indicated that this service had not been affected by settlement at this depth. The new southbound carriageway had been constructed parallel to and between the existing road and the services alignment. Summary points in timeline:

- 1958 – Narre Warren – Cranbourne (NWC) Rd is sealed single carriageway road
- 1982 – MMBW Sewer installed at about 5m depth in verge parallel to NWC Rd
- 1988 – Retarding basin constructed to west of road
- 2000 – Concrete footway constructed & vegetation planting in east verge parallel to road.
- 2001 – Wetland constructed in retarding basin
- 2004 – NWC Rd duplicated & old table drain infilled. Wetland completed
- 2009 – First patch & regulation to correct settlement
- 2010 – Second regulation to correct settlement
- 2013 – Third (extensive) regulation to correct settlement

The topographic survey information identified a noticeable regional settlement affecting the alluvial flatland, including the remainder of the Narre Warren – Cranbourne Road alignment. This ruled out the use of a rigid piled foundation as an appropriate solution. The survey also confirmed the magnitude (up to 700mm between 2001 and 2016) and localised nature of the extreme settlement along the southbound carriageway since construction.

Assessment of trees within one section of the council reserve adjacent to the southbound carriageway indicated that they were of mature age, having been planted at about the time that the road was duplicated, and produced vertical loading near the area of settlement. However, the placement of the trees was not confined to the site and could not fully explain the severity of settlement observed. The drainage survey confirmed the extreme settlement was preventing the existing road drainage functioning correctly, with disruption to the fall on the system.

The field investigation work and increased coverage of borehole and CPT information confirmed a geological stratigraphy across the site as shown in table 1 below. The CPT testing in the paludal cover recorded high friction ratios in the upper 4m of soil, suggesting the prevalence of organic clay across the site from ground level to 4m depth. The investigation locations for both the 2013 and 2017 investigations are depicted in Figure 4. The additional groundwater monitoring points provided the groundwater observations described in Table 2. The CPT also confirmed the existence of perched water tables within the first metre below much of the site, and deeper water bearing intercalations of coarser material with rapid piezometric response, confined by high plasticity clay units, producing a water table encountered at between 6m and 8m below ground level, but with static head at or near to ground level. Chemistry of the (deeper level) water from the 2013 borehole indicated it to be

representative of regional groundwater, rather than derived from leaking services. A summary cross section through the affected area from east to west is shown in Figure 5.

The settlement of the southbound carriageway was regarded as most probably resulting from a localised deep area of very soft natural organic clays. This carriageway had apparently shown little settlement in the two years immediately following construction, but for the ten years afterwards had undergone settlement at an average of 40mm per year. There appeared to be no clear defining explanation for the quantum of settlement observed, with a mostly undrained environment and without the presence of significant thicknesses of peat, but it appeared most likely to be the result of a combination of services construction work (in the years prior to the road duplication) to a floor depth of 4.7m below ground surface, and re-use of locally excavated clay for backfill, combined with the effects of the trees that grew from saplings to maturity on very soft organic clays. as in Figure 6.

On the northbound carriageway, the damage was recent and appeared to result from wetting of the subgrade, caused by damage to the drainage infrastructure along the road median resulting from the extreme settlement taking place along the southbound side of the road.

As well as reconstruction of the highway drainage to an operable state, two separate solutions were recommended to repair the road. That for the southbound carriageway involved the construction of a mechanically stabilised rock platform with geosynthetic separation layers, to bridge the problem area and allow it to settle at an even rate in line with the rest of the road alignment. For the northbound carriageway, a conventional softened subgrade repair was specified.

Table 1 – Summary stratigraphy

Material	Depth to Upper surface	Depth to lower surface
FILL (i.e. Topsoil, asphalt, crushed rock, engineered clay)	0	0.6 – 1.9
Organic CLAY	0.6 – 1.9 (typical 2.0m at SB carriageway, 1.0m at NB carriageway).	1.8 – 5.0 (typical 4.0m at SB carriageway, 2.0m at NB carriageway)
High plasticity CLAY	1.8 – 5.0 (typical 4.0m at SB carriageway, 2.0m at NB carriageway)	5.2 – 11.5 (typical 10.0m at SB carriageway, 7.0m at NB carriageway)
Silty CLAY and SAND (Werribee Formation?)	5.2 – 11.5 (typical 10.0)	18.2 – 22.5 (typical 18.5)
MUDSTONE (Murrindindi supergroup.)	18.5 – 22.5 (typical 18.5)	>23

Table 2 – groundwater monitoring summary

Location	No. of BHs.	Water monitoring information
West side verge adjacent to northbound carriageway	2	Shallow, responsive to rainfall events, not related to groundwater table
Median	1	Shallow, water level in granular pavement
East side verge and adjacent locations (shallow – 3m deep)	1	Dry
East side verge and adjacent locations (shallow – 3m deep)	2	Deep, pressurised, represents water in Holocene sandy clays, sands & silts

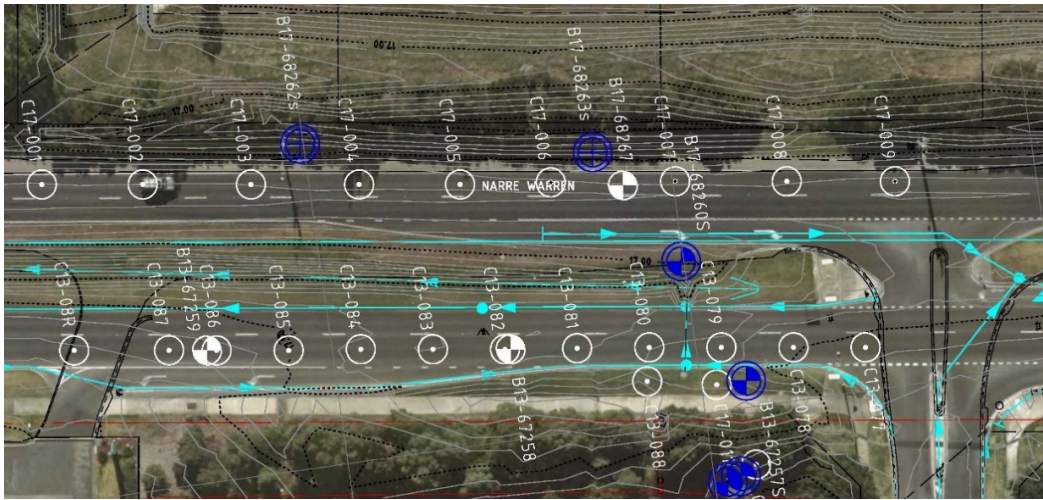


Figure 4. Site investigation locations (north to right)

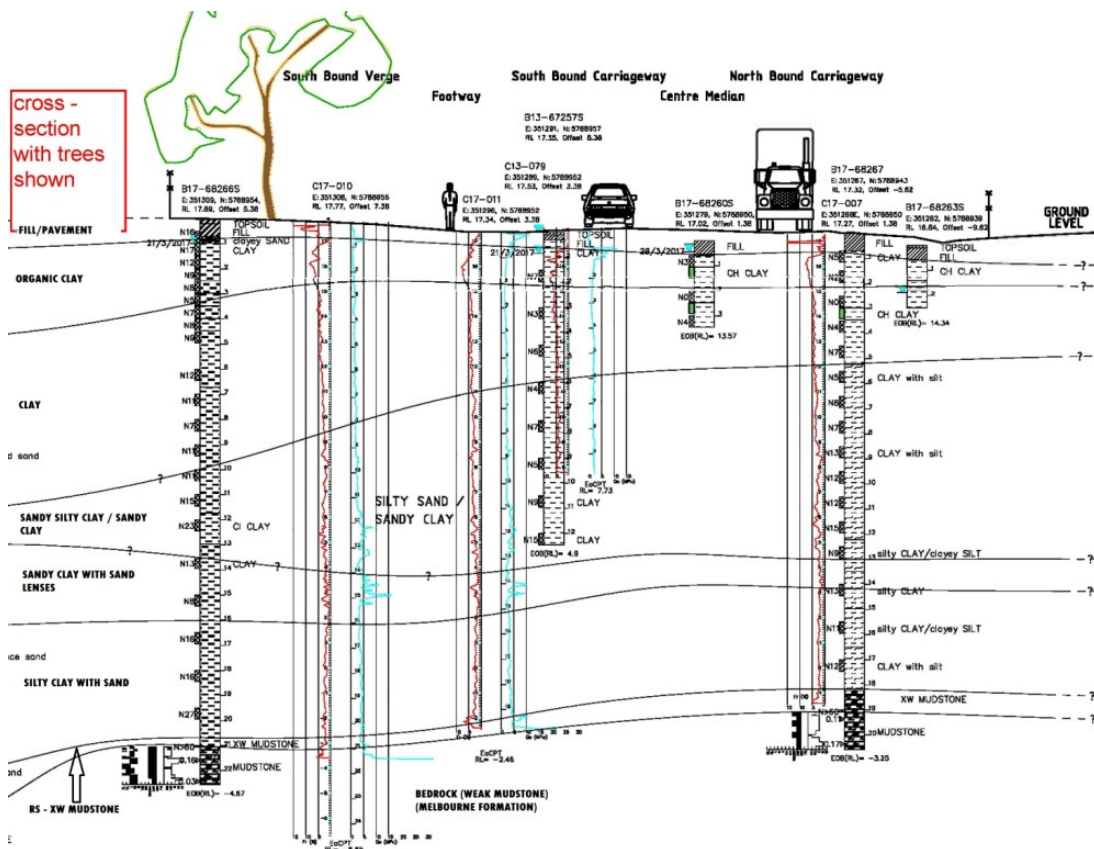


Figure 5. Model section (east to left)

6 CONCLUSION

An adequately funded and appropriately resourced sequential investigation, including the review of historical data, allowed the development of a conceptual model that identified separate causes for two individual pavement settlement problems, and development of appropriate designs for each. This visual approach to information enabled it to be readily understood by non-technical staff.

7 ACKNOWLEDGEMENTS

The authors wish to thank VicRoads Metro South East Region for permission to publish the information relating to this site.

The author(s) of the papers should send their contributions in accordance with these layout instructions to ensure a uniform layout for the conference proceedings. Please note that these instructions have been formatted to resemble a final paper. To ensure a uniform image of the proceedings this template can be directly used.

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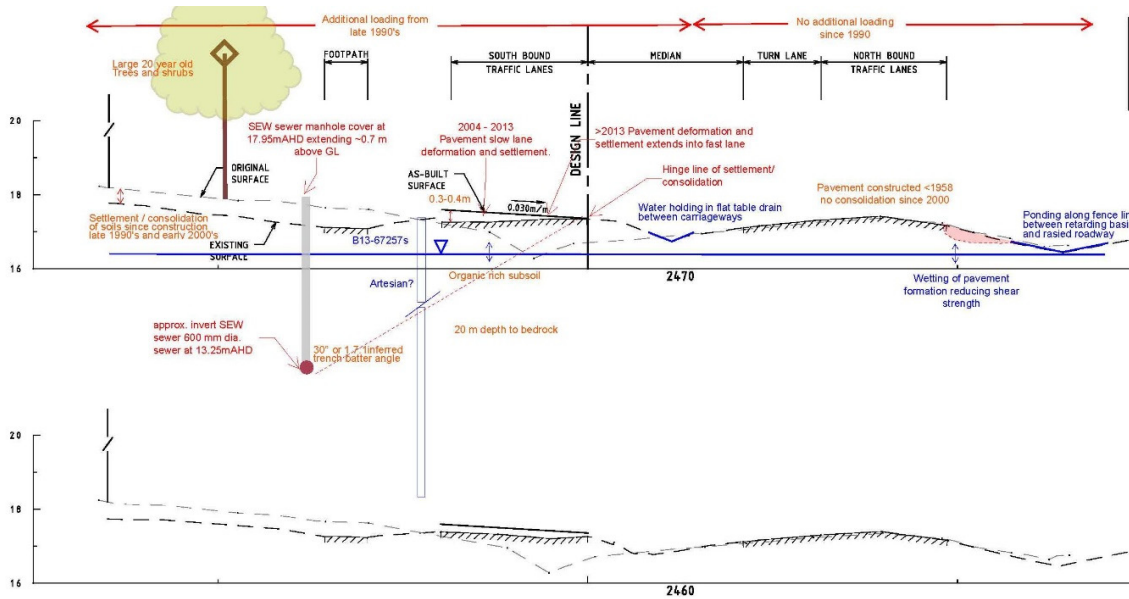
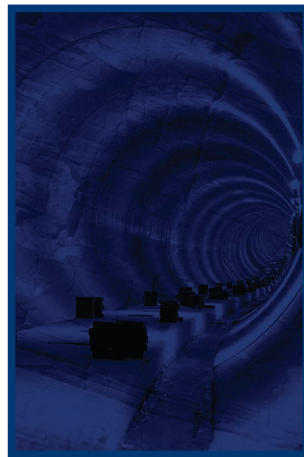


Figure 6. Interpreted section (east to left)

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