Technical Report 36

# Geotechnical Interpretive Report

NZ TRANSPORT AGENCY
WAKA KOTAHI

MacKays to Peka Peka Expressway

## Revision History

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## Document Acceptance

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## Executive Summary

The Geotechnical Interpretive Report presents an assessment of the geotechnical and geological conditions for the proposed MacKays to Peka Peka Expressway (the 'Expressway), and is one of the report supporting the AEE.

Several geotechnical investigations have previously been undertaken across the proposed Expressway site, for the proposed Sandhills Motorway and the existing WLR designation, the MacKays Crossing project, and Kāpiti Coast District Council borefield project (refer to Section 1). Geotechnical investigations have been undertaken by the MacKays to Peka Peka Expressway Project team[1] to provide additional coverage. The proposed Expressway corridor traverses sand dunes, swamp deposits, and alluvium, underlain by a thick sequence of older marine and alluvial sand and gravel deposits, with greywacke bedrock at depth. The topography, geological development and the groundwater setting of the proposed Expressway corridor are outlined in Sections 3.1 and 3.2.

The geological units for the project are identified in Section 3.3, and the engineering geological model is illustrated on the long-section and peat plans (refer Appendix 36.B).

North-east to south-west oriented active faults surround the proposed Expressway route. Though none pass directly through the route it is possible that splinters of major active faults are present (refer section 3.1), a splinter of the Ohariu Fault known as the Hadfield Fault has been identified. Faulting is discussed further in Sections 3.4 and 3.5.

The proposed Expressway alignment is located in an area of high seismicity. The Project team has completed a site-specific seismic hazard assessment to refine the seismic hazard. The subsoil classification is generally Class D – deep or soft soil, except to the north where it is Class C - shallow soil. The seismic design hazard is discussed in Section 3.6.

Loose to medium dense sands are present which are susceptible to liquefaction where saturated during a moderate or significant earthquake event. Liquefaction is expected to result in settlements, seismically induced slope instability and horizontal movements of dunes, and of new embankments. Liquefaction is discussed in Section 3.7.

The geological conditions are summarised for each of the four sectors of the proposed Expressway in Section 4.

Some key geotechnical constraints for the proposed Expressway include: the presence of peat and the potential for settlement, and the high seismic hazard and potential for liquefaction. These and other related constraints are considered further in Section 5.

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[1] This Technical Report refers to the Project team as carrying out works on behalf of and as contracted by the NZTA. The NZTA is the requiring authority and the consent holder.

Section 6 presents the basis for selection of, and recommendations for the geotechnical design parameters to be adopted for preliminary design. The parameter values are based on all available investigation data, and previous experience with similar materials. Available *in situ* and laboratory testing data for each of the primary units has been summarised along with the recommended ranges for the geotechnical design parameters.

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# 1. Introduction

## 1.1. Scope and Purpose

The the Project team has been commissioned to undertake scheme assessment stage design for the proposed Expressway. This phase of design is part of a scheme assessment to enable the design of the proposed Expressway, and to allow an Assessment of Environmental Effects (AEE) to be undertaken with the aim of securing the necessary approvals under the Resource Management Act 1991 (RMA) for the proposed Expressway.

The purpose of this report is to provide an interpretive assessment of the geotechnical/ geological conditions for the proposed Expressway. The report presents geological models and a summary of laboratory testing data to show how the soil properties to be used for geotechnical design have been derived.

In addition, this report has been prepared to provide advice and detail for the consenting of the design for this phase of the proposed Expressway. Further phases of design will require additional geotechnical investigation and this report will then be updated.

The MacKays to Peka Peka Expressway Geotechnical Design Report (M2PP Scheme Assessment Report, 2011) outlines the geotechnical design approach for this phase, which is based on the recommended parameters presented in this report.

This report covers the Project from just north of the MacKays Crossing (chainage 0 m) to north of Peka Peka Road (chainage 18050 m). It is noted that for RMA consenting purposes, the Project commences at chainage 1900 m. Maintenance work will be undertaken on the existing State Highway 1 (SH1) within the existing designation between MacKays Crossing to south of Poplar Avenue.

## 1.2. Project Description

For the scheme assessment, the designation for the proposed Expressway is proposed to generally follow the existing WLR designation designation, and span a length of approximately 16km from just south of Poplar Ave (chainage 1,900 m) to just north of Peka Peka Road (chainage 18,050 m). For the purposes of the AEE, the proposed Expressway designation is proposed to have a general width of 100 m.

The proposed Expressway will provide for two lanes of traffic in each direction, connections with local roads at four interchanges, construction of new local roads and access roads to maintain local connectivity.

For further details refer to Project Description (Construction and Operation) within Part D, Chapters 7 and 8, Volume 2 of the AEE.

The proposed Expressway alignment has been divided into four geographic sectors. Each of the sectors covers a geographic area that is described below and illustrated in Figure 1:

- Sector 1 – Raumati South: from 700 m South of Poplar Avenue to just north of Raumati Road between chainages 1,900 – 4,500 m;
- Sector 2 – Raumati/Paraparaumu: from north of Raumati Road to north of Mazengarb Road between chainages 4,500 – 8,300 m;
- Sector 3 – Otaihanga/Waikanae: from north of Mazengarb Road to north of Te Moana Road between chainages 8,300 – 12,400 m;
- Sector 4 – Waikanae North: from north of Te Moana Road to Peka Peka between chainages 12,400 – 18,050 m.

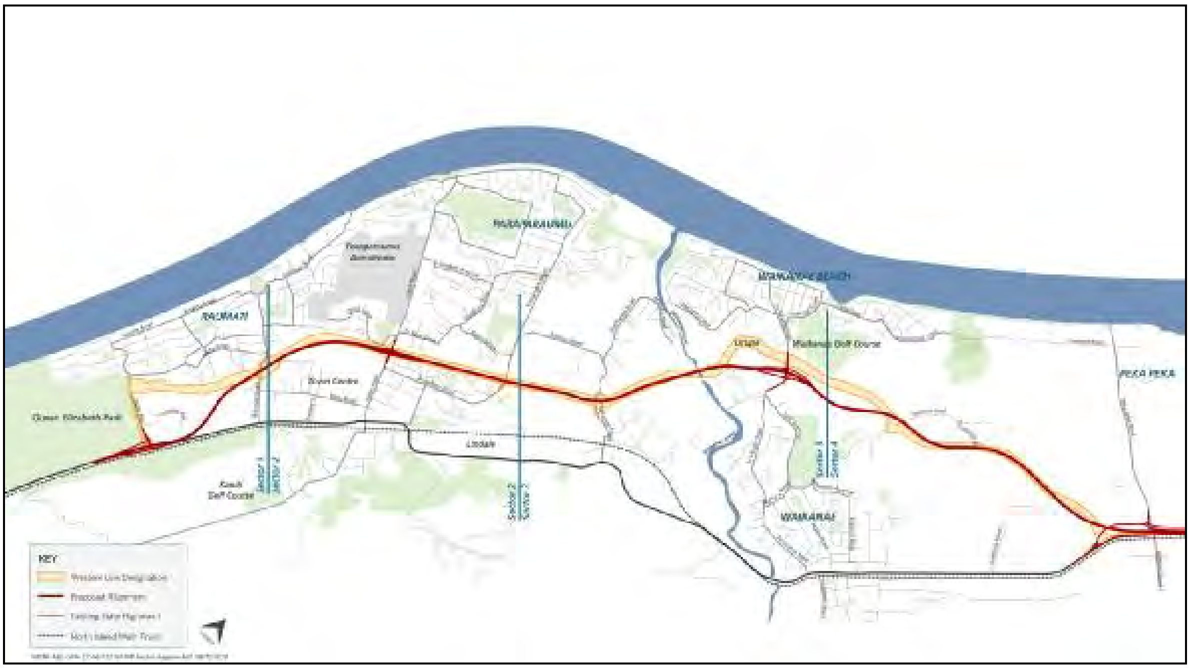



Figure 1: Sector Illustration of the Expressway

## 1.3. Geotechnical Investigation

Several geotechnical investigations have previously been undertaken across the proposed Expressway site, both for the development of a north-south link along the designation (proposed Sandhills Motorway and existing WLR designation) and the MacKays Crossing project. In addition, there is geotechnical data available for the Waikanae area from the Kāpiti Coast District Council borefield project.

Geotechnical investigations were recently undertaken by the the Project team during the investigation and scoping phase of the Project, primarily in areas where geotechnical information or deep information in particular, was limited.

The locations of sub-surface investigations are presented in the historic and Alliance investigation plans, Appendix 36.A. The following list provides a summary of the ground investigation information made available for this report:

Western Link Road Geotechnical Reports (Opus):

- Stage 1, Raumati Rd to Te Moana Rd Design and Project Documentation Stage, Geotechnical Report May 2008;
- Stage 1, Raumati Rd to Te Moana Rd Design and Project Documentation Stage, Site Investigation Report (addition to July 2007) April 2008;
- Stage 1, Raumati Rd to Te Moana Rd Site Investigation Report July 2007;
- Stage 1, Raumati Rd to Te Moana Rd Design and Project Documentation Stage, Groundwater Monitoring Plan November 2008;
- Stage 1 Boreholes and Trial Pits, complete copy of bore logs and variable head tests May 2007;
- Stage 3 Geotechnical Investigations Site Investigations Report March 2009;

Other Geotechnical Reports:

- Opus, 1997: State Highway 1 Poplar Avenue to MacKays Crossing Scheme Assessment: Geotechnical Report. Prepared for Transit New Zealand;
- Opus, 1999: SH1 Poplar Avenue to MacKays Crossing: Safety Improvements, Geotechnical Assessment of Trial Embankment;
- URS, 2005: Waikanae Borefield Technical Report, Prepared for KCDC;
- Works 1992: Paraparaumu Bypass/Arterial Land Disposal Study: Geotechnical Report;
- Opus, 1998: Kāpiti Urban Roading Project, Geotechnical Investigations for Estimation of Peat Thickness, Factual Report, prepared for KCDC;

MacKays to Peka Peka Alliance Reports:

- MacKays to Peka Peka Expressway Alliance: Phase 1 Investigation – Factual Geotechnical Report.

### 1.3.1. Engineering Geological Logging

The field logging of materials recovered from boreholes, test pits, and hand augers during the the Project team investigations were undertaken in general accordance with the New Zealand Geotechnical Society Guidelines.

### 1.3.2. Instrumentation

Various standpipe piezometers were installed in the the Project team investigations (refer to the Phase 1 Investigation – Factual Geotechnical Report for details). These installations are primarily related to understanding the regional groundwater regime to further define the hydrogeological model for analysis. The installations have been monitored on a regular basis, with some monitored at a greater frequency by use of pressure transducers.

### 1.3.3. Laboratory Testing

Selected peat and sand samples recovered from the boreholes were tested at IANZ accredited geotechnical soils laboratory, Geotest Ltd.

The laboratory testing results from the the Project team investigations are presented in the factual report. Geotechnical design parameters have been determined from all available laboratory test results (including those included in previous investigations listed in section 1.3 above) and from correlations with field observations and in situ testing. These parameters are discussed in Section 6.

## 1.4. Engineering Geological Model

The proposed Expressway traverses sand dunes and swamp deposits, the dunes rising to around
20 m elevation, with intervening low lying areas and depressions typically containing peat. Recent river and fan alluvial deposits form low level terraces adjacent to the Waikanae River, including the present floodplain. Underlying all these deposits is a thick sequence of older marine and alluvial sand and gravel deposits, with greywacke bedrock at 70 – 120 m depth, though rock occurs at much shallower depths in an area toward the north end of the route, where it is inferred to be uplifted along the Hadfield Fault.

An engineering geological long-section of the proposed Expressway route has been prepared for geotechnical analysis, and is presented in Appendix 36.B. The section shows the engineering geological units that have been developed for this site based on the material and soil behaviour, rather than age and origin. These engineering geologic units are described in detail in Section 3.3.

The long-section is exaggerated vertically (with five times vertical exaggeration) to allow detail of the thin and complexly bedded near-surface units to be seen. A section at natural scale must be used for measuring steepness of strata. Data from other sources such as groundwater well records held by KCDC are included on the section. Boreholes that have been extrapolated from outside the corridor (up to 200 m offset from the centreline) are identified by brackets around the borehole identification label on the section.

In addition, a plan has been developed illustrating the distribution of peat (and conversely, areas of non-peat) along the route, as this unit has significant effects on the proposed Expressway. The peat plan is presented on the top half of the long section sheets. This plan is based on all available geotechnical investigation data. The lateral extent of the peat has been mapped from the interpretation of the landforms shown on aerial photographs.

## 2. Applicability

This report has been prepared by Beca Infrastructure Ltd on the specific instructions of our Client. It is solely for our Client's use for the purpose for which it is intended in accordance with the agreed scope of work.

Notwithstanding this, it is understood and accepted that this report will be included in the AEE documentation and may be relied upon by the BoI in reaching its decision on the Expressway. Any use or reliance by any person contrary to the above, to which the NZTA has not given its prior written consent, is at that person's own risk.

Should you be in any doubt as to the applicability of this report and/or its recommendations for the proposed development as described herein, and/or encounter materials on site that differ from those described herein, it is essential that you discuss these issues with the authors before proceeding with any work based on this document.

## 3. Site Interpretation

### 3.1. Topography

The proposed Expressway route traverses the Kāpiti coastal lowlands along their inland (eastern) margin, adjoining and roughly parallel to the Tararua Ranges foothills. The route is undulating to rolling, with sand dunes forming areas of higher relief (up to around 20 m elevation) between low-lying interdune areas, located within a relatively flat coastal plain a few metres above sea level. Low alluvial terraces associated with Waikanae River and streams in the area also occur. The geology along the route is reflected in the landforms and topography observed.

### 3.2. Geological and Groundwater Setting

The proposed Expressway route is bounded by the Tararua Ranges in the east; these are steep greywacke hills which have formed by the uplifting and tilting of basement rock along NE-SW oriented faults. The proposed Expressway crosses the coastal plain west of the Ranges, an area which has been shaped by repeated cycles of glaciation that have occurred in the past 2 million years.

During the glacial cycles, sea levels were approximately 120 m lower than present, as water was locked in ice-sheets and glaciers. The Tararua Ranges held valley glaciers during these times, and physical weathering of rock combined with sea level fall, contributed to severe erosion in the Ranges generating alluvial fans and floodplains.

Conversely in the warm interglacials, sea levels rose due to melting ice sheets and glaciers, and erosion in the Ranges reduced. Consecutive glacial and interglacial events resulted in a series of terraces in the area abutting the western flanks of the Ranges (i.e.

the glacially deposited material became eroded by rising sea levels during the interglacials, leaving behind terraces where sea level reached a maximum).

A prominent cliff occurs approximately 4 – 6 m above the present sea level, referred to as the Interglacial Cliff, it marks the maximum sea level reached in the last Interglacial period. The material eroded by the rising sea became reworked as beach sands and gravels, and onshore winds deposited sand inland as dunes. These materials form a thick wedge (the Pleistocene wedge) over greywacke basement rock (depth to rock variable).

Towards the end of the last Glaciation (10,000 – 15,000 years ago) sea level rose as the climate warmed, so rivers cut terraces in their upper reaches, and deposited their sediment load as new floodplains in their lower reaches. These deposits form aggradational terraces known as the Parata Gravels (an aquifer at RL -10 to -20 m) in the Kāpiti Coast area.

6,500 years ago, the sea reached a maximum level, eroding a low cliff (the post glacial cliff) into the wedge of Pleistocene deposits, and cutting a flat sea bed. This flat seabed marks the boundary between the Pleistocene and Holocene deposits, which (based on geotechnical investigation data) appears to be just above or fairly close to present sea level.

During the Holocene (the last 6500 years) the coast has then prograded (advanced seaward) by the deposition of sands and gravels from inland erosion, moving the coast westward by as much as 3.5 km. These Holocene deposits include estuarine sands and gravels, dune sands (several successively younger phases, aging inland), peat, and river gravel. It is the Holocene dune sands (collectively referred to as the Himatangi Group) and interdune deposits (named Paraparaumu Peat) which dominate the geology along the proposed Expressway route, the dunes rising to around 20 m elevation, with intervening low lying areas typically containing peat. The dune sands are often interfingered with peat deposits; the dune sands have in places advanced over the swampy ground.

The groundwater regime consists of unconfined aquifers in the Holocene sand and peat deposits above a series of unconfined aquifers in the Pleistocene sand and alluvium layers. Below these, within the terrestrial gravels, there are two confined aquifers, the Waimea Aquifer, and the Parata Aquifer.

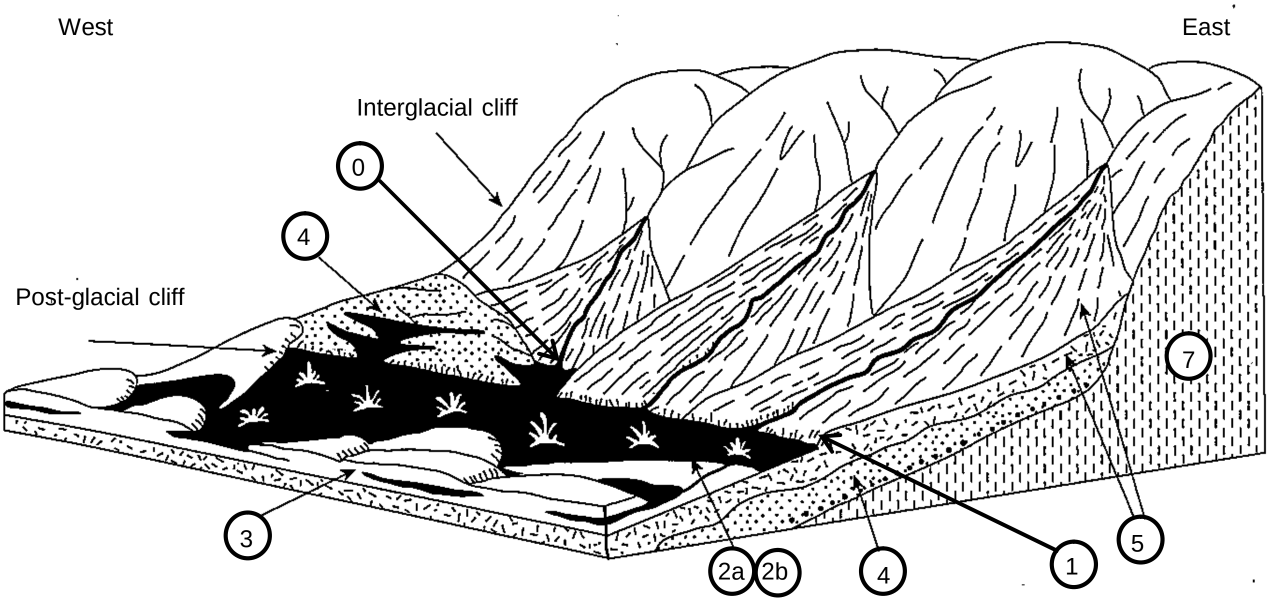
Typically the groundwater level within the peat deposits is between 0 and 1m below the ground level.

The peat ranges from amorphous organic silt to fibrous woody peat of variable permeability and compressibility. The peat is significant in that it supports a number of wetlands of high ecological value. The construction of the proposed Expressway has the greatest potential to affect the shallow groundwater system (i.e. the Holocene sand, peat, and alluvium) because earthworks will largely be carried out within these materials.

In the Holocene Sand, the groundwater level is typically around 2 m below ground level in low lying areas and up to around 10 to 14 m below the ground level in some sand dunes.

### 3.3. Stratigraphy

Materials that underlie the proposed Expressway route are known to vary in terms of lateral extent and thickness. The isometric section in Figure 2 below illustrates the typical stratigraphic relationship of the materials encountered. The numbered regions correspond to those in Table 1 below, which defines the engineering geological units that have been logged in the site investigations.




1.1. Key to Geological Units

| Unit Number | Geological Unit Name |
|---|---|
| 0 | Holocene alluvium (Waikanae River) |
| 1 | Fill / Holocene alluvium / colluvium |
| 2a | Holocene peat |
| 2b | Holocene organic silt / clay / sand |
| 3 | Holocene sand |
| 4 | Pleistocene sand |
| 5 | Pleistocene gravel |
| 6 | Pleistocene silt / clay |
| 7 | Rakaia Terrane Greywacke (Triassic) |

Figure 2: Isometric cross section of Kāpiti Coast area (modified from Maclean, C & Maclean, J, 2010). Refer to Table 1 for additional information on these units.

1.2. Table 1: Stratigraphy of the MacKays to Peka Peka Expressway route

| Engineering Geological Unit | | Location |
|---|---|---|
| 0 | Holocene alluvium (Waikanae River) | The most recent deposits include the alluvial gravel deposits in and around the present course of the Waikanae River. Generally moderately sorted, subrounded gravel to cobble sized greywacke with a sandy/ silty matrix, with local lenses of sand/ sandy silt. |
| 1 | Fill | Some investigation points south of Poplar Avenue contain fill material associated with the highway/ rail corridor. The fill comprises mainly sand and gravel, including rail ballast. |
| | Holocene alluvium | Generally encountered at the south end of the route, the material deposited is for the most part derived from the greywacke hills, comprising rounded fine to medium gravel. The alluvium is encountered either near surface or beneath a veneer of peat and/ or sand. |
| | Colluvium | Encountered almost exclusively at the south end of the route, comprising debris (subangular as opposed to rounded) in the near surface soils, derived from slope movements on the adjacent greywacke hills. |
| 2a | Holocene peat | Interdune deposits, referred to as Paraparaumu Peat. The peat typically comprises a sequence of fibrous woody material over amorphous, silty and silty to sandy peat. Application of the Von Post peat classification yields a degree of humification ranging from H3 to H9. Swamp deposits include soft peat and loose peaty sand through to spongy vegetable matter with high water content (some between 400 to 900 % water by weight). Woody peat with clay/ silt and sand lenses is common. |
| 2b | Holocene organic silt/ clay/ sand | Where the interdune deposits are organic but not strictly classifiable as peat, the terms organic silt/ organic clay/ organic sand have been applied. Typically the material is predominantly silt/ clay or sand, with an organic component. |

| Engineering Geological Unit | | Location |
|---|---|---|
| 3 | Holocene sand | Fine to medium sand, typically as dunes (Himatangi Group), and less commonly fine to coarse sand with some gravel (beach deposits, estuarine deposits). This unit has includes sand which occurs both as dunes and sand in low lying areas occurring above the Holocene/ Pleistocene boundary (the boundary being interpreted from material descriptions and density changes identified in geotechnical investigations). Loose, medium sand, fresh/ slightly weathered, with occasional thin clay/ silt beds. Thin iron pans may be found near the water table in older (inland) dunes. The sand is typically loose to medium dense. |
| 4 | Pleistocene sand | The Pleistocene sand unit describes all sand deposits beneath the Holocene/ Pleistocene boundary, regardless of origin and deposition, including reworked dune sands, marine, beach and estuarine sands. The sands are typically dense to very dense; however, for a large proportion of the northern sectors (primarily in Sectors 3 and 4) of the proposed Expressway alignment, a moderately thick (typically 2 m, locally up to 7 m) medium dense to dense sand layer is present near the Holocene/ Pleistocene boundary. |
| 5 | Pleistocene gravel | The Pleistocene gravel unit describes all gravel deposits beneath the Holocene/ Pleistocene boundary, including glacial outwash, reworked beach sands and gravels. This unit typically comprises of poorly sorted greywacke gravel to boulder sized clasts in a matrix of coarse sand, with localised thin lenses of sand/ sandy silt. Typically slightly weathered, but older deposits may be moderately weathered. Loess may be found separating successive gravel deposits. |
| 6 | Pleistocene silt/ clay | The Pleistocene silt/ clay unit describes all silt/ clay deposits encountered beneath the Holocene/ Pleistocene boundary, including estuarine, marine or alluvial deposits. |

| Engineering Geological Unit | | Location |
|---|---|---|
| 7 | Rakaia Terrane Greywacke (Triassic) | The Rakaia Terrane greywacke forms the basement rock, and occurs at depth (e.g. 60 – 120 m depth) beneath the proposed Expressway footprint, dipping westward from the Tararua Ranges foothills. However, toward the north end of the route, beyond Ngarara Road (paper road section) at chainage 16,800 - 17,000 m in situ greywacke is encountered at just 5.5 m depth, with rockhead apparently dipping northward to 80 m depth north of Peka Peka Road at chainage 18000 m. The NE-SW trending Hadfield Fault is mapped as crossing the alignment in this area, and is likely to be responsible for the shallow occurrence of rock. Alternatively, it may be a buried spur of the Tararua Ranges foothills. In either case, the greywacke in this area is sheared and crushed, typical of rock associated with a fault zone. |

### 3.4. Geological Structure & Seismicity

The proposed Expressway traverses the inland margin of the coastal plain between Kāpiti Island in the west, and the Tararua Ranges foothills in the east. Kāpiti Island is described as an outlier of the Tararua Ranges; being the westernmost of a series of ridges, bound by NE-SW orientated faults.

There are NE-SW oriented active faults located north, south, and east of the proposed Expressway route. Though no active faults are mapped passing directly through the site, it is possible that splinters of these major active faults are present. Table 2 summarises the active faults in the area, their distance from the proposed Expressway site, and their characteristics (largely based on the published information contained in the geological map bulletin, Begg and Johnston (2000), supplemented by more recent research).

Table 2: Active Faults

| Fault name | Distance from Expressway route | Estimated Characteristic Magnitude (Mw) | Recurrence Interval (1000 years) | Recurrence Interval Class | Elapsed time since last EQ (1000 years) | Est. single event displacement | Confidence of Recurrence Interval Class |
|---|---|---|---|---|---|---|---|
| Pukerua Fault* | 7.5 km SW of southern end | 7.6 | 2.5 – 5.0 | Class II | Ohariu F. (>1.06 – 1.14) | 3.5 – 4.0 m (horz) | Low |
| Hadfield Fault** | 1-2 km east of Peka Peka Rd end of route | ? | ? | ? | ? | ? | ? |
| Ohariu Fault | 3 km E of route | 7.6 | 1.3 – 3.8 | Class II | 1.06 – 1.14 | 3 – 5 m (horz) | Low |
| Gibbs Fault | 4 – 5 km E of route | ? | > 3.0 to <5.0 | Class III | <10 | 1.5 m (vert) | Low |
| Northern Ohariu Fault | 2 km NE of northern end of route | 7.3 – 7.7 | 3 – 3.5 | Class II | < 4 | 3 – 3.5 m | Low |
| Ōtaki Forks | 15 k m E of route | 7.3 – 7.6 | > 3.0 to <5.0 | Class III | ? | 2.5 -3.5 m (horz) | Low |
| Wellington Fault*** | 25 km E of route | 7 – 7.6 | 0.9 | Class I | 0.3 | 3.5 – 5 m (horz) | High |

Pukerua Fault is considered part of the same geologic structure as the Shepherds Gully Fault, and rupture characteristics for the two are grouped in the geological map bulletin, Begg and Mazengarb (1996). While this grouping is not given in the later map of Begg and Johnston (2000), it is assumed the rupture characteristics of the Shepherds Gully Fault also hold for the Pukerua Fault (in the absence of specific information for the Pukerua Fault).

** Currently the presence of the Hadfield Fault is disputed. It is likely to be a splinter fault as the Ohariu Fault steps to become the Northern Ohariu Fault. Earthquakes on the Ohariu and Northern Ohariu are fault likely to govern seismic class.

*** The recurrence interval and elapsed time since last earthquake for the Wellington Fault quoted above are based on the media release on the GNS website, dated 18th September 2009.

## 3.5. Fault Hazard

A splinter fault of the Ohariu Fault known as the Hadfield Fault has been identified at the northern extent of the proposed Expressway, near the proposed Peka Peka Interchange Structure. The fault is considered active, however this is disputed. The fault complexity (i.e. possibly a fault zone as opposed to single fault trace), and level of uncertainty regarding its location, is indicated by the shaded triangle on the KCDC Fault Hazard Map (Appendix 36.C).

The fault is relatively well defined to the north-east of the proposed Expressway route, but is less well constrained in the vicinity of the proposed Expressway. The poorly constrained region crosses the proposed Expressway in an area of low embankments only, where there are no structures or large embankments.

Consequently specific investigation (e.g. trenching) to better understand this fault is not considered warranted.

## 3.6. Seismic Design Hazard

The proposed Expressway alignment is located in an area with a seismic hazard that is relatively high compared to other parts of New Zealand.

The the Project team has completed a site-specific seismic hazard assessment of three sites along the proposed Expressway alignment to refine the seismic hazard. A summary of key design parameters of this assessment are shown in Table 3 below. Refer to the report, MacKays to Peka Peka Expressway Site Specific Hazard Assessment and the MacKays to Peka Peka Expressway Geotechnical Design Report (M2PP Scheme Assessment Report, 2011) for further information. The subsoil classification of the proposed Expressway is Class D – deep or soft soil, except between chainage 16,800 to 17,000 m where it is Class C - shallow soil. There are no proposed structures located in the area classified as Class C.

Table 3: Design Peak Ground Accelerations for the Expressway

| Return Period (years) | Peak Ground Acceleration, PGA (g) | |
|---|---|---|
| | Class C | Class D |
| 250 | 0.47 | 0.36 |
| 500 | 0.59 | 0.45 |
| 1000 | 0.74 | 0.56 |
| 2500 | 0.98 | 0.74 |

### 3.7. Liquefaction Hazard

There is the potential for liquefaction to occur along the proposed Expressway route, based on the high seismicity and ground conditions present.

Loose to medium dense sand deposits are present within the sand dunes and underlying marine and alluvial deposits. These deposits are susceptible to liquefaction where saturated, based on material characteristics and grain size. Above the ground water level, they will be susceptible to shaking induced settlement.

A preliminary liquefaction assessment has been carried out, considering the available borehole and cone penetration test (CPT) strength data and water levels from adjacent piezometers. This assessment indicates these saturated, loose to medium dense sand deposits are expected to liquefy under the 250 year return period event. These deposits are expected to be encountered across the entire site.

The liquefaction hazard may be mitigated at specific locations by ground improvement techniques. Liquefaction potential, liquefaction analyses, and the likely effects are specifically addressed in the MacKays to Peka Peka Expressway Geotechnical Design Report (M2PP Scheme Assessment Report, 2011).

## 4. Sector Specific Conditions

### 4.1. Sector 1 (ch 1,900 – 4,500 m) Raumati South

From MacKays Crossing to just north of Raumati Road, the topography is fairly low lying, comprising peat and/ or organic silts overlying Holocene alluvium and sand, and Pleistocene gravel at depths of 5 to 10m below ground level until chainage 4,000m, where dunes of around 15m height overlay the Pleistocene sand and gravel.

### 4.2. Sector 2 (ch 4,500 – 8,300 m) Raumati/ Paraparaumu

From north of Raumati Road to north of Mazengarb Road, the topography is undulating. The route crosses dunes which reach up to 15 m in height, with lesser amounts of lower-lying interdune areas in between. It appears that much of this sector of the corridor preserves a remnant of what was a larger dune field which has undergone extensive earthworks for residential development in Paraparaumu. The geology generally comprises Holocene sand (dune), overlying Pleistocene sand, with peat and organic silt in low lying areas.

### 4.3. Sector 3 (ch 8,300 – 12,400 m) Otaihanga/ Waikanae

From north of Mazengarb Road to north of Te Moana Road the topography is undulating, the route passing over dunes (which reach up to 20m height) and lower-lying interdune areas. The geology generally comprises Holocene sand (dune), overlying Pleistocene sand, with peat and organic silt in low lying areas. Toward the centre of this sector the Waikanae River cuts through the route east-west, with associated low-lying alluvial terraces on either side. Geology at depth beneath the Waikanae River area comprises very dense Pleistocene gravel, and some Pleistocene silt.

### 4.4. Sector 4 (ch 12,400 – 18,050 m) Waikanae North

From north of Te Moana Road to Peka Peka the topography is undulating, dominated by dunes until Smithfield Road, east of which the route flattens out. The geology comprises Holocene (dune) sand overlying Pleistocene sand and at depth, Pleistocene gravel. Beyond Smithfield Road there are areas of peat and organic silt in low lying areas, particularly north of chainage 15,600 m. At chainage 16,200 to 16,700 m the alignment crosses the Hadfield Fault zone, as extrapolated from the mapped 'well-defined' zone on the KCDC fault map (refer Appendix 36.D for map). For the purposes of interpreting borehole data for the engineering geological long section, and also for groundwater modeling, the fault is inferred to cross at the midpoint of this zone at chainage 16,450 m. Note however that the map has a broad 'uncertain poorly constrained' fault zone shown in this area. In terms of the KCDC fault mapping, the District Plan Change 61 indicates that development over the 'uncertain poorly constrained' fault zone does not required detailed assessment to prove the position of the fault trace, and that there are no Council requirements for protection against earthquake fault rupture hazard.

## 5. Geotechnical Constraints

The key geotechnical considerations that have been identified for the proposed Expressway are:

- The presence of peat deposits across the site, and associated embankment settlements and stability;
- The high seismic hazard and known active faults;
- The presence of relatively loose to medium dense saturated sand deposits with the potential to liquefy during the moderate to significant design seismic events;
- Liquefaction induced slope instability and settlements;
- Founding conditions for bridge structures comprising alluvial deposits to depth, predominately interbedded dense sands and gravels.

The presence of peat deposits and the seismic aspects are described further below.

### 5.1. Peat Deposits and Settlements

Peat deposits are present along the route in the low lying inter-dunal depressions. The peat is very soft, with a high water content and compressibility. These deposits are typically 0.5 m to 4.0 m thick, and up to 6m thick in some locations.

The presence of peat deposits is a key geotechnical aspect for the proposed Expressway. Considerations associated with construction of an embankment over peat deposits include:

- Large settlements of embankments. Settlement is caused by constructing embankments above peat deposits or by the lowering of the groundwater table within the peat. The amount of settlement is dependent on the compression parameters of the peat, the peat thickness and the height of the embankment.
- Long term creep or secondary settlement of peat deposits post construction. This can cause differential settlements that may impact on the performance of the proposed Expressway, resulting in poor rideability, altered surface drainage patterns and increased maintenance.
- Potential settlement of services beneath the embankment and adjacent structures and property from construction and post construction settlement. The assessment of settlement effects are provided in Technical Report 35, Volume 3.
- Time taken for consolidation of peat deposits to occur during embankment construction where the peat is preloaded. This is affected by the thickness of the peat and its compression parameters of the peat.
- Stability of higher embankments constructed on the relatively weak peat deposits, in particular the temporary (construction stage) and seismic stability case.

## 5.2. Seismic Hazard and Liquefaction

The site is located in a highly seismic area, with known active faults, as detailed in Section 3.6.

Loose to medium dense sand deposits are present within the sand dunes, and underlying marine and alluvial deposits. A moderate or significant seismic event, somewhat less than the ultimate design event, is expected to result in:

§ Liquefaction of these sand deposits, where saturated;

§ Settlement of these sand deposits, as a result of densification in the dry sands and liquefaction induced settlements in the saturated sands;

§ Seismically induced slope instability and horizontal movements of existing sand dunes and new embankments constructed over these deposits;

§ Potentially lateral spreading or flow failure of existing sand dunes, new embankments, and the new approach embankments for the bridge structures, including the Waikanae River Crossing.

The performance of the proposed Expressway, both during and following the seismic design events is a key design aspect. The acceptable level of damage, emergency access and post-earthquake repair requirements under design events has been considered by the NZTA, and balanced against the economics and risk profile.

The seismic hazard and potential consequences of liquefaction are discussed further in the MacKays to Peka Peka Expressway Geotechnical Design Report.

# 6. Design Parameters

## 6.1. Introduction

This section presents the basis for selection of geotechnical design parameters and recommended geotechnical parameters to be adopted for preliminary design. These parameters are based on the investigation data from various investigations referenced in Section 1.3 above, and previous experience with similar materials. We consider the scope and detail of this parameter derivation to be appropriate to the current level of design. However, further phases of design may require more detailed interpretation of some aspects.

## 6.2. Geotechnical Design Parameters

Geotechnical design parameters are given for primary geological units that have impact on the design, namely:

- Interdune Deposits (peat/ organic silt);
- Holocene sand;
- Pleistocene sand;
- Pleistocene gravel; and
- Rakaia Terrane Greywacke.

Other materials have been logged that are not considered to have major influence on the scheme assessment stage design, based on their limited occurrence. These include fills, Holocene alluvium, minor colluvium, Pleistocene silt/clay, and recent alluvium confined to the Waikanae River.

The parameters are based on previously issued factual reports together with data from the the Project team investigations.  Experience with similar materials has also been considered, and engineering judgement applied.

The available *in situ* and laboratory testing data for each of the primary units above has been summarised below, along with the recommended ranges for the geotechnical design parameters.

## 6.3. Interdune Deposits (peat and organic silt)

Peat deposits underlie around 50 % of the proposed Expressway alignment. Peat consists of predominantly organic matter and has a very high water content. Consequently, it has very high compressibility (in the order of 30 % for a 50 kPa load applied), low strength (undrained shear strength typically of 10 to 20 kPa) and secondary settlement/ creep that continue to occur many years after the deposits have been constructed on.

While peat occurs across the alignment, some organic silt deposits are present that contain lower organic contents (5 to 15%), and water contents (25 to 150 %) than peat. Limited data has been collected on these deposits. Further investigation to differentiate between the organic soils and peat is required to select appropriate parameters for the organic soils.

For the purpose of preliminary design, the peat parameters presented below have conservatively been adopted for both peat and organic soils.

The nature, distribution and extent of the Interdune deposits vary along the route, by Sector these deposits may be summarised (from available investigation data) as follows:

Sector 1 and 2: typically 1 – 3.5 m of silty PEAT, minor ORGANIC SILT

Sector 3: typically <1-2.5 m of silty PEAT in the vicinity of Otaihanga landfill, and ORGANIC SILT and sand elsewhere;

Sector 4: typically 0.5 – 4.5 m of silty PEAT, some ORGANIC SILT.

The peat and organic silt material properties, as described from the logs and available laboratory testing data, are summarised in Table 4 below.

Table 4: Interdune Deposits (peat) Material Testing

| Material Property | Peat |
|---|---|
| SPT 'N' (blows / 300mm) | 0 |
| CPT $Q_c$ (MPa) | <0.1 – 0.4 (typically <0.1) |
| Natural Water Content (%) | 150 to 900 (typically 550) |
| Organic Content (%) | 15 to 95 (typically 80) |
| Initial Void Ratio | 4 to 11 (typically 8) |
| Coefficient of Compressibility, Mv ($m^2$ / MN) | 0.4 to 9 (typically 3.5 |

Given the similar origins and the difficulty in precisely defining the boundaries between them, it is recommended that these parameters be adopted for both the peat and organic silt deposits.

The geotechnical compression parameters, used to predict the consolidation settlements in the peat deposits, have been derived from available laboratory data, *in situ* testing and a number of field trials, as well as the historic data. The key sources are summarised in Table 5 below.

Table 5: Information Sources

| Type of data | Information source |
|---|---|
| Geotechnical Field Investigations (In-situ testing and laboratory data) | Western Link Road Geotechnical Investigations |
| | Project team Geotechnical Investigations |
| Field Trials | Opus Trial Embankment, undertaken for the existing SH1 Raumati Straight widening |
| | Project team Trial Embankment |
| | Project team Trial Excavation |
| Construction Records | SH1 Raumati Straight Widening |
| | MacKays Crossing Project |
| Historic Performance | Existing SH1 Raumati Straight |

The trial embankments were constructed to analyse the behaviour of the peat when loaded in a similar manner to the proposed development. The Opus trial embankment was constructed on peat deposits around 3 m thick immediately adjacent to the existing SH1 at Raumati Straight. The embankment showed 0.3 m to 0.5 m of settlement when loaded with 1 m of bulk fill and 1 m of preload and surcharge that was removed after 6 months. One half of the embankment had wick drains installed and the other half did not. There was no significant difference in the rate of settlement between the embankment with wick drains and the embankment that had no wick drains. The the Project team trial embankment was constructed on peat deposits around 2.5 m thick in a paddock south of Poplar Avenue. The embankment was constructed with around 3 m thickness of fill and was left to settle. Around 0.4 m of settlement was observed.

The widening of SH1 at Raumati Straight involved constructing an embankment on peat deposits immediately adjacent to SH1. Records of the as built dimensions of the embankment and the observed settlement were used.

The proposed Expressway project (Palmer, 2010) involved constructing an embankment up to 8.5 m high on up to 6 m thickness of peat. A maximum of around 2 m of settlement was observed during construction of the embankment.

The compression parameters for the peat deposits are presented in Table 6. Non-linear parameters, based on a compression index (Cc) approach, have been used to characterise the peat deposits. The non-linear approach provides a better fit for back analyses of historic data and field trails compared to a linear (Mv) approach, where a variety of embankment heights have been considered. The parameters are applicable for both embankment settlement and assessment of settlement effects.

Table 6: Peat Compression Parameters

| Compression parameter | Symbol | Unit | Value |
|---|---|---|---|
| Unit Weight | $\gamma$ | (kN / m³) | 9.6 to 12 (typically 10.5) |
| Compression Index Parameter | $C_c$ / $1+e_0$ | - | 0.35 |
| Pre-consolidation Stress | $P_0$ | kPa | 15 |
| Recompression Index Parameter | $C_r$ / $1+e_0$ | - | 0.06 |
| Coefficient of Consolidation (vertical) | $C_v$ | $m^2$/year | 3.0 |
| Recompression Co-efficient of Consolidation (vertical) | $C_{vr}$ | $m^2$/year | 3.0 |
| $C_c$ – Compression Index<br>$C_r$ – Recompression Index<br>$e_0$ – Initial Void Ratio | | | |

Immediate, secondary compression and long term creep settlements were not separately assessed and considered as these settlements are typically at least an order of magnitude less than the consolidation settlements and thus lie within the accuracy of those calculations.

Drying of peat may result in volume change and therefore settlement. The construction of the proposed Expressway (and modification of the foundations) and construction of the stormwater features is expected to result in lowering of groundwater levels. Although the mean groundwater level is lowered by a small amount, the moisture content of the peat is expected to remain high based on the infiltration recharge. Drying is not therefore expected. The settlements from drying induced volume change are expected to be relatively small and have not been separately quantified.

### 6.4. Holocene Sand

The Holocene sand is described as a medium dense, fine to medium grained sand. The parameters have been based on based on the logs, laboratory particle size analysis (refer to summary grading graph, and SPT 'N' value versus depth graph in Appendix 36.D. Table 7, below, summarises the Holocene sand material properties.

Table 7: Holocene Sand Material Properties

| Unit/ sub-unit | SPT 'N' (blows/300mm) | CPT $Q_c$ (MPa) | Unit weight (kN/m³) | Friction angle, f (°) | Effective cohesion , c' (kPa) |
|---|---|---|---|---|---|
| Loose to medium dense | 5 to 50 + typically 20 | 5 to 20, typically 12 | 17 | 32 | 0 |

## 6.5. Pleistocene Sand

The Pleistocene sand is described as a medium dense or dense, fine to medium grained sand, with trace silt and occasionally trace gravel. The parameters have been derived from the logs and laboratory particle size analysis (refer to summary grading graph, and density versus depth graph in Appendix 36.D). Table 8, below, summarises the Pleistocene sand material properties.

Table 8: Pleistocene Sand Material Properties

| Unit/ sub-unit | SPT 'N' (blows/300mm) | CPT $Q_c$ (MPa) | Unit weight (kN/m³) | Friction angle, f (°) | Effective cohesion , c' (kPa) |
|---|---|---|---|---|---|
| Medium dense | 11 to 29, typically 25 | 8 to18, typically 12 | 18 | 34 | 0 |
| Dense to very dense | 30 to 50+ typically 50+ | 20+ | 19 | 36 | 0 |

## 6.6. Pleistocene Gravel

The Pleistocene gravel typically ranges from a dense to very dense, fine to coarse grained gravel with a matrix of minor sand, through to a sandy gravel, and occasionally, a silty gravel, as described from the logs. Table 9, below, summarises the Pleistocene gravel material properties.

## 6.7. Table 9: Pleistocene gravel Material Properties

| Unit/ sub-unit | SPT 'N' (blows/300mm) | Unit weight (kN/m3) | Friction angle, f (°) | Effective cohesion , c' (kPa) |
|---|---|---|---|---|
| Dense to very dense | 30 to 50+, typically 50+ | 19 | 36 | 0 |

## 6.8. Rakaia Terrane Greywacke (Triassic)

The greywacke encountered in two (2010/BH15 and 2010/BH16) of the the Project team borehole investigations near Peka Peka Road was characterised as a crushed zone, typical of rock associated with a fault zone. The material properties are therefore more appropriately defined in terms of soil parameters.  Table 8, below, summarises the Rakaia Terrane Greywacke material properties.

Table 8: Rakaia Terrane Greywacke (Triassic) Material Properties

| Unit/ sub-unit | SPT 'N' (blows/300mm) | Unit weight (kN/m³) | Friction angle, f (°) | Effective cohesion , c' (kPa) |
|---|---|---|---|---|
| Rock (crushed/ sheared) | 50+ | 20 | 40 | 10 |

## 7. Summary of Parameters

The recommended geotechnical design parameters are summarised in Table 9 below.

Table 9: Recommended Geotechnical Design Parameters

| Engineering Geological Unit | | Unit weight (kN/m$^3$) | Friction angle, f (°) | Effective cohesion , c' (kPa) | Undrained shear strength, $c_u$ (kPa) |
|---|---|---|---|---|---|
| 2a | Holocene peat | 10.5 | - | - | 10 |
| 3 | Holocene sand | 17 | 32 | 0 | - |
| 4 | Pleistocene sand | 18 to 19 | 34 to 36 | 0 | - |
| 5 | Pleistocene gravel | 19 | 36 | 0 | - |
| 7 | Rakaia Terrane Greywacke (Triassic) | 20 | 40 | 10 | - |

Other materials have been logged that are not considered to have major influence on the preliminary design based on their distribution. Where properties of units are not detailed above, parameters are to be determined on a case by case basis using the relevant investigation data.

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Appendix 36.A

## Geotechnical Investigation Plans

(Refer to Drawings GT-GI-100 - 111, Technical Report Appendices, Report 36, Volume 5)

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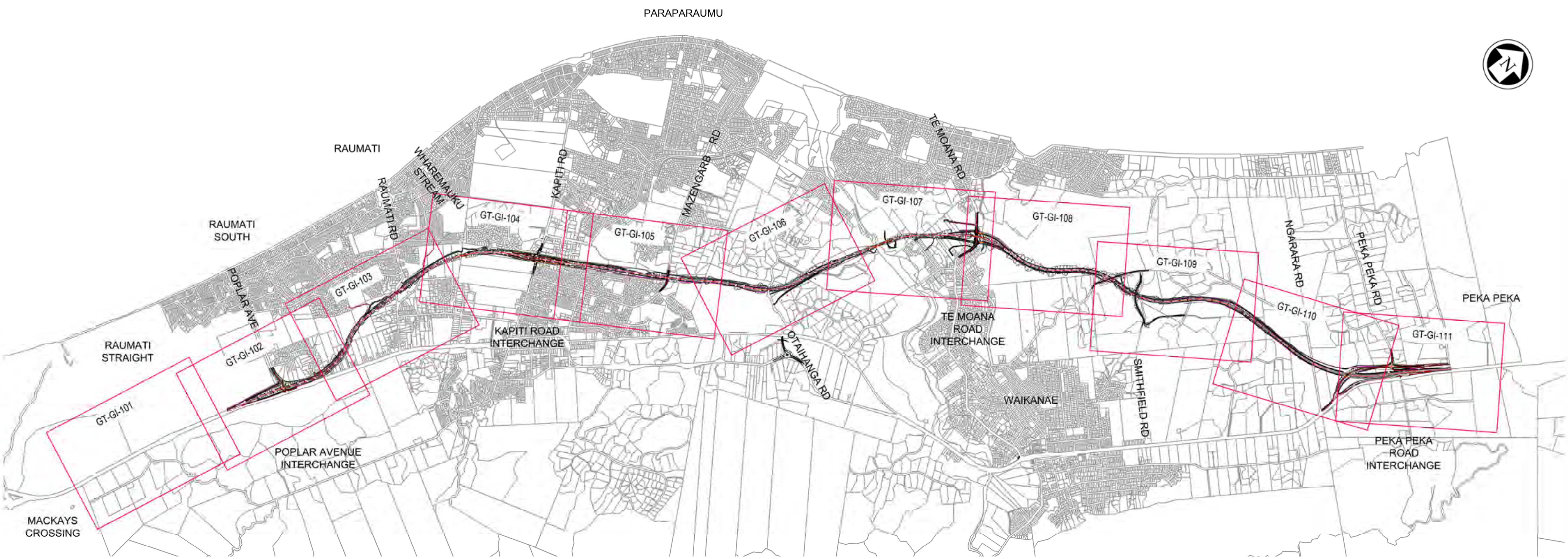


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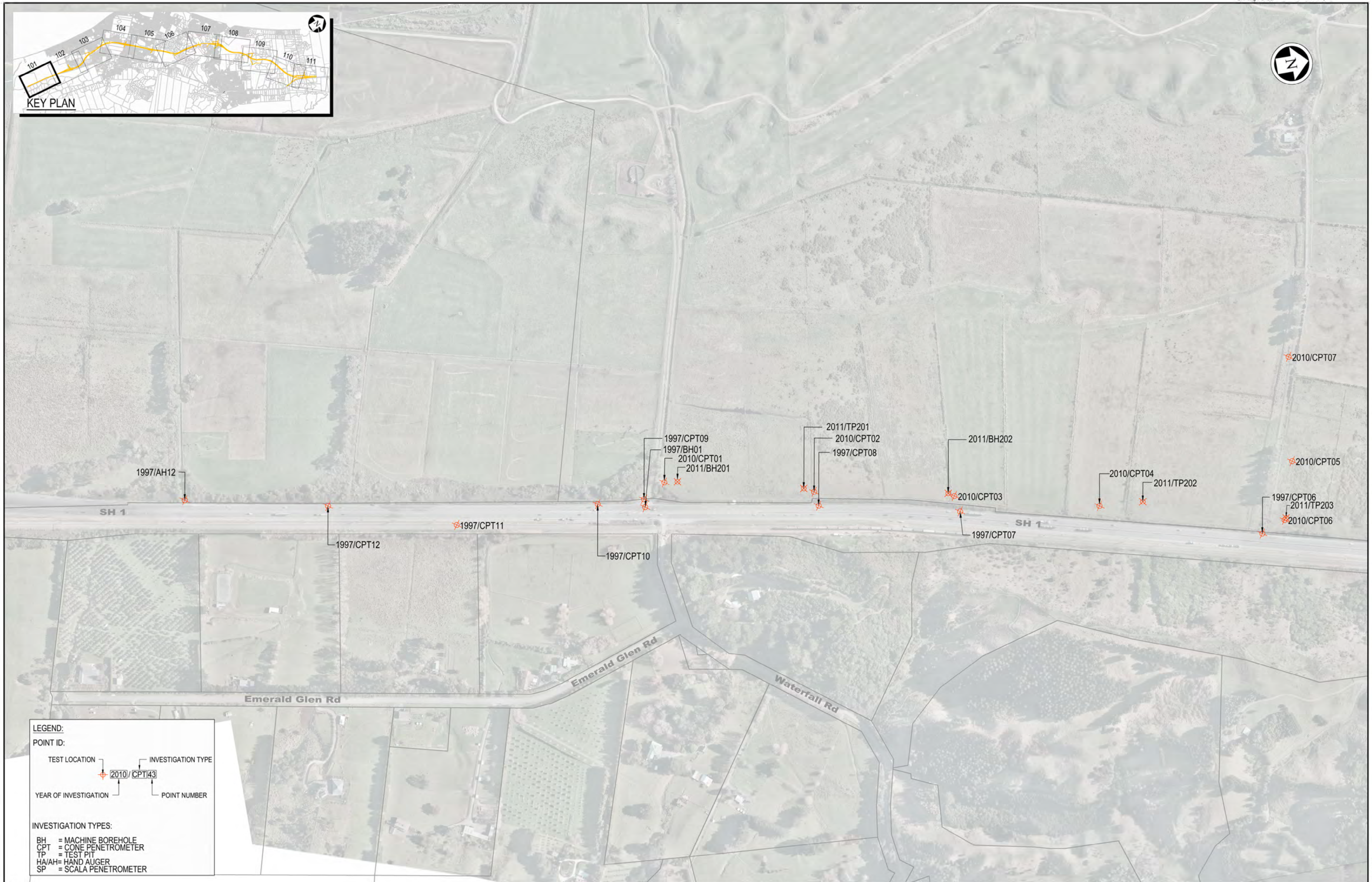


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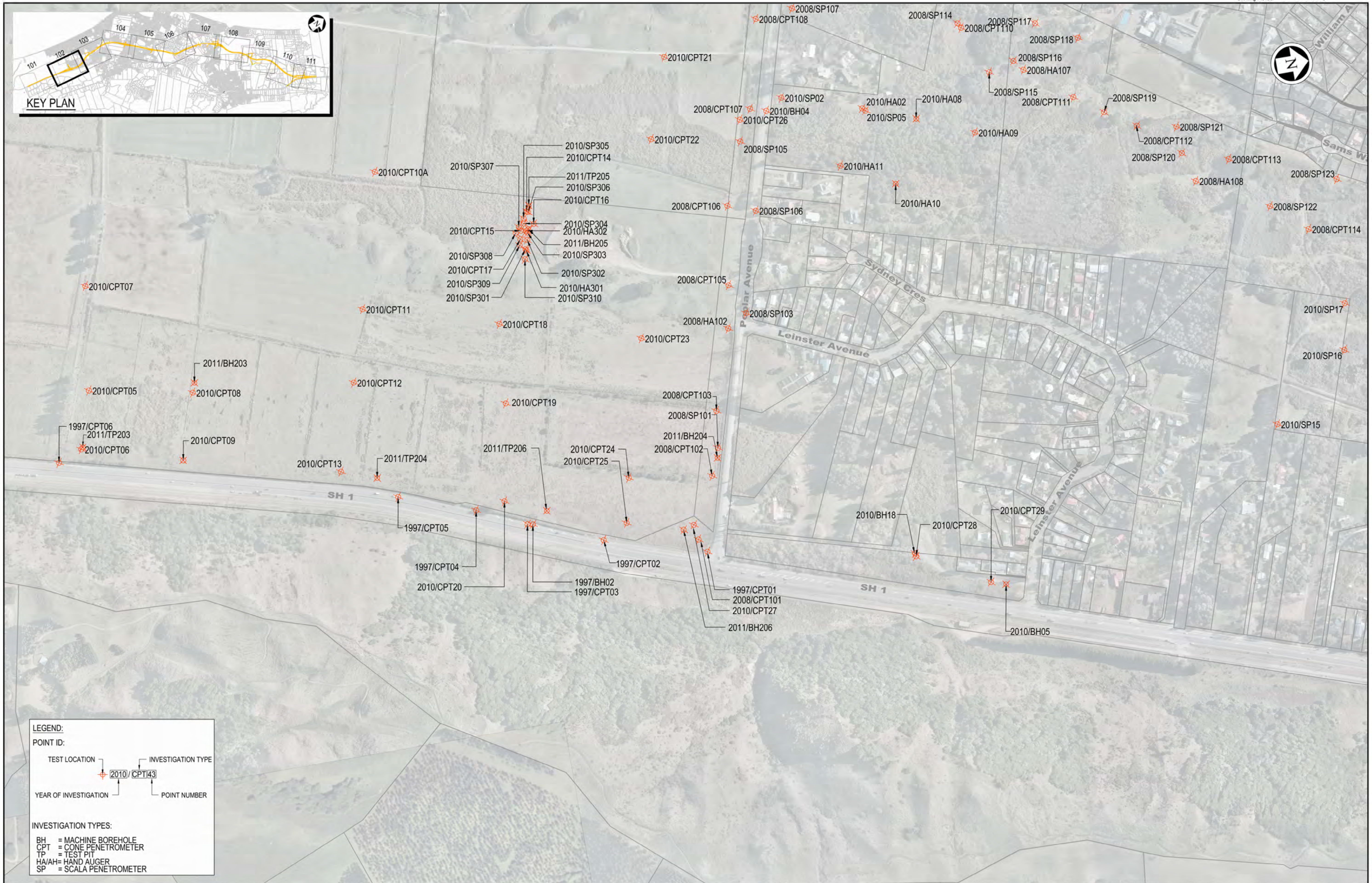


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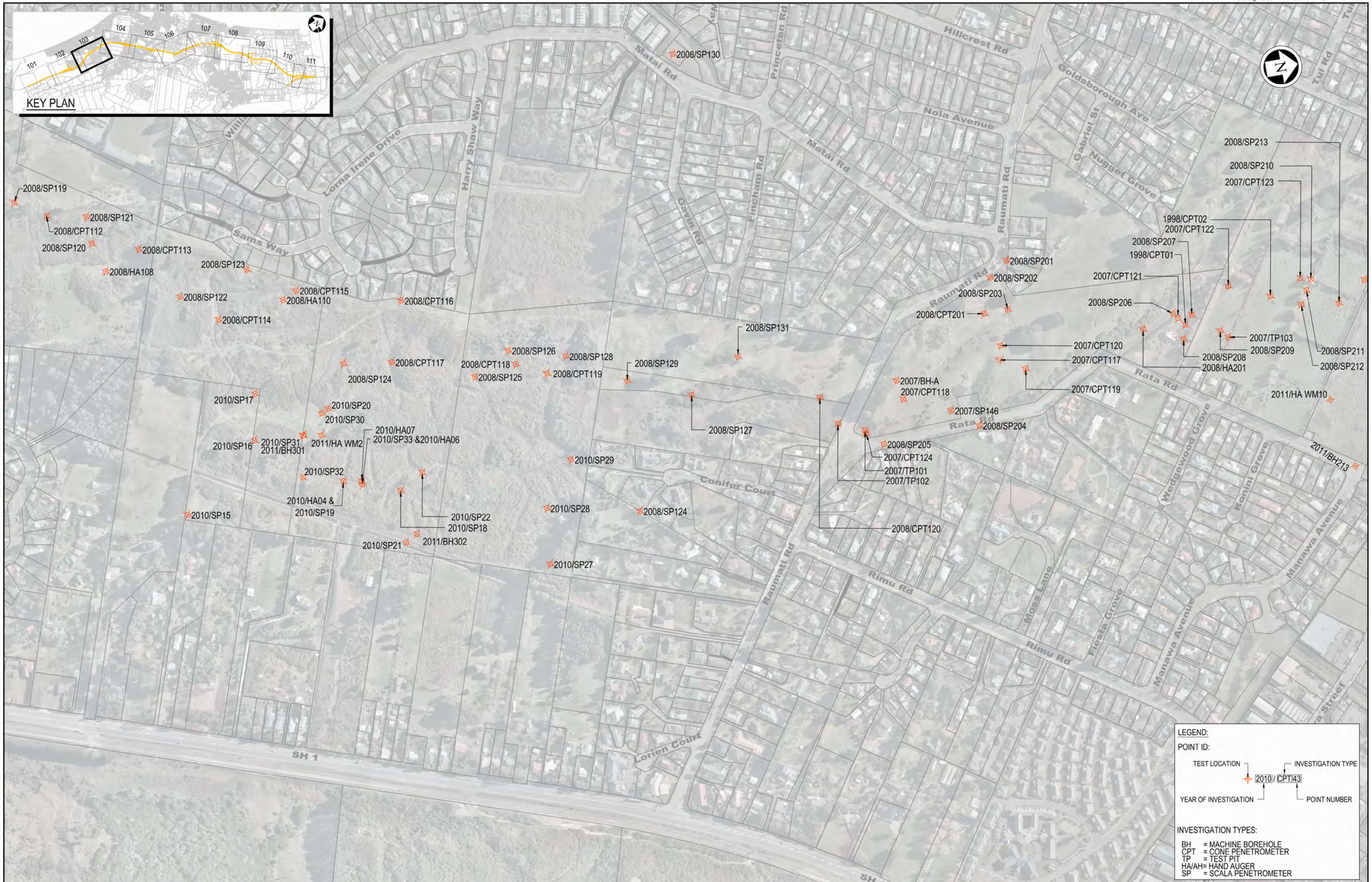


LEGEND:

POINT ID:

TEST LOCATION — INVESTIGATION TYPE

2010 / CPT 43

YEAR OF INVESTIGATION — POINT NUMBER

INVESTIGATION TYPES:

BH = MACHINE BOREHOLE
CPT = CONE PENETROMETER
TP = TEST PIT
HA/AH= HAND AUGER
SP = SCALA PENETROMETER

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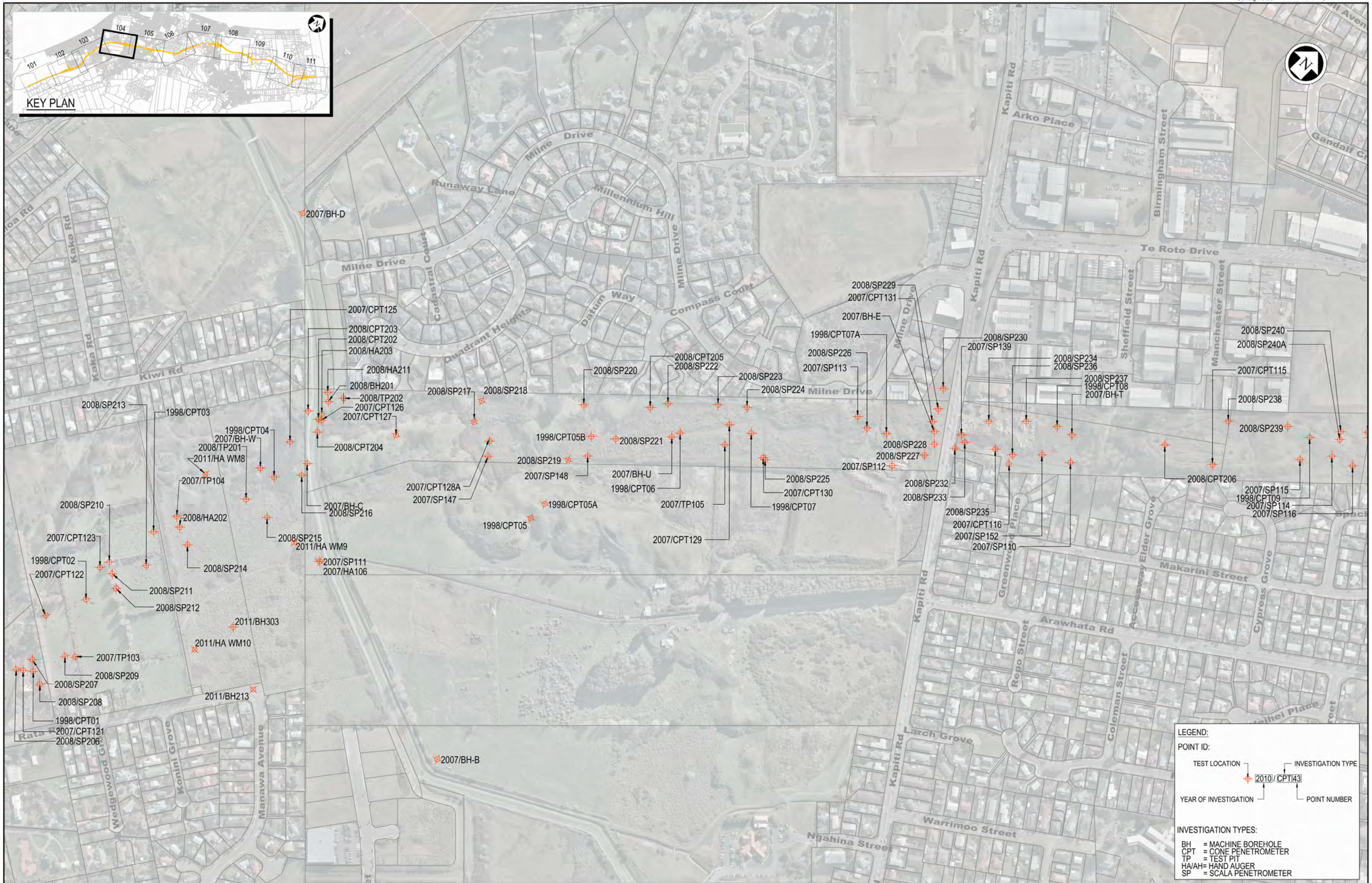


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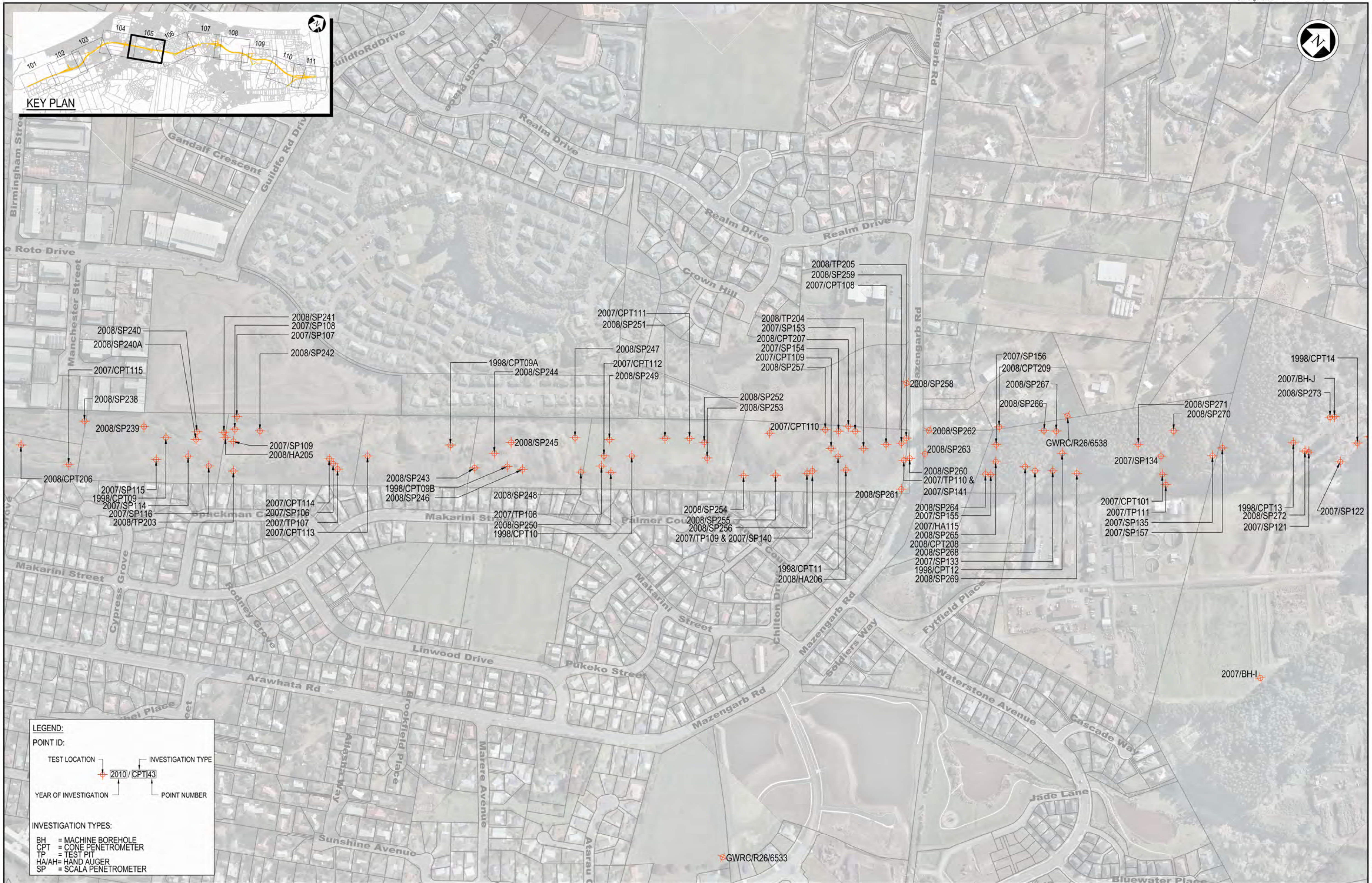


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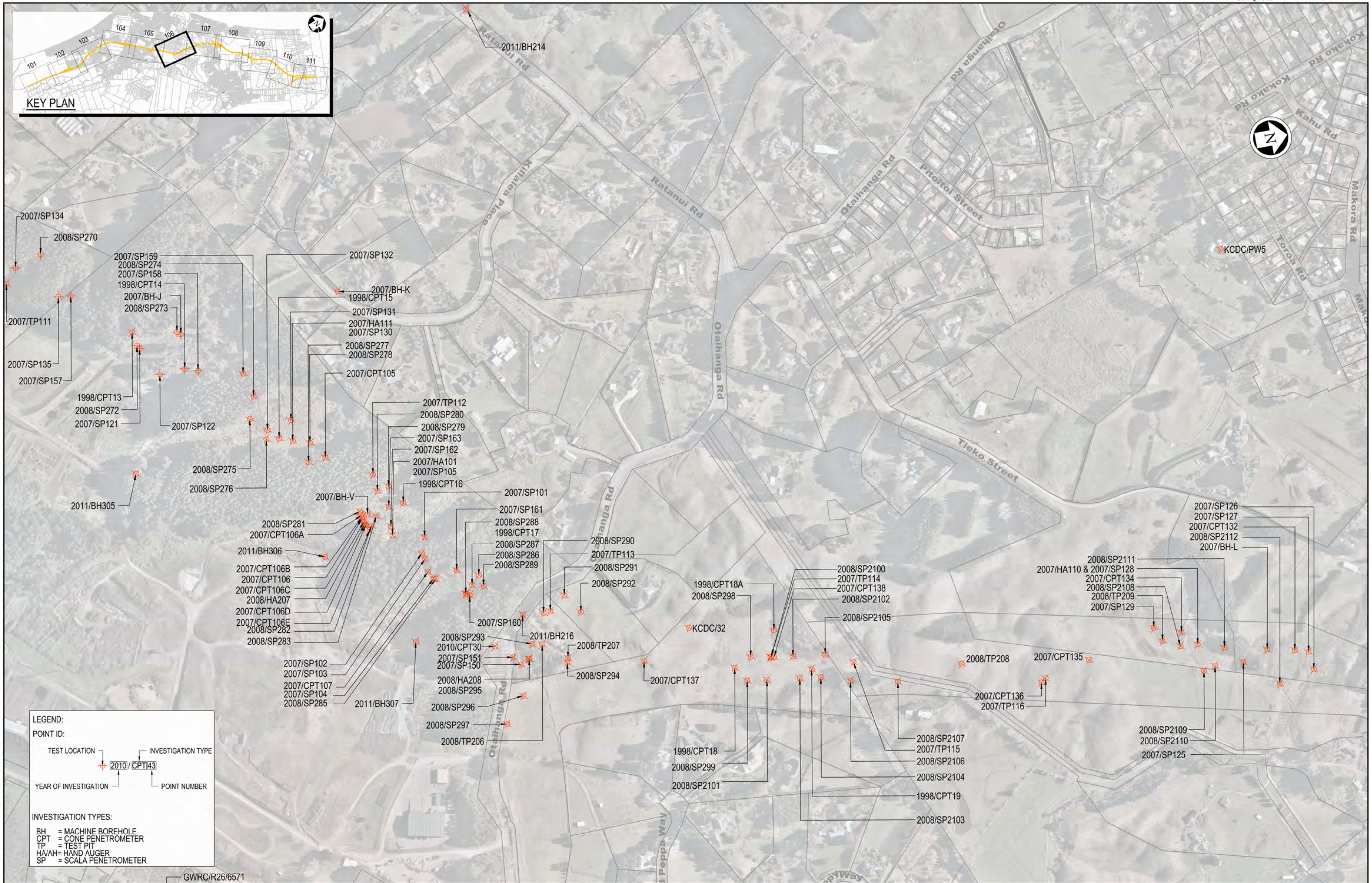


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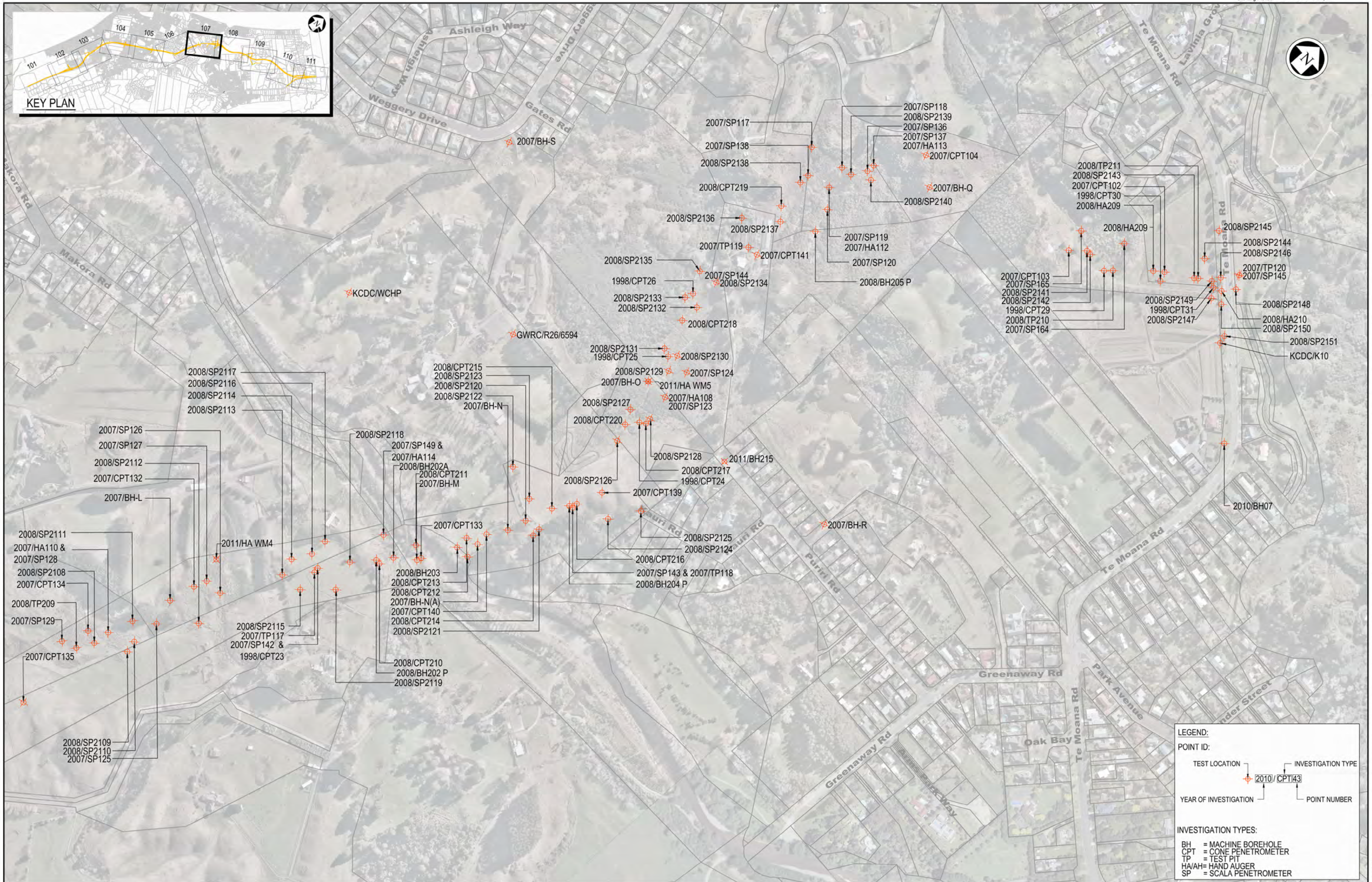


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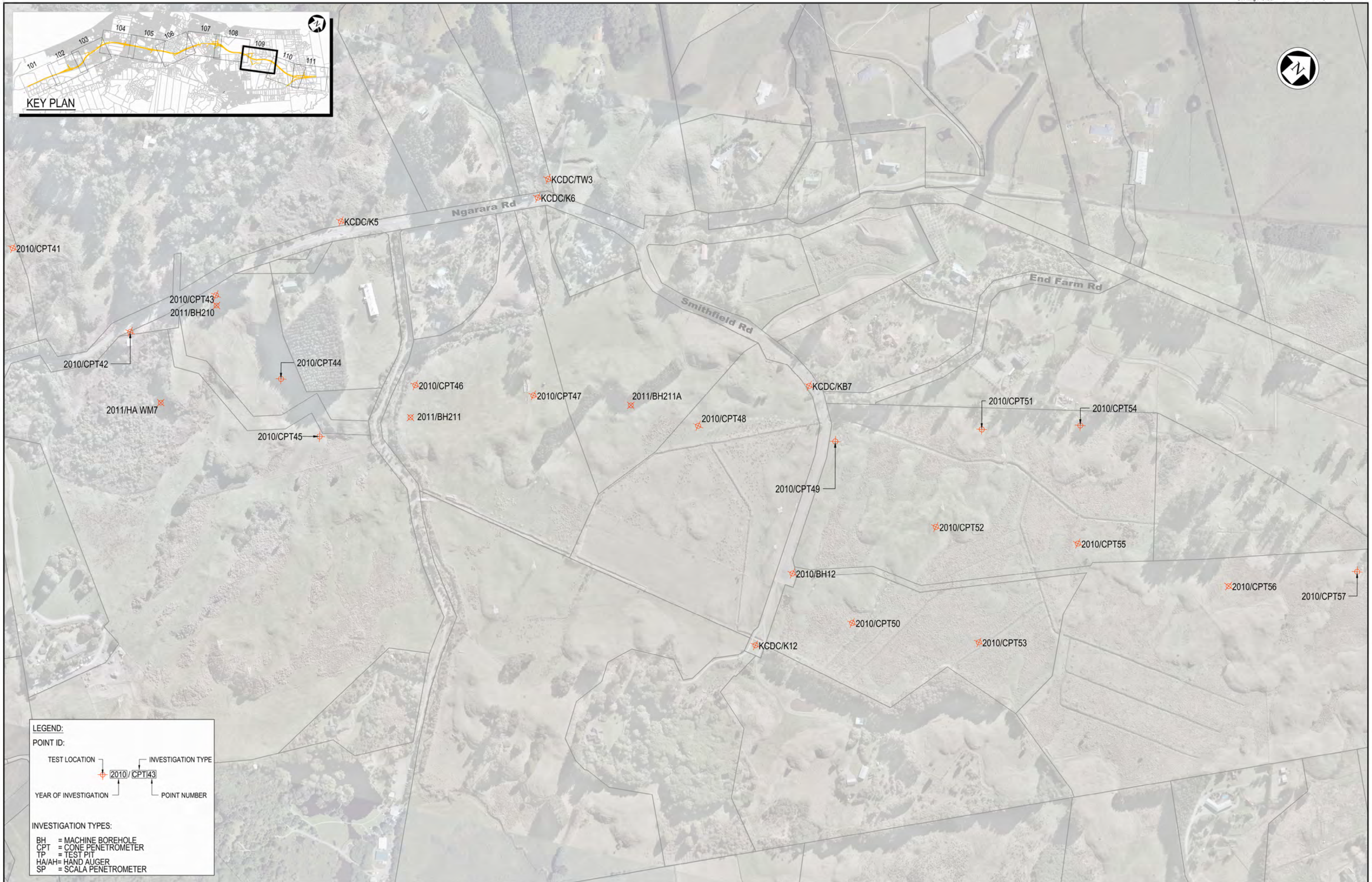


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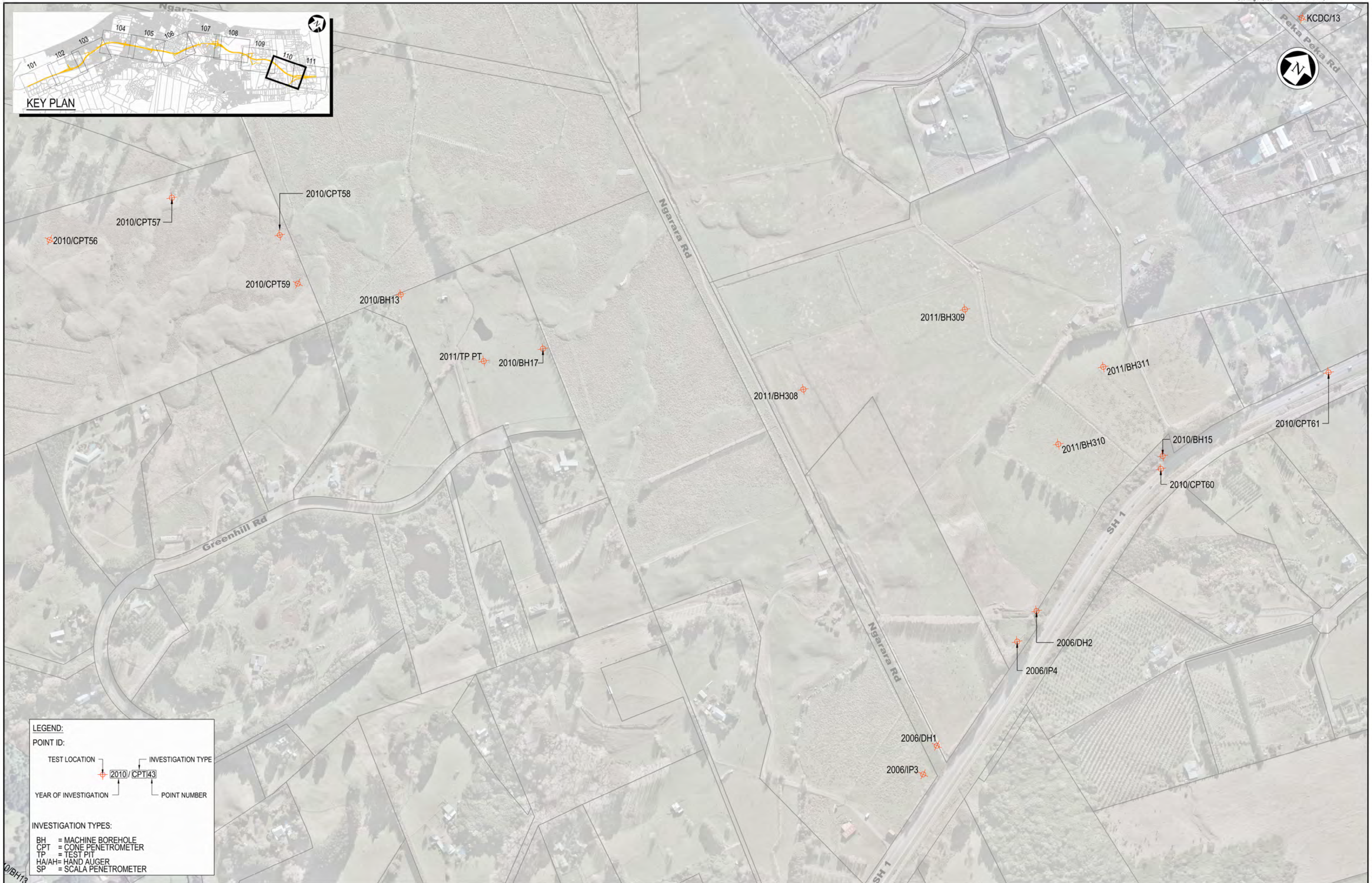
Drawing No: GT-GI-109
Rev: 1

Document No. M2PP-AEE-DWG-GT-GI-109.DWG




NOTES:

Original Scale (A3)

| Revision. | Amendment. | Approved. | Date. |
|---|---|---|---|
| 1 | AEE LODGEMENT | NRN | 15.03.12 |

NZ TRANSPORT AGENCY
WAKA KOTAHI

Project:
# MACKAYS TO PEKA PEKA EXPRESSWAY

Title:
GEOTECHNICAL
INVESTIGATION LOCATIONS
SHEET 10 OF 11

Status: - FOR CONSENTING
Document ID: M2PP-AEE-DWG
Drawing No: GT-GI-110
Rev: 1

Document No. M2PP-AEE-DWG-GT-GI-110.DWG


NOTES:

Original Scale (A3)

| Revision. | Amendment. | Approved. | Date. |
|---|---|---|---|
| 1 | AEE LODGEMENT | NRN | 15.03.12 |

NZ TRANSPORT AGENCY
WAKA KOTAHI

Project:
# MACKAYS TO PEKA PEKA EXPRESSWAY

Title:
GEOTECHNICAL
INVESTIGATION LOCATIONS
SHEET 11 OF 11

Status: - FOR CONSENTING

Document ID: M2PP-AEE-DWG

Drawing No: GT-GI-111

Rev: 1

Document No. M2PP-AEE-DWG-GT-GI-111 DWG

Appendix 36.B

## Long Section and Peat Plan

(Refer to Drawings GT-GE-100 – 111, Technical Report Appendices, Report 36, Volume 5)

Drawing Plotted: 13 Mar 2012 11:58 a.m.

## Legend: Ground Conditions Plan

### Borelog legend:

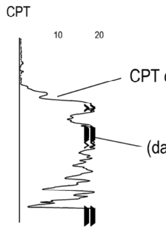
- Gravel
- Sand
- Silt
- Clay
- Organics/ peat
- Fill
- No recovery
- Water level

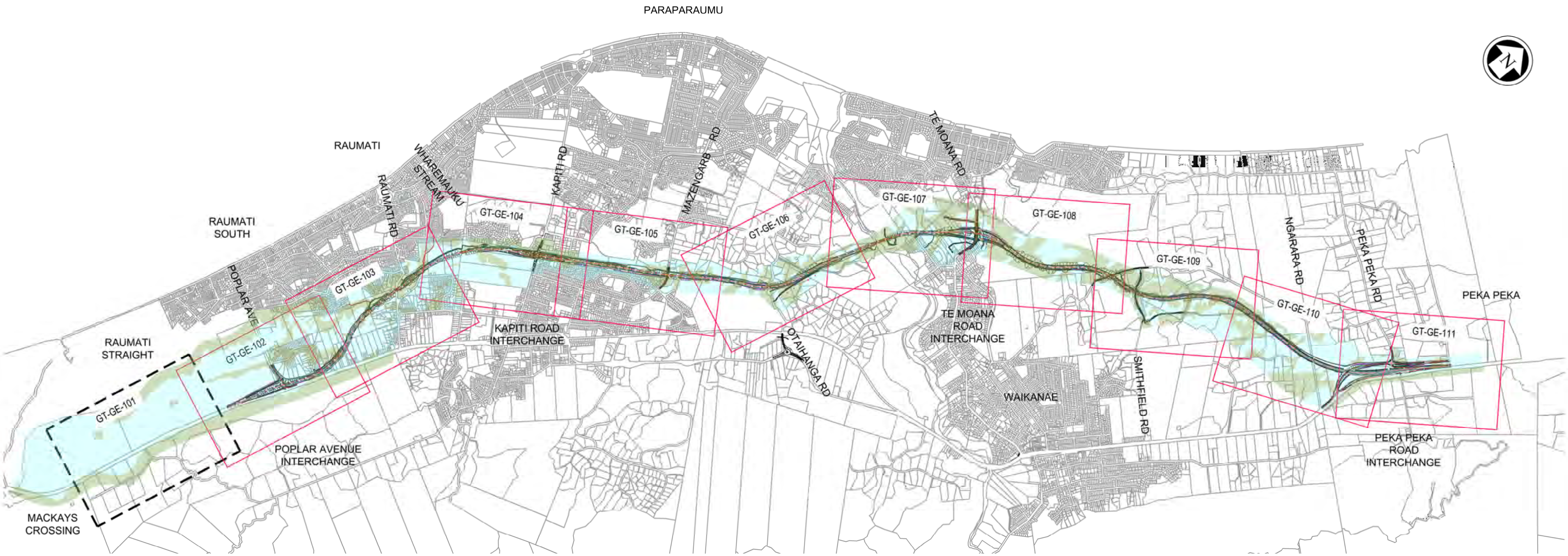
### Data labels:

Data plots within 20 m (either side) of the design centreline: 2010/BH17

(Bracketed) data plots between 20 and 200m (either side) of the design centreline: (2010/BH17)

### CPT legend:




INDICATES SHEETS NOT USED

NOTES:

Original Scale (A3)

| Revision. | Amendment. | Approved. | Date. |
|---|---|---|---|
| 1 | AEE LODGEMENT | NRN | 15.03.12 |

NZ TRANSPORT AGENCY
WAKA KOTAHI

Project: MACKAYS TO PEKA PEKA EXPRESSWAY

Title: GEOTECHNICAL GROUND CONDITIONS PLAN SHEET PLAN

Status: - FOR CONSENTING

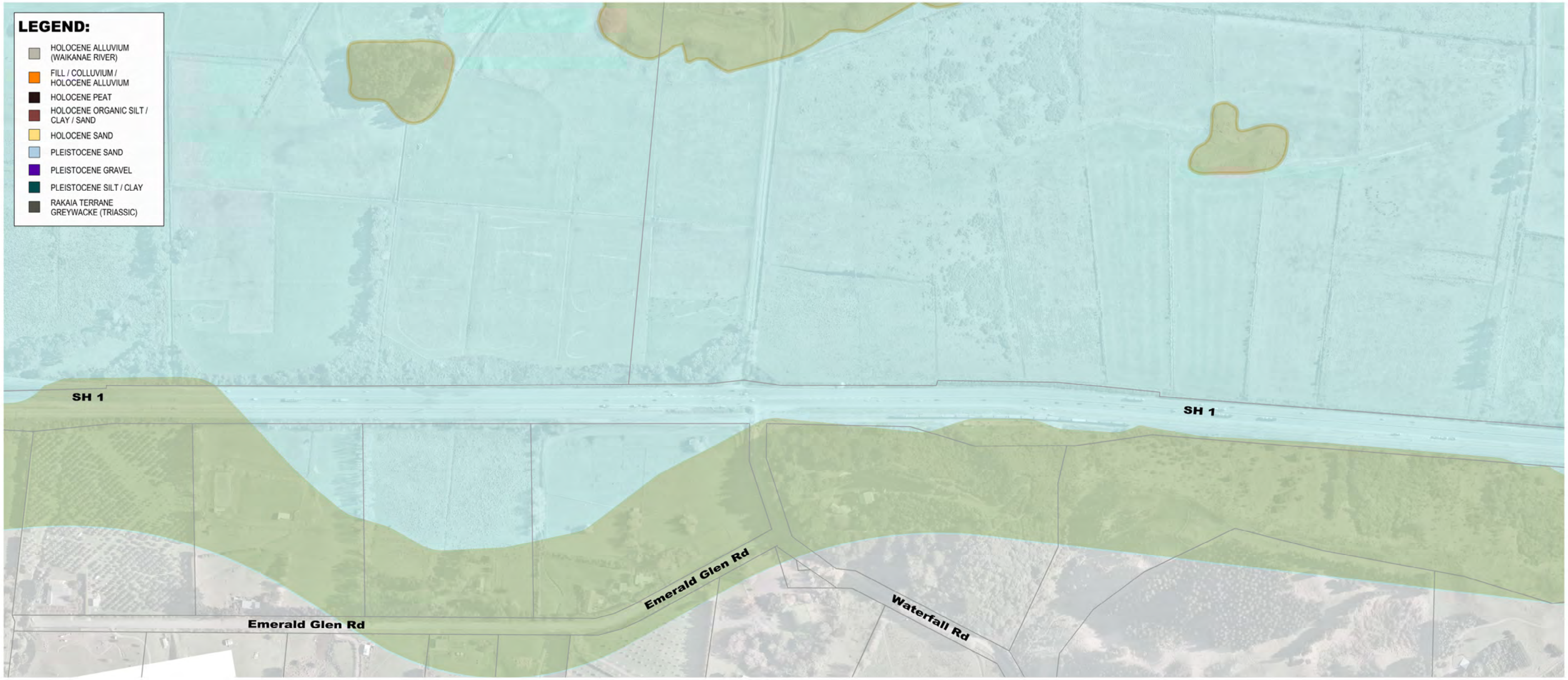
Document ID: M2PP-AEE-DWG

Drawing No: GT-GE-100

Rev: 1

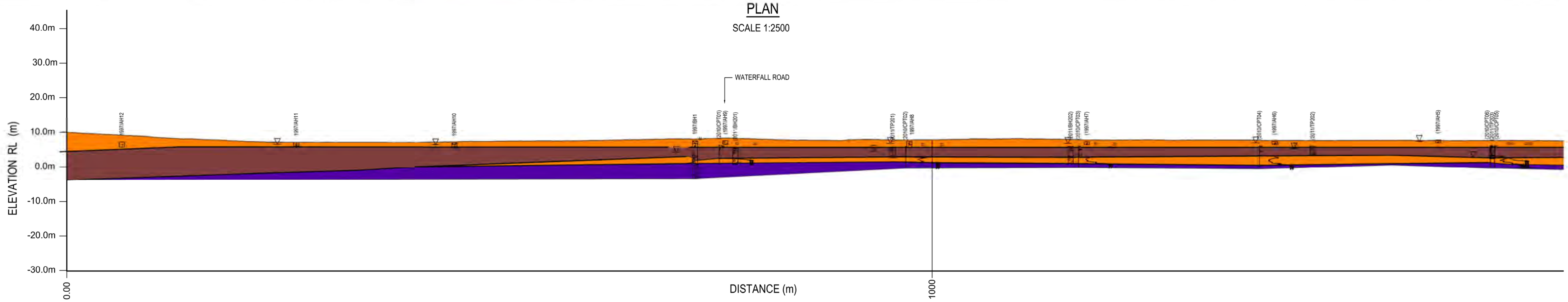
Document No. M2PP-AEE-DWG-GT-GE-100.DWG

Drawing Plotted: 13 Mar 2012 11:59 a.m.




PLAN

SCALE 1:2500




LONGITUDINAL SECTION

SCALE HORIZ = 1:2500 VERT = 1:500

NOTES:

Original Scale (A3)

| Revision. | Amendment. | Approved. | Date. |
|---|---|---|---|
| 1 | AEE LODGEMENT | NRN | 15.03.12 |

NZ TRANSPORT AGENCY
WAKA KOTAHI

Project:
# MACKAYS TO PEKA PEKA EXPRESSWAY

Title:
GEOTECHNICAL
GROUND CONDITIONS PLAN
SHEET 1 OF 11

Status: - FOR CONSENTING

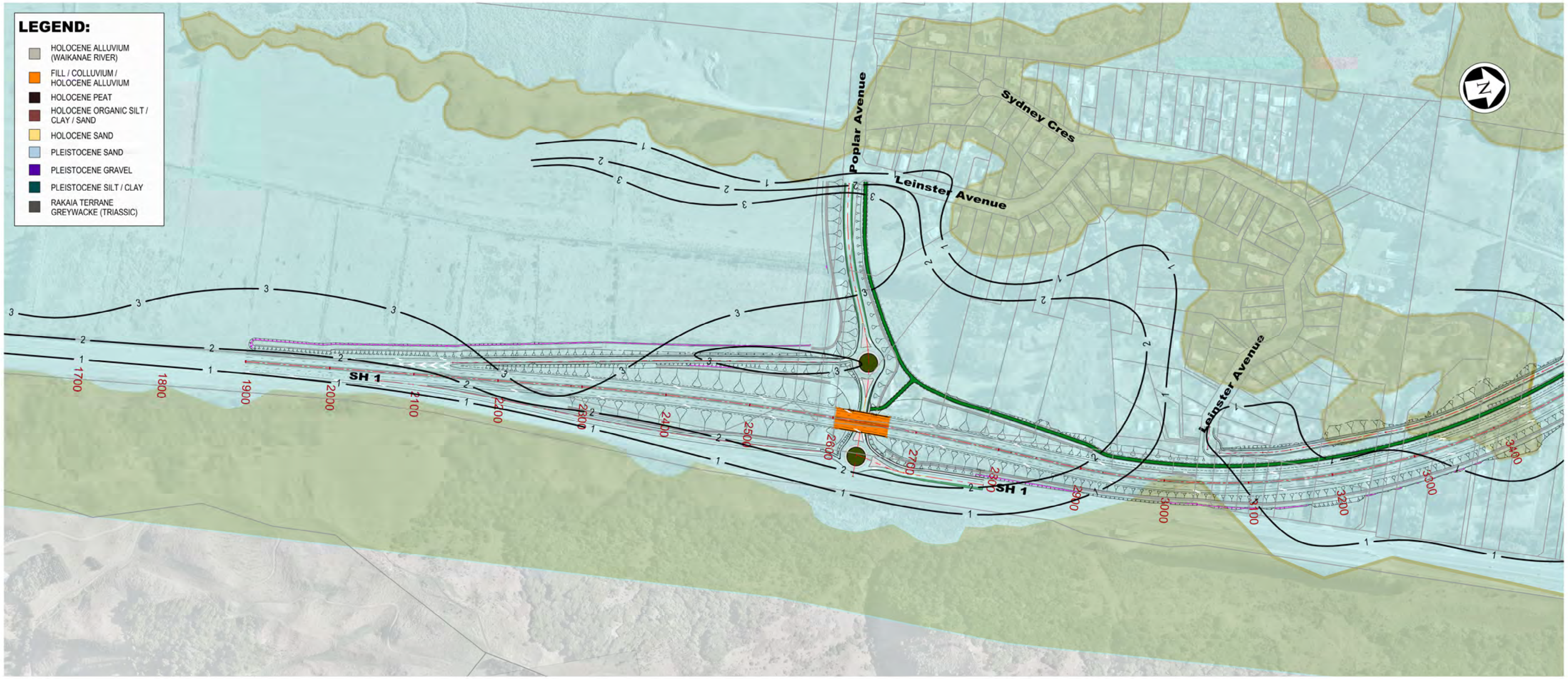
Document ID: M2PP-AEE-DWG

Drawing No.: GT-GE-101

Rev.: 1

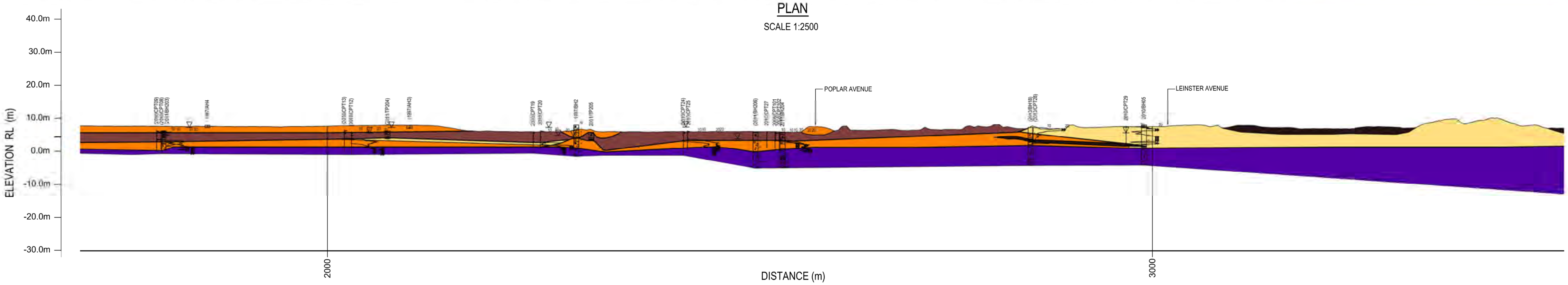
Document No. M2PP-AEE-DWG-GT-GE-101.DWG

Document created for NZTA by M2PP Alliance, Level 2, 17-21 Whitmore St, WELLINGTON




PLAN

SCALE 1:2500




LONGITUDINAL SECTION

SCALE HORIZ = 1:2500 VERT = 1:500

NOTES:

Original Scale (A3)

| Revision. | Amendment. | Approved. | Date. |
|---|---|---|---|
| 1 | AEE LODGEMENT | NRN | 15.03.12 |

NZ TRANSPORT AGENCY
WAKA KOTAHI

Project:

# MACKAYS TO PEKA PEKA EXPRESSWAY

Title:

GEOTECHNICAL
GROUND CONDITIONS PLAN
SHEET 2 OF 11

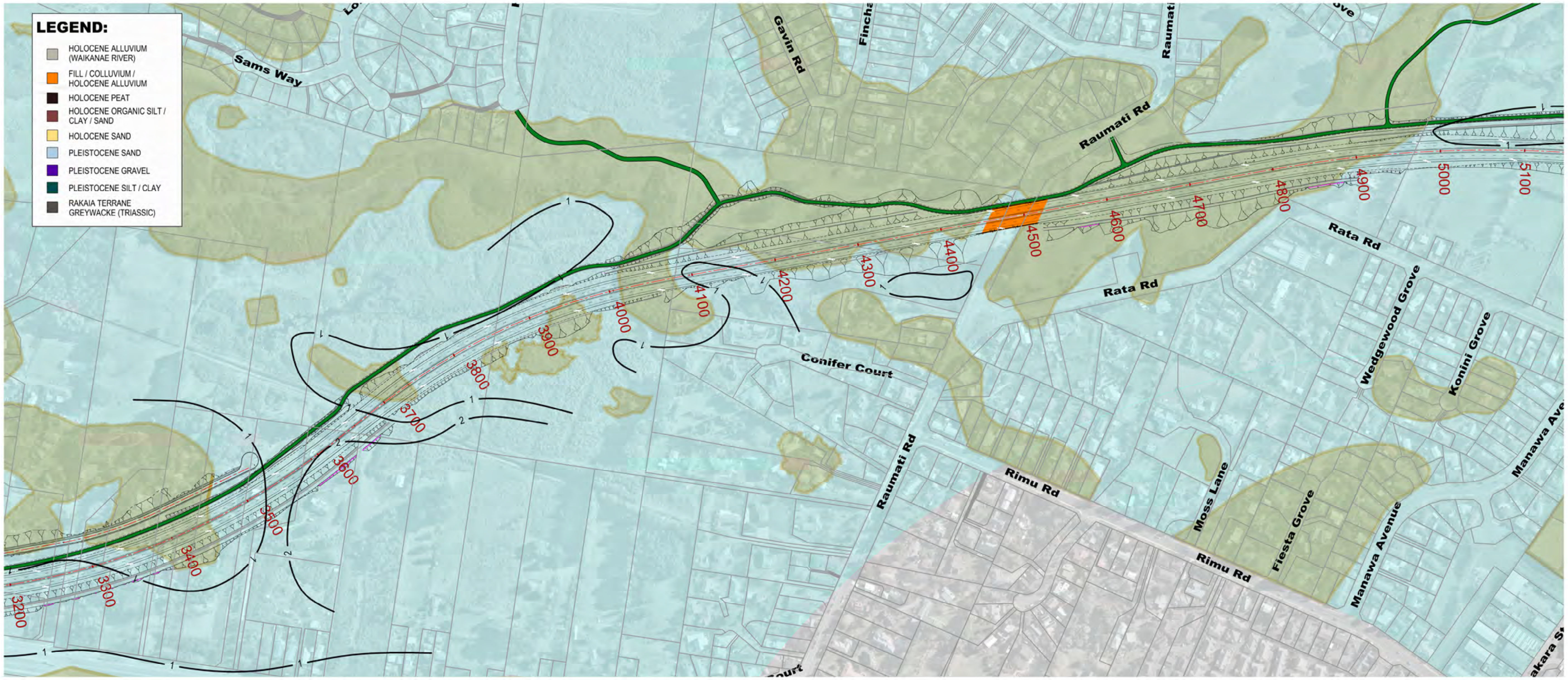
Status: - FOR CONSENTING

Document ID: M2PP-AEE-DWG

Drawing No: GT-GE-102

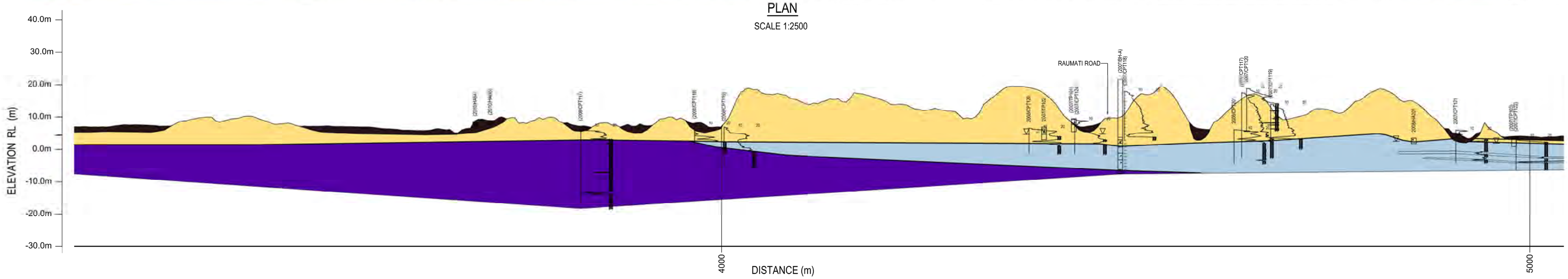
Rev: 1

Document No. M2PP-AEE-DWG-GT-GE-102.DWG




PLAN

SCALE 1:2500




LONGITUDINAL SECTION

SCALE HORIZ = 1:2500 VERT = 1:500

NOTES:

Original Scale (A3)

| Revision. | Amendment. | Approved. | Date. |
|---|---|---|---|
| 1 | AEE LODGEMENT | NRN | 15.03.12 |

NZ TRANSPORT AGENCY
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Project:
MACKAYS TO PEKA PEKA EXPRESSWAY

Title:
GEOTECHNICAL
GROUND CONDITIONS PLAN
SHEET 3 OF 11

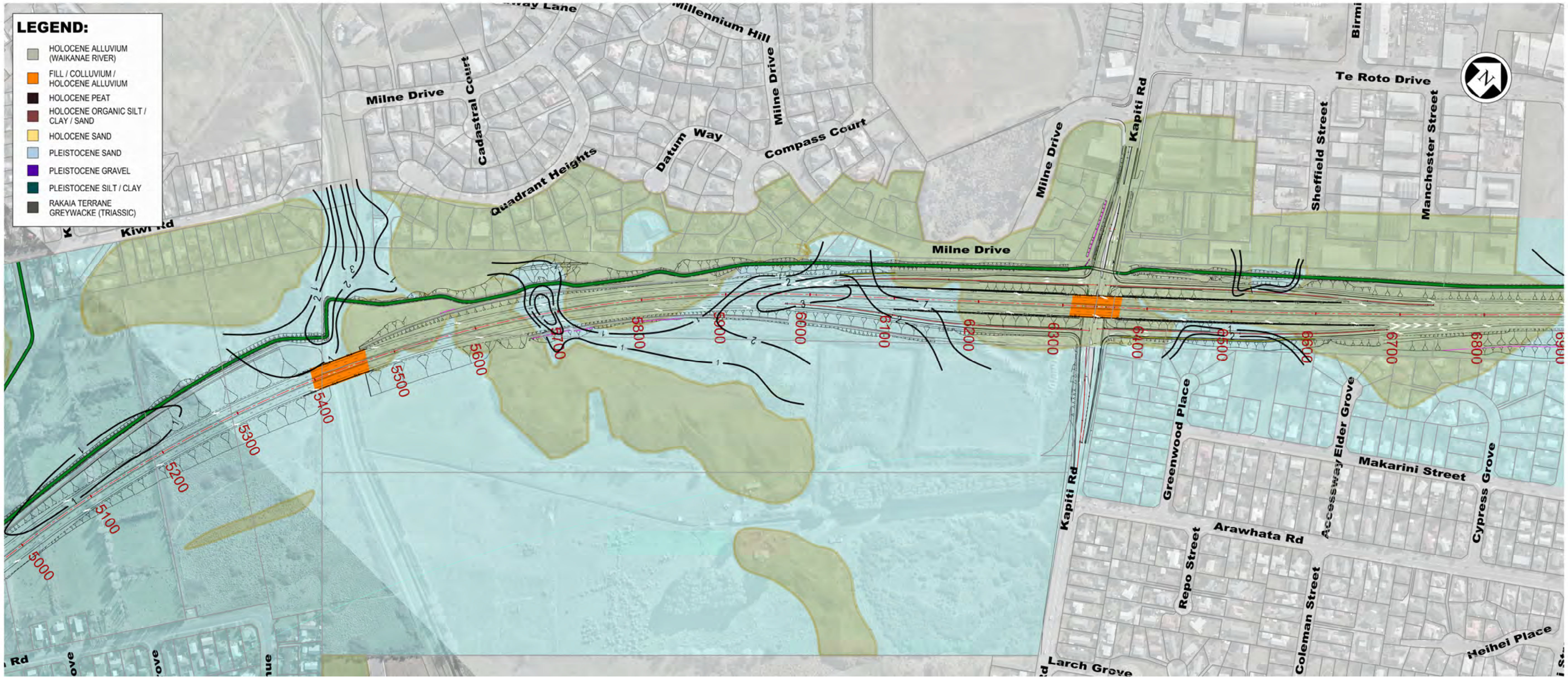
Status: - FOR CONSENTING

Document ID: M2PP-AEE-DWG

Drawing No.: GT-GE-103

Rev.: 1

Document No.: M2PP-AEE-DWG-GT-GE-103.DWG

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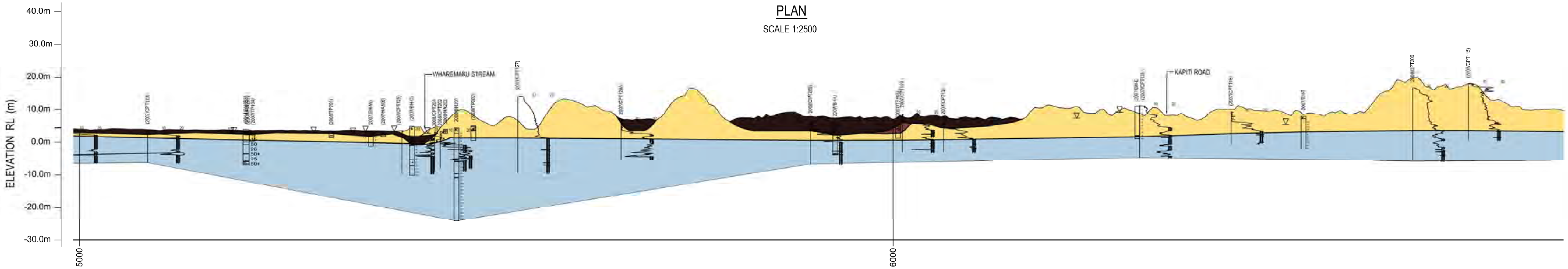



LONGITUDINAL SECTION

SCALE HORIZ = 1:2500 VERT = 1:500

NOTES:

Original Scale (A3)

| Revision. | Amendment. | Approved. | Date. |
|---|---|---|---|
| 1 | AEE LODGEMENT | NRN | 15.03.12 |

NZ TRANSPORT AGENCY
WAKA KOTAHI

Project:
# MACKAYS TO PEKA PEKA EXPRESSWAY

Title:
GEOTECHNICAL
GROUND CONDITIONS PLAN
SHEET 4 OF 11

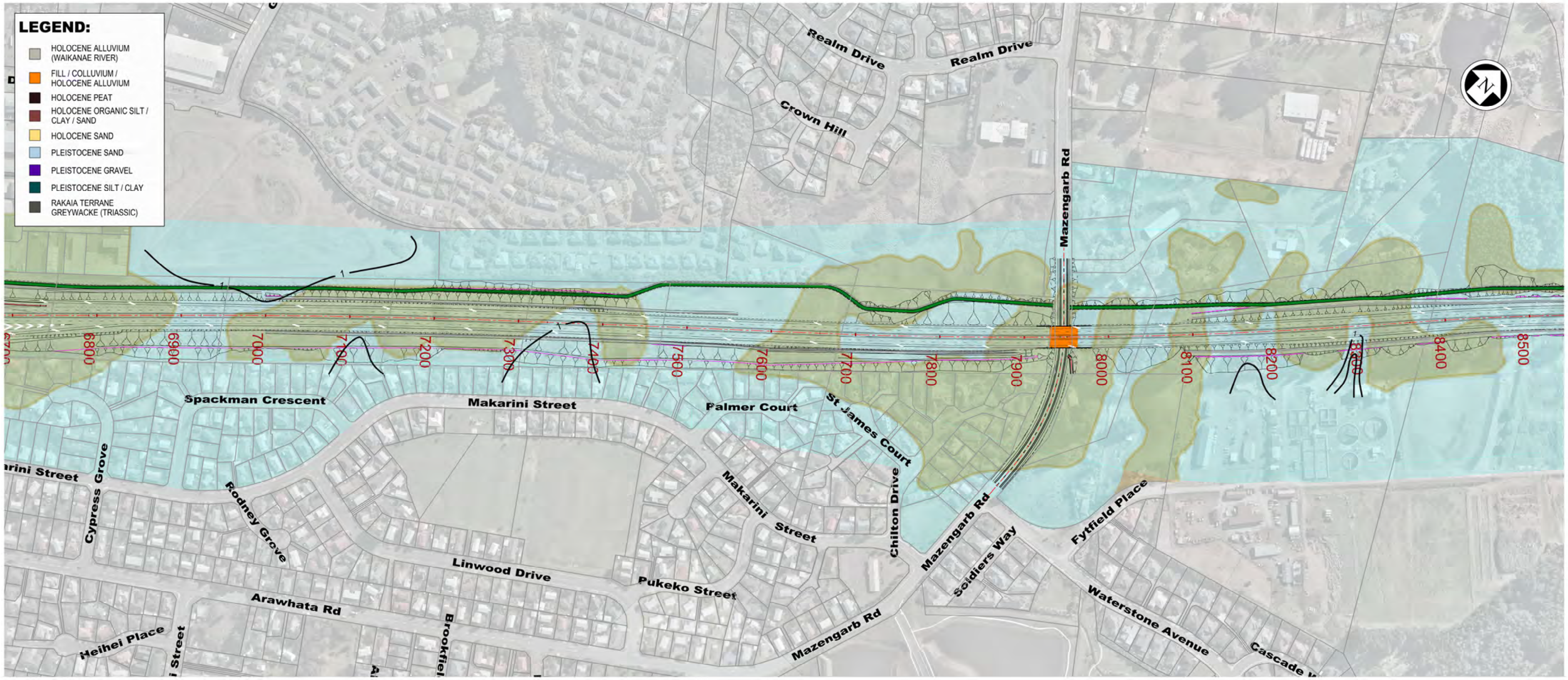
Status: - FOR CONSENTING

Document ID: M2PP-AEE-DWG

Drawing No: GT-GE-104

Rev: 1

Document No. M2PP-AEE-DWG-GT-GE-104.DWG

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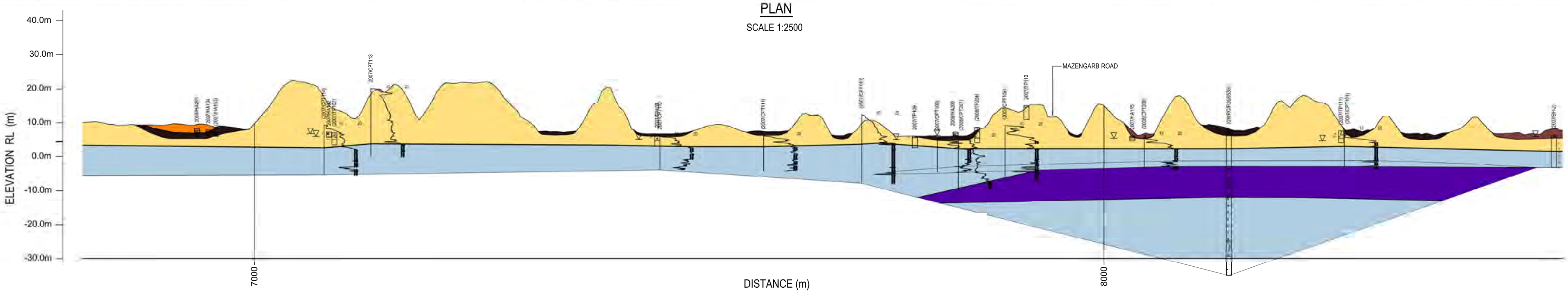



LONGITUDINAL SECTION

SCALE HORIZ = 1:2500 VERT = 1:500

NOTES:

Original Scale (A3)

| Revision. | Amendment. | Approved. | Date. |
| --- | --- | --- | --- |
| 1 | AEE LODGEMENT | NRN | 15.03.12 |

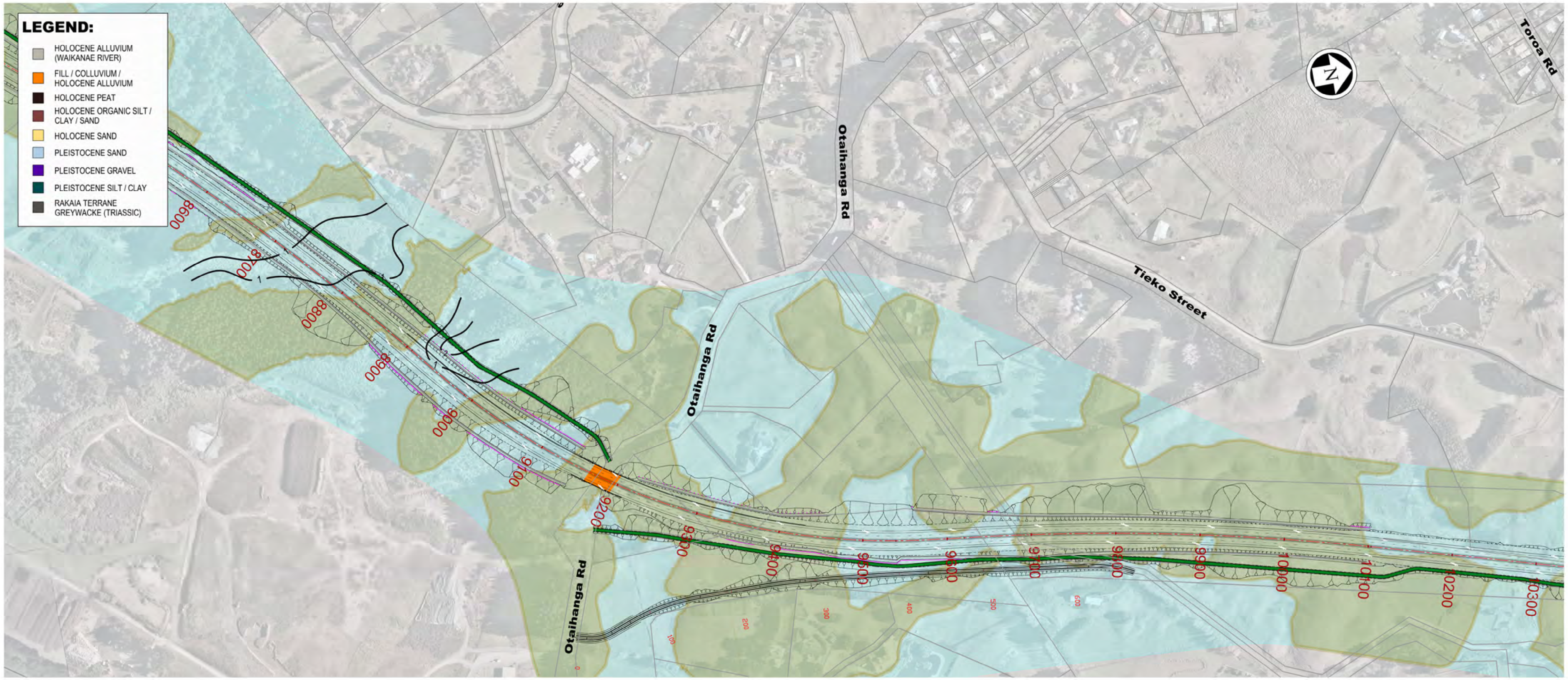
NZ TRANSPORT AGENCY
WAKA KOTAHI

Project:
# MACKAYS TO PEKA PEKA EXPRESSWAY

GEOTECHNICAL
GROUND CONDITIONS PLAN
SHEET 5 OF 11

Status: - FOR CONSENTING
Document ID: M2PP-AEE-DWG
Drawing No.: GT-GE-105
Rev.: 1

Document No. M2PP-AEE-DWG-GT-GE-105.DWG

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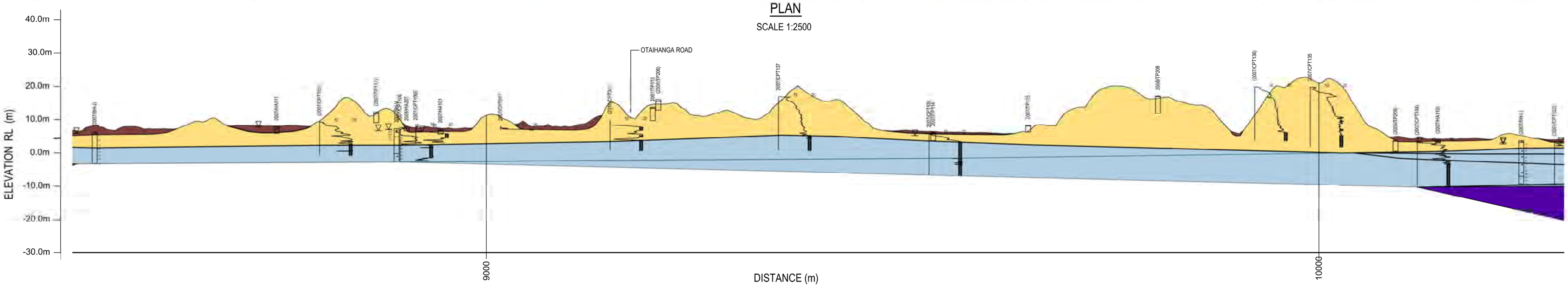


LONGITUDINAL SECTION

SCALE HORIZ = 1:2500 VERT = 1:500

NOTES:

Original Scale (A3)

| Revision. | Amendment. | Approved. | Date. |
|---|---|---|---|
| 1 | AEE LODGEMENT | NRN | 15.03.12 |

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WAKA KOTAHI

Project:
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Title:
GEOTECHNICAL
GROUND CONDITIONS PLAN
SHEET 6 OF 11

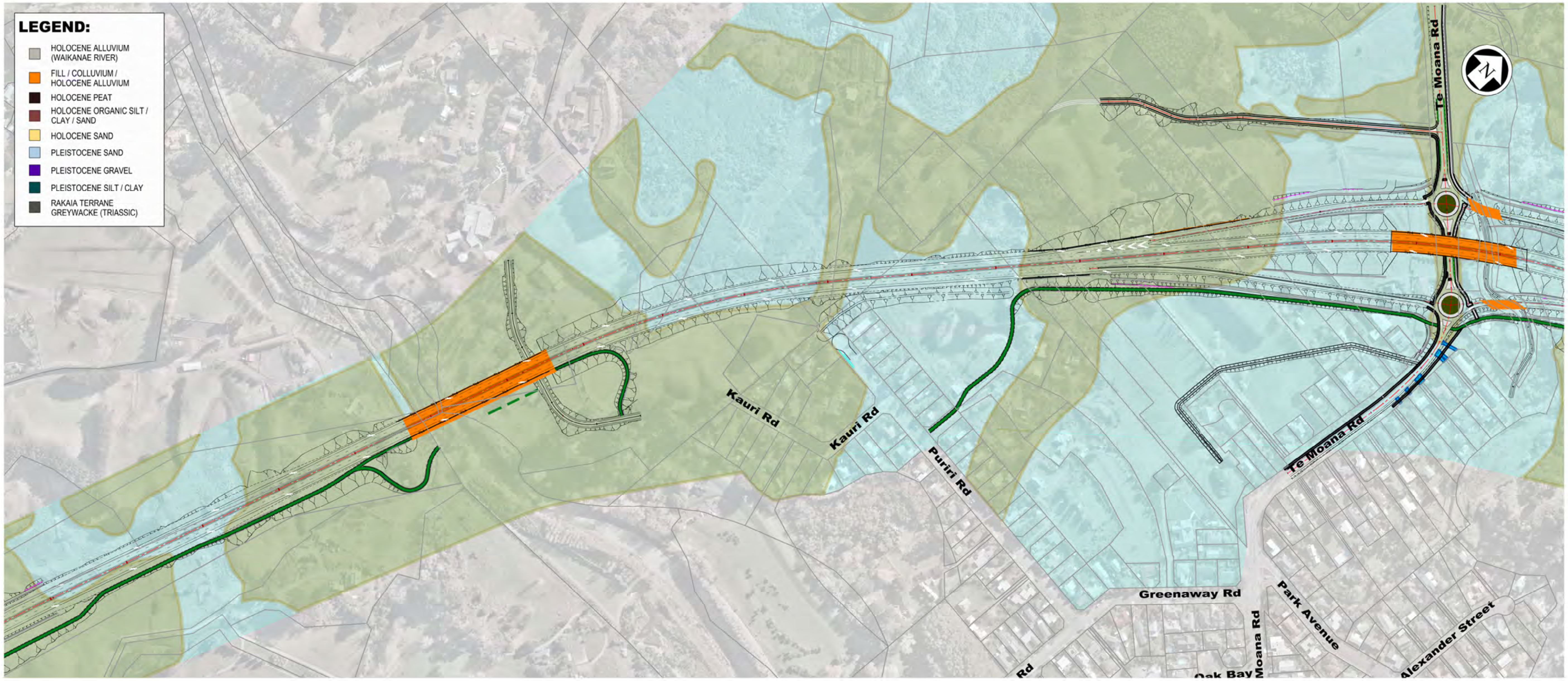
Status: - FOR CONSENTING

Document ID: M2PP-AEE-DWG

Drawing No: GT-GE-106

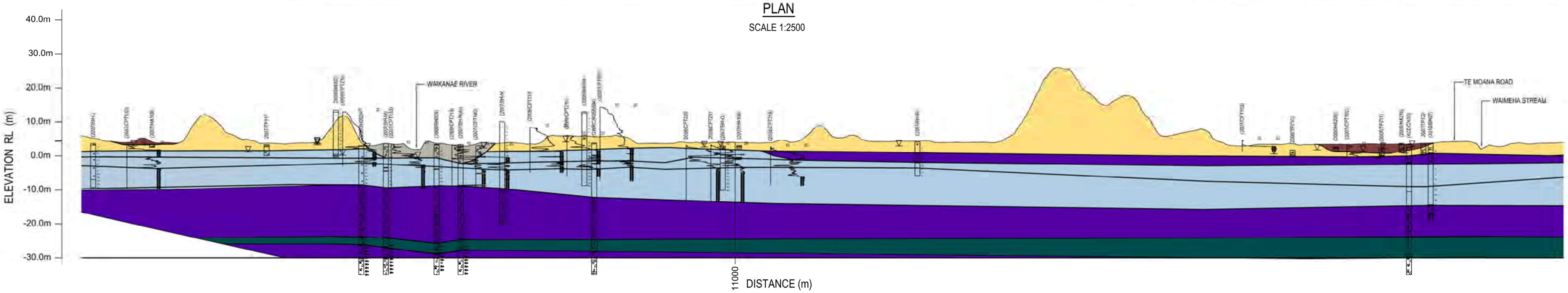
Rev: 1

Document No. M2PP-AEE-DWG-GT-GE-106.DWG




PLAN

SCALE 1:2500




LONGITUDINAL SECTION

SCALE HORIZ = 1:2500 VERT = 1:500

NOTES:

Original Scale (A3)

| Revision. | Amendment. | Approved. | Date. |
|---|---|---|---|
| 1 | AEE LODGEMENT | NRN | 15.03.12 |

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Project: MACKAYS TO PEKA PEKA EXPRESSWAY

Title: GEOTECHNICAL
GROUND CONDITIONS PLAN
SHEET 7 OF 11

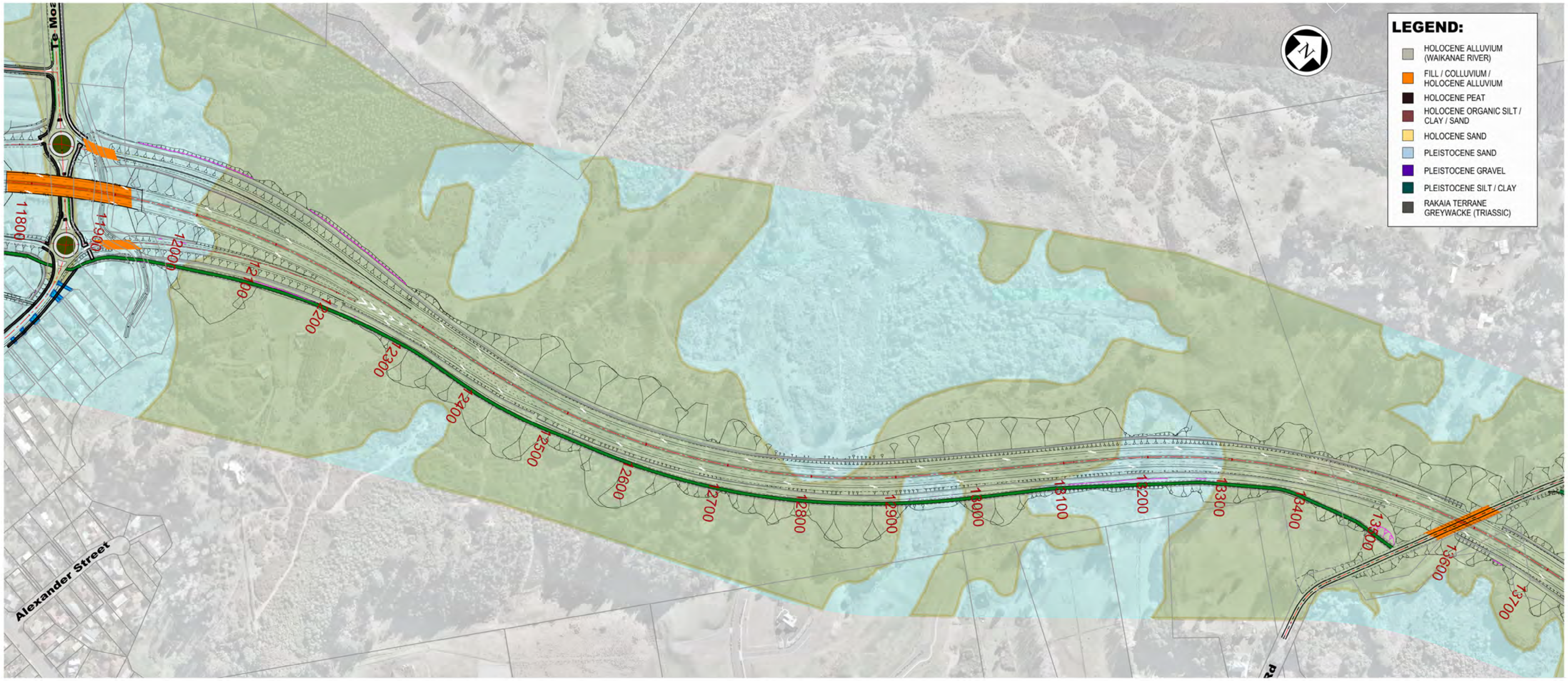
Status: - FOR CONSENTING

Document ID: M2PP-AEE-DWG

Drawing No.: GT-GE-107 | Rev.: 1

Document No. M2PP-AEE-DWG-GT-GE-107.DWG

Drawing Plotted: 13 Mar 2012 12:09 p.m.

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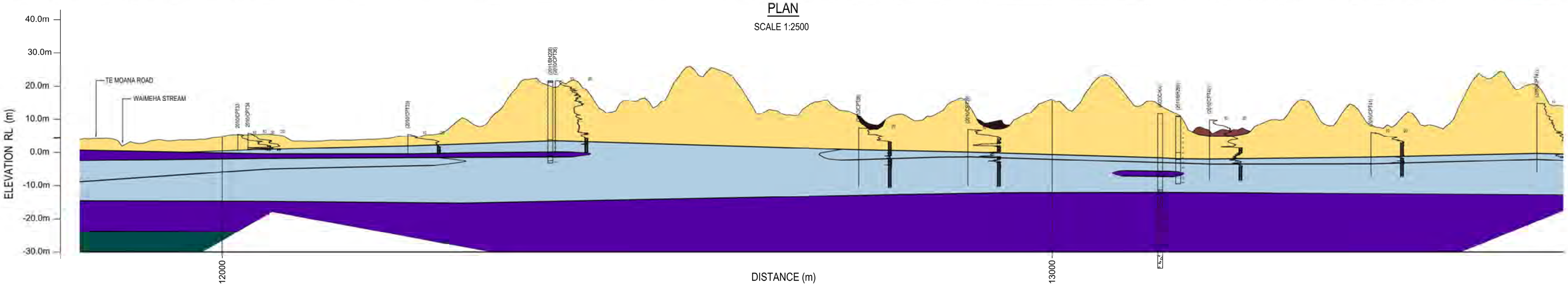



LONGITUDINAL SECTION

SCALE HORIZ = 1:2500 VERT = 1:500

NOTES:

Original Scale (A3)

| Revision. | Amendment. | Approved. | Date. |
|---|---|---|---|
| 1 | AEE LODGEMENT | NRN | 15.03.12 |

NZ TRANSPORT AGENCY
WAKA KOTAHI

Project:
# MACKAYS TO PEKA PEKA EXPRESSWAY

Title:
GEOTECHNICAL
GROUND CONDITIONS PLAN
SHEET 8 OF 11

Status: - FOR CONSENTING

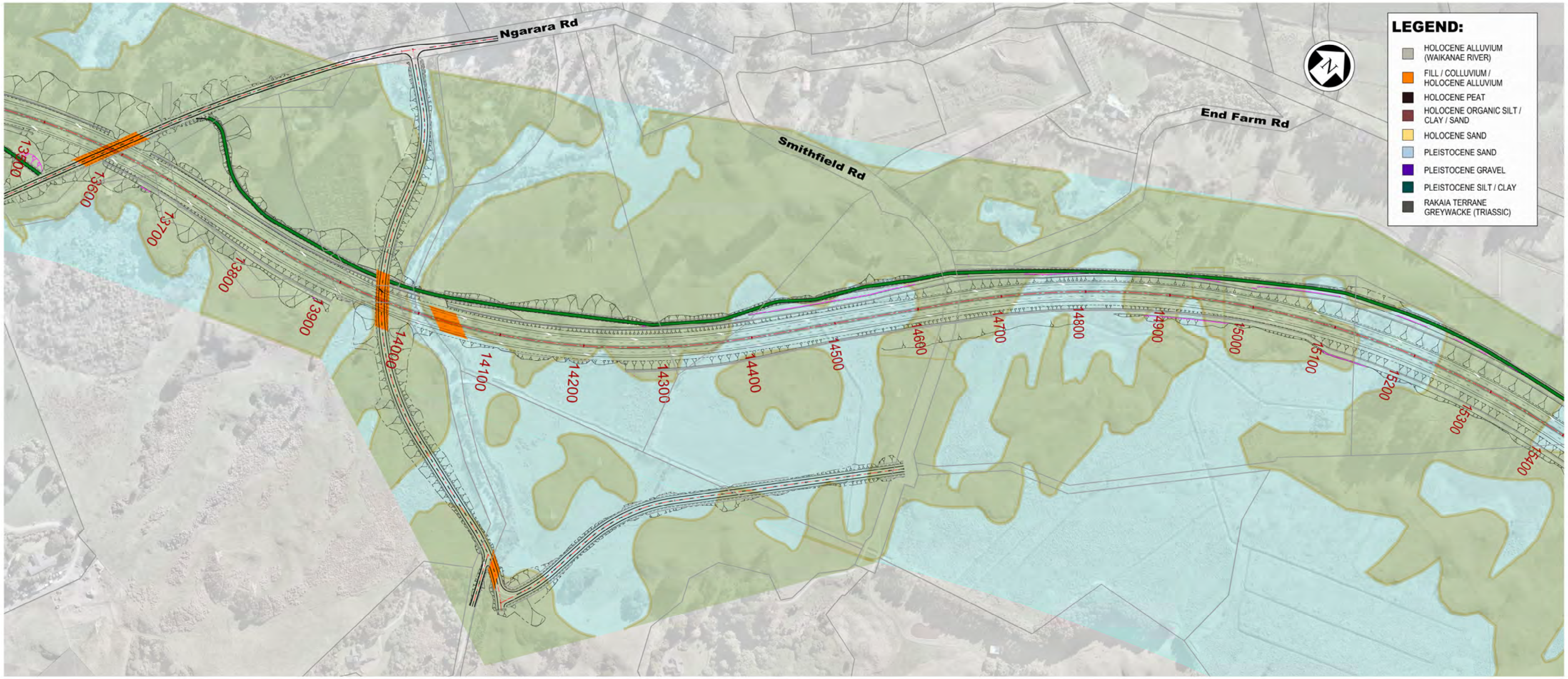
Document ID: M2PP-AEE-DWG

Drawing No: GT-GE-108

Rev: 1

Document No. M2PP-AEE-DWG-GT-GE-108.DWG

Document created for NZTA by M2PP Alliance, Level 2, 17-21 Whitmore St, WELLINGTON




PLAN

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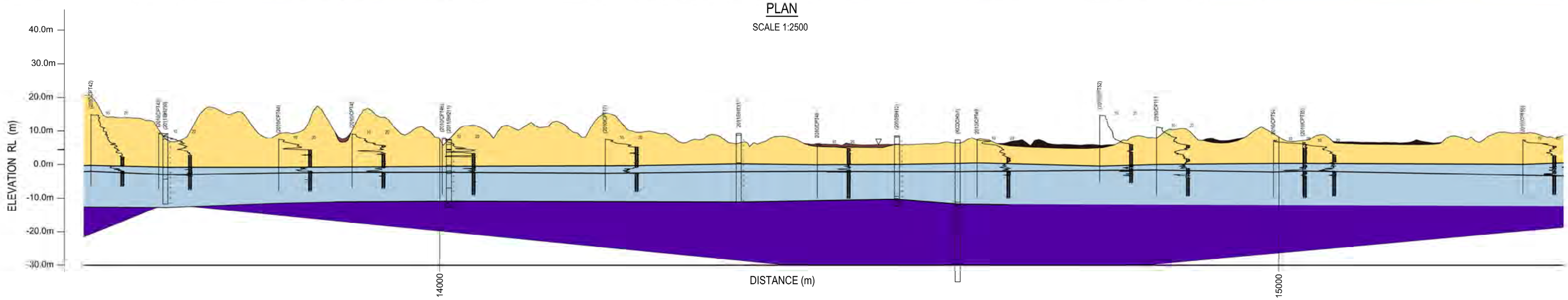



LONGITUDINAL SECTION

SCALE HORIZ = 1:2500 VERT = 1:500

NOTES:

Original Scale (A3)

| Revision. | Amendment. | Approved. | Date. |
|---|---|---|---|
| 1 | AEE LODGEMENT | NRN | 15.03.12 |

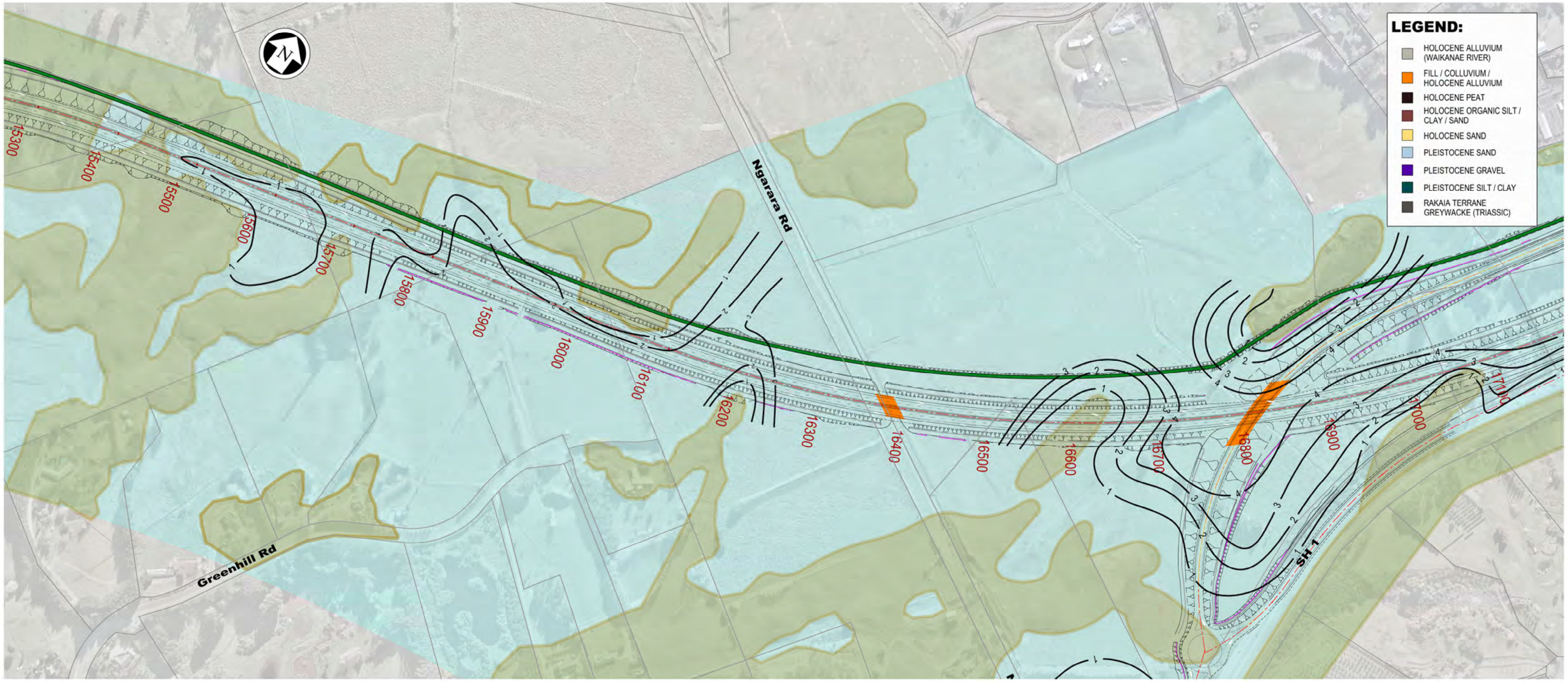
NZ TRANSPORT AGENCY
WAKA KOTAHI

Project:
# MACKAYS TO PEKA PEKA EXPRESSWAY

Title:
GEOTECHNICAL
GROUND CONDITIONS PLAN
SHEET 9 OF 11

Status: - FOR CONSENTING
Document ID: M2PP-AEE-DWG
Drawing No: GT-GE-109
Rev: 1

Document No. M2PP-AEE-DWG-GT-GE-109.DWG

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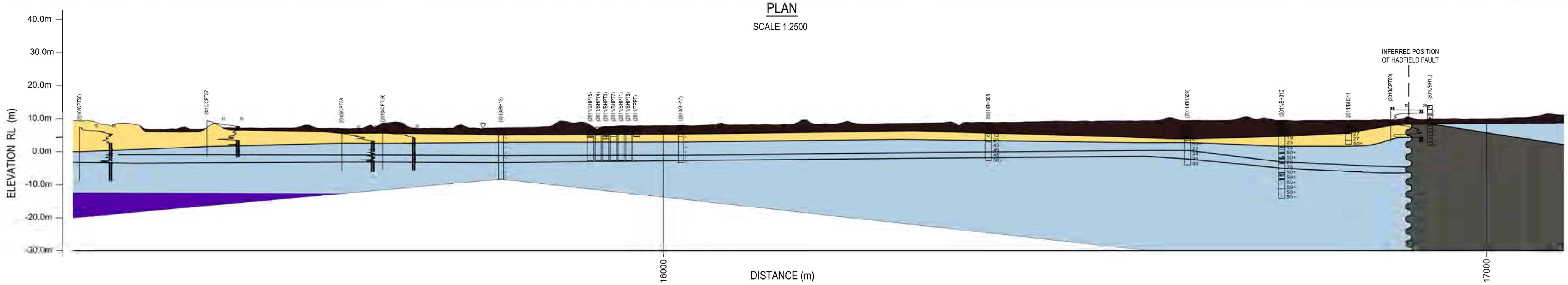
SCALE 1:2500




LONGITUDINAL SECTION
SCALE HORIZ = 1:2500 VERT = 1:500

NOTES:

Original Scale (A3)

| Revision. | Amendment. | Approved. | Date. |
|---|---|---|---|
| 1 | AEE LODGEMENT | NRN | 15.03.12 |

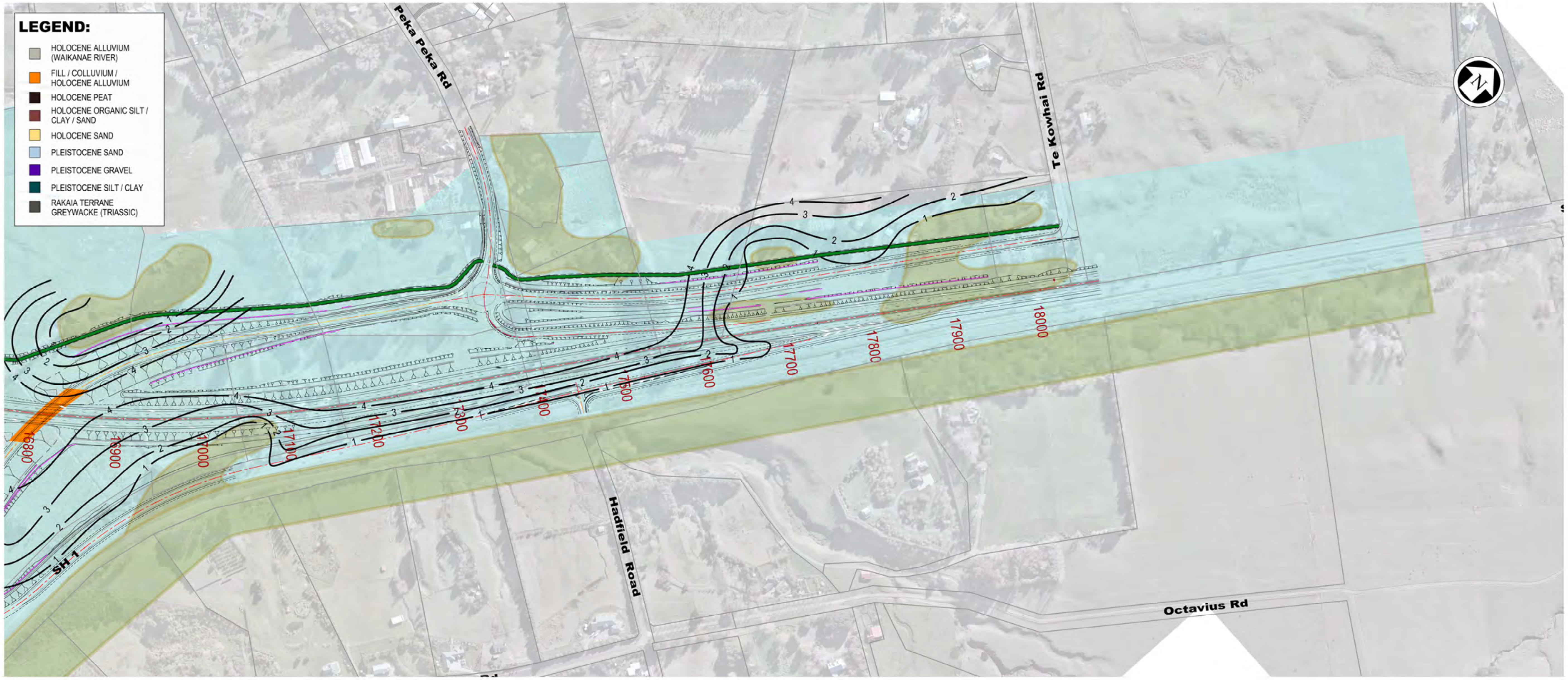
NZ TRANSPORT AGENCY
WAKA KOTAHI

Project:
# MACKAYS TO PEKA PEKA EXPRESSWAY

Title:
GEOTECHNICAL
GROUND CONDITIONS PLAN
SHEET 10 OF 11

Status: - FOR CONSENTING
Document ID: M2PP-AEE-DWG
Drawing No: GT-GE-110
Rev: 1

Document No. M2PP-AEE-DWG-GT-GE-110.DWG

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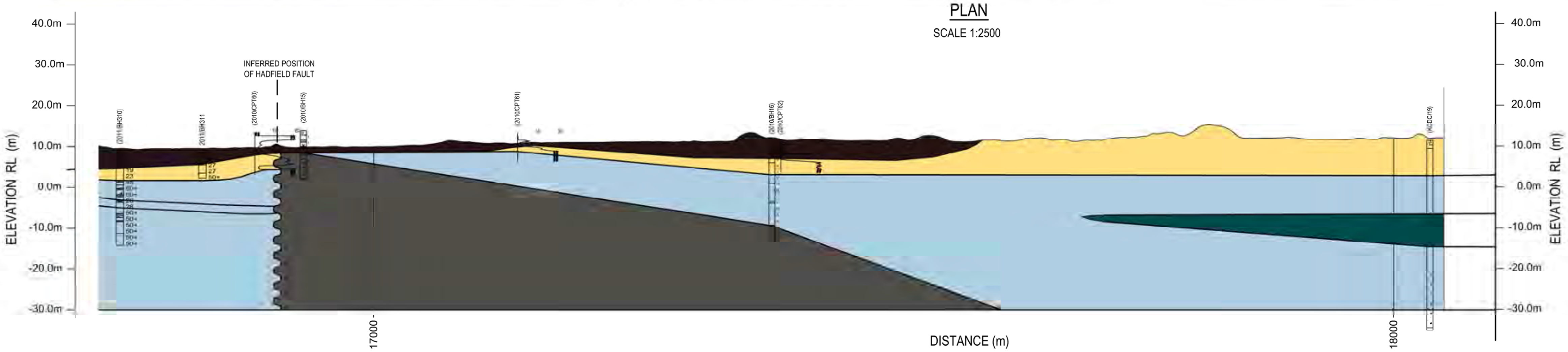



LONGITUDINAL SECTION

SCALE HORIZ = 1:2500 VERT = 1:500

NOTES:

Original Scale (A3)

| Revision. | Amendment. | Approved. | Date. |
|---|---|---|---|
| 1 | AEE LODGEMENT | NRN | 15.03.12 |

NZ TRANSPORT AGENCY
WAKA KOTAHI

Project:
# MACKAYS TO PEKA PEKA EXPRESSWAY

Title:
GEOTECHNICAL
GROUND CONDITIONS PLAN
SHEET 11 OF 11

Status: - FOR CONSENTING

Document ID: M2PP-AEE-DWG

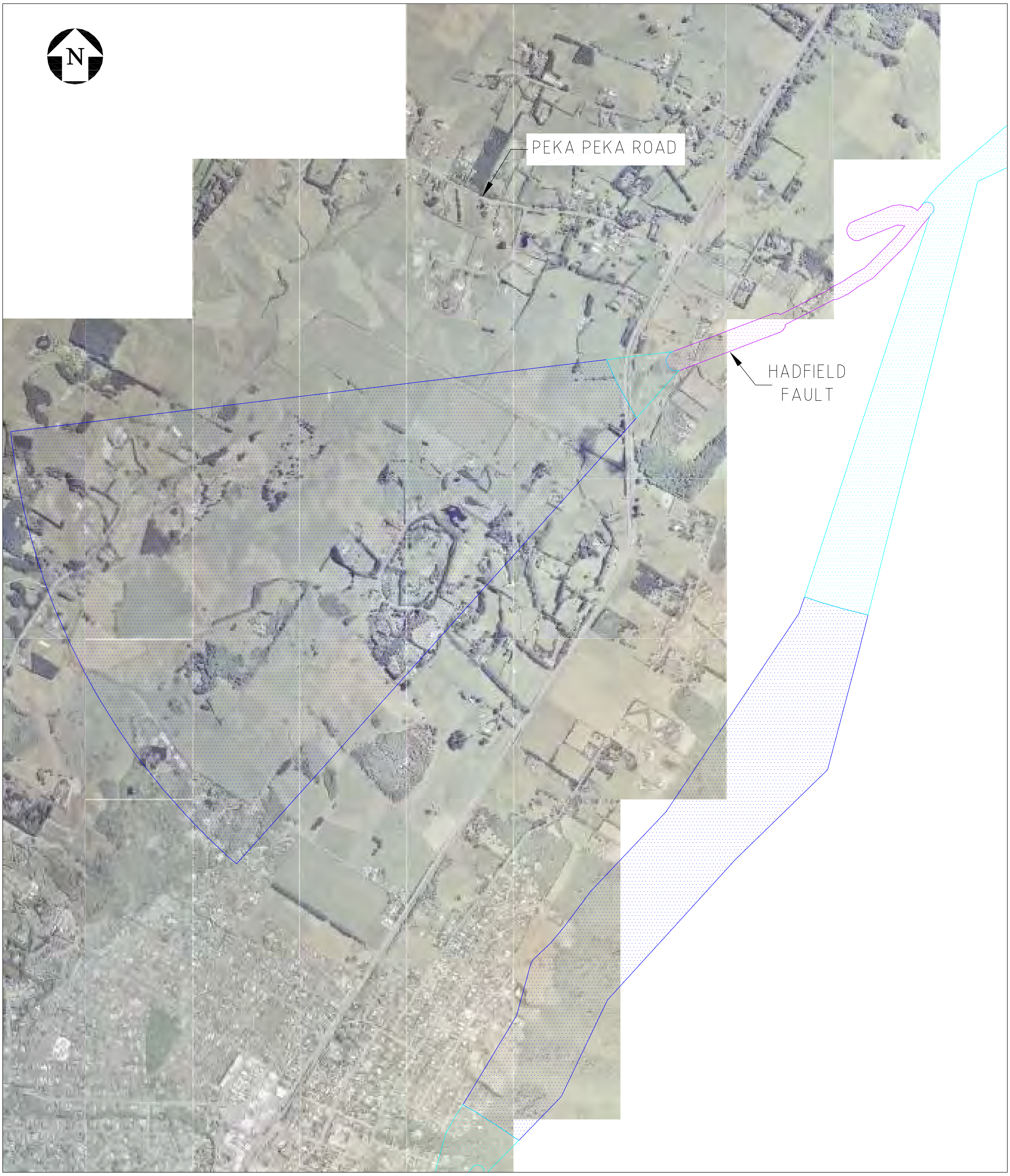
Drawing No: GT-GE-111

Rev: 1

Document No. M2PP-AEE-DWG-GT-GE-111.DWG

Appendix 36.C

## Hadfield Fault Map




WELL DEFINED

UNCERTAIN - CONSTRAINED

UNCERTAIN - POORLY CONSTRAINED

KAPITI DISTRICT COUNCIL FAULT ZONES

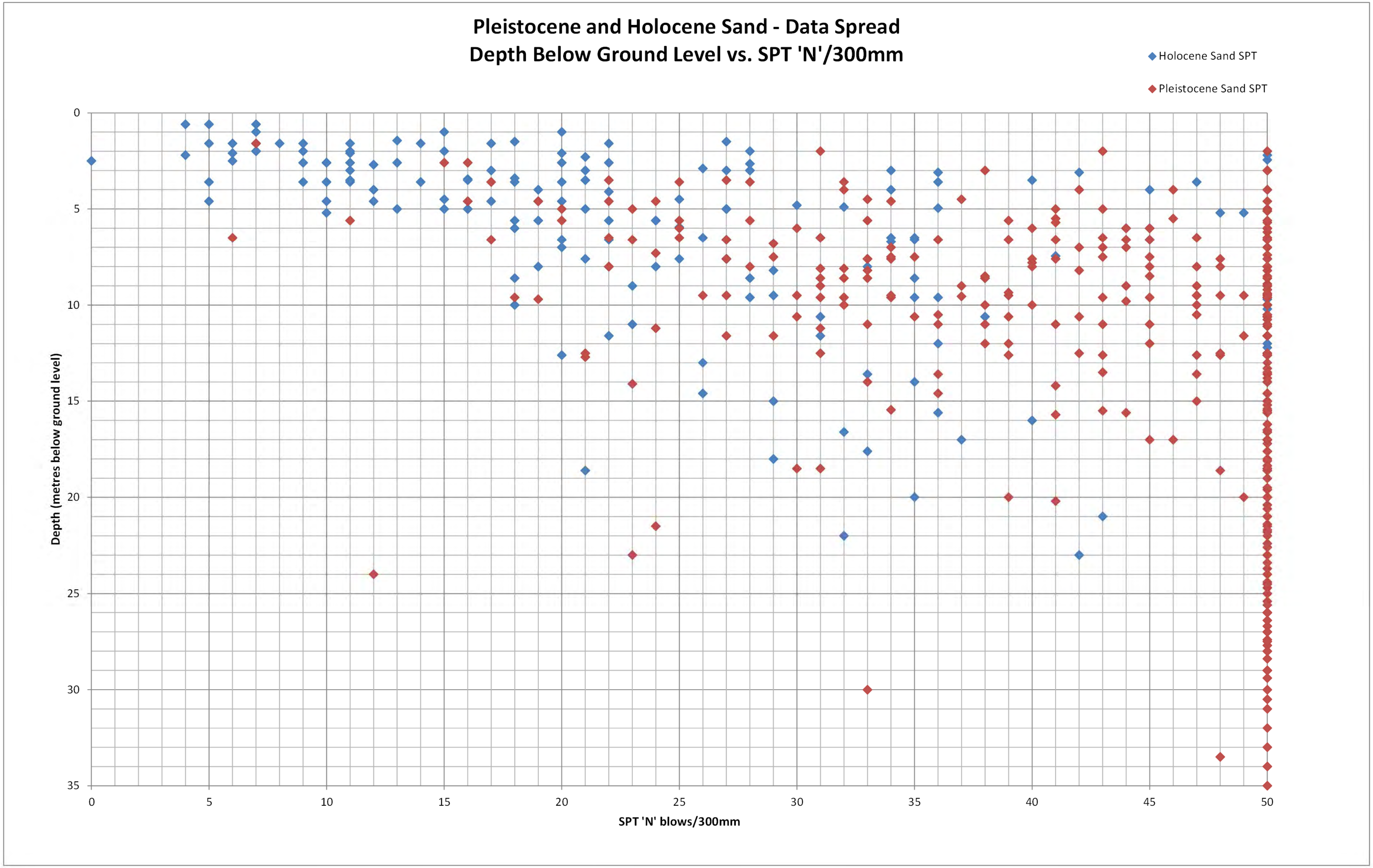
HADFIELD FAULT

SCALE A4: 1:2500

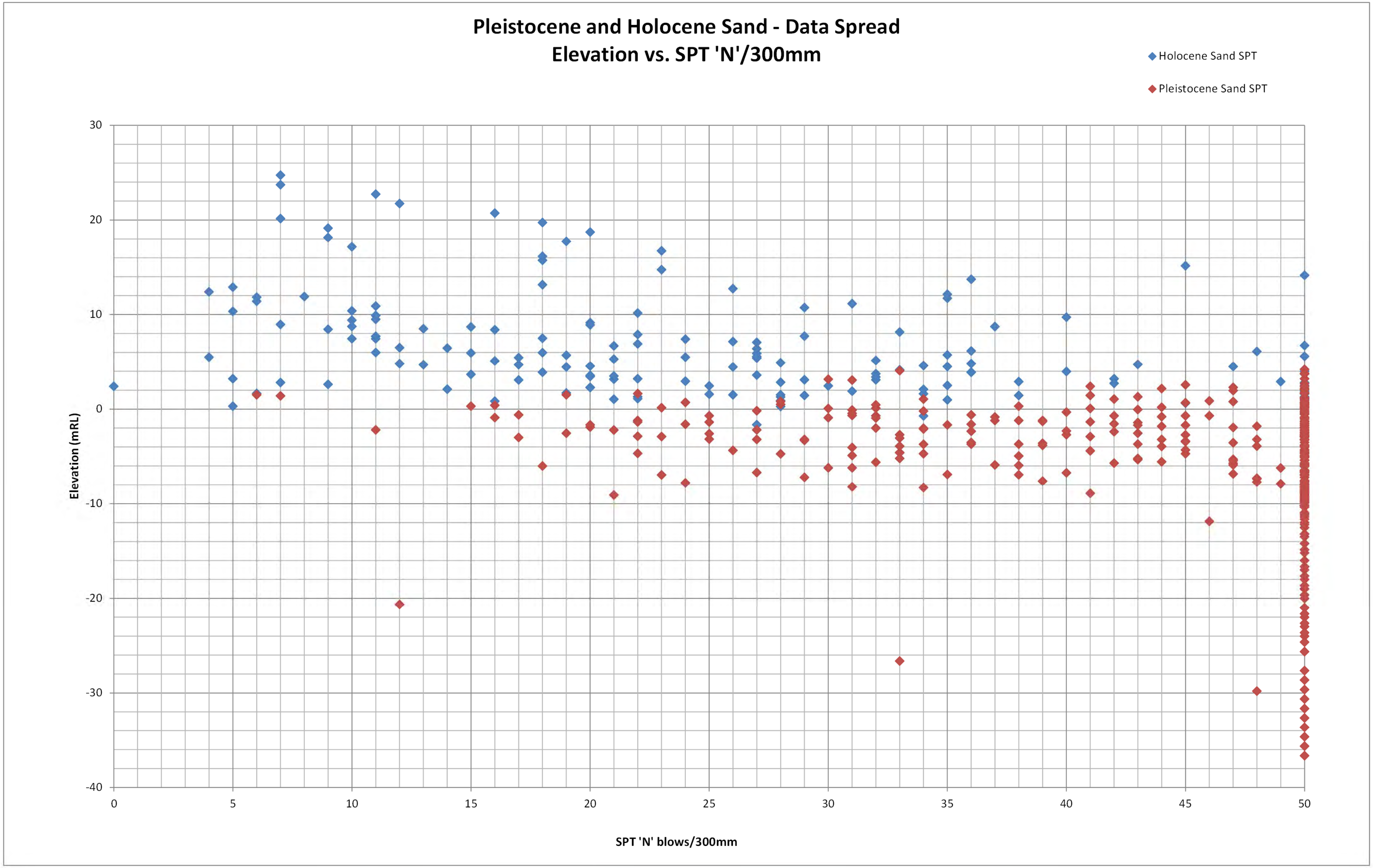
PROJECT No. 3320901
CAD FILE No. 3320901-GK41

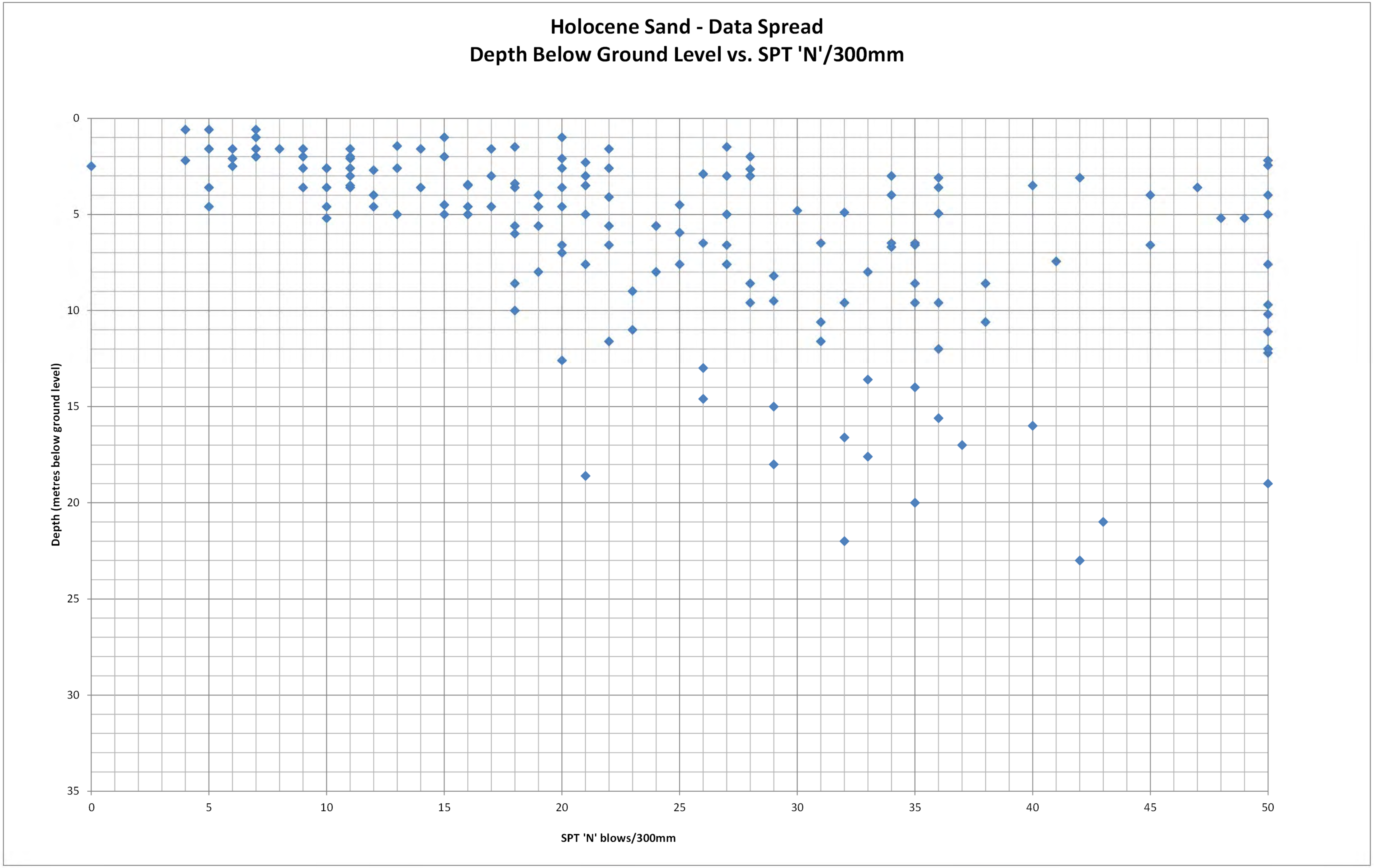
Appendix 36.D

## Sand Characteristics

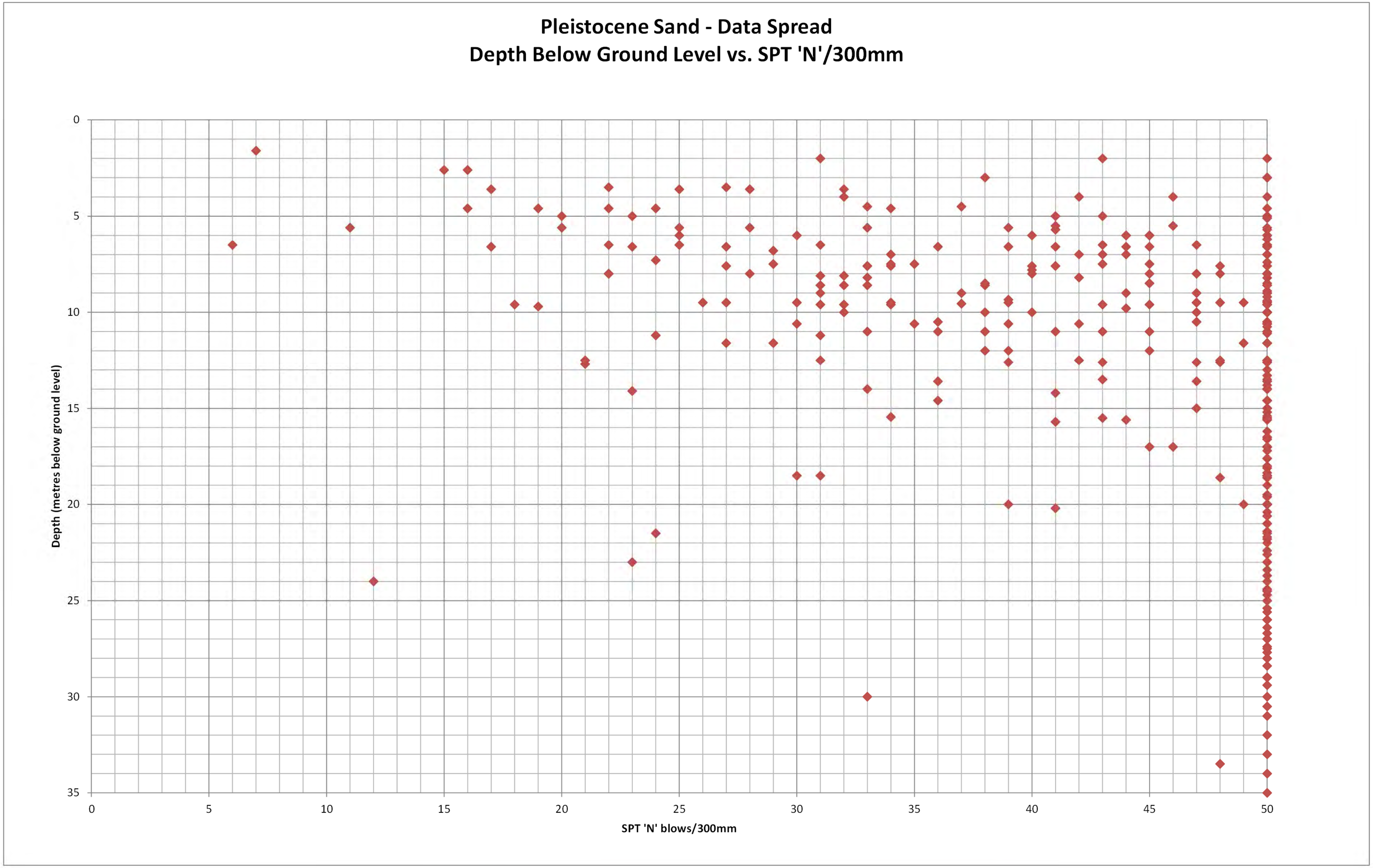


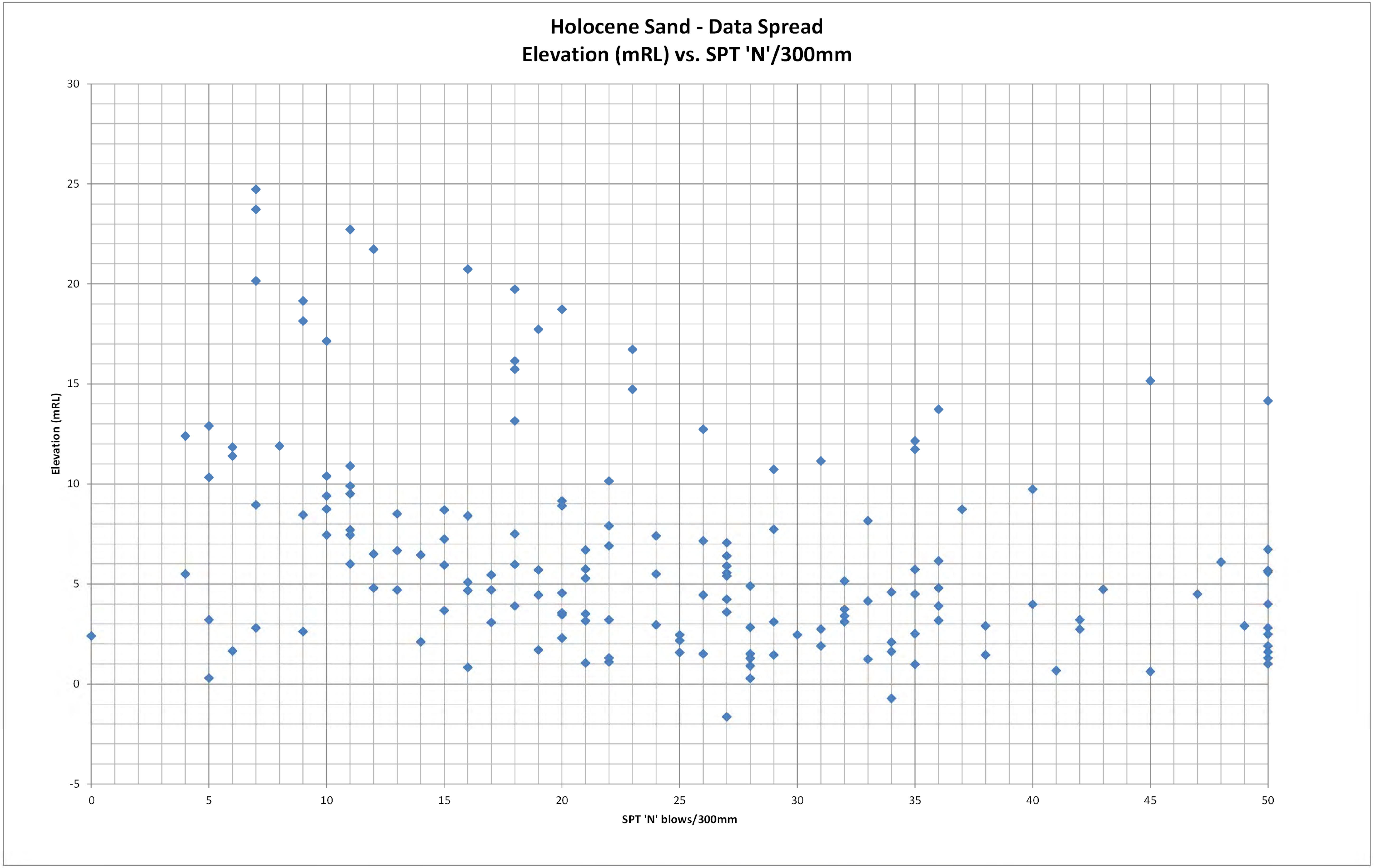
Pleistocene and Holocene Sand - Data Spread
Depth Below Ground Level vs. SPT 'N'/300mm
Holocene Sand SPT
Pleistocene Sand SPT
Depth (metres below ground level)
0
5
10
15
20
25
30
35
0
5
10
15
20
25
30
35
40
45
50
SPT 'N' blows/300mm

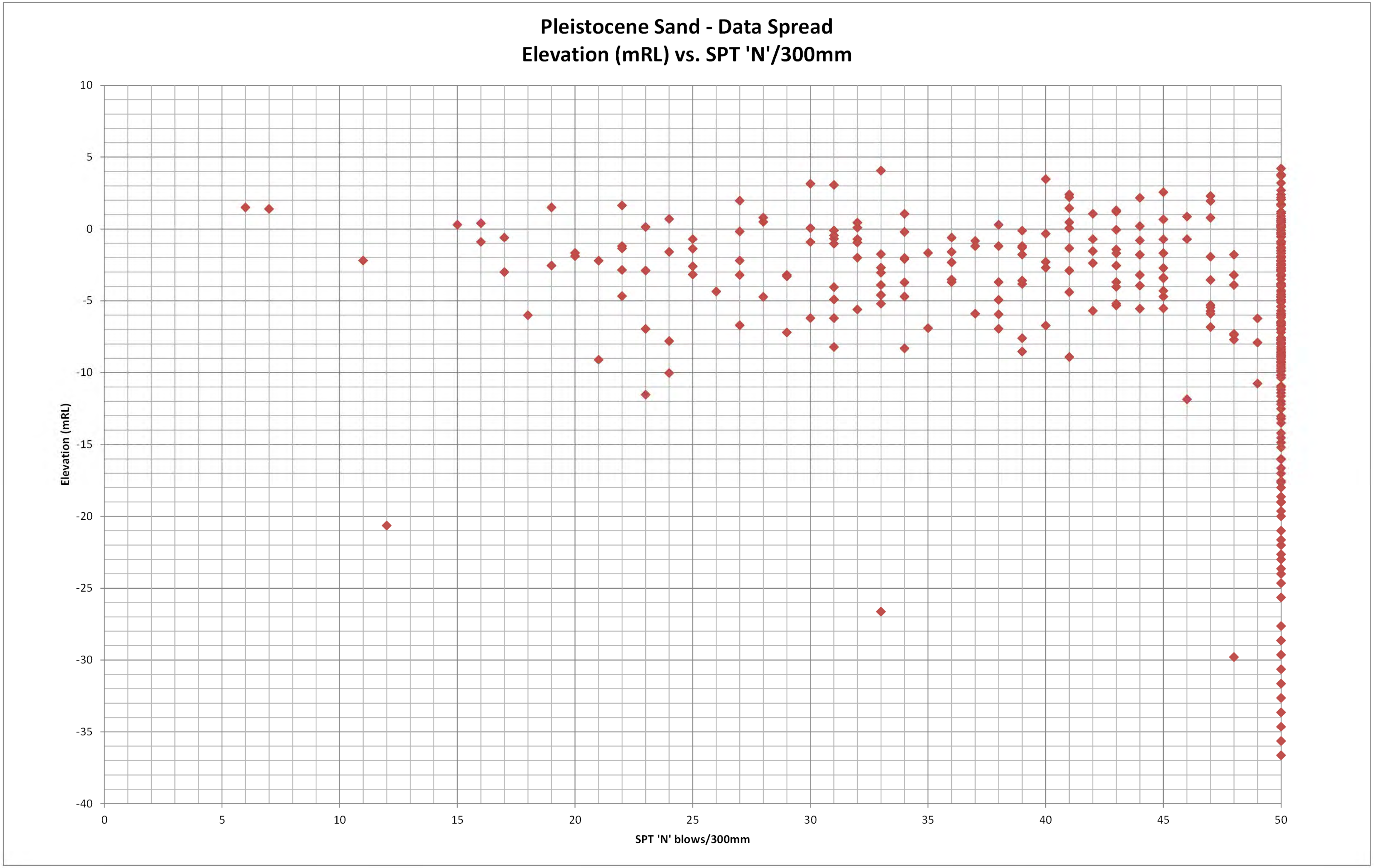

Pleistocene and Holocene Sand - Data Spread
Elevation vs. SPT 'N'/300mm
Holocene Sand SPT
Pleistocene Sand SPT
30
20
10
0
-10
-20
-30
-40
Elevation (mRL)
0
5
10
15
20
25
30
35
40
45
50
SPT 'N' blows/300mm

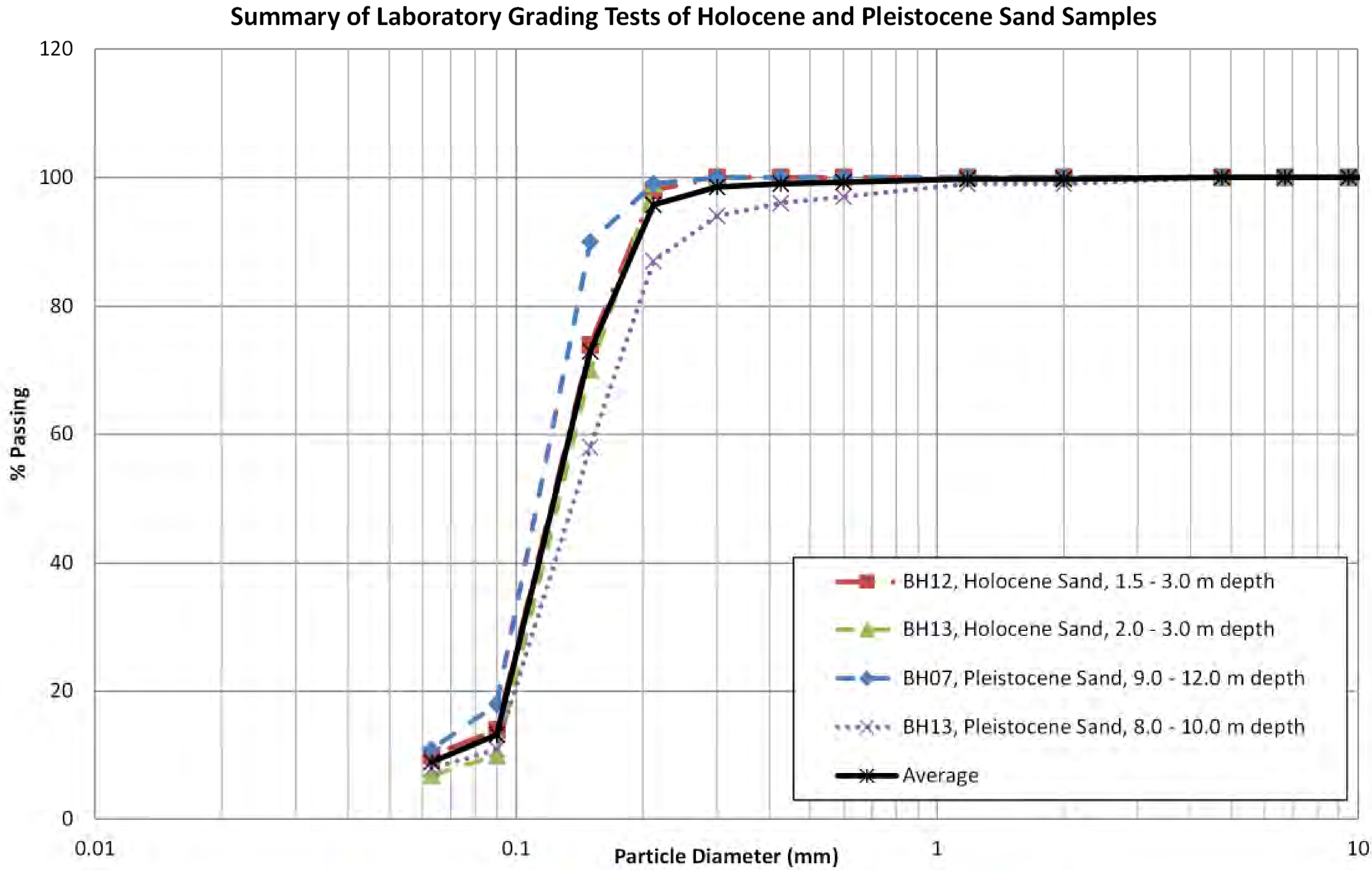


Holocene Sand - Data Spread
Depth Below Ground Level vs. SPT 'N'/300mm
Depth (metres below ground level)
SPT 'N' blows/300mm
0
5
10
15
20
25
30
35
40
45
50


Pleistocene Sand - Data Spread
Depth Below Ground Level vs. SPT 'N'/300mm
Depth (metres below ground level)
0
5
10
15
20
25
30
35
0
5
10
15
20
25
30
35
40
45
50
SPT 'N' blows/300mm


Holocene Sand - Data Spread
Elevation (mRL) vs. SPT 'N'/300mm
Elevation (mRL)
SPT 'N' blows/300mm
30
25
20
15
10
5
0
-5
0
5
10
15
20
25
30
35
40
45
50


Pleistocene Sand - Data Spread
Elevation (mRL) vs. SPT 'N'/300mm
Elevation (mRL)
SPT 'N' blows/300mm
10
5
0
-5
-10
-15
-20
-25
-30
-35
-40
0
5
10
15
20
25
30
35
40
45
50




NZ TRANSPORT AGENCY WAKA KOTAHI

1 MacKays to Peka Peka