Before a Board of Inquiry
MacKays to Peka Peka Expressway Proposal

under: the Resource Management Act 1991

in the matter of: Notice of requirement for designation and resource consent applications by the NZ Transport Agency for the MacKays to Peka Peka Expressway Proposal

applicant: **NZ Transport Agency**
Requiring Authority

Statement of evidence of **Gavin Alexander** (Ground Settlement) for the NZ Transport Agency

Dated: 3 September 2012

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STATEMENT OF EVIDENCE OF GAVIN ALEXANDER FOR THE NZ TRANSPORT AGENCY

QUALIFICATIONS AND EXPERIENCE

1 My full name is Gavin John Alexander. I am a Technical Director in Beca Infrastructure Limited's (*Beca*) Geotechnical Group based in Auckland.

2 I have the following qualifications and experience relevant to the evidence I shall give:

2.1 I hold a Bachelor of Civil Engineering from the University of Auckland (1986) and a Masters Degree in Soil Mechanics and Engineering Seismology from Imperial College, University of London (1991).

2.2 I am a New Zealand Chartered Professional Engineer, a Fellow of the Institution of Professional Engineers of New Zealand, and a Member of the New Zealand Geotechnical, Structural Engineering and Large Dam Societies. I am currently an elected member of the Management Committee of the New Zealand Geotechnical Society, and hold the role of Vice-Chair.

2.3 I have 30 years' experience in geotechnical and civil engineering, and over the past 26 years I have provided geotechnical advice on a wide variety of civil, commercial, industrial, and land development projects in many parts of New Zealand, and in Australia and further afield.

2.4 Projects I have provided advice on include the Tauranga Eastern Link highway (*TEL*), the Ngaruawahia Section of the Waikato Expressway (*Ngaruawahia*), and the recent Board of Inquiry hearing on the Waterview Connection Project (*Waterview*).

2.5 The TEL project comprises a new four lane highway some 23 km in length with seven bridges and some three million cubic metres of earthworks. I was the lead geotechnical engineer for the early stages of that project, and reviewed the geotechnical work of my colleagues as it developed and was consented. TEL is currently being designed and built by a consortium of constructors and designers, and I continue to review the work of my colleagues as they fulfil Beca's role as advisor to the NZ Transport Agency (*NZTA*). From a geotechnical perspective, it has many similarities to the Mackays to Peka Peka Expressway (*the Project*), in that it requires the construction of a multi-lane highway through sand dunes and over peat lands, and involves the careful

consideration of ground settlement, liquefaction potential and the seismic performance of relatively high embankments at bridges.

2.6 The Ngaruawahia project comprises 12 km of new four lane expressway, with six bridges and some 1.2 million cubic metres of earthworks, and is located in the northern Waikato. It is currently being constructed by a design-build team, with Beca providing geotechnical design. I am the geotechnical reviewer for that project. It includes the construction of a multi-lane highway over peat lands and, as for TEL, involves the careful consideration of ground settlement, liquefaction potential and the seismic performance of relatively high embankments at bridges.

2.7 Both of these projects are, therefore, directly relevant to the Mackays to Peka Peka Project.

2.8 My role on Waterview was focussed on the ground settlement effects from tunnel and retaining wall construction. It involved the estimation of the quantum of ground settlement resulting from the project and assessment of the effects of that settlement on houses, other structures and buried and surface infrastructure. I have adopted the same assessment methodologies used on Waterview for the current Project.

2.9 I led the drafting of the proposed settlement effects management plan and the ground settlement conditions for Waterview, and participated in expert conferencing to develop an agreed set of conditions for consideration by the Board of Inquiry (*BOI*).

2.10 I am currently the reviewer for ground settlement related assessments and monitoring for the Well Connected Alliance which is designing and constructing the Waterview Connection project.

3 My evidence is given in support of the Notice of Requirement (*NoR)* and applications for resource consent lodged with the Environmental Protection Authority (*EPA)* by the NZTA for the construction, maintenance and operation of the Project.

4 I am familiar with the area that the Project covers and the State Highway and local roading network in the vicinity of the Project.

5 I have directed and reviewed all geotechnical aspects of the design and the ground settlement effects assessment for this Project since mid-2010. In the course of my involvement, I have worked closely with my colleagues, particularly **Ms Ann Williams**, who has undertaken groundwater modelling.

6 I am the reviewer of the Assessment of Ground Settlement Effects Technical Report and of the Geotechnical Interpretive Report[1] which form part of the Assessment of Environmental Effects (*AEE)* lodged in support of the Project.

7 My evidence covers the assessment of potential ground settlement associated with the construction and operation of the Project, and the potential effects of these settlements on existing buildings, services and infrastructure. It describes the monitoring regime proposed, together with potential mitigation measures for ground settlement effects (if any).

8 I have read the Code of Conduct for Expert Witnesses as contained in the Environment Court Consolidated Practice Note (2011), and I agree to comply with it as if this Inquiry were before the Environment Court. My qualifications as an expert are set out above. I confirm that the issues addressed in this brief of evidence are within my area of expertise. I have not omitted to consider material facts known to me that might alter or detract from the opinions expressed.

SCOPE OF EVIDENCE[2]

9 My evidence will deal with the following:

9.1 Executive summary;

9.2 Background and role;

9.3 A brief description of the existing ground conditions (which are discussed more fully in the evidence of Ms Ann Williams);

9.4 Assessment of ground settlement effects;

9.5 Response to submissions;

9.6 Response to the BOI's section 92 request;

9.7 Proposed conditions; and

9.8 Conclusions.

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1 Technical Reports 35 and 36 respectively.

2 I have reviewed the section 149G Key Issues Reports prepared by Greater Wellington Regional Council and Kāpiti Coast District Council. There are no issues raised that relate to ground settlement or that otherwise require a response from me.

EXECUTIVE SUMMARY

10 My evidence addresses the potential ground settlement effects resulting from construction and operation of the proposed Expressway. It also discusses the general ground conditions and key geotechnical considerations that have been identified for the proposed Expressway.

11 There are four predicted sources of settlement associated with construction and operation of the Expressway, of which the first two listed below are by far the most significant:

11.1 *Ground consolidation due to the construction of road embankments*. This consolidation occurs beneath and for a small distance beyond the embankments where they are constructed on peat.

11.2 *Ground consolidation due to lowering of the groundwater as a result of excavation*. This is also confined to peat soils. It is time dependant and will extend for a greater distance beyond the earthworks footprint. Permanent lowering of the groundwater level in peat may also result in drying induced volume change settlement.

11.3 *Mechanical settlement of the ground due to movement of retaining walls*. This is much more localised and of considerably smaller magnitude than consolidation settlement.

11.4 *Mechanical settlement of the ground due to vibration*. This is expected to only result from construction activities which are intended to densify the adjacent soil. It is, therefore, extremely localised and the effects are built out by subsequent construction.

12 Field and laboratory investigations have been carried out to characterise the soils at the Project site. These investigations have included a trial embankment to investigate the settlement behaviour of the peat soils that underly a significant portion of the site and in which the most significant settlement is expected to occur.

13 Numerical analysis of settlement has been undertaken for each of the potential sources identified, and these have been combined where appropriate to determine total settlement contours. The largest component of settlement results from embankment loading and as a result has little effect on surrounding properties or infrastructure. Settlement arising from groundwater drawdown in peat soils is more extensive, but the magnitude is typically small because of the limited groundwater change expected.

14 The effects on buildings have been assessed following the approach that was adopted for the Waterview Connection project. Applying this approach, the assessment concluded that there will be negligible setlement effects on all buildings from the construction and operation of the Expressway. Similarly low effects are predicted on buried services that are not proposed to be relocated as part of the project, and on rail infrastructure. Road surfaces that are affected by the Project will be remediated by resurfacing.

15 Monitoring is proposed to confirm the predicted settlement and the predicted effect of that settlement. While the current assessment indicates that mitigation of settlement effects is not required, there are mitigation measures that can be implemented if required. These include changing the construction methodology in areas of peat to reduce the extent of dewatering, and the installation of groundwater recharge trenches.[3]

16 I have reviewed submissions lodged on the Project relevant to my area of expertise. Nothing raised in those submissions causes me to depart from the conclusions reached in my technical assessment of the Project.

BACKGROUND AND ROLE

17 The NZTA selected an alliance comprising Fletcher Construction, Higgins Group, and Beca Infrastructure, together with several support organisations (the *Alliance*) in mid-2010 to design and construct the Project.

18 I have directed and reviewed all geotechnical aspects of the Project since the inception of the Alliance. That has included participation in workshops to develop the initial concepts, contribution to the multi-criteria analysis of the various options, and direct discussion with inter-related disciplines, in particular with **Ms Ann Williams** on groundwater and **Mr James Whitlock** on vibration.

19 A team of engineers and engineering geologists from Beca undertook the current geotechnical investigations and prepared the Geotechnical Interpretive Report (Technical Report 36) and the Assessment of Ground Settlement Effects (Technical Report 35). That team consisted of:

19.1 Ms Lucy Coe − Associate, Geotechnical Engineering;

19.2 Ms Jennifer Bradshaw − Engineering Geologist;

19.3 Mr Aidan Thorp − Geotechnical Engineer; and

[3] Further examples are provided in Technical Report 35, Section 7.2.

19.4 Mr Jamil Khan – Associate, Structural Engineering.

20 My role was to guide development of the assessment methodology and to peer review the Technical Reports.

21 Assessment of ground settlement requires consideration of the magnitude of ground movements resulting from groundwater changes and from the direct loading of compressible soils (known as consolidation settlement) and of movement resulting directly from excavation (known as mechanical settlement).

22 For this Project, the settlement of by far the greatest magnitude (and hence interest) arise from the preloading of peat[4] (by the proposed embankments) and from long term groundwater lowering within adjoining peat lands resulting from permanent excavation, typically for some of the proposed stormwater wetlands and offset flood storage areas. The settlement occurs predominantly within the underlying and surrounding peat. Settlement within the underlying sand is much (typically several orders of magnitude) less than that occuring within the peat, so has not been separately considered.

23 Embankment loading related settlement is largely confined to the land beneath and extending a short distance away from the fill area. As a result, it has little effect on adjoining property or services. It is only an issue when considering earthworks volumes.

24 Groundwater lowering of peat by the formation of permanent ponds or offset storage areas with outlets below the existing groundwater level results in more widespread effects, albeit of smaller magnitude than the settlement arising from embankment loading. Consequently, the Assessment of Groundwater Effects Report (Technical Report 21) is of fundamental importance to the assessment of settlement. My team has used the groundwater changes from that report (as discussed in the evidence of **Ms Ann Williams**) to calculate consolidation settlement resulting from groundwater lowering.

25 Ground settlement effects comprise not just the amount of surface movement but, more importantly, the effects of that movement on buildings and infrastructure. Those assessments were made by my civil and structural engineering colleagues at Beca and on the Alliance and have been reviewed by me.

[4] Peat typically comprises unconsolidated black or dark brown soil consisting largely of slightly decomposed or undecomposed vegetable matter that has accumulated in a waterlogged environment. The level of decomposition varies along the Project site. For the purpose of this assessment, fully decomposed (termed amorphous) peat and organic rich sandy soils have also been treated as peat.

26 The Assessment of Ground Settlement Effects Report which addresses each of these issues was lodged with the EPA on 20 April 2012 as part of the overall AEE (specifically, Volume 2 Chapter 26, and Volume 3, Technical Report 35).

27 The proposed approach for monitoring and, if required, mitigation of settlement effects associated with the Project is included in Section 7 of that Report. This has informed the Settlement Effects Management Plan (*SEMP*) (contained in Construction Environmental Management Plan (*CEMP*) Appendix J, Volume 4), which describes the proposed settlement monitoring and mitigation measures in detail.

28 Technical Report 35 was informed by, and relies upon other technical reports lodged with the EPA in support of the Project, those reports being primarily:

28.1 Assessment of Groundwater Effects (Technical Report 21); and

28.2 Geotechnical Interpretive Report (Technical Report 36).

GROUND CONDITIONS

29 An assessment of the geotechnical and geological conditions for the Project is presented in Technical Report 36, the Geotechnical Interpretive Report, and forms part of the Assessment of Environmental Effects Report. Technical Report 36 is based on the results of earlier geotechnical investigations by others and on more recent investigations carried out by the Project team in 2010 and 2011. The extent and location of all investigation work is shown on plans contained in Technical Report 36.[5]

30 A description of the existing geology is provided by **Ms Ann Williams** in her evidence and hence this section of my evidence presents a summary of the relevant geotechnical aspects of the Project.[6]

31 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.

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[5] Appendix 36.A of Technical Report 36.

[6] This is further detailed in Section 3 (Existing environment) of Technical Report 35.

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

32.1 The presence of peat deposits across the site, and associated embankment settlements and stability;

32.2 The high seismic hazard and known active faults;

32.3 The presence of relatively loose to medium dense saturated sand deposits with the potential to liquefy during moderate to significant design seismic events;

32.4 The potential for liquefaction induced slope instability and settlement; and

32.5 Founding conditions for bridge structures comprising alluvial deposits to depth, predominately interbedded dense sands and gravels.

33 These considerations have been responded to and are reflected in the Project's scheme design (through avoidance and mitigation).

34 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, but are up to 6m thick in some locations.

35 The presence of peat deposits presents constraints to the design of embankments due to the relatively large and ongoing settlement that occurs when these soils are loaded. Such settlement can affect the smoothness of the road surface and cause rainwater to pond, as well as affecting underlying and adjacent services and adjacent structures and properties.

36 Groundwater level lowering in peat deposits can also lead to ground surface settlement. These groundwater changes, and the resulting settlement, can extend some distance beyond the footprint of the Project.

37 The relatively weak peat deposits can also affect the stability of higher embankments, in particular during the construction stage and during or following a seismic event.

38 The alignment is located in an area of high seismicity and the Alliance has completed a site-specific seismic hazard assessment to refine the seismic hazard.[7] My analyses indicate that, where saturated, the loose to medium dense sands present on the site are susceptible to liquefaction during a moderate or significant

[7] Technical Report 36, Section 3.6.

earthquake event. Liquefaction is expected to result in settlement, slope instability and horizontal movements of dunes and embankments.[8]

ASSESSMENT OF GROUND SETTLEMENT EFFECTS

39 In this section of my evidence, I will briefly describe the key points of Technical Report 35.

40 The Report presents the results of the assessment of potential ground settlement associated with the construction and operation of the proposed Expressway, and the expected effects of that settlement on existing buildings, services and transport infrastructure.[9]

41 In the Report, the sources of settlement are detailed and the magnitude of settlement calculated to assess the settlement effects including the effects on buildings, services and infrastructure.[10] A monitoring regime and potential mitigation measures are also provided in the Report.[11]

42 The Report, and the accompanying SEMP, focuses predominantly on the damage potential arising from settlement (i.e. the effects), rather than the quantum of settlement itself.

Sources of settlement effects

43 There are four predicted sources of settlement associated with the construction and operation of the proposed Expressway, as described below:

44 *Consolidation of the ground due to the construction of embankments.*[12] Such settlement occurs beneath and for a small distance beyond the embankments where they are constructed on peat. As a result, it primarily affects the completed highway pavement, roadside drainage and furniture, and any services buried within the underlying peat. Consolidation settlement is time dependent and is directly related to the embankment height and to the nature, thickness and permeability of the peat. Most of this movement will occur during construction, with ongoing secondary compression (creep) settlement continuing at a reducing rate through operation. The magnitude and rate of this settlement greatly affects construction planning and earthworks volumes, but

8 Technical Report 36, Section 3.7.

9 Technical Report 35, Sections 5 and 6.

10 Technical Report 35, Section 5.

11 Technical Report 35, Section 7.

12 Technical Report 35, Section 5.1.

has little effect on buildings and infrastructure beyond the Project footprint due to its localised extent.

45 *Consolidation of the ground due to lowering of the groundwater:*[13] Lowering of the groundwater level will occur as a result of excavation, which may be either temporary (e.g. short term undercutting to remove peat from beneath the embankment footprint or in other areas) or long term around some of the excavated stormwater wetlands and offset flood storage areas. Consolidation settlement is time dependent, and will extend beyond the earthworks footprint. Consequently, it has the potential to affect buildings and infrastructure beyond the Project footprint, particularly where the groundwater changes are essentially permanent.

46 Permanent lowering of the groundwater level will potentially result in drying induced volume change settlement. The change in moisture content is expected to be relatively small as a result of infiltration recharge. The groundwater drawdown beyond the Project footprint is modest, and complete drying is not expected to occur. Consequently, the drying induced volume change is expected to be relatively small in comparison with the settlements resulting from consolidation due to the groundwater lowering.

47 There is one potential exception to this, around Offset Flood Storage Area 2, where permanent groundwater lowering is proposed and more extensive drawdown has been predicted.[14] I will return to this later in my evidence.

48 I acknowledge that there are uncertainties involved in the prediction of settlement of peat and other organic rich soils. Many of these have been identified in the BOI's section 92 request,[15] which I respond to below. I accept that it is not practical to precisely define the distribution of likely ground settlement resulting from the Project. As a result, in my assessment, I have adopted a conservative approach to assessing the extent and quantum of settlement that is likely to occur, and have based my assessment of the resulting effects on buildings and infrastructure on that conservative assessment.

49 Consequently, I consider that my assessment presents an upper bound to the likely ground settlement effects of the Project. Monitoring of settlement and of effects on buildings and infrastructure will be used to confirm the effects are no worse than this assessment, and mitigation measures are available in the event that the effects are greater than has been predicted.

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13 Technical Report 35, Section 5.2.

14 Technical Report 21, Figure F8b.

15 Section 92 request dated 9 August 2012.

50 *Mechanical settlement of the ground due to the movement of retaining walls:*[16] Lateral movement of embedded retaining walls (as the ground is excavated in front of them) results in localised settlement of the ground above. These settlements occur relatively quickly, during and immediately following wall construction. I expect them to be of small magnitude and of localised extent when compared to the settlement resulting from embankment loading.

51 *Mechanical settlement of the ground due to vibration*[17]*:* Vibration is used in construction to densify sandy or gravelly soils. This densification results in immediate settlement of the ground surface extremely close to the vibration source. Vibration resulting from general construction operations, and from traffic on the completed Expressway, is not expected to generate sufficiently high shear stresses to cause ground settlement. Consequently, vibration induced settlement is confined to the construction footprint and is essentially "built out" by the construction operation.

Methodology of calculating settlement effects

52 The methods used for calculating settlement and assessing the subsequent effects are detailed in Section 4 (Methodology) of Technical Report 35.

53 The extent of ground settlement resulting from the Project has been determined by combining, as applicable, the settlement caused by the various sources described above. Plans showing the area of expected effects are provided in Appendix 35.G to Technical Report 35 and are attached to my evidence as **Annexure A**.

54 The consolidation settlement from the two primary sources (new road embankment and groundwater lowering) have been analysed separately, at a number of cross-sections along the length of the proposed Expressway.[18] The same cross-sections have been used for each set of analyses. The settlement profiles have then been combined to assess the total predicted consolidation settlement. The cross-sections have been selected to be representative of the varying peat thicknesses and peat treatment methodologies for the new road embankment. In addition, the cross-sections cover the new stormwater wetlands and offset flood storage areas that may result in lowering of the groundwater level.[19]

55 Mechanical settlements will occur as a result of construction of the new retaining walls and from construction vibrations. These settlements are significantly smaller, in both magnitude and extent,

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16 Technical Report 35, Section 5.3.

17 Technical Report 35, Section 4.6.

18 The embankment and groundwater drawdown settlement methodologies are presented respectively in Sections 4.3 and 4.4 of Technical Report 35.

19 As identified in Technical Report 21, Volume 3.

than the consolidation settlements. They have been considered independently and then incorporated into the total settlement assessment as applicable.[20]

56 The groundwater consolidation settlement is based on worst case drawdowns, conservatively ignoring time effects and the likelihood of recharge before temporary drawdown resulting from peat undercut and backfill (which will occur on the same day in any particular area of embankment construction) has time to fully develop. Mechanical settlement develops almost immediately as construction proceeds. As a result, it has a single critical stage, which is the long term.

57 The effects on buildings were assessed using an internationally accepted method.[21] This method was also used to assess the effects for the Waterview Connection project in Auckland, and remains the most commonly used and recommended method in international references. The method determines the curvature and horizontal strain in a building and plots these values against criteria to assess the likely effect on a structure. The classification of potential effects (Damage Category) is then determined. The method has been derived for unreinforced masonry buildings, so can be considered conservative for timber framed and reinforced concrete buildings.[22]

58 The assessment considered a "generic" residential building and also looked at 15 specific commercial and industrial buildings that were identified as being close to the potential area of settlement, as well as the KCDC Waste Water Treatment Plant and the Waikanae Christian Holiday Camp ('El Rancho').

59 The effects on local services and transport infrastructure were assessed by calculating the predicted change in their gradient as a result of any differential settlement and then determining whether that change can be tolerated by each item being assessed.[23]

Settlement Estimates and Effects

60 The consolidation settlement arising from construction of the new road embankment governs the settlement below the proposed Expressway footprint. The predicted settlement away from the proposed Expressway is predominately from groundwater drawdown settlement due to construction of those stormwater ponds, wetlands

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[20] The method for assessing the new retaining wall settlements and the vibration assessment of settlements are presented in Sections 4.5 and 4.6 respectively of Technical Report 35.

[21] Burland, J.B. (1997), "Assessment of risk of damage to buildings due to tunnelling and excavation", Earthquake Geotechnical Engineering, Ishihara (ed), Balkema, Rotterdam.

[22] This is discussed in Section 4.8.1 of Technical Report 35.

[23] This is discussed in Sections 4.8.2 and 4.8.3 of Technical Report 35.

and offset flood storage areas alongside the proposed Expressway which result in groundwater lowering. Within the 10m immediately adjacent to the proposed Expressway footprint, settlement results from a combination of these two sources.[24]

61 Plans showing the extent and magnitude of expected settlement are provided in Appendix 35.G to Technical Report 35 (and attached as **Annexure A** to my evidence).

62 The effects assessment predicts that there will be negligible effects on all buildings from the construction and operation of the Expressway. The predicted damage from this category is defined as no more than "hairline cracks" less than 0.1mm wide.[25]

63 This classification includes the specifically assessed commercial and industrial buildings, Kāpiti Coast District Council Waste Water Treatment Plant and the Waikanae Christian Holiday Camp. I note that there is no predicted settlement arising from the Project within the extent of the Camp.[26]

64 The assessment predicts negligible settlement effects on those services not proposed to be relocated.[27]

65 Where the proposed Expressway crosses existing roads, the physical construction works will include modification and re-surfacing of the local road at those crossings. The settlement effects will be remediated as part of the resurfacing of these roads. The effects on rail infrastructure are assessed to be low, and any re-levelling, if required, will be agreed with KiwiRail.[28]

66 Construction of Offset Flood Storage Area 2 is expected to result in groundwater lowering for some distance beyond the Project footprint, as noted earlier in my evidence. Groundwater lowering of 0.6m has been modelled in the immediate vicinity of this wetland.[29] The resulting settlements have been calculated based on a groundwater level at 0.5m depth below the ground surface. Eight hand auger bores have been put down in the potentially affected area as part of a recent stage of geotechnical investigations, which followed completion of Technical Report 35. Those bores indicated a lesser plan extent of peat than had been assumed in our assessments. They also identified late autumn (May) groundwater

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[24] This can be seen on cross sections showing total settlements and the two component parts presented in Appendix F of Technical Report 35.

[25] Technical Report 35, Section 4.8.1, Table 10.

[26] Technical Report 35, Sections 6.2.2 to 6.2.5.

[27] Technical Report 35, Section 6.3.

[28] Technical Report 35, Section 6.4.

[29] Technical Report 21, Figure F8b, and Section 5.2.4 of Technical Report 35.

levels at between 1.2m and 1.4m depth below the ground surface. The groundwater model was calibrated to an average groundwater level close to the surface beneath Rata Road.[30] Consequently, the predicted groundwater drawdown remains within the current seasonal range, and additional drying related settlement is not expected. As a result, I expect that groundwater lowering will not extend as far beyond the Project as has been modelled,[31] and that it will not produce additional drying induced volume change settlement.

Monitoring

67 Monitoring of actual ground settlements and the resulting effects will be undertaken to confirm the estimated settlements and the predicted effects of those settlements. The proposed monitoring is described in detail in Technical Report 35 and the SEMP.[32] It comprises vertical monitoring of survey marks, condition assessments of specified buildings and specific monitoring of retaining walls and services.

68 Monitoring of groundwater levels and their changes can provide an early warning of potential consolidation settlements. Groundwater monitoring thus forms part of the overall settlement mitigation monitoring strategy proposed for the Project.[33]

69 The frequency of monitoring will depend on the vulnerability of the object being monitored and its proximity to the active construction area, the stage of construction and the results of previous monitoring.

Mitigation and remediation

70 The current assessment indicates that mitigation is not required from settlement effects. However, Technical Report 35 does present mitigation measures available that could be implemented to cover the unlikely scenario of greater than predicted damage occurring.[34]

71 The Report sets out contingency measures for road embankment settlement, groundwater drawdown settlement, and retaining wall settlement. Building mitigation available includes repair of any non-structural defects once settlement is substantially complete (ie when the rate of movement is sufficiently low that repair is worthwhile) and the immediate repair of any issues that are structural or will affect the weather tightness of a building.

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30 Technical Report 21, Section F3.2.

31 Technical Report 21, Figure F8b.

32 Section 7 of Technical Report 35, and Section 3.2 of the SEMP (see CEMP, Appendix J, Volume 4).

33 Refer Groundwater (Level) Management Plan (CEMP, Appendix I, Volume 4).

34 Section 7.2 of Technical Report 35.

72 Services mitigation available depends on the type of service and its construction, but includes temporary or permanent diversion, repair or replacement. Road and rail could be remediated, if necessary, by relatively minor surface reconstruction methods.

RESPONSE TO SUBMISSIONS

73 I have read all of the submissions lodged on the Project that raise ground settlement or issues relevant to my expertise in geotechnical engineering. Submitters have raised a number of ground settlement concerns. A larger number of submitters identify the potential challenges that the peat and sand at the site pose for earthworks, performance during earthquakes, and liquefaction potential. In this section of my evidence, I will firstly address the submissions that are directly related to ground settlement effects. I will then turn to the broader geotechnical concerns that have been raised.

74 Neither the Greater Wellington Regional Council nor the Kāpiti Coast District Council has raised concerns or issues in their respective submissions in relation to ground settlement or other geotechnical matters. Accordingly, I do not refer to their submissions here.

Ground settlement issues

75 *D and D Waterson, 16 Rata Rd, Raumati*[35] – express concerns that they may begin experiencing problems with their property including the foundations of their house as a result of nearby peat removal, filling and groundwater changes. The estimated settlements resulting in this area are shown in Technical Report 35[36] and on Sheet 3 of **Annexure A**. This property is located well beyond the Project footprint, and beyond the modelled extent of measurable groundwater drawdown.[37] Consequently, it is not expected to experience settlement resulting from fill loading or groundwater changes.

76 *B Harrison, 106 Leinster Ave, Raumati South*[38] – expresses concerns regarding land subsidence due to the water table being changed, as well as potential damage to his house. The potential for such subsidence, and the expected distribution of the resulting ground settlement effects, is addressed in Technical Report 35. The estimated settlements resulting in this area are shown in Technical Report 35[39] and on Sheet 2 of **Annexure A**. This property is located beyond the Project footprint, and beyond the extent of measurable groundwater drawdown. Consequently it is not expected to

35 Submitter 26.

36 Appendix G, Sheet 3 of 11.

37 Technical Report 21, Figure F8b.

38 Submitter 323.

39 Appendix G, Sheet 2 of 11.

experience settlement resulting from fill loading or groundwater changes.

77 *A Laing, 169B Te Moana Rd, Waikanae*[40] – expresses concerns that increased stormwater runoff will exacerbate subsidence on her property that is underlain by peat deposits. It is not appropriate for me to comment on the potential for stormwater runoff from the Project affecting this property. I would, however, expect subsidence to result from groundwater lowering rather than raising, and for increased runoff to raise rather than lower groundwater levels. Consequently, this concern is, in my opinion, unwarranted.

78 *R Mackay, 14 Gavin Rd, Raumati Beach*[41] – states that settlement may have a negative impact on homes near the Expressway. This concern is the reason that considerable effort has been put into modelling the ground settlement effects, as summarised in Technical Report 35. As I state in paragraph 62 above, my effects assessment predicts that there will be negligible effects on all buildings from the construction and operation of the Expressway.

79 *Paraparaumu/Raumati Community Board*[42] – identifies the potential for adverse effects on ground stability of properties west of Rata Road as a result of earthworks for Offset Flood Storage Area 2. The Community Board requests continuous monitoring of groundwater levels in this area before, during, and for 3 years after construction. Ground settlement in this area has been specifically assessed[43] and is predicted to be less than 12.5mm. I have discussed the potential for drying induced settlement in paragraph 66 above. Consequently, I do not expect adverse ground stability effects to occur as a result of the Project earthworks in this area. While monitoring of groundwater changes is an important part of managing settlement effects, as I discuss in paragraph 68 above, changes are progressive and gradual, so in my view continuous monitoring is not warranted. I expect periodic water level monitoring, as has been proposed by **Ms Williams**, to be adequate to provide advance warning of potential ground settlement.

80 *Save Kãpiti Inc*[44] – identifies that the proposal will result in drawdown of groundwater level and cause ground settlement over an area extending well beyond the footprint of the designation. It also identifies considerable uncertainty over the magnitude of settlements and consequent adverse effects. While I share this view, I consider that the settlement effects have been

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40 Submitter 337.

41 Submitter 404.

42 Submitter 501.

43 Technical Report 35, Section 5.2.4.

44 Submitter 505.

comprehensively modelled, as summarised in Technical Reports 21 and 35. The residual uncertainty is managed by the proposed ground settlement and building condition monitoring programme, which is described in the proposed Ground Settlement Conditions in **Annexure B**.

81 *Highway Occupants Group*[45] – identifies the absence of geotechnical testing undertaken between chainage 3000 and 3700, immediately north of Leinster Avenue, and suggests that this lack of technical information undermines the assessment of effects. I do not agree. The ground settlement effects have been assessed based on contours of peat thickness[46] derived from nearby subsurface data and interpretation of the surface topography. Six hand auger bores have been put down along this portion of the alignment as part of a recent stage of geotechnical investigations, which followed completion of Technical Report 35. Those investigations have identified peat thicknesses close to (within 0.5m) the values used for the assessment.[47] I consider that the difference in ground settlement effects will be small and that the current assessment remains reasonable at this stage.

Building on sand and peat

82 Many submitters refer to the building of this Project on sand and peat as carrying great risks and being expensive.[48] I have discussed these issues earlier in my evidence (paragraphs 32 to 37 above). I can confirm that these issues have been carefully assessed and quantified in the course of the geotechnical investigations and design for the Project, and are, in my view, appropriately reflected in the designs that have been developed to date and which form the basis of the assessments of effects.

Earthquakes and liquefaction

83 Many submitters draw attention to the high earthquake hazard in this part of New Zealand, to the high groundwater level, and to the consequent potential for liquefaction of loose sandy soils.[49] I note

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45 Submitter 542.

46 Technical Report 35, Appendix B.

47 Namely the contours of peat thickness in Technical Report 35 Appendix B Sheets 2 and 3, which cover this area.

48 Submitters include C & M Dearden (261), D & D Waterson (267), Religious Society of Friends (330), C & I Baxter (422), B & J Inge (429), S Madden (459), R. Love (470), Smart Transport Network (484), G Allen (523), L Allen (524), J Short & G Schwass (531), M Ellis (534), S Arnold (567), D Connal (616), D & S Simmons (648), J Nisbet (649), D Peters (693), and J Svendsen (733).

49 Submitters include D Hawken (072), K Hare (150), T & A Davies (184), B Tennyson (191), L Taylor (210), C & M Dearden (261), D & D Waterson (267), R Marshall (279), M Burton (299), L Pomare (309), Religious Society of Friends (330), H Hopkirk (336), J Downie (346), C Keno (357), C & I Baxter (422), B & J Inge (429), S Madden (459), K Pomare (465), W & D Lattey (466), R. Love (470), Smart Transport Network (484), D Kieboom (494), K Allan (502), S Edbrooke (517), G Allen (523), L Allen (524), J Short & G Schwass (531), M Ellis (534), S Arnold (567), R Starke (589), S Heppenstall (598), K Nauta & D Jones

that these issues have been previously identified and discussed in the Geotechnical Interpretive Report,[50] and I have discussed them in paragraphs 32, 33 and 38 above. I can confirm that these issues have been carefully assessed and quantified in the course of the geotechnical investigations and design development, and are, in my view, appropriately reflected in the designs that have been developed and which form the basis of the assessments of effects. The seismic design standards for this Project are considerably higher than would commonly be adopted for a new building, and result in extensive mitigation of the liquefaction risk in the vicinity of new structures and specific measures to limit earthquake induced displacement of the higher embankments.

RESPONSE TO THE BOI'S SECTION 92 REQUEST

84 I have reviewed the section 92 RMA request made by the BOI (by letter dated 7 August 2012) and in this section of my evidence I will address matters identified in Appendix One relating to peat settlement. I have reproduced the matters raised and respond to each item in turn below.

85 The request asks for further comment on the following items in relation to ground settlement effects:

85.1 ***The assessment of peat properties and the subsequent effects of ground settlement. Including the long term effects of loading and dewatering to confirm predictions used.*** The derivation of peat properties is described in the Geotechnical Interpretive Report.[51] Those properties have been developed from field and laboratory test results from historic and current geotechnical investigations in the area, along with interpretation of field trials and construction records.[52] These parameters have been used to calculate settlement resulting from embankment loading and due to groundwater drawdown (dewatering), as has been presented in the Assessment of Ground Settlement Effects[53] and as I have summarised above. As I have stated in paragraphs 48 and 49 above, there are many uncertainties involved in the prediction of settlement on peat. As a result, I have made a conservative assessment, and have proposed a

(600), D Connal (616), A Cherrill (630), D & S Simmons (648), A Soncodi (652), N Beechey (663), E Hinkley (673), M O'Sullivan (675), R & M Starke (690), D Peters (693), M & J Harris (713), R Snyders (720), S Woods (723), and J Svendsen (733).

50 Technical Report 36 at Sections 3.4 to 3.7, and Section 5.2.

51 Technical Report 36, Section 6.3.

52 As identified in Table 5, p.20, Technical Report 36.

53 Technical Report 35.

monitoring programme[54] to confirm the predictions and that the effects are no worse than has been assessed.

85.2 ***Possible further mechanisms that led to settlement of peat or the timeframes under which ongoing settlement may take place. In particular:***

(a) ***The susceptibility of organic matter in the peat to biological oxidation.*** Oxidation is recognised as one of the components of peat land subsidence resulting from drainage.[55] While I am not aware of any studies in New Zealand, subsidence resulting from oxidation of peat has been found in the Netherlands to contribute around 50% of the total subsidence arising from drainage.[56] As I have discussed in paragraph 66 above, extensive permanent groundwater drainage modelled to result from the Project is largely confined to the area around Offset Flood Storage Area 2. The predicted groundwater drawdown at this location remains within the current seasonal range, and oxidation and additional drying related settlement is not expected.

(b) ***Likely proportion of shrinkage induced volume change on changing water contents.*** This aspect has not been specifically studied, as groundwater changes beyond the Project are limited in extent, and the moisture content of the peat is expected to remain high as a result of infiltration recharge.[57]

(c) ***Design parameters for secondary consolidation.*** The trial embankment constructed as part of this Project continues to be monitored and will ultimately provide useful data on secondary consolidation. Monitoring and analysis for the nearby Mackays Crossing Project[58] indicates secondary consolidation of peat over a 10 year period to comprise around 10% of the total settlement arising from the highest part of that embankment. As a result, secondary consolidation

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54 Paragraphs 67 to 69 above.

55 With the others being shrinkage due to withdrawal of moisture from surface layers by evapotranspiration, and consolidation/compression (as I have assessed in Technical Report 35), refer Schothorst, C.J. 1977. Subsidence of low moor peat soils in the Western Netherlands. Institute for Land and Water Management Research, Wageningen. Technical Bulletin No. 102, referenced in Andriesse, J.P. (1988), Nature and management of tropical peat soils, FAO Soils Bulletin 59.

56 Andriesse, J.P. (1988), Nature and management of tropical peat soils, FAO Soils Bulletin 59

57 Technical Report 35, Section 4.4.3 and Technical Report 36, Section 6.3.

58 Palmer, S.J. (2010), An embankment on peat. Mackays crossing road over rail bridge, Wellington, NZ, in Geologically Active, Taylor and Francis Group, London

has not been separately assessed at this stage.[59] It is considered to lie within the accuracy of the current settlement assessments.

(d) ***Proportion of peat with Cv higher or lower than the adopted typical proposed value.*** Fifteen consolidation tests have been carried out on samples of peat. From these, the Coefficient of Consolidation, Cv, over a low stress range representative of groundwater drawdown effects ranges from 0.75 to 62 m^2/yr. Neglecting the largest value (to avoid a single large value skewing the data), the numerical average Cv from these samples is 9 m^2/yr. The coefficient of consolidation has also been derived from the monitoring of two trial embankments, and a design value of 3.0 m^2/yr has been adopted.[60] Three of the test results (20%) are less than this design value over a low stress range, and the remainder are higher. A small Cv results in a longer time for consolidation, so it follows that, in most cases, primary consolidation settlement will occur more rapidly than has been predicted.

(e) ***Drill hole logs and laboratory test data.*** Field investigation locations are shown on plans contained in the Geotechnical Interpretive Report.[61] Subsurface and laboratory test data has been obtained from a number of sources, which are referenced in the Geotechnical Interpretive Report.[62] A Factual Geotechnical Report has been prepared which contains the results of the Phase 1 investigations undertaken specifically for this Project.[63] All of this data has been used to build up the geotechnical model for the Project area, which forms the basis of the assessment of effects.

(f) ***Spatial distribution of the various types/grades of peat.*** The nature of the peat across the Project is described in general in the Geotechnical Interpretive Report.[64] Contours of inferred peat thickness are presented in that report.[65] The degree of

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59 Technical Report 36, Section 6.3.

60 Technical Report 36, Table 6.

61 Ibid, Appendix 36.A.

62 Ibid, Section 8.

63 M2PP-AEE-RPT-GT-GE-090 (2011): MacKays to Peka Peka Expressway Alliance: Phase 1 Investigation – Factual Geotechnical Report.

64 Technical Report 36, Section 6.3.

65 Ibid, Appendix 36.B.

decomposition, from undecomposed fibrous peat to completely decomposed amorphous peat, has been assessed in the course of recent investigations using the widely adopted methodology of von Post,[66] and is presented on the bore and pit logs.

(g) ***The secondary and tertiary (creep) consolidation that will take place.*** As I have discussed under (c) above, secondary consolidation is assessed to form only a small component of settlement beyond the Project, so has not been separately considered. I expect these aspects of settlement of peat to be more closely addressed in the course of detailed design, as they have greater bearing on the design of the embankments themselves to achieve particular long term settlement performance.

(h) ***The annual rate of settlement and duration of settlement.*** The trial embankment undertaken for this Project provides useful field scale guidance on the rate and duration of settlement that will occur as a result of embankment loading. The trial suggests that the majority of primary consolidation occurs relatively quickly (within 1-2 months of completion of loading).

(i) ***The sensitivity of settlement predictions to variations in the parameters adopted in the analysis.*** The sensitivity of calculated settlement to various input parameters has been checked in the course of assessing the ground settlement effects.[67] The analyses showed little sensitivity to the selected parameters for peat thicknesses of up to 1.5m. At greater peat thickness, the calculated settlement becomes more sensitive to the pre-existing building load, with heavier buildings proving more sensitive to groundwater level changes than lighter ones.

PROPOSED CONDITIONS

86 In the documentation lodged with the AEE, the NZTA included a set of Proposed Resource Consent Conditions.[68] This included proposed ground settlement conditions G.31 and E.12 to E.23 which are attached to my evidence as **Annexure B**.

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[66] Farrell, E.R. (2012), Organics/peat soils, Chapter 35 of ICE Manual of Geotechnical Engineering, Institution of Civil Engineers, Table 35.3.

[67] Technical Report 35, Section 4.4.3.

[68] AEE, Chapter 33.

87 Condition G.31 requires a SEMP to be finalised and submitted for certification before works commence.

88 A draft SEMP has been prepared and is included as Appendix J of the Proposed CEMP. The purpose of the SEMP is to address potential ground settlement associated with construction and operation of the Expressway, and the effects of that settlement on existing buildings, services and transport infrastructure. That draft will be updated, finalised and certified by the GWRC before works commence.

89 The process for managing and mitigating settlement effects is set out in the draft SEMP, and follows the following steps (*items in brackets refer to the relevant Proposed Conditions*)*:*

89.1 Identify susceptible buildings, services and other infrastructure *(E.17).*

89.2 Estimate settlements and resulting effects, and establish trigger levels, to form the basis of monitoring *(Technical Report 35, updated as required following BOI decision and detailed design).*

89.3 Establish current conditions by pre-construction monitoring *(E.12, E.13)* and condition assessments *(E.18, E.19, E.23).*

89.4 Monitor *(E.13, E.20, E.23)* and report *(E.16, E.22),* responding to any alerts *(E.14).*

89.5 Mitigate as required during construction, by modifying the construction approach or by implementing interim repairs *(E.14, E.23).*

89.6 Undertake a post construction condition assessment and repair as required *(E.21, E.23).*

90 I consider that these Proposed Conditions set out an appropriate process for addressing ground settlement effects.

CONCLUSIONS

91 The ground settlement effects arising from the Project are predominantly seated in the underlying and adjacent peat soils. They result directly from loading of those soils, and from groundwater changes that may occur in them. Settlement arising from groundwater changes is of greatest interest beyond the immediate Project footprint.

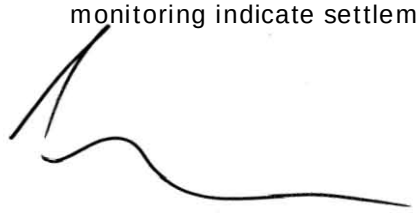
92 The extent of peat beneath and adjacent to the Project has been assessed using geotechnical data from the current and earlier investigations in the area. Settlement parameters for the peat have

been derived from published data, from laboratory test results and from the results of a trial embankment built for this project. Groundwater changes have been adopted from the studies undertaken by my colleagues as part of the Assessment of Groundwater Effects.[69]

93 The settlement effects on buildings have been assessed and indicate that there will be negligible settlement effects on all buildings from the construction and operation of the Expressway. Similarly low effects are predicted on buried services that are not proposed to be relocated as part of the project, and on rail infrastructure. Road pavements that are affected by the Project will be remediated by resurfacing.

94 Monitoring is proposed to confirm the predicted settlement and the predicted effect of that settlement. While the current assessment indicates that mitigation of settlement effects is not required, there are mitigation measures that can be implemented if necessary.

95 I therefore consider that the effects of the Project on ground settlement will be no more than minor and can be effectively managed by mitigation measures and consent conditions, should monitoring indicate settlement that is greater than anticipated.



Gavin Alexander
3 September 2012

[69] Technical Report 21.

ANNEXURE A: PREDICTED SETTLEMENT PLANS - APPENDIX 35.G, TECHNICAL REPORT 35

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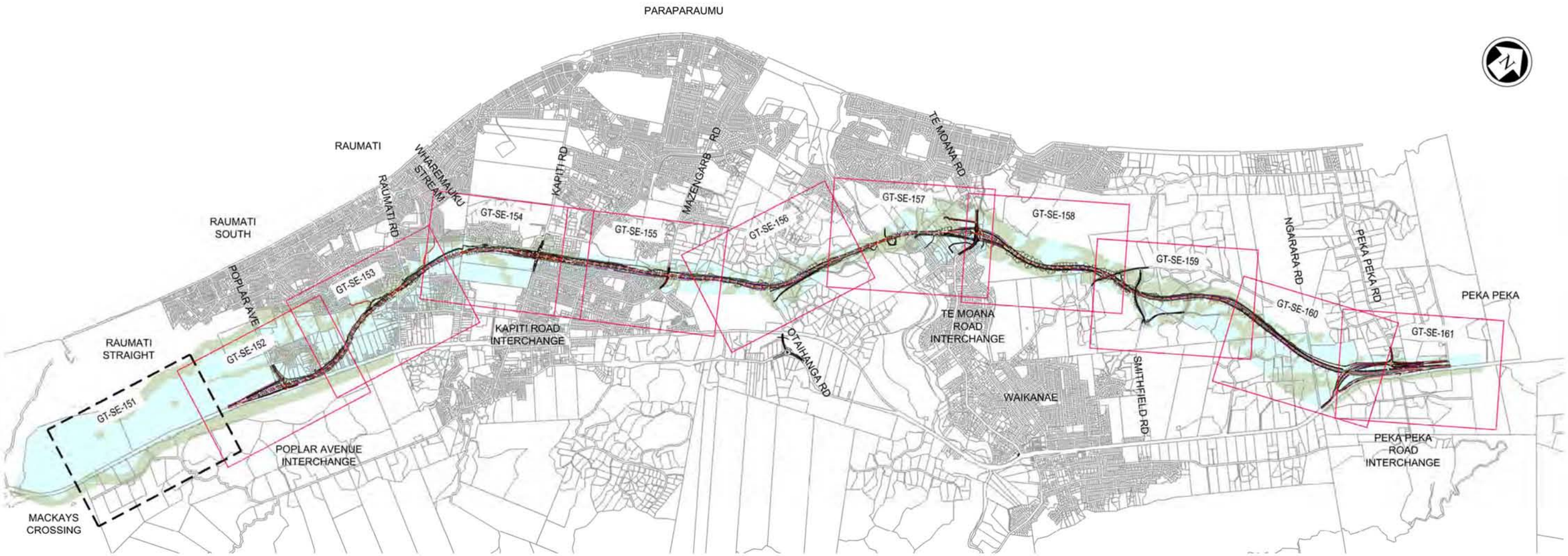

INDICATES SHEETS NOT USED

NOTES:

Original Scale (A3)

NTS

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

NZ TRANSPORT AGENCY
WAKA KOTAHI

Project:
MACKAYS TO PEKA PEKA EXPRESSWAY

Title:
TOTAL ESTIMATED SETTLEMENTS
SHEET INDEX

Status: - FOR CONSENTING
Document ID: M2PP-AEE-DWG
Drawing No: GT-SE-150
Rev: 1

Document No: M2PP-AEE-DWG-GT-SE-150.DWG

Drawing Plotted: 08 Mar 2012 04:22 p.m.

CH 2450

CH 3050

Poplar Avenue

Sydney Cres

Leinster Avenue

Leinster Avenue

SH 1

SH 1

PEAT TO BE EXCAVATED

LEGEND:

- SETTLEMENT ANALYSES - CROSS SECTIONS
- ROAD ALIGNMENT
- CONSTRUCTION DESIGNATION LINE
- NON PEAT
- PEAT
- OFFSET FLOOD STORAGE AREA
- STORMWATER WETLAND

TOTAL ESTIMATED SETTLEMENT (mm)

- 12.5mm - 25mm
- 25mm - 50mm
- 50mm - 100mm
- 100mm - 200mm
- > 200mm

NOTES:

Original Scale (A3)

1:5000

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

NZ TRANSPORT AGENCY
WAKA KOTAHI

Project: MACKAYS TO PEKA PEKA EXPRESSWAY

Title: TOTAL ESTIMATED SETTLEMENTS
SHEET 2 OF 11

Status: - FOR CONSENTING

Document ID: M2PP-AEE-DWG

Drawing No.: GT-SE-152

Rev.: 1

Document No.: M2PP-AEE-DWG-GT-SE-152.DWG

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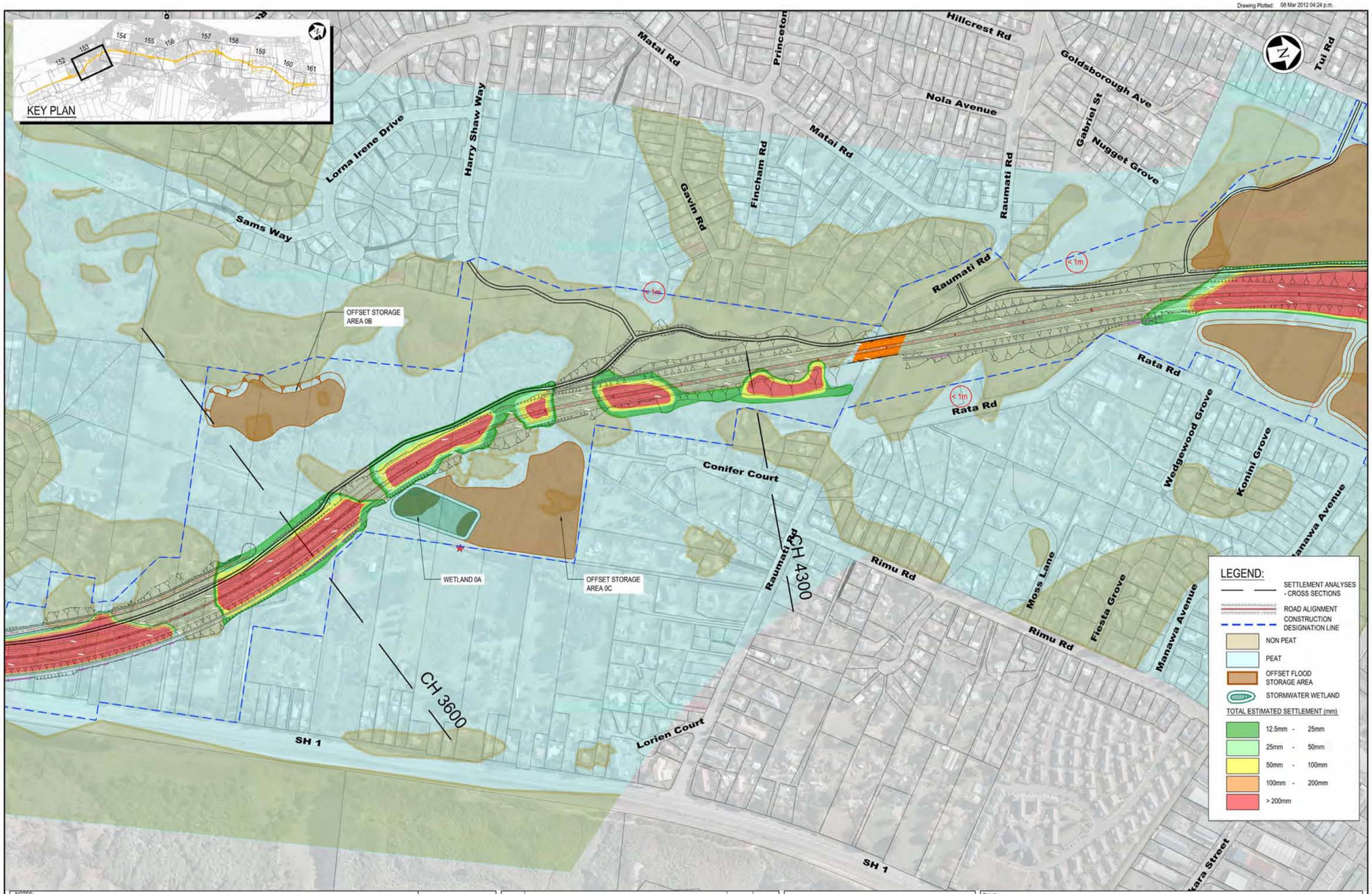

NOTES:

Original Scale (A3)

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

NZ TRANSPORT AGENCY
WAKA KOTAHI

Project:
MACKAYS TO PEKA PEKA EXPRESSWAY

Title:
TOTAL ESTIMATED SETTLEMENTS
SHEET 3 OF 11

Status: - FOR CONSENTING

Document ID: M2PP-AEE-DWG

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Rev: 1

Document No. M2PP-AEE-DWG-GT-SE-153.DWG

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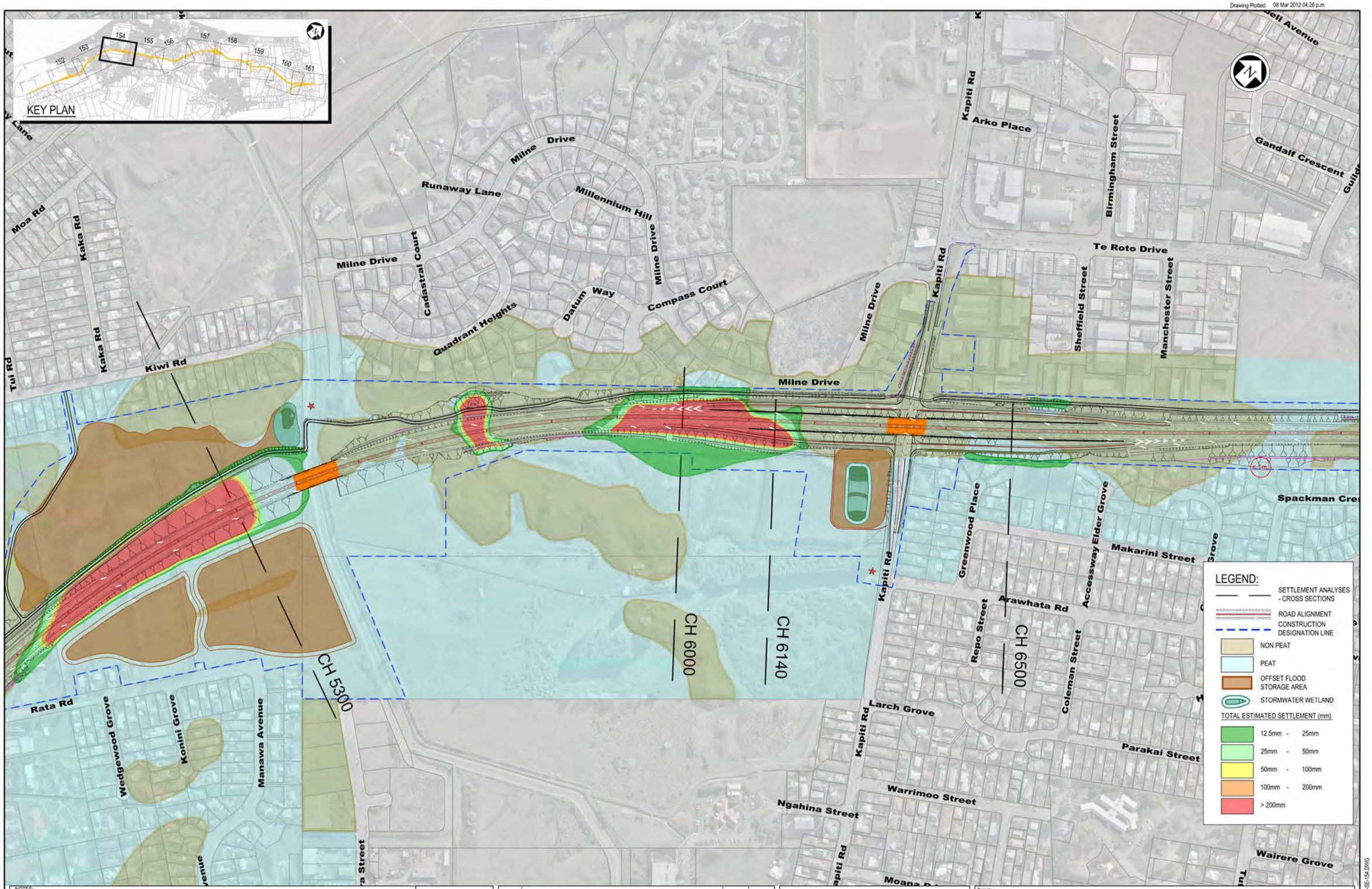

NOTES:

Original Scale (A3)

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

NZ TRANSPORT AGENCY
WAKA KOTAHI

Project:

MACKAYS TO PEKA PEKA EXPRESSWAY

Title:

TOTAL ESTIMATED SETTLEMENTS
SHEET 4 OF 11

Status: - FOR CONSENTING

Document ID: M2PP-AEE-DWG

Drawing No: GT-SE-154

Rev: 1

Document No: M2PP-AEE-DWG-GT-SE-154.DWG

Drawing Plotted: 08 Mar 2012 04:27 p.m.

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Original Scale (A3)

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

NZ TRANSPORT AGENCY
WAKA KOTAHI

Project: MACKAYS TO PEKA PEKA EXPRESSWAY

Title: TOTAL ESTIMATED SETTLEMENTS
SHEET 5 OF 11

Status: - FOR CONSENTING

Document ID: M2PP-AEE-DWG

Drawing No: GT-SE-155

Rev: 1

Document No.: M2PP-AEE-DWG-GT-SE-155.DWG

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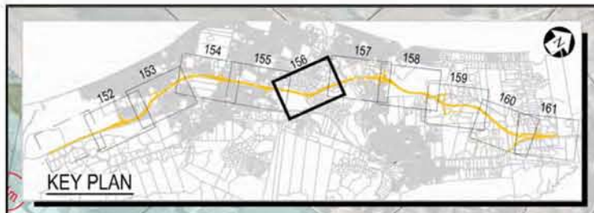

Rd
Killalea Place
Ratanui Rd
Otaihanga Rd
Pitoitoi Street
Kokako Rd
Kahu Rd
Toroa Rd
Otaihanga Rd
Tieko Street
Otaihanga Rd
PEAT TO BE EXCAVATED
< 1m
< 1m
< 1m
< 1m
< 1m
< 1m
PEAT TO BE EXCAVATED
CH 8900
Otaihanga Rd
Grand Poppa Way
Greendale Drive
Sea PoppyWay

LEGEND:

- SETTLEMENT ANALYSES - CROSS SECTIONS
- ROAD ALIGNMENT
- CONSTRUCTION DESIGNATION LINE
- NON PEAT
- PEAT
- OFFSET FLOOD STORAGE AREA
- STORMWATER WETLAND

TOTAL ESTIMATED SETTLEMENT (mm)

- 12.5mm - 25mm
- 25mm - 50mm
- 50mm - 100mm
- 100mm - 200mm
- > 200mm

NOTES:

Original Scale (A3)

1:5000

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

NZ TRANSPORT AGENCY
WAKA KOTAHI

Project:

MACKAYS TO PEKA PEKA EXPRESSWAY

Title:

TOTAL ESTIMATED SETTLEMENTS
SHEET 6 OF 11

Status: - FOR CONSENTING

Document ID: M2PP-AEE-DWG

Drawing No.: GT-SE-156

Rev.: 1

Document No.: M2PP-AEE-DWG-GT-SE-156.DWG

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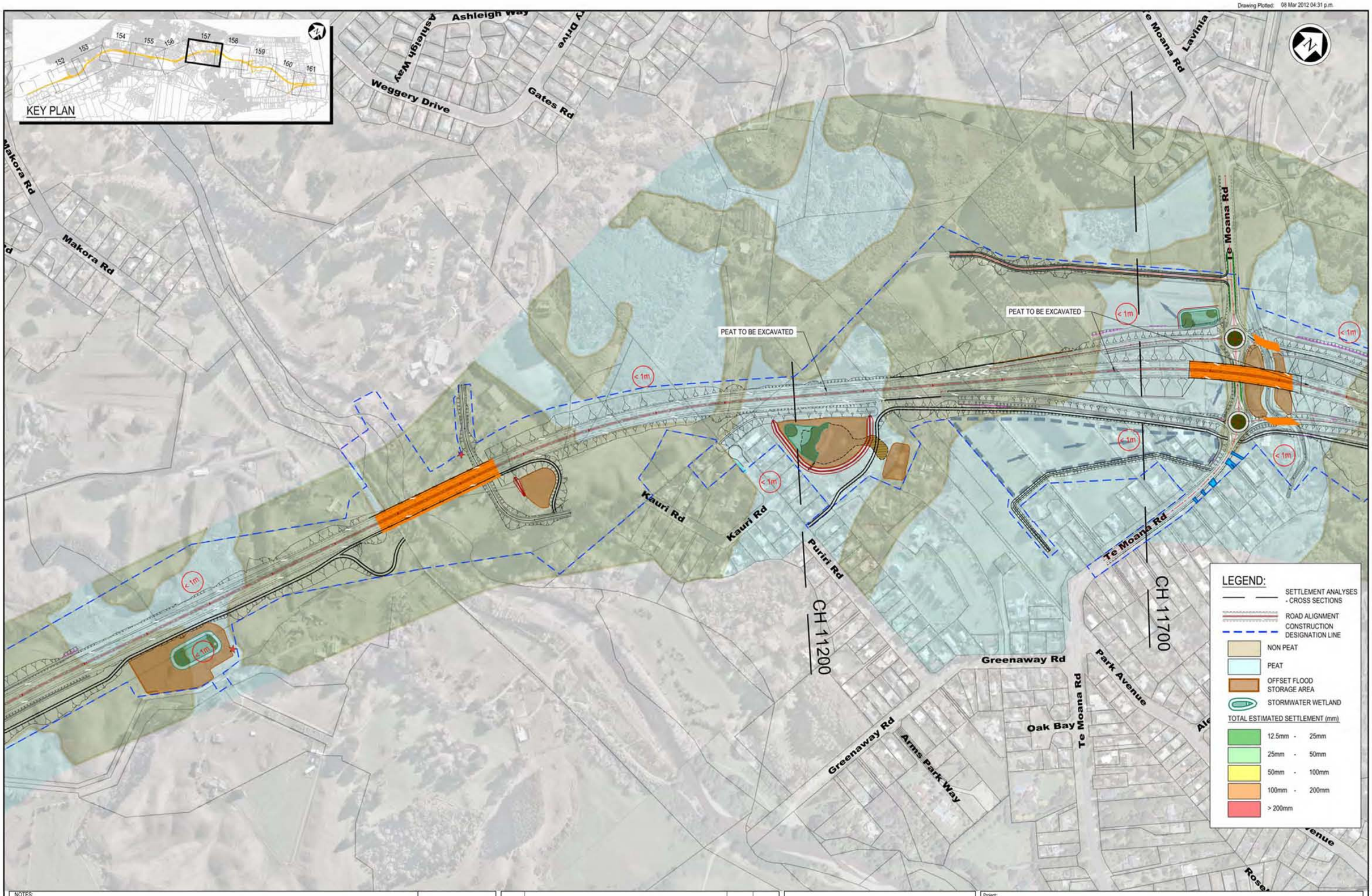


NOTES:

Original Scale (A3)

1:5000

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

NZ TRANSPORT AGENCY
WAKA KOTAHI

Project:
MACKAYS TO PEKA PEKA EXPRESSWAY

Title:
TOTAL ESTIMATED SETTLEMENTS
SHEET 7 OF 11

Status: - FOR CONSENTING

Document ID: M2PP-AEE-DWG

Drawing No: GT-SE-157

Rev: 1

Document No.: M2PP-AEE-DWG-GT-SE-157.DWG

Drawing Plotted: 08 Mar 2012 04:33 p.m.

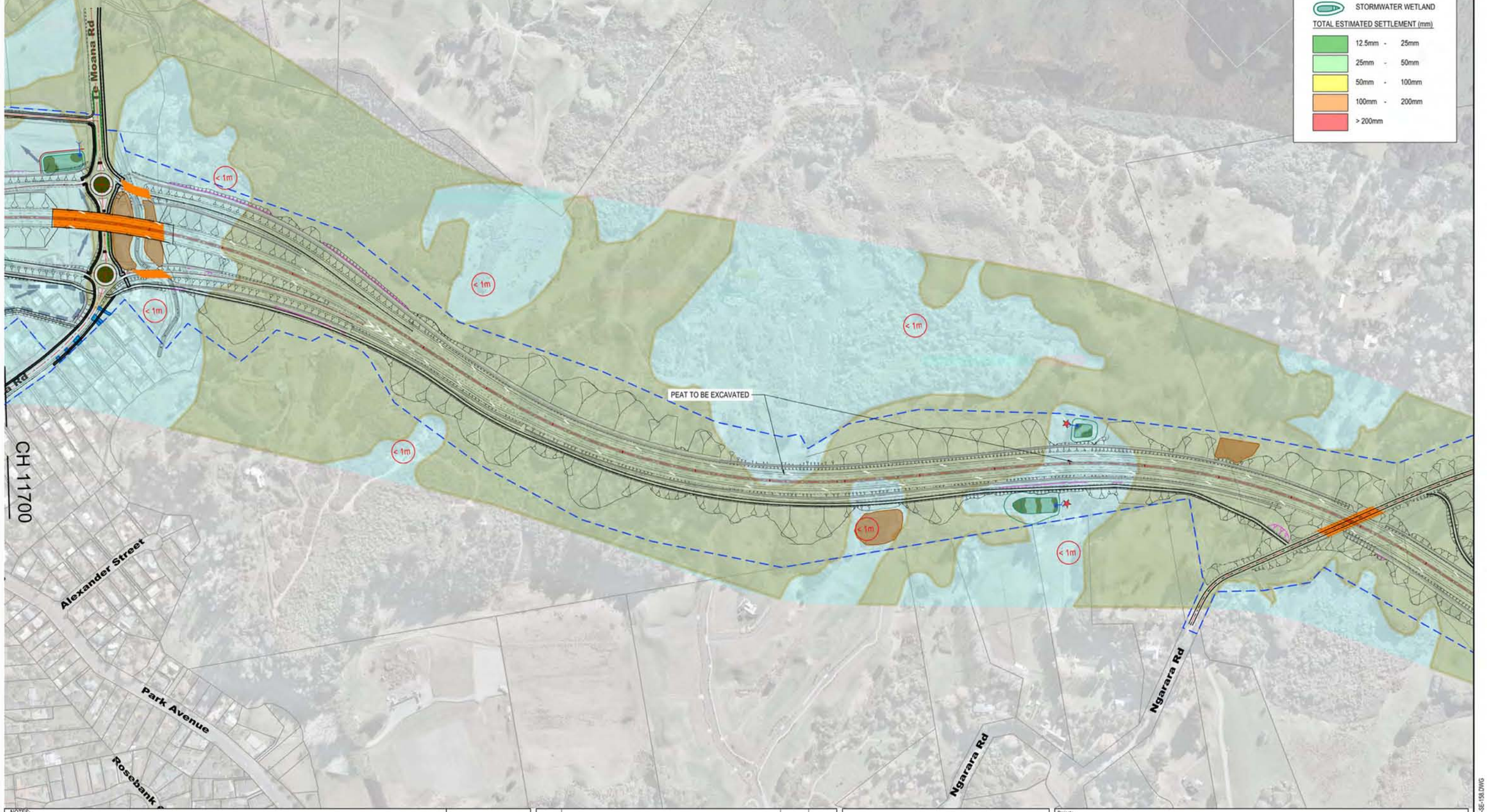
KEY PLAN

LEGEND:

- SETTLEMENT ANALYSES - CROSS SECTIONS
- ROAD ALIGNMENT
- CONSTRUCTION DESIGNATION LINE
- NON PEAT
- PEAT
- OFFSET FLOOD STORAGE AREA
- STORMWATER WETLAND

TOTAL ESTIMATED SETTLEMENT (mm)

- 12.5mm - 25mm
- 25mm - 50mm
- 50mm - 100mm
- 100mm - 200mm
- > 200mm



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Original Scale (A3)

1:5000

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

NZ TRANSPORT AGENCY
WAKA KOTAHI

Project:
MACKAYS TO PEKA PEKA EXPRESSWAY

Title:
TOTAL ESTIMATED SETTLEMENTS
SHEET 8 OF 11

Status: - FOR CONSENTING
Document ID: M2PP-AEE-DWG
Drawing No: GT-SE-158
Rev: 1

Document No.: M2PP-AEE-DWG-GT-SE-158.DWG

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

Drawing Plotted: 23 Mar 2012 02:25 p.m.

Ngarara Rd

Smithfield Rd

End Farm Rd

PEAT TO BE EXCAVATED

< 1m

CUT OUT SAND DUNES AND REBUILD WITH PEAT. REFER CV-SW-125

CH 14400

LEGEND:

- SETTLEMENT ANALYSES - CROSS SECTIONS
- ROAD ALIGNMENT CONSTRUCTION DESIGNATION LINE
- NON PEAT
- PEAT
- OFFSET FLOOD STORAGE AREA
- STORMWATER WETLAND

TOTAL ESTIMATED SETTLEMENT (mm)

- 12.5mm - 25mm
- 25mm - 50mm
- 50mm - 100mm
- 100mm - 200mm
- > 200mm

NOTES:

Original Scale (A3)

1:5000

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

NZ TRANSPORT AGENCY
WAKA KOTAHI

Project: MACKAYS TO PEKA PEKA EXPRESSWAY

Title: TOTAL ESTIMATED SETTLEMENTS SHEET 9 OF 11

Status: FOR CONSENTING

Document ID: M2PP-AEE-DWG

Drawing No: GT-SE-159

Rev: 1

Document No: M2PP-AEE-DWG-GT-SE-159.DWG

Drawing Plotted: 08 Mar 2012 04:36 p.m.

Kensington Drive

Peka Peka Rd

Ngarara Rd

CH 16000

Greenhill Rd

PEAT TO BE EXCAVATED

SH 1

Ngarara Rd

LEGEND:

- SETTLEMENT ANALYSES - CROSS SECTIONS
- ROAD ALIGNMENT CONSTRUCTION DESIGNATION LINE
- NON PEAT
- PEAT
- OFFSET FLOOD STORAGE AREA
- STORMWATER WETLAND

TOTAL ESTIMATED SETTLEMENT (mm)

- 12.5mm - 25mm
- 25mm - 50mm
- 50mm - 100mm
- 100mm - 200mm
- > 200mm

NOTES:

Original Scale (A3)

1:5000

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

NZ TRANSPORT AGENCY
WAKA KOTAHI

Project:
MACKAYS TO PEKA PEKA EXPRESSWAY

Title:
TOTAL ESTIMATED SETTLEMENTS
SHEET 10 OF 11

Status: - FOR CONSENTING

Document ID: M2PP-AEE-DWG

Rev: 1

Drawing No: GT-SE-160

Document No. M2PP-AEE-DWG-GT-SE-160.DWG

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Drawing Plotted: 23 Mar 2012 02:28 p.m.

Peka Peka Rd

Te Kowhai Rd

SH 1

Hadfield Road

Hadfield Rd

Octavius Rd

Octavius Rd

SH 1

LEGEND:

SETTLEMENT ANALYSES - CROSS SECTIONS

ROAD ALIGNMENT

CONSTRUCTION DESIGNATION LINE

NON PEAT

PEAT

OFFSET FLOOD STORAGE AREA

STORMWATER WETLAND

TOTAL ESTIMATED SETTLEMENT (mm)

12.5mm - 25mm

25mm - 50mm

50mm - 100mm

100mm - 200mm

> 200mm

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: TOTAL ESTIMATED SETTLEMENTS
SHEET 11 OF 11

Status: - FOR CONSENTING

Document ID: M2PP-AEE-DWG

Rev.: 1

Drawing No.: GT-SE-161

Document No.: M2PP-AEE-DWG-GT-SE-161.DWG

ANNEXURE B: PROPOSED CONDITIONS

	Settlement Management Plan
G.31	The consent holder shall finalise, submit and implement through the CEMP, the Settlement Management Plan (SEMP) to be submitted to the Manager for certification at least 15 working days prior to works commencing. The purpose of the management plan is to address the potential ground settlements (settlements) associated with construction and operation of the Expressway, and the effects of these settlements on existing buildings, services and transport infrastructure. The SEMP shall include information regarding: i. implementation and operational procedures; ii. estimated total settlements iii. monitoring methods; iv. monitoring locations set out on a plan; v. monitoring frequency; vi. reporting requirements; vii. alert and action programmes; and viii. review procedures.

	Settlement Conditions
E.12	The consent holder shall establish a series of ground settlement monitoring marks to monitor potential settlement that might occur as a result of construction of embankments and drawdown of the groundwater table. The survey marks will be generally located as follows: a) 2 to 4 marks, established in cross-sections along the length of the Expressway as set out in Appendix D of the SEMP (as required by Condition G.31); b) adjacent to stormwater features where groundwater drawdown of more than 0.1 m has been predicted; c) at the KCDC wastewater treatment plant; and d) structures identified close to the Expressway where settlement of more than 12.5 mm is predicted. The locations of each type of settlement monitoring marks shall be confirmed in the SEMP.

	Settlement Conditions
E.13	The consent holder shall survey the settlement monitoring marks at the following frequency: a) Pre-construction – vertical at monthly intervals starting at least 12 months prior to construction commencing b) During construction i. vertical at 3 monthly intervals ii. within 500 m of active construction – vertical at monthly intervals iii. within 50 m of excavation in front of retaining walls – vertical at monthly intervals. c) Post-construction i. Vertical at 3 monthly intervals for 6 months ii. Vertical at 6 monthly intervals for a further period of at least 2 years.
E.14	a) Immediately following each monitoring round, the consent holder shall use the settlement monitoring results (together with the results of groundwater monitoring where they may provide an earlier indication of future settlements) to reassess the building damage categories and compare them to those estimated in Technical Report 35 – Assessment of Ground Settlement Effects, as included in Condition G.1a) – b). b) If the reassessment indicates that a building or structure has increased its damage category, this shall be considered to be an Alert Level and additional specific assessment of the structure shall be carried out by the consent holder to confirm this reassessment within 72 hours. c) If the additional assessment confirms the increase in damage category, this shall be considered an Action level and the owner and occupier of the structure shall be notified within 72 hours. d) Following consultation with the property owner and occupier, subsequent actions may include increased frequency and/or extent of monitoring, modification to the construction approach or mitigation works to the affected structure.
E.15	The consent holder may reduce the frequency of settlement monitoring required by Condition E.13: a) Once the active construction stage has passed; and b) 3-monthly monitoring has been carried out for a minimum of 6 months; and c) The monitoring indicates that any potential settlement effects are within a satisfactory range as specified in the SEMP; and d) The criteria in E.15a)-c) has been certified by GWRC.

	Settlement Conditions
E.16	The consent holder shall collate the results of the settlement monitoring (undertaken pursuant to Conditions E.12–E.15) and prepare a report that shall be made available to GWRC. A settlement monitoring report shall be prepared: a) prior to the commencement of construction; and b) at 3–monthly intervals throughout the construction period; and c) following completion of construction, a settlement monitoring report shall be prepared following each round of settlement monitoring undertaken (i.e. 3 monthly and then 6 monthly). The purpose of the reports is to highlight any Alerts or Actions and provide a full interpretation and/or explanation as to why these occurred, the likely effects and any mitigation measures initiated as a result.
E.17	The consent holder shall review and update the schedule of buildings and structures considered to be at risk in accordance with the criteria of the SEMP and maintain this schedule for review by GWRC. This schedule shall include but not be limited to, the following properties: a) KCDC wastewater treatment plant; b) The Waikanae Christian Holiday Park (El Rancho); and c) Specific buildings identified during the course of detailed design where the total settlements are estimated to be greater than 25 mm.
E.18	The consent holder shall consult with owners of buildings and structures identified in Condition E.17a)–c) and, subject to the owner's approval of terms acceptable to the consent holder, shall undertake a pre–construction condition assessment of these structures in accordance with the SEMP.
E.19	The consent holder shall employ a suitably qualified person to undertake the building assessments required pursuant to Condition E.18 and identify this person in the SEMP.
E.20	The consent holder shall undertake monthly visual inspections of the following properties during active construction: a) Dwellings where the total settlements are estimated to be greater than 25 mm; b) Dwellings where the predicted Building Damage category is greater than 'negligible' (noting that there are none in this category at this stage); c) KCDC wastewater treatment plant; and d) All other specifically identified buildings in Condition E.17. Active construction shall be defined as starting when earthworks commence within 500m of a particular location and ending when pavement construction is complete at that location.

	Settlement Conditions
E.21	a) The consent holder shall, subject to the owner's approval, undertake a post-construction condition assessment covering the matters identified in the SEMP and provide a copy to the owner. The assessment report shall include a determination of the cause of damage identified (if any) since the pre-construction condition assessment. b) The consent holder shall agree with the owner appropriate remedial works (if any) in conjunction with arrangements for implementation and/ or compensation. The requirements of this condition need not be fulfilled for any particular building with the written approval of the current owner of a building or where the NZTA can provide reasonable evidence to GWRC that the current owner of the building has agreed they do not require such a survey.
E.22	The consent holder shall provide a copy of the pre, post-construction and any additional building condition assessment reports for each building be forwarded to the respective property owner within 15 working days of completing the reports. The consent holder shall notify GWRC that the assessments have been completed.
E.23	Prior to construction commencing, the consent holder shall undertake CCTV surveys of services identified in the SEMP as being susceptible to damage or particularly critical. The consent holder shall monitor these services by undertaking additional CCTV surveys throughout the construction period. If damage is determined in relation to the Project, the consent holder shall undertake remedial action as required in consultation with the service provider.