REPORT

Tonkin+Taylor

Assessment of Settlement Effects

Northern Interceptor Project: Notices of Requirement

Prepared for
Watercare Services Limited

Prepared by
Tonkin & Taylor Ltd

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Exceptional thinking together

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Glossary of terms and abbreviation

Term	Definition
Northern Interceptor	New wastewater interceptor to convey wastewater flows from the Northern Strategic Growth Area (NorSGA) and South Rodney (Kumeu/Huapai/Riverhead) via the Hobsonville Pump Station (PS) to the Rosedale Wastewater Treatment Plant (WWTP).
Horizontal directional drilling	Is a steerable trenchless method of installing underground pipes in a shallow arc along a prescribed bore path using a surface launched drilling rig.
Micro tunnelling	Is a technique used to construct small diameter tunnels. The Micro-tunnel boring machine and jacking frame are installed in a shaft at the required depth. The Micro-tunnel boring machine is directed by an operator located at the surface.
Mechanical settlement	Settlement due to physical movement of the ground, either as a result of lateral movement at the perimeter of trenches/excavations or volume loss resulting from over excavation of tunnels.
Consolidation settlement	Settlement due to a process by which saturated soil is compressed as a result of flow of pore water either arising from applied pressure or changes in groundwater levels.
Total settlement	The magnitude of downward movement resulting from consolidation of soil at any given point.
Differential settlement	Non-uniform settlement or the difference in settlement between any two points.
Zone of influence	The area of land within the 5mm settlement contour associated with the construction of the NI.

Abbreviation	Definition
AEE	Assessment of Effects on the Environment
DN	Nominal Diameter
HDD	Horizontal Directional Drill
MTBM	Micro Tunnel Boring Machine
NI	Northern Interceptor
NoR	Notice of Requirement
Watercare	Watercare Services Limited
WWTP	Wastewater Treatment Plant

Executive summary

Watercare Services Limited (Watercare) has engaged Tonkin & Taylor Ltd (T+T) to carry out an assessment of the potential effects that may arise from the construction and operation of proposed new wastewater pipelines and associated infrastructure to convey wastewater from The Concourse in Henderson to the Rosedale Wastewater Treatment Plant ("WWTP") in Albany, hereafter referred to as the Northern Interceptor (Waitakere and North Shore) project.

This report provides a preliminary assessment of the potential ground settlement along and adjacent to the proposed corridor that may result from construction and operation of the pipeline. The purpose of the assessment is to provide technical inputs to the Assessment of Effects on the Environment supporting the application for corridor designation. Further assessments will be required for future consent applications, and these assessments will be based on the more detailed information that will be available at that time, in particular we note that during the consenting design and detailed design processes the alignment of the pipeline within the designation corridor may change from that described here.

This early assessment is based on the information that is currently available from a number of sources. That information has enabled us to gain an appropriate level of understanding of the geological environment along the corridor – as a key input to understanding the potential for construction and operation induced settlement. This assessment estimates the potential total and differential settlements that might occur given the current design, and the associated potential effect of this settlement on the typical building stock that currently inhabits the corridor. Where the potential effects could exceed to the tolerances of the structures, the range of mitigation measures that are available to Watercare to control the effects are described.

Short term potential construction induced total settlements can be expected to be acceptable along the majority of the alignment as currently presented except where excavations (including pits) are greater than 5 m deep and close to structures (within approximately 10 m). For the current design alignment, differential settlements may exceed the tolerances of existing structures over less than 5% of the corridor. The use of a tunnel boring machine in earth pressure balance (EPB) mode and application of specifically designed excavation side support and groundwater control might be required in such cases and would be expected to control settlements to within acceptable limits.

Long term potential operation induced settlements have been assessed based on the conservative assumption that groundwater will be drawn down to pipe invert level during the life of the pipeline. Estimates indicate that based on this conservative assumption and at the location of worst case geology (representing approximately 15 % of the alignment), up to 300 mm total settlement, and 1:80 differential settlement could occur if specific measures to prevent it are not employed. Specific measures that are commonly employed on projects like this one to mitigate this potential include:

- Pipe joints and buried structures sealed to a high standard.
- Incorporating groundwater cut off features into the design of trench backfill.

Based on the assessment, and the mitigation measures available to Watercare, we consider the short and long term settlement effects of the project on existing buildings and structures along the alignment can be controlled to less than minor and that this should be confirmed with further work in future consenting and detailed design stages.

A detailed assessment of the vulnerability of key/typical buildings (where there is significant settlement potential) will be required to support detailed design and consenting (including groundwater related consents) in the future. This would include further development of the geotechnical models and refinement of the design alignment to minimise depth of trenched sections wherever possible.

1 Introduction

1.1 General

Tonkin & Taylor Limited (T+T) has been commissioned by Watercare Services Limited (Watercare) to assess the potential settlement related land use effects related to the construction, operation and maintenance of Watercare's proposed Northern Interceptor (the Project).

This report informs, and should be read in conjunction with the Assessment of Effects on the Environment (AEE) prepared by MWH New Zealand Limited[1] and the Northern Interceptor Phase 2 to 6 Preliminary Ground Investigation – Factual Geotechnical Report[2].

1.2 Objectives and scope of work

The objective of this report is to present the results of an assessment of estimated total and differential surface settlements that could be induced by construction and operation of the Northern Interceptor, comment on the effects of these settlements on surrounding structures and outline proposals for mitigation and monitoring where required.

The assessment also takes account of the potential settlement effects associated with groundwater drawdown of key sections of the alignment and provides high level comment around potential impacts and mitigation options.

The assessment discussed in this report considers the potential effects arising from trench, open cut, micro tunnelling and horizontal directional drilling construction methodologies and includes the following scope of works:

- A description of the environmental baseline for the particular receiving environment(s) potentially affected by the Project;
- Description of specific aspects of the Project in relation to the subject area being investigated;
- Description of the investigations undertaken to assess the underlying geology and assessment of effects of the proposed works within the technical field (without mitigation);
- Recommended mitigation and management measures and resultant post mitigation assessment of effects;
- A high level assessment of the actual or potential effects on the environment (construction, operation and maintenance). This includes the identification of activities that could result in potential adverse effects and, in turn, identifying design refinements or construction methodologies that could avoid, remedy or mitigate such effects;
- Conclusions.

We expect that in future the design will develop from that shown in the current concept drawings. As it is not possible to foresee the extent or impact such changes may have on the required scope or quantum of work to prepare the technical report specific assessments of the design have been generalised to incorporate the potential for future alignment changes within the designation areas.

1.3 Report structure

The main body of this report outlines the key considerations of the assessment of effects as they relate to the designation of the proposed corridor. Technical supporting information, including the assessment methodology, assessment of effects and recommended mitigation and monitoring measures, is presented in Appendix A.

2 Project description

2.1 Project overview

The Northern Interceptor comprises a new wastewater interceptor and associated infrastructure, from the existing storage tank located at The Concourse, Henderson to the Rosedale Wastewater Treatment Plant (WWTP). It will divert flows from three existing branch sewers (Swanson, Whenuapai and Massey) and connect flows originating from the North West Transformation Area (including Red Hills, Massey North, Kumeu, Riverhead, Huapai and Whenuapai). These flows will be transferred north to the Rosedale WWTP, rather than south to the Mangere WWTP.

Phase 1 of the Northern Interceptor was granted consent in January 2016. Phase 1 will transfer existing flows from the existing Hobsonville Pump Station to the Rosedale WWTP. The section of the Northern Interceptor between Hobsonville Road and the western abutment of the Greenhithe Bridge, is in the same corridor as a water infrastructure project, the North Harbour No. 2 Watermain. A Notice of Requirement (NoR) for the works within the shared corridor, which include this portion of the Northern Interceptor, was lodged with the Council in June 2016.

This technical report provides specialist input for the Northern Interceptor AEE report, prepared by MWH New Zealand Limited[1] which supports the NoR for the remainder of the route (Project), these being NoR – NI (Waitakere) and NoR – NI (North Shore).

The works within NoR - NI (Waitakere) will transfer wastewater flows from the Concourse Storage Tank to Hobsonville Road, where it will connect with the works in the shared corridor.

The works within NoR - NI (North Shore) will transfer wastewater flows from the edge of the future harbour crossing at the eastern abutment of the Greenhithe Bridge to the Rosedale WWTP.

Construction will be staged in response to growth in the area.

The Project and a detailed construction methodology are described in detail in the AEE report. In summary, the Project works included within NoR – NI (Waitakere) and NoR – NI (North Shore) will comprise of the following elements:

- A new Pump Station at the Concourse Storage Tank site which will divert flow north away from the Western Interceptor;
- A new Booster Pump Station at Wainoni Park to accommodate additional flows from the Northwest Transformation Area;
- A new Intermediate Pump Station at Wainoni Park North to accommodate further growth in the Northwest Transformation Area, and the diverted flows from the Concourse Storage Tank site (Swanson and Waitakere);
- Installation of a wastewater pipe from the Concourse Storage Tank to Hobsonville Road;
- Installation of a wastewater pipe from the eastern abutment of the Greenhithe Bridge, to the Rosedale WWTP;
- Duplication of the rising main section of wastewater pipe from the Intermediate Pump Station at Wainoni Park North to the Rosedale WWTP;
- Associated structures at connection points, including access shafts, drop shafts, flow control structures, etc.; and
- Installation of a pipe bridge at Manutewhau Reserve, West Harbour.

2.2 Sources of settlement

2.2.1 General

There are two potential sources of settlement associated with the construction and operation of the proposed NI pipeline. The sources are:

- Mechanical settlement – settlement due to physical movement of the ground, either as a result of lateral movement at the perimeter of trenches/excavations or volume loss resulting from over excavation of tunnels. This type of settlement typically occurs within a short period of time and is controlled by the construction methodology.
- Consolidation settlement– settlement due to lowering of groundwater levels (resulting in a reduction in porewater pressure within the soils). This settlement is dependent on the rate, magnitude and extent of groundwater level lowering and the sensitivity of the soils to consolidation, and is controlled by the pipeline and structures design and specification.

The Project is expected to utilise construction methodologies that are frequently used and are well understood by the engineering and contracting community. Very similar construction methodologies are used throughout Auckland and New Zealand to construct pipelines for stormwater networks, wastewater networks, and water supply pipelines.

For short sections of the corridor, more specialised methodologies (such as horizontal directional drilling, HDD) are required. The equipment and skills required for these sections of the corridor are also readily available in New Zealand.

The construction methodologies are described below, with specific comment on how they are likely to be used within the project.

2.2.2 Excavations

2.2.2.1 Trenches

As currently designed, approximately half of the pipeline will be constructed by open excavation of trenches. In these areas the design generally situates the pipeline in the road and park reserves a considerable distance from nearby buildings or structures. Such construction will involve excavation, potentially shoring of the trench (particularly where the trench is located close to existing structures) and backfilling subsequent to installation of the pipeline.

Much of the pipeline varies between 2.5 m and 5 m below existing ground. Short sections of deeper trenching are likely to be required where conflicts with existing services have been identified.

2.2.2.2 Manholes

The pipelines are typically laid in straight lines with direction changes made at manholes. Where the pipeline is locally deeper, deeper manholes are also required. Currently, one manhole is shown at approximately 6 m deep. While this depth of manhole is not strictly routine construction, it is at a depth that has been regularly constructed around Auckland for wastewater and stormwater networks.

2.2.3 Trenchless technology

As currently designed, approximately a third of the pipeline, will be constructed using trenchless technology (at this stage assumed to comprise micro tunnelling techniques). The tunnelling will be completed using a micro tunnel boring machine (MTBM) with access shafts located at regular intervals. Micro tunnelling methodologies excavate a slightly larger hole than the external dimension of the pipeline segments to be installed. Without this "overcut", the segments would be prone to binding against the excavation during installation, and only very short runs would be possible. This small overcut eventually collapses onto the pipe and, depending on ground conditions, may result in surface settlement.

It is also common in soft ground for the volume of excavated material to exceed the open volume of the excavation. As the hole is advanced, the material at the face of the excavation moves into the void created (as the unsupported ground relaxes) and additional material is therefore excavated. The potential consequence of material moving into the face of the excavation sometimes results in settlement at the ground surface.

Micro tunnelling methodologies are available which employ a number of techniques specifically developed to control these sources of surface settlement. The methodologies are widely used and primarily involve pressure being applied to the face and/or the annulus to stabilise it during excavation and backfilling of the annulus before it closes, e.g. a slurry shield capable machine in closed operation mode also known as earth pressure balance (EPB).

For the pipeline as currently designed, micro tunnel temporary access shafts (pits) are typically 6 m wide and 8 m long and vary in depth between 3.5 and 22.6 m deep anchor installed at regular intervals as jacking and receiving points for the MTBM. The micro tunnel pits will require specific detailed design and excavation support which could comprise timber lagging, steel sheet piles or reinforced concrete lining depending on the depth of excavation.

2.2.4 Horizontal directional drilling

Four short sections of horizontal directional drilling (HDD) totalling approximately 2 km are proposed where the pipeline is to run beneath watercourses and intertidal/marine areas. HDD is typically used to minimise the potential for environmental effects during construction of the pipeline as it avoids excavations through the watercourse.

The proposed HDD locations are:

- Henderson Creek crossing from Selwood Road to Kopi Place;
- Te Wharau Creek crossing north of Wainoni Park to North Shore Memorial Park (NSMP);
- Lucas Creek tributary crossing west of North Shore Golf Club (NSGC); and
- Alexandra Stream crossing, west of Rosedale Park.

A temporary pit or shallow excavation is likely to be required at either end of the HDD runs to allow for connection to the remainder of the alignment and to adequately control drilling muds. The dimension of these trenches has not yet been determined but are unlikely to be significantly larger than that required for the trenched excavations preceding them.

Pipeline construction beneath the watercourses has the potential to result in settlement, in much the same way that it does on the dry land. The magnitude of stream bed settlement would be expected to be similar or less than that predicted on dry land (for equivalent construction methodologies). However, the settlement that does occur is likely to be of an order that is not locally noticeable in estuaries or stream beds, and there is not expected to be any impact to the natural processes in these areas. Nor does the settlement have the potential to effect structures. We note that the proposed designation does not include marine or coastal areas where HDD may be utilised. The effects of HDD are therefore not assessed further in this report, and will need to be considered in future resource consent applications.

3 Assessment methodology

3.1 General

A brief description of the assessment methodology is presented below, further detail on the methodology is included in Appendix A.

The construction of the NI has the potential to induce vertical and lateral ground movements that could affect the condition of structures within the zone of influence (typically defined as the area of land within the 5 mm settlement contour shown on the Figures in Appendix B).

Mechanical settlements caused by construction of the NI are expected to occur within several weeks from the start of construction and are therefore relatively instantaneous. Consolidation settlements, on the other hand, occur relatively slowly and may not be fully realised for many years after completion of the project. The effects of construction phase settlement are therefore typically more adverse than the longer term settlement which is dependent primarily on the degree of water tightness achieved at the pipe joints and the permeability of the overburden material.

The potential magnitude of construction effects is strongly dependant on the construction methodology (refer to Section 2.2) and the local geological and hydrogeological conditions. The potential for short term (mechanically induced settlement) effects therefore depends on the excavation method that is adopted i.e. open excavation, (MTBM) in open EPB mode or HDD whereas the potential for long term (consolidation settlement) effects depends on the stiffness and permeability of the underlying materials. The total settlements at the ground surface will result from a combination of the two settlement sources.

This report presents an assessment of short term settlement and high level comment around the potential additional impacts of groundwater drawdown induced settlement. A more detailed assessment of short term and long term settlement effects will be required as the design is progressed and regional consents are sought.

3.2 Methodology for assessment of effects

3.2.1 Buildings

A structure's tolerance to total and differential settlement is unique to each structure and depends upon the materials used in framing, cladding and foundations as well as the type of foundation system adopted (shallow or piled), the quality of construction and the existing condition of the structure.

The level of settlement that is generally accepted in New Zealand as being the upper limit for buildings is a total settlement of 50 mm and a differential settlement of 1:1,000. This settlement limit is conservative and applies to a broad range of structures, including structures of timber, concrete and brick construction. It has been adopted for other sections of the Northern Interceptor project as it is considered unlikely to result in damage to standard, modern industrial/commercial buildings and residential buildings of timber and brick construction.

The assessment is based on 'greenfield' estimates of ground movement and does not take into account the degree to which the building stiffness resists ground movement. The assessment of effects is therefore considered to be conservative as a result.

Buildings that are more than 10 m from the edge of the proposed corridor or within the corridor and subjected to less than 5 mm settlement and differential settlement slopes greater than 1:1,000 are classified to have negligible effects and have not been further assessed.

It has been assumed, at this initial stage that all structures along the proposed alignment are supported on shallow foundations. This assumption in based on the observed building types (typically 1 to 2 storey residential buildings and portal framed structures) and the inferred geology. However, building records have not been reviewed and it is possible that some of the larger commercial/industrial structures along the alignment may be supported on piled foundations. Vertical and lateral ground movement can result in increased and often asymmetric loads on piled foundations.

The applicability of settlement limits should be reviewed once detailed condition surveys of key/typical structures have been completed, including identification of piled buildings as these will not necessarily settle along the predicted ground settlement trough and will require more detailed assessment. Such an assessment may include 2D or 3D finite element analyses using PLAXIS, FLAC or other similar software.

3.2.2 Services

Services are typically relatively flexible and can therefore tolerate large differential settlements. Published literature[11] indicates that the maximum differential settlement for cast iron pipes and brittle services with a diameter of 200 mm or greater is in the order of 1:140. Cast iron is generally regarded as being particularly susceptible to damage as a result of differential settlement.

The majority of the major services along the NI alignment are likely to comprise more flexible materials. A reference slope of 1V:200H has therefore been conservatively adopted to assess potential for adverse effects. For any services passing above the pipeline, or within a zone of potential settlement, the actual service will need to be identified and checked during detailed design for its tolerance to the predicted settlement magnitude and shape, with specific mitigation measures developed in the instance where tolerances may be approached. Mitigation measures could include physical isolation of the service from the settling ground, relaying the service, or using a construction methodology that provides specific control of the magnitude of settlement that might occur.

3.2.3 Local roads

The alignment has the potential to impact local roads. For the purposes of this assessment it has been assumed that the settlement tolerance limits for local road crossings will be as follows (based on our experience on other project interfaces with Auckland Transport):

a 20 mm total vertical displacement;

b 1:500 differential settlement.

The most likely impact would be changes to the surface water flow regime resulting from the raising or lowering of drainage grades. These should be checked as the design is progressed to ensure that the overall surface water flow regime is not negatively affected.

3.2.4 Highways

Construction of the NoR – NI (North Shore) has the potential to impact approximately 500 m of SH18, in the vicinity of the eastern abutment of the Greenhithe Bridge. Guidelines in relation to acceptable settlements in and around New Zealand Transport Agency (NZTA) assets should be considered in this area.

NZTA generally release a number of requirements as part of the documentation for the major road projects in New Zealand. The requirements below are reproduced from the Ngaruawahia project but T+T has sighted these conditions for a number of other large infrastructure projects:

"Fill embankments and foundation treatment shall be designed such that the predicted cumulative pavement surface vertical displacements within 5 years after completion of pavement construction are not greater than:

a *150mm total vertical displacement;*

b *1% transverse differential vertical displacement measured over the formation width either side of the median. Minimum design crossfalls shall be maintained;*

c *20mm differential vertical displacement over any 10m length;*

d *In any event, settlement after pavement constructions shall not result in more than 10% change in equivalent design speed at any location"*

Condition c is considered the most applicable when assessing the potential impacts along State Highway 18, west of Tauhinu Road.

As for local roads, the most likely impact would be changes to the surface water flow regime resulting from the raising or lowering of drainage grades. These should be checked as the design is progressed to ensure that the overall surface water flow regime is not negatively affected.

4 Description of receiving environment and assessment of effects

4.1 General

An understanding of the existing environment has been developed on the basis of review of aerial photography, site visits and general observations of structures that may be more sensitive to the ground movements arising from the NI. This is provided below - along with general comments about the potential effects of pipeline construction and operation as assessed from the concept design (Section 4.4). General comments relating to alignment changes and how they may impact surrounding land and buildings are provided in Appendix A and Section 7.

4.2 Notice of Requirement Northern Interceptor (Waitakere)

4.2.1 The Concourse to Selwood Road

The Concourse to Selwood Road section is a heavily built up commercial/industrial environment that includes large, modern, portal frame structures, concrete and timber frame commercial premises and a small number of bungalows which have been converted to commercial premises.

Under the current concept design, these buildings are unlikely to be affected by construction or operation induced settlement, as the pipeline is expected to be shallow (some 2 m deep only) and more than 10 m away from the structures in the road reserve.

Excavations associated with the construction of the proposed new pump station have the potential to impact buildings within 20 m of the excavation before implementation of mitigation measures. The measures outlined in Section 5 would be expected to control the settlements to within acceptable tolerances.

4.2.2 Selwood Road to Huruhuru Road

The southern portions of this section is through a heavily built up industrial zone while the central portion crosses Henderson Creek. In both these cases the pipeline is distant from buildings and structures. Settlement that might arise from the design as shown is not expected to extend as far as the structures.

The northern portion of this section is a residential zone typically comprising single storey timber framed residential dwellings with light weight cladding (timber or composite materials). The central portion is within the open space zone. The southern portion is within the commercial / industrial zone and is currently undeveloped.

As per the concept design, the pipeline in this area is expected to be constructed between 2 m and 5 m deep by a combination of trenched and trenchless technologies within private, public and road reserve. Buildings are unlikely to be affected by construction or operation induced settlement, where the pipeline is shallow (2 m deep or less) and more than 10 m away from structures. Where the pipeline is constructed between 2 m and 5 m deep, settlements are expected to be more significant and have the potential to impact existing houses, in the area north of Henderson Creek. The mitigation measures outlined in Section 5 are likely to be required if the deeper sections remain in the final design, and would be expected to control the settlements to within acceptable tolerances.

4.2.3 Huruhuru Road to Cedar Heights Avenue

The northern and southern portions of this section is a through a residential area with single and double storied dwellings of light weight construction. The central portion of this section crosses the Lowtherhurst Reserve and is currently a significant distance from existing buildings and structures.

We are aware however, that a stormwater pond is proposed to be constructed in close proximity to the Project.

The pipeline is currently planned to be constructed between approximately 3 m and 5 m deep by open trench construction through private property and public and road reserve. Construction related settlements are unlikely to impact existing structures as they are generally beyond the zone affected by settlements. While the future stormwater detention pond is shown to possibly be within this zone, given the width of the proposed designation it is considered that the NI pipeline can be successfully constructed without impacting on the proposed pond.

4.2.4 Cedar Heights Avenue to Holmes Reserve

This section of the alignment is located in an area of residential properties generally one to two storeys high and of timber frame construction with lightweight cladding (timber or brick veneer). At the northern end of the alignment the tunnel runs beneath the Massey Badminton Club building at 163 Royal Road. The building appears to be a steel framed structure with light weight cladding.

The pipeline is currently planned to be constructed between approximately 4 m and 20 m deep by a combination of trenched and trenchless construction within public and road reserve. Construction related settlements are unlikely to impact existing structures which are beyond the potential settlement trough, or in the case of the Badminton Club building, at such a depth that surface settlements are expected to be manageable by the mitigation measures presented in Section 5.

4.2.5 Holmes Reserve to Holmes Drive

This section of the alignment is located in an area of residential properties generally one to two storeys high and of timber frame construction with lightweight cladding (timber or brick veneer).

The pipeline is currently planned to be constructed between approximately 6 m and 14 m deep by trenchless construction within the road reserve. Where the pipeline is at its deepest the construction related settlements have the potential to impact the existing houses adjacent to the alignment. In this case, the mitigation measures described in Section 5 will be required to control settlements to acceptable levels.

4.2.6 Holmes Drive to Hobsonville Road

This section of the alignment is located in an area of residential properties generally one to two storeys high and of timber frame construction with lightweight cladding (timber or brick veneer).

The pipeline is currently planned to be constructed between approximately 8 m and 19 m deep by trenchless construction within private, public and road reserve. Where the pipeline is at its deepest the construction related settlements have the potential to impact the existing structures at the southern end of the alignment where construction is through Tauranga Group and ECBF soils. In this case, the mitigation measures described in Section 5 will be required to control settlements to acceptable levels. The northern portion of the pipeline in this area is through ECBF rock and at such a depth that surface settlements are expected to be negligible.

4.3 Notice of Requirement Northern Interceptor (North Shore)

4.3.1 The Knoll to Wainoni Park

This section of the alignment is located in an area of residential properties generally one to two storeys high and of timber frame construction with lightweight cladding (timber or brick veneer).

The pipeline is currently planned to be constructed between approximately 15 m and 21 m deep by trenchless construction within public and road reserve and through private properties. Where the pipeline is at its deepest the construction related settlements has the potential to impact the existing houses adjacent to the alignment. A portion of SH18 west of Tauhinu Rd may also be affected. At these locations, the mitigation measures described in Section 5 will be required to control settlements to acceptable levels.

4.3.2 South Wainoni Park to Schnapper Rock Road

The pipeline from Wainoni Park to Schnapper Rock Road runs through greenfield areas, a significant distance from buildings and structures and will therefore have no effect on these structures.

The proposed new pump station at the northern end of Wainoni Park is also located at such a distance from existing structures that surface settlements are expected to have a negligible effect.

4.3.3 Schnapper Rock Road to Appleby Road (through North Shore Golf Course)

The northern side of Schnapper Rock Road and both sides of Appleby Road are occupied by modern residential dwellings of one to two stories of timber frame construction with lightweight cladding (cement and brick veneer). Structures along Schnapper Rock Road are approximately 10 m from the pipe alignment.

Albany Junior High School is located along the eastern side of Appleby Road, near the junction with Albany Highway. The school buildings are located approximately 30 m from the pipe alignment, beyond the potential zone of influence and are of precast concrete slab construction.

The pipeline is currently planned to be constructed between approximately 3 m and 5 m deep by trenched construction within greenfield land and road reserve. Due to the very limited geological information along Schnapper Rock Road, construction related ground movements along this portion of the alignment have not been assessed in detail. Based on findings from other sections however, settlements are considered to be manageable, with the mitigation measures as outlined in Section 5 required in some places.

4.3.4 Appleby Road to William Pickering Drive

The area surrounding this section of the project is occupied by low rise commercial/industrial premises. The structures are predominantly of precast concrete construction and are typically located in excess of 10 m from the designation boundary except for a short section along Albany Highway where the designation boundary is in close proximity to a number of residential and commercial structures.

The pipeline is currently planned to be constructed between approximately 4.5 m and 6 m deep by trenched construction within the road reserve and through private property (14 John Glenn Drive). Under the current concept design, the construction related settlements have the potential to impact existing structures adjacent to the designation. In this case, the mitigation measures described in Section 5 will be required to control settlements to acceptable levels.

4.3.5 William Pickering Drive to Bush Road

The area surrounding this section of the project is occupied by low rise commercial/industrial premises. The structures are predominantly of precast concrete construction with a small number of older warehouse type steel framed structures with lightweight cladding. Most structures are located more than 10 m from the designation boundary.

The pipeline is currently planned to be constructed between approximately 4-5 m and 6 m deep by trenched construction within the road reserve. Where the pipeline is at its deepest the construction related settlements could impact existing structures adjacent to the alignment. In this case, the mitigation measures described in Section 5 will be required to control settlements to acceptable levels.

4.3.6 Bush Road to Rosedale Wastewater Treatment Plant

A series of interconnected commercial structures are located near the western end of this section of the alignment. The structures appear to be steel framed with lightweight cladding.

A stormwater pond is located approximately 15 m north of the designation boundary, north of Rosedale Park.

The pipeline is currently planned to be constructed approximately 4.5 m deep by trenched construction predominantly on public land and within the road reserve with a short section through private property. The central portion of this section will be installed by trenchless construction across the waterway. Construction related settlements may impact the existing commercial premises at the western end of this section and the mitigation measures described in Section 5 will be required to control settlements to acceptable levels. Settlements along the remainder of the designation in this area are unlikely to impact existing structures which are beyond the zone where settlements may arise.

4.4 Long term effects

Long term potential operation induced settlements have been assessed based on the conservative assumption that groundwater will be drawn down to pipe invert level/pump station base slab level during the life of the Project. Estimates indicate that based on this conservative assumption total settlements of up to 300 mm and differential settlements of up to 1:80 could occur in isolated locations of adverse geology if specific measures to prevent such drawdown occurring are not employed. Specific measures that are commonly employed to mitigate this potential are presented in Section 5. On this basis, provided such commonly employed measures are used, long term settlement is expected to be controlled to within acceptable tolerances.

This report is provided in support of the NoR to designate the corridor. Any ‘regional’ resource consents required for the Project will be sought at a later date once the design is further developed.

4.5 Existing utilities

The majority of underground services along the Project alignment (either within or adjacent to the designation corridor) currently are water, wastewater and stormwater pipelines between 100 mm and 800 mm in diameter.

Watercare intend to continue the practice of liaising with service authorities, and ensuring that the assets owned by other authorities are avoided, protected, relocated or repaired.

5 Mitigation measures

5.1 Excavations

Where estimated ground movements are anticipated to exceed the tolerances set out in Section 3.2 and A5.4 (Appendix A) either during construction (mechanically induced) or in the long term as a result of consolidation settlement, the following mitigation measures may be considered:

- Reduce depth of excavation (where possible for rising main sections) and install excavation wall support/struts earlier or at closer vertical spacing to reduce wall deflections.
- Pipe joints and buried structures being sealed to a high standard.
- Adopt a tight construction programme (e.g. by reducing the length of excavations open at any one time).
- Increase the size of the struts being installed to reduce excavation wall deflections.
- Design and install low permeability backfill and/or construct drainage cut-offs to reduce long term groundwater drawdown.
- Adopt rigid retaining wall systems such as diaphragm or secant pile systems for deep, permanent excavations such as pump stations, to minimise ground settlement induced by wall deflection.
- Adopt a “tanked” system for deep, permanent excavations such as pump stations, to minimise the degree to which groundwater levels are affected during operation.

It should be noted that the suitability of mitigation techniques must be considered on a case by case basis in order to achieve the best results at a given location.

5.2 Tunnels

Consolidation settlement is time dependant and may be managed by adopting a tight construction programme and excavating the tunnel using a MTBM in EPB mode to reduce groundwater seepage during construction and control volume loss.

Long term settlement effects related to ongoing groundwater drawdown can be managed by ensuring that tunnel segments are sealed to a high standard.

If site specific groundwater monitoring indicates that groundwater drawdown exceeds seasonal lows, or if it is desired to achieve tighter tolerances, further mitigation may be required and could include settlement compensation by jet grouting or installation of grout curtains at locations where total or differential settlement tolerances may be exceeded.

6 Consenting process

6.1 Designation – Concept design

This assessment has been carried out to inform the AEE which supports the NoR to designate the NI.

The assessment presented in this report is based on concept design and conservative assumptions from high level ground investigation information. It takes into account the potential for the pipe alignment and depth to vary within the proposed designation boundary as well as the potential for future changes in the receiving environment.

The assessment provides guidance on the range of mitigation measures that are commonly used that would enable the Project to be constructed in a way that does not impact on the performance of existing or proposed surrounding structures (i.e. measures that would control expected settlements to within acceptable tolerances).

6.2 Resource consents – Preliminary design

Prior to construction, any necessary regional consents will be sought. By that time the design will be developed in more detail and a more detailed assessment of potential effects and potential mitigations measures will be provided in the application documents.

In recent resource consents for projects similar to this one, resource consent conditions have been set which recognise:

1 The potential for the design alignment to necessarily shift within the corridor after the consent has been issued, and;

2 That settlement effects may arise from a combination of mechanical and groundwater drawdown related effects.

These conditions usually require the final design to undergo a further settlement hazard study to identify the particular locations and buildings along the alignment where monitoring and contingency measures will be necessary to confirm that general consent conditions relating to the protection of all buildings and structures are met. These requirements are typically set out in a monitoring and contingency plan that is prepared by the consent holder and submitted to Council for approval, as a consent condition requirement, prior to construction commencing.

We anticipate that a similar approach would be appropriate at resource consenting stage for this Project.

7 Conclusions

Watercare Services Limited (Watercare) has engaged Tonkin & Taylor Ltd (T+T) to carry out an assessment of the potential effects that may arise from the construction and operation of proposed new wastewater pipelines and associated infrastructure to convey wastewater from The Concourse in Henderson to the Rosedale Wastewater Treatment Plant ("WWTP") in Albany.

The assessment is required to inform the AEE which supports the NoR to designate the NI.

Construction of the NI is expected to utilise methodologies that are frequently used and are well understood by the engineering and contracting community. Very similar construction methodologies are used throughout Auckland and New Zealand to construct pipelines for storm water networks, wastewater networks, and water supply pipelines.

Much of the corridor is located in road reserves and reserve land some distance from existing buildings and structures. In such instances settlement arising from pipeline construction is unlikely to extend far enough from the alignment to impact the structures irrespective of how it is constructed.

Where the pipeline or pump station is necessarily close to structures, and if the settlement predicted to arise from construction had the potential to cause damage to, or adversely affect the performance of the structure, there are commonly adopted mitigation measures available to Watercare that can be expected to control the settlements to within acceptable tolerances.

The design of these mitigation measures, and the particular locations where they may be required would be the subject of the more detailed design phases that would support any future resource consents required for the works. They would be supported by more comprehensive geotechnical and hydrogeological investigation data than is available at this early stage of project design.

Based on the assessment described in this report, and the mitigation measures available to Watercare, we consider the short and long term settlement effects of the project on existing buildings and structures along the alignment can be expected to be controlled to less than minor.

A detailed assessment of the vulnerability of key/typical buildings (where there is significant settlement potential) will be required to support detailed design and consenting in the future. This would include further development of the geotechnical models and refinement of the design alignment to minimise depth of trenched sections wherever possible.

8 Applicability

This report has been prepared for the exclusive use of our client Watercare Services Limited, with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose, or by any person other than our client, without our prior written agreement.

Tonkin & Taylor Ltd

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Appendix A: Technical appendix

A1 Site investigations

A1.2 Ground investigation

Subsurface investigations were carried out between 17 November 2014 and 25 January 2016. The investigations comprised 13 rotary cored boreholes, 4 CPTs and 10 hand auger holes. The boreholes were completed by a tracked rotary machine drill rig, while the CPTs were completed using a truck mounted CPT rig. The boreholes were drilled by McMillan Drilling Ltd, CPTs were undertaken by Ground Investigation Ltd while hand augers were undertaken by T+T staff.

The investigation locations are presented on Figures 1 to 13 (Appendix B).

Core recovered from the boreholes was logged and photographed, with selected samples taken for laboratory testing. A full description of the site activity completed as part of this investigation is detailed in the T+T factual geotechnical report (2016)[4].

A1.3 Site walkover

A T+T geotechnical engineer carried out a site walkover on 1 February 2016 to identify structures which may be susceptible to settlement. Existing developments such as buildings and services which may be susceptible to settlement effects were recorded. Relevant observations made at the time of the inspection from west to north east of the alignments are summarised in Section 4.

A1.4 Review of aerial photographs

T+T has completed a review of available photographs on the Auckland Council GIS website to identify areas of historic gullies where elevated groundwater levels and historic fill may be encountered. Historical photos available on the Auckland Council are dated available between 1959 and 2010 and identify historical gullies and area of fill which may affect the NI project. In particular, the following should be noted:

- A gully was present near William Pickering Drive in the 1959 aerial photograph, the gully has been infilled. T+T records indicate that the fill is greater than 5m in thickness in this location.
- Aerial photography from 1959 also shows a gully in the western part of Piermark Avenue, this gully has been infilled.
- Two large sludge ponds are located to the south of the Rosedale WWTP. These have been infilled and the area grassed.

A1.5 Historical ground investigation data

Historical investigation data from various historical T+T projects has been used supplement the project specific investigation data. The following investigations are relevant to the NI project:

- State Highway 16 (SH16) development
- Hobsonville Sewer Pump Station Upgrade
- State Highway 18 (SH18) Upgrade
- Schnapper Rock Development
- North Shore Golf Course Development

Further detail of historical ground investigations used in our assessment are presented in Appendix C.

A2 Geology

A2.1 Geological model

A2.1.1 General

The area around the Northern Interceptor alignment is characterised by two major stratigraphic groups:

- Miocene Waitemata Group marine sedimentary rocks.
- Late Pliocene to Holocene Tauranga Group alluvial and estuarine sediments.

The Auckland Isthmus is dominated by the weak sandstones and mudstones/siltstones of the Waitemata Group, in particular the East Coast Bays Formation (ECBF) of the Warkworth Subgroup. The Warkworth Subgroup is known to include discrete lenses or beds of Albany Conglomerate comprising well rounded gravels to boulder sized clasts within a medium to very coarse grained sand matrix, in the Greenhithe to Rosedale area. Tauranga Group alluvium deposits are typically located within the base and flanks of present day and paleo-drainage channels.

A2.1.2 Geological units

A2.1.2.1 Fill

Fill material was encountered in many of the hand auger and machine boreholes on the alignment. This material typically comprised re-worked soft to stiff, clay/silt mixtures derived from natural Tauranga Group or ECBF soils. Gravel layers were also encountered in machine boreholes in proximity to roads and SH16. The fill material is often underlain by a thin layer of buried topsoil at the contact with natural underlying material.

Locally around the Hobsonville Pump Station (BH-T57) the fill material comprises a mixture of construction debris at the surface (concrete, steel, and timber) and silt/clay soils at depth.

A2.1.2.2 Tauranga Group

Tauranga Group materials encountered were typically light grey to grey brown clay/silt or silty sand. Cohesive units are typically described as very soft through to stiff, while sand dominated units are described as very loose through to loose. Organic material is disseminated through the Tauranga Group soils, with some boreholes in the Hobsonville area (BH-T57 and BH-T61) exhibiting thicker units of soft organic clay or peat. This is most pronounced in the upper half of the Tauranga Group encountered.

A2.1.2.3 Albany Conglomerate

The Albany Conglomerate comprises dark grey very weak to weak conglomerate, agglomerate, with localised boulders. This material was only encountered in BH-T62 in the Greenhithe area. Interbedded within the Albany Conglomerate unit is extremely weak to very weak coarse grained volcaniclastic sandstone (Parnell Grit). Overlying the unweathered Albany Conglomerate rock is a 0.3m thick layer of weathered coarse sand.

A2.1.2.4 Weathered East Coast Bays Formation (ECBF)

The weathered ECBF consists of two geological units subjectively differentiated by the degree of in-situ weathering. These units are defined as residual soil and completely weathered ECBF. The residual soil comprises either a firm to stiff, orange brown to brownish grey silt/clay mixture, or a loose, grey mottled orange brown silty sand. The completely weathered ECBF is typically either a very stiff to hard grey silt or a medium dense to very dense grey sand. This material usually retains some relict rock structure but behaves as a soil material.

A2.1.2.5 Slightly weathered to unweathered East Coast Bays Formation

The underlying basement rock along the proposed Northern Interceptor alignment is an extremely weak to weak interbedded sandstone and siltstone. All of the boreholes carried out for the investigation programme encountered the slightly weathered to unweathered ECBF rock at varying depths of 7.1m to 24m below the ground surface, except for BH-T61 (>28.95m). BH-T52 in the West Harbour area encountered coarse grained volcaniclastic sandstone interbedded (up to 0.8m thick) within the sandstone and siltstone (Parnell Grit). This coarse sandstone unit is also noted to be interbedded where Albany Conglomerate was observed as noted in Section A2.1.2.3 above.

A3 Hydrogeology

A3.1 Groundwater

The Auckland Region is broadly characterised by perched transient groundwater levels within near surface deposits and a deeper more stable groundwater level within the ECBF. The ECBF groundwater level is typically a subdued reflection of surface topography, with gradients of the order of 2-5% from the coast.

Within the ridges, groundwater seepage is typically dominated by vertical seepage patterns, (including cascading perched systems) percolating to the deeper regional level. In gullies seepage from ECBF rock supports stream base flow, or where historic gullies have been in filled by more recent alluvial or volcanic deposits combine in directional seepage along the ancient drainage paths.

Ground investigations and groundwater monitoring undertaken along the northern section of the NI (North Shore) section as part of the Phase 1 assessment[6] indicate that this part of the alignment is underlain by an unconfined aquifer with groundwater level between 1 m and 3 m below the ground level. The groundwater table in the Tauranga Group soils appears to be interconnected with the groundwater in the ECBF materials (both soil and rock). Groundwater monitoring between 17 December 2014 and 6 March 2015 shows localised groundwater level fluctuations of approximately 2m. Greater seasonal variations may be recorded as the monitoring period extends into the winter months when increased rainfall and elevated groundwater levels are expected. It therefore is possible groundwater levels may be at or close to the surface and may be up to 5m below ground level (approximately 2m below pipe invert level) for this portion of the corridor.

Project specific groundwater information for the NI (Waitakere) section is currently limited, however, based on our experience and historical investigation records it is considered likely that groundwater levels along much of the alignment will be high and could be at or close to ground level at many locations during the winter. The range of summer to winter variation in groundwater level in this section could be expected to be similar to the NI (North Shore) section.

For the purposes the potential groundwater drawdown induced settlement assessment presented in this report, which is based on very limited groundwater level information it has been assumed that groundwater levels coincide with ground level throughout the alignment – which is clearly a worst case scenario. Based on the limited information currently available, parts of the corridor may in fact be constructed above the summer low groundwater level – indicating that no groundwater drawdown related settlement would be expected to occur.

A4 Derivation of geotechnical parameters

A4.1 Stiffness

Understanding the stiffness of the various rock and soil units is of importance in assessing the potential settlement effects due to groundwater changes and ground loss associated with tunnel construction methodologies. Very stiff soils are unlikely to result in settlement, even when groundwater lowering is significant – conversely, very soft soils may settle even when groundwater level is lowered by a small amount.

In situ and laboratory testing is only available for the northern half of the NI (North Shore) section, where the alignment coincides with Phase 1 of the Northern Interceptor project. This information combined with experience from previous projects has been used to derive typical stiffness values for Tauranga Group and weathered ECBF soils.

Laboratory testing was targeted at Tauranga Group materials as these soils are considered to be more compressible and problematic than ECBF soils along the alignment. Field investigation and laboratory testing data is presented in detail in the Terrestrial Geotechnical Factual Report for Phase 1 of the development[10], details of the derivation of stiffness parameters are presented in the Phase 1 assessment report[6].

Material property values adopted for the purposes of this assessment are summarised in Table A4.1 while Table A4.2 presents design parameters from other projects in the wider Auckland area.

Table A4.1: Summary of material stiffness parameters

Geological Unit	Deformation Modulus, E (MPa)
Tauranga Group (above 12m depth)	4
Weathered ECBF soil	10

Table A4.2: Comparison of material stiffness parameters with other Auckland projects

Geological Unit	Deformation Modulus, E (MPa)					
	Central Interceptor	Waterview Connection	Rosedale Tunnel	Hobson Bay Tunnel	Vector Tunnel	Britomart
Tauranga Group (above 12 m depth)	6	1.5 to 10 (stress range dependant)	3	8 to 10	N/A	N/A
Weathered ECBF soil	15	2.5 to 10 (stress range dependant)	10	11	N/A	N/A
ECBF rock	500	150 to 1050	N/A	450	560	670

A4.2 Permeability

A site specific permeability assessment including groundwater level measurements was carried out along the northern half (approximately) of the NI (North Shore) section as part of the NI Phase 1 assessment[6].

The horizontal permeability derived from tests carried out on Tauranga Group materials range between 1×10^{-7} and 2×10^{-9} m/s. Typically adopted parameters in the Auckland area for Tauranga

Group range between 2x 10^{-6} and 2 x 10^{-8} m/s, i.e. slightly more permeable. Historically, similar horizontal permeability values are attributed to the weathered ECBF soils.

Permeability tests have not been carried out along the NI (Waitakere) section.

For the purposes of this assessment a horizontal permeability of k_h=2 x 10^{-7} m/s has been adopted for both Tauranga Group and ECBF soils throughout the alignment.

A5 Settlement assessment methodology

A5.1 General

The construction of the NI has the potential to induce vertical and lateral ground movements that could affect the condition of structures within the zone of influence.

Mechanical settlements caused by the construction of the NI project are expected to occur within several weeks from the start of construction and are therefore relatively instantaneous. Consolidation settlements, on the other hand, occur relatively slowly and may not be fully realised for many years after completion of the project. The effects of construction phase settlement are therefore typically more adverse than the longer term settlement which is dependent primarily on the degree of water tightness achieved at the pipe joints and the permeability of the overburden material.

The potential magnitude of construction effects is strongly dependant on the construction methodology (refer to Section 2.2) and the local geological and hydrogeological conditions. The potential for short term effects therefore depends on the excavation method that is adopted i.e. open excavation, micro tunnel boring machine (MTBM) in open or earth pressure balance (EPB) mode or HDD (mechanically induced settlement) whereas the potential for long term effects depends on the stiffness and permeability of the underlying materials (consolidation settlement). The total settlements at the ground surface will result from a combination of the two settlement sources. The method used to combine the settlements is a simple superposition of the settlement values from each individual source.

A5.2 Mechanically induced settlement

A5.2.1 Tunnelling

Mechanically induced settlements have been estimated on the basis of correlations between soil type and volume loss using the methods described in Sinclair *et al* (1988)[7] and Andrews *et al* (1984)[8] for tunnels and summarised in Table A5.1 below.

Table A5.1: Assumed tunnel conditions for mechanical settlement estimates

Geological Unit	Adopted tunnelling conditions	Volume loss, VL (%)
Tauranga Group Soil (sandy silt)	I	7.5
ECBF Soil	II	2.5
ECBF Rock	IV	0
Mixed Face Tauranga Group / ECBF soil	III/I	10
Mixed Face ECBF soil / ECBF rock	II/IV	1.25

A5.2.2 Excavations

The method described by Peck (1969)[9] has been used to estimate the mechanically induced settlement for excavations. This simplified method is empirical and based on actual recorded settlements adjacent to excavations in soft clay. The data are from excavations using standard ground retention techniques such as sheet piles, and the results suited to excavations where walls are able to deflect inwards towards the excavation.

The soil categorisation proposed by Peck is presented in Table A5.3 below. The site soils are considered to fall within Zone I/II.

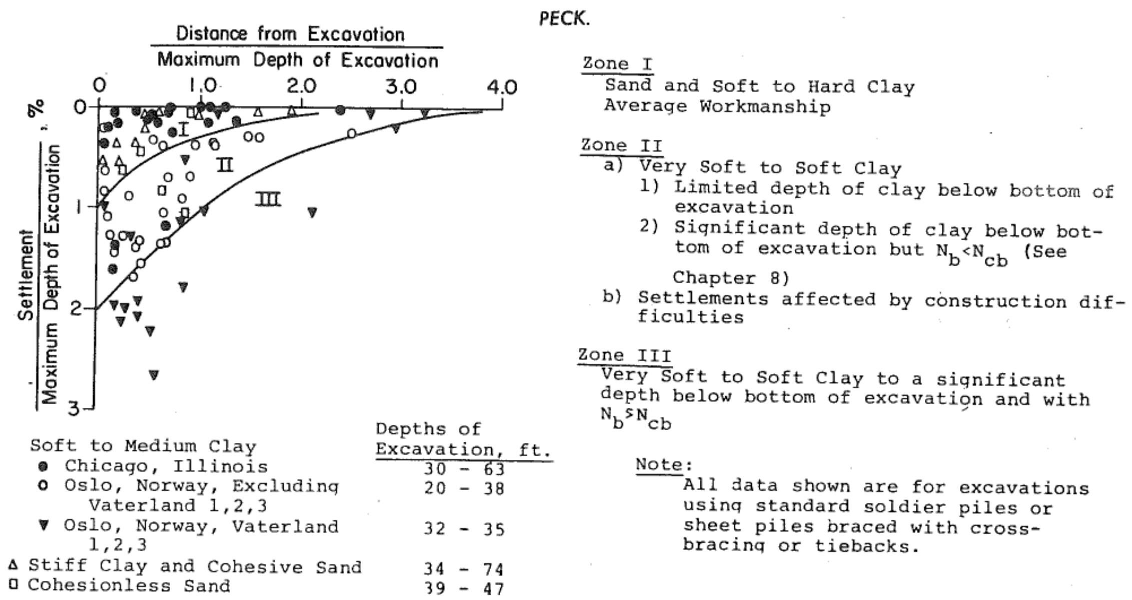


Figure A1: Summary of settlements adjacent to open cuts in various soils as function of distance from edge of excavation.

A5.3 Groundwater drawdown induced settlement

The potential magnitude and extent of temporary and long term groundwater drawdown behind excavations, or adjacent to pipe jacking operations have been estimated using the method in Somerville (1988)[11]. The potential change in porewater pressure has been predicted from the estimated drawdown, assuming groundwater levels are presently at or near ground level and that groundwater is drawn down to the base of the tunnel or excavation being assessed. The magnitude of consolidation settlement is estimated using one dimensional consolidation theory and the soil stiffness adopted in Section A4.

The pipe bedding has the potential to act as a drain long term unless groundwater cut-offs (i.e. less permeable layers) are incorporated in the bedding. Once the trench is backfilled to an appropriate standard it is considered unlikely that further groundwater drawdown will occur.

A5.4 Methodology for assessment of effects

A5.4.1 Buildings

A structure's tolerance to total and differential settlement is unique to each structure and depends upon the materials used in framing, cladding and foundations as well as the quality of construction and existing condition of the structure.

A5.4.1.1 Shallow foundations

The NZ building code provides guidance on settlement tolerances in Appendix B B1/VM4, clause B1.0.2:

“Foundation design should limit the probable maximum differential settlement over a horizontal distance of 6m to no more than 25mm under serviceability limit state load combinations of NZS 4203:1992[updated in 2004], unless the structure is specifically designed to prevent damage under a greater settlement.”

This clause effectively sets a deflection guidance limit of approximately 1:240 for tolerable differential settlements (note that differential settlement is commonly expressed as the ratio of differential vertical deflection to horizontal distance over which the differential movement occurs, as adopted within this report).

Further guidance on the tolerance of specific building types and/or uses to differential settlement is provided by Bjerrum[12] for buildings on shallow foundations as summarised in Table A5.4 below.

Table A5.3: Building damage assessment criteria

Category No.	Description	Maximum slope of ground
1	Limit for typical settlement sensitive machinery	1:750
2	Potential damage to frames with diagonals	1:600
3	Potential limit for cracking	1:500
4	Tilting of high structures becomes noticeable	1:250
5	Structural damage likely, considerable cracking	1:150

The level of settlement that is generally accepted in New Zealand as being the upper limit for buildings is a total settlement of 50 mm and a differential settlement of 1:1000. These settlement limits are conservative values which apply to a broad range of structures, including structures of timber, concrete and brick construction and have been adopted for other sections of the Northern Interceptor project as they are considered unlikely to result in damage to standard, modern industrial/commercial buildings and residential buildings of timber and brick construction.

The assessment is based on ‘greenfield’ estimates of ground movement and does not take into account the degree to which the building stiffness resists ground movement. The assessment of effects would therefore be conservative as a result.

Buildings that are more than 10 m from the edge of the proposed corridor or within the corridor and subjected to less than 10 mm settlement and differential settlement slopes greater than 1:1000 are classified to have negligible effects and have not been further assessed.

A5.4.1.2 Piled foundations

Vertical and lateral ground movement result in increased and often asymmetric loads on piled foundations.

It has been assumed, at this initial stage that all structures along the proposed alignment are supported on shallow foundations. This assumption in based on the observed building types (typically 1 to 2 storey residential buildings and portal framed structures) and the inferred geology.

However, building records have not been reviewed and it is possible that some of the larger commercial/industrial structures along the alignment may be supported on piled foundations.

The applicability of settlement limits should be reviewed once detailed condition surveys of key/typical structures have been completed, including identification of piled buildings as these will not necessarily settle along the predicted ground settlement trough and will require more detailed assessment. Such an assessment may include 2D or 3D finite element analyses using PLAXIS, FLAC or other similar software.

A5.4.2 Utilities

Services are typically relatively flexible and can therefore tolerate large differential settlements. Published literature[13] indicates that the maximum differential settlement for cast iron pipes and brittle utilities with a diameter of 200mm or greater is in the order of 1:140. Cast iron is generally regarded as being particularly susceptible to damage as a result of differential settlement.

The majority of the major services along the NI (Waitakere and North Shore) alignment are likely to comprise more flexible Concrete Lined Steel (CLS) pipes.

A reference slope of 1V:200H has therefore been conservatively adopted for the services along the NI Phase 1 development to assess potential for adverse effects. For any services passing above the pipeline, or within a zone of potential settlement the actual service will need to be checked during detailed design for its tolerance to the predicted settlement magnitude and shape, with specific mitigation measures developed in the instance where tolerances may be approached. Mitigation measures could include physical isolation of the service from the settling ground, relaying the service, or using a construction methodology that provides specific control of the magnitude of settlement that might occur.

A5.4.3 Roads

The alignment has the potential to impact local roads. The most likely impact would be changes to the surface water flow regime resulting from the raising or lowering of drainage grades. For the purposes of this assessment it has been assumed that the settlement tolerance limits for local road crossings will be as follows (based on our experience on other project interfaces with Auckland Transport):

e 20 mm total vertical displacement;

f 1:500 differential settlement.

A5.4.4 Highways

Construction of the NoR – NI (North Shore) has the potential to impact approximately 500m of SH18, in the vicinity of the eastern abutment of the Greenhithe Bridge. Guidelines in relation to acceptable settlements in and around New Zealand Transport Agency (NZTA) assets should be considered in this area.

NZTA generally release a number of requirements as part of the documentation for the major road projects in New Zealand. The requirements below are reproduced from the Ngaruawahia project but T+T has sighted these conditions for a number of other large infrastructure projects:

Fill embankments and foundation treatment shall be designed such that the predicted cumulative pavement surface vertical displacements within 5 years after completion of pavement construction are not greater than:

a *150mm total vertical displacement;*

b *1% transverse differential vertical displacement measured over the formation width either side of the median. Minimum design crossfalls shall be maintained;*

c *20mm differential vertical displacement over any 10m length;*

d *In any event, settlement after pavement constructions shall not result in more than 10% change in equivalent design speed at any location.*

Condition c is considered the most applicable when assessing the potential impacts along State Highway 18, west of Tauhinu Road.

As for local roads, the most likely impact would be changes to the surface water flow regime resulting from the raising or lowering of drainage grades. These should be checked as the design is progressed to ensure that the overall surface water flow regime is not negatively affected.

A6 Settlement assessment

A6.1 Overview

This section presents the findings of the settlement assessment. The effects of short term (mechanically induced) settlement have been assessed throughout the alignment whereas groundwater drawdown related settlements have been carried out only at the locations considered to have the potential to result in the worst case total and differential settlements.

Settlement contours for mechanically induced settlements are presented in Figures 1 to 13 in Appendix B.

A number of locations have been identified where structures could be affected by settlement troughs either in their current state or as a result of future development. These are presented in Section 4 of this report. It is anticipated that further development of the geotechnical models and refinement of the design and construction methods may limit the potential settlement effects assessed herein and potentially reduce total and differential settlements.

A6.2 Settlement estimates

A6.2.1 Excavations

The relationship between potential ground settlement with distance from excavation in sand and soft to hard clay is provided in Figure A2, developed based on the methodology outlined in Section A5. The calculations include allowance for soft soils and complications during the construction.

The calculations indicate that settlements in excess of 50 mm may occur at locations where open excavations greater than 5 m deep are proposed, specific geotechnical analysis and design would be required to limit potential mechanically induced settlements where structures or services are in the vicinity. In most cases settlements can be expected to reduce to minimal levels (5 mm or less) some 10-15 m from the edge of the excavation.

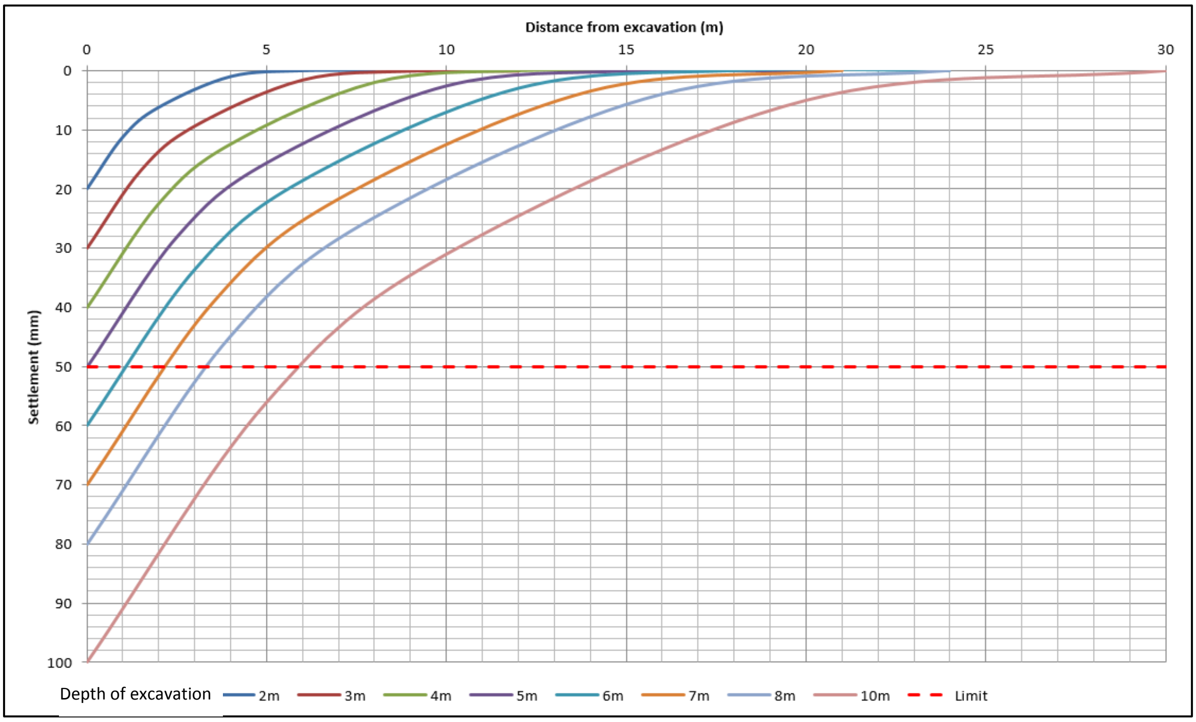


Figure A2: Estimate of excavation induced surface settlement – Zone I/II[9]

A6.2.2 Micro tunnelling

The estimated mechanical settlement for the proposed micro tunnel, assuming excavation is carried out using a MTBM in open mode, is presented in Table A6.1. The total and differential settlements presented are based on greenfield conditions (i.e. not taking into account the influence of building stiffness).

The calculations suggest that the short term total settlement (vertical) induced by the micro tunnelling is within acceptable limits at all locations where receptors are in the vicinity and is likely to remain within acceptable limits in the long term provided groundwater drawdown is controlled during construction and tunnel joints are well sealed to limit long term groundwater inflows into the pipeline. Mechanical settlement is likely to increase if the cover to crown is reduced or the pipe diameter is increased. These results should be reviewed once the pipeline alignment and diameter are confirmed and site specific groundwater monitoring data is available.

Differential settlements exceed the generally accepted tolerances at a number of locations (Table A6.1) and it is likely that specific engineering design and/or mitigation measures will be required at these locations.

A6.2.3 Summary of settlement estimates

Table A6.1: Summary of mechanically induced settlements

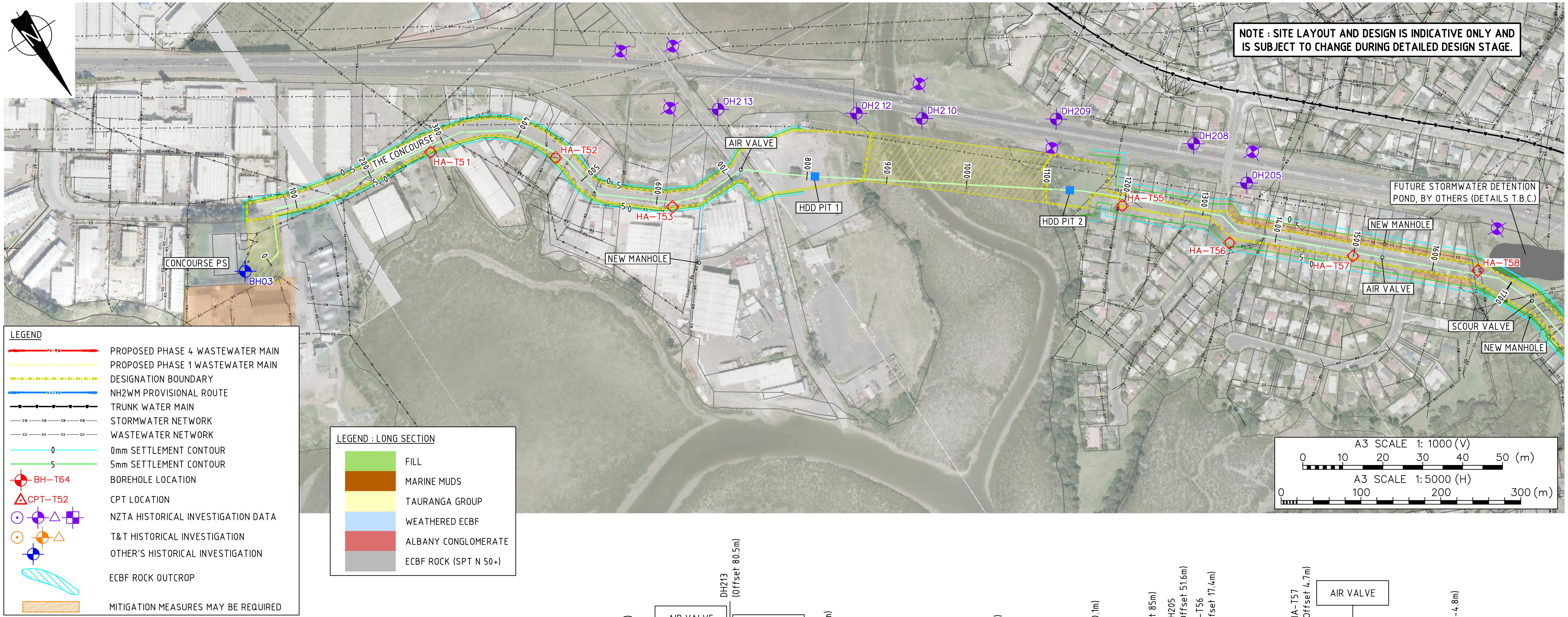
Location	Chainage (m)		Estimated mechanical settlement (mm)	Estimated radius of influence (m)	Estimated maximum differential settlement (V:H)	Potential to impact existing structures? Y/N
	From	To				
Waitakere						
The Concourse to Selwood Rd	0	663	20	5	1:300	Y
	663	793	20	5	1:300	
Selwood Rd to Huruhuru Rd	793	1145	N/A Note 1	N/ A Note 1	N/ A Note 1	Y
	1145	1400	50	15	1:300	
Huruhuru Rd to Cedar Heights Ave	1400	1650	50	15	1:300	N
	1650	1850	32	9	1:300	
Cedar Heights Ave to Holmes Reserve	1850	2000	42	12	1:300	Y
	2000	2144	42	12	1:300	
	2144	2400	5	14	1:1900	
	2400	2568	40	8	1:100	
	2568	2789	3	18	1:3200	
	2789	3000	0	0	N/A	
Holmes Reserve to Holmes Drive	3000	3400	2	15	1:2200	Y
	3400	3900	15	11	1:450	
Holmes Drive to Hobsonville Road	3900	4300	9	15	1:800	Y
	4300	4528	0	0	N/A	
North Shore						
The Knoll to Collins Park	2800	3300	0	0	N/A	Y
	3300	3600	8	20	1:1200	
Collins Park to Wainoni Park	3600	3700	128	6	1:50	Y
	3700	4100	0	0	0	
South Wainoni Park	4100	4437	0	0	0	N
	4437	4600	0	0	0	
	4600	4700	0	0	0	
North Wainoni Park to North Shore Memorial Park	4700	5000	0	0	0	N
	5000	5113	14	11	1:300	
	5113	5203	30	8	1:300	
	5203	5890	No information available			N
	5890	6500				
North Shore Memorial Park to	6500	6700				

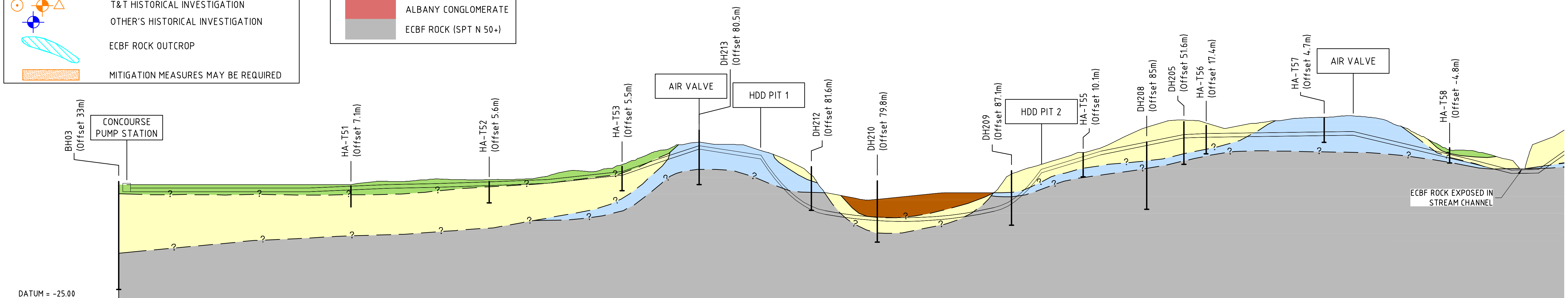
Location	Chainage (m)		Estimated mechanical settlement (mm)	Estimated radius of influence (m)	Estimated maximum differential settlement (V:H)	Potential to impact existing structures? Y/N
	From	To				
Schnapper Rock Road						
Schnapper Rock Road to North Shore Golf Course	6700	7033				
	7033	7504				
North Shore Golf Course to Appleby Road	7504	7700				
	7700	8200	35	9	1:300	Y
Appleby Road to William Pickering Drive	8200	8600	46	11	1:300	Y
	8600	9200	58	14	1:300	
William Pickering Drive to Bush Road	9200	9600	58	14	1:300	Y
	9600	9900	58	14	1:300	
Bush Road to Rosedale Wastewater Treatment Plant	9900	10150	35	9	1:300	Y
	10150	10400	N/ANote 1	N/ ANote 1	N/ ANote 1	
	10400	10835	40	10	1:300	
Note	1: No assessment carried out for HDD sections					

A6.2.4 Groundwater drawdown

High level groundwater drawdown assessments carried out at key locations indicate that total and differential settlement tolerances are likely to be exceeded at any location where the depth to rock is greater than 7 m and groundwater is drawn down by 2 m or more.

Appendix B: Figures





CHAINAGE	GROUND LEVEL	DEPTH TO INVERT
0.00	4.00	1.75
22.98	4.00	
50.00	4.00	
78.37	4.00	
100.00	4.00	
134.22	4.00	
150.00	4.00	
200.00	4.00	
228.65	4.00	
250.00	4.00	
300.00	4.54	
326.15	4.81	
350.00	4.81	
388.50	5.44	
400.00	5.32	
450.00	5.24	
464.88	5.31	
500.00	5.42	
527.12	6.15	
550.00	7.28	
600.00	8.01	
621.16	9.03	
650.00	11.28	
663.56	12.32	
700.00	14.19	
716.64	14.62	1.76
750.00	14.03	
793.95	12.55	
800.00	12.16	2.11
850.00	7.71	
900.00	1.06	
950.00	0.55	
1000.00	1.53	
1050.00	2.00	
1100.00	5.42	
1145.22	9.98	
1150.00	9.33	2.14
1201.49	12.15	
1220.19	13.18	
1250.00	16.04	
1300.00	19.75	
1323.70	20.16	
1351.48	19.42	
1400.00	18.98	
1450.00	20.19	
1500.00	20.81	
1535.60	21.20	4.85
1550.00	21.01	
1600.00	18.22	
1650.00	13.21	
1683.92	12.54	
1700.00	11.87	
1733.88	10.09	3.34
1750.00	8.00	
1800.00	17.65	

PIPE SIZE & TYPE:
- 0.00 – 800.00: ø900 PE RISING MAIN, OPEN TRENCH CONSTRUCTION
- 800.00 – 1150.00: ø900 PE RISING MAIN, HORIZONTAL DIRECTIONAL DRILLING
- 1150.00 – : ø900 PE RISING MAIN, OPEN TRENCH CONSTRUCTION

SCALES : HOR, 1:5000 / VERT, 1:1000

DESIGNED :	RLXB	Jun. 16
DRAWN :	JC	Jun. 16
DESIGN CHECKED :	CJL	Jun. 16
DRAFTING CHECKED :	AMM	Jun. 16

CADFILE : \\28773.3420-F1_F4.dwg

APPROVED :
NOT FOR CONSTRUCTION
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REVISION	DESCRIPTION	BY	DATE
0	First Issue		

NOTES :
1. All dimensions are in millimetres unless noted otherwise.
2. Layout plan and longsection supplied by MWH, reference drawing file name 2011119.005_007 & 2011123.005_007 – Geological Long Section" dated 11 Feb 2016.

REFERENCE :

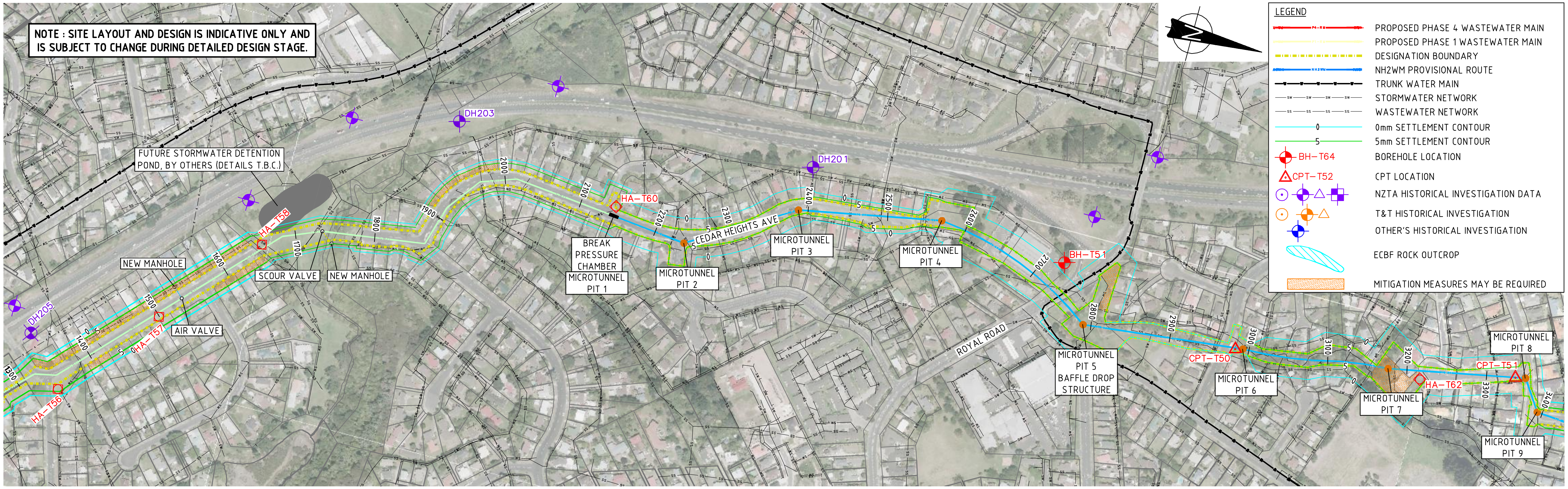
Tonkin+Taylor
MWH
Watercare Services
An Auckland Council Organisation

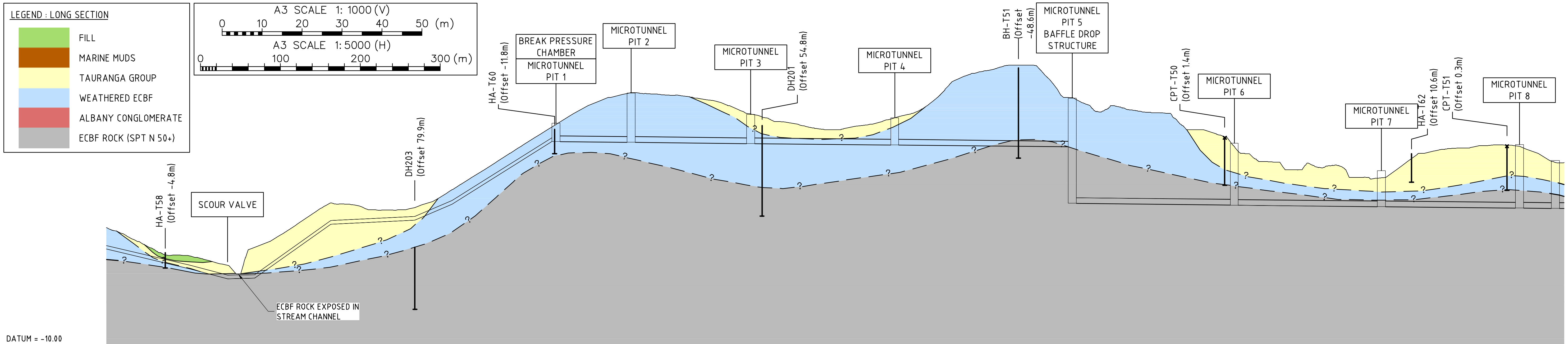
CLIENT, PROJECT
WATERCARE SERVICES LIMITED
NORTHERN INTERCEPTOR PROJECT

TITLE
DESIGNATION DESIGN NOR NI WAITAKERE
Geological Long Section & Mechanical Settlement Contours: Sheet 1 of 10

SCALES (AT A3 SIZE): AS SHOWN
DWG. No.: Figure 1
REV.: 0

I:\28773\28773.3420\workingmaterial\CAD\FIG\28773.3420-F1_F4.dwg, 2011123.005, 14/06/2016 12:08:53 p.m., jc





CHAINAGE	GROUND LEVEL	DEPTH TO INVERT
1600.00	18.22	
1650.00	13.21	
1683.92	12.54	
1700.00	11.87	
1733.88	10.09	3.34
1750.00	8.00	
1800.00	17.65	
1850.00	24.25	
1863.14	25.65	
1900.00	24.79	
1916.40	23.95	
1950.00	23.99	
1968.27	24.53	
2000.00	27.15	
2014.60	28.94	
2050.00	33.36	
2100.00	39.71	
2144.53	45.26	4.25
2150.00	45.92	
2200.00	51.20	
2238.59	53.17	12.36
2250.00	53.04	
2300.00	52.49	
2350.00	50.77	
2387.99	47.88	7.36
2400.00	47.28	
2450.00	45.09	
2500.00	44.00	
2550.00	45.86	
2568.01	46.88	6.74
2600.00	48.90	
2650.00	56.84	
2678.95	58.57	
2700.00	59.58	
2750.00	58.89	
2789.90	51.93	12.28
2800.00	50.95	25.93
2850.00	49.60	
2900.00	48.18	
2950.00	43.97	
2992.47	39.71	15.78
3000.00	38.08	13.41
3053.63	35.63	
3053.75	34.55	
3100.00	34.52	
3115.04	35.03	
3145.73	32.00	
3150.00	32.02	
3176.37	31.91	7.15
3200.00	34.71	
3250.00	38.99	
3300.00	40.00	
3350.00	39.69	15.37
3393.78	35.77	11.44
3400.00	35.68	

PIPE SIZE & TYPE: ø900 PE RISING MAIN, OPEN TRENCH CONSTRUCTION (CH 1600.00 – 2144.53); ø1350 RCRRJ GRAVITY MAIN, MICROTUNNEL CONSTRUCTION (CH 2144.53 – 3400.00)

SCALES : HOR, 1:5000 / VERT, 1:1000

DESIGNED :	RLXB	Jun. 16
DRAWN :	JC	Jun. 16
DESIGN CHECKED :	CJL	Jun. 16
DRAFTING CHECKED :	AMM	Jun. 16

CADFILE : \\28773.3420-F1_F4.dwg

APPROVED : NOT FOR CONSTRUCTION

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REVISION	DESCRIPTION	BY	DATE
0	First Issue		

NOTES :
1. All dimensions are in millimetres unless noted otherwise.
2. Layout plan and longsection supplied by MWH, reference drawing file name 2011119.005_007 & 2011123.005_007 – Geological Long Section" dated 11 Feb 2016.

REFERENCE :

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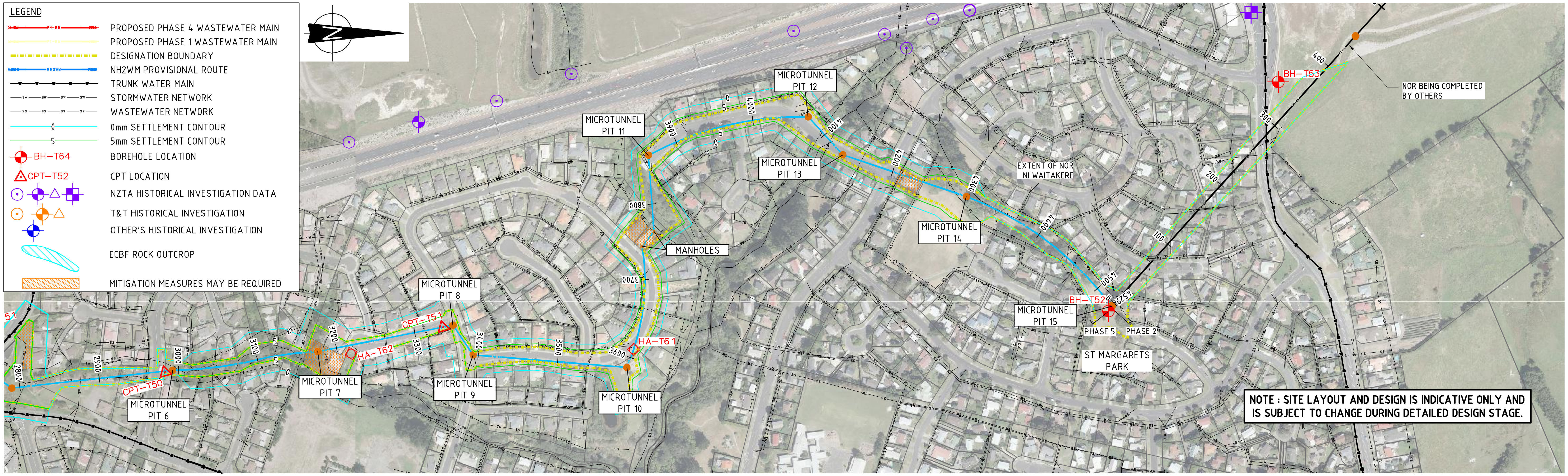
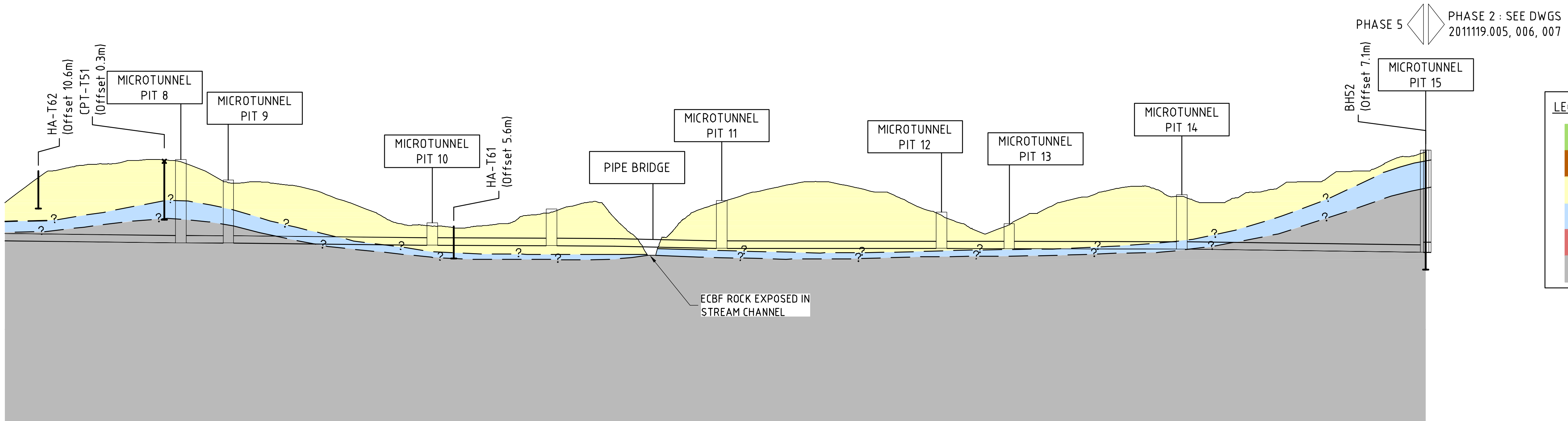
NORTHERN INTERCEPTOR PROJECT

TITLE
DESIGNATION DESIGN NOR NI WAITAKERE
Geological Long Section & Mechanical Settlement Contours: Sheet 2 of 10

SCALES (AT A3 SIZE): AS SHOWN
DWG. No.: Figure 2
REV.: 0

I:\28773\28773.3420\workingmaterial\CAD\FIG\28773.3420-F1_F4.dwg, 2011123.006, 14/06/2016 12:09:09 p.m., jc





LEGEND : LONG SECTION

- FILL
- MARINE MUDS
- TAURANGA GROUP
- WEATHERED ECBF
- ALBANY CONGLOMERATE
- ECBF ROCK (SPT N 50+)

CHAINAGE	GROUND LEVEL	DEPTH TO INVERT
3200.00	34.71	
3250.00	38.99	
3300.00	40.00	
3350.00	39.69	15.37
3393.78	35.77	11.44
3400.00	35.68	
3450.00	35.36	
3500.00	32.57	
3550.00	28.33	
3586.93	27.52	3.59
3600.00	27.44	
3650.00	27.98	
3664.41	28.43	
3700.00	30.21	6.34
3741.89	32.23	
3750.00	31.48	
3765.57	27.88	5.31
3800.00	22.83	
3850.00	31.34	
3861.36	32.09	8.70
3900.00	34.30	
3950.00	36.00	
3965.47	35.85	
4000.00	34.31	
4050.00	31.02	
4069.58	29.60	6.28
4100.00	26.95	
4133.81	27.78	4.46
4150.00	29.60	
4200.00	32.92	
4250.00	35.09	
[illegible]	[illegible]	
4300.00	33.11	9.95
4350.00	32.93	
4400.00	35.89	
4413.00	35.95	
4450.00	37.91	
4500.00	40.41	
4528.59	41.62	18.98

PIPE SIZE & TYPE: Ø1350 RCRRJ GRAVITY MAIN MICROTUNNEL CONSTRUCTION (3200.00 – 3700.00); Ø1350 RCRRJ GRAVITY MAIN OPEN TRENCH CONSTRUCTION (3700.00 – 3861.36); Ø1350 RCRRJ GRAVITY MAIN MICROTUNNEL CONSTRUCTION (3861.36 – 4528.59)

SCALES : HOR, 1:5000 / VERT, 1:1000

A3 SCALE 1: 1000 (V)
0 10 20 30 40 50 (m)

A3 SCALE 1: 5000 (H)
0 100 200 300 (m)

REV.	REVISION DESCRIPTION	BY	DATE
0	First Issue		

DESIGNED :	RLXB	Jun. 16
DRAWN :	JC	Jun. 16
DESIGN CHECKED :	CJL	Jun. 16
DRAFTING CHECKED :	AMM	Jun. 16

CADFILE : \\28773.3420-F1_F4.dwg

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NOTES :
1. All dimensions are in millimetres unless noted otherwise.
2. Layout plan and longsection supplied by MWH, reference drawing file name 2011119.005_007 & 2011123.005_007 – Geological Long Section" dated 11 Feb 2016.

REFERENCE :

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MWH
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WATERCARE SERVICES LIMITED
NORTHERN INTERCEPTOR PROJECT

TITLE
DESIGNATION DESIGN NOR NI WAITAKERE
Geological Long Section & Mechanical Settlement Contours: Sheet 3 of 10

SCALES (AT A3 SIZE): AS SHOWN
DWG. No.: Figure 3
REV.: 0

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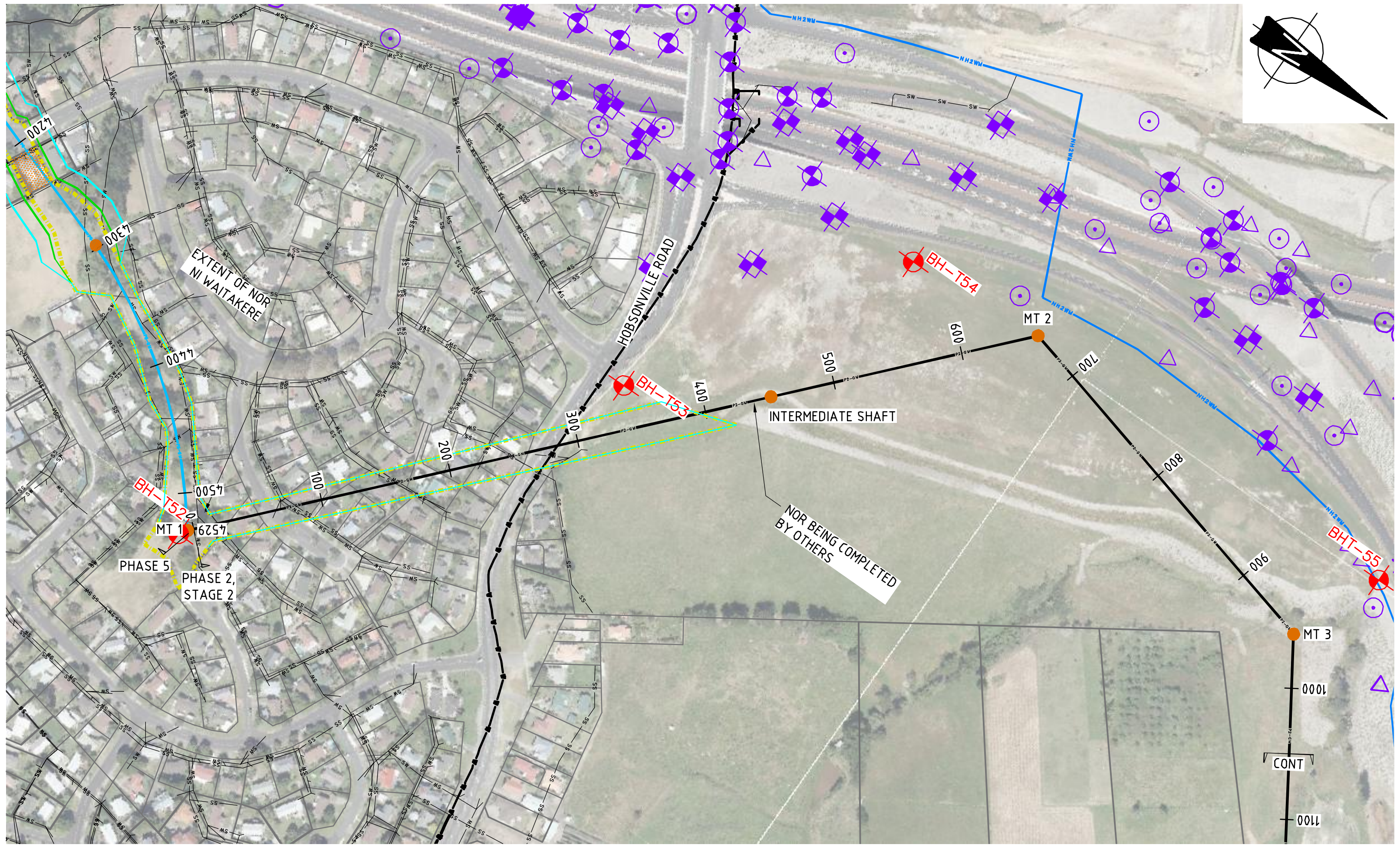
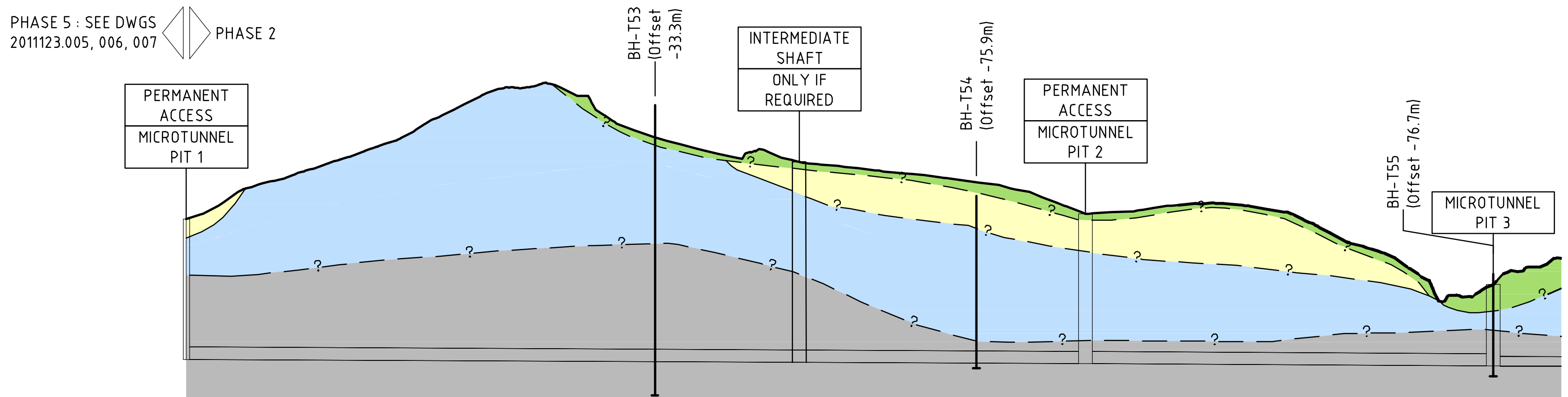
LEGEND

- PROPOSED PHASE 4 WASTEWATER MAIN
- PROPOSED PHASE 1 WASTEWATER MAIN
- DESIGNATION BOUNDARY
- NH2WM PROVISIONAL ROUTE
- TRUNK WATER MAIN
- STORMWATER NETWORK
- WASTEWATER NETWORK
- 0mm SETTLEMENT CONTOUR
- 5mm SETTLEMENT CONTOUR
- BH–T64 — BOREHOLE LOCATION
- CPT–T52 — CPT LOCATION
- NZTA HISTORICAL INVESTIGATION DATA
- T&T HISTORICAL INVESTIGATION
- OTHER'S HISTORICAL INVESTIGATION
- ECBF ROCK OUTCROP
- MITIGATION MEASURES MAY BE REQUIRED



LEGEND : LONG SECTION

- FILL
- MARINE MUDS
- TAURANGA GROUP
- WEATHERED ECBF
- ALBANY CONGLOMERATE
- ECBF ROCK (SPT N 50+)



DATUM = 0.00

CHAINAGE	50.00	100.00	150.00	200.00	250.00	300.00	350.00	400.00	450.00	500.00	550.00	600.00	650.00	700.00	750.00	800.00	850.00	900.00	950.00	1000.00
GROUND LEVEL	46.87	49.89	53.29	58.40	61.35	58.14	53.59	51.13	50.38	49.29	48.19	46.78	43.51	43.31	44.33	43.19	38.83	34.45	31.58	35.74

DEPTH TO INVERT: 20.51 (Pit 1); 21.92 (Pit 2); 11.88 (Pit 3)

PIPE SIZE & TYPE: PHASE 2, STAGE 2 : 1800 RCRRJ GRAVITY MAIN MICROTUNNELLED CONSTRUCTION

SCALES : HOR, 1:5000 / VERT, 1:1000

A3 SCALE 1: 1000 (V) — 0 10 20 30 40 50 (m)

A3 SCALE 1: 5000 (H) — 0 100 200 300 (m)

REVISION	DESCRIPTION	BY	DATE
0	First Issue		

DESIGNED :	RLXB	Jun. 16
DRAWN :	JC	Jun. 16
DESIGN CHECKED :	CJL	Jun. 16
DRAFTING CHECKED :	AMM	Jun. 16

CADFILE : \\28773.3420-F1_F4.dwg

APPROVED : NOT FOR CONSTRUCTION

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NOTES :
1. All dimensions are in millimetres unless noted otherwise.
2. Layout plan and longsection supplied by MWH, reference drawing file name 2011119.005_007 & 2011123.005_007 – Geological Long Section" dated 11 Feb 2016.

REFERENCE :

Tonkin+Taylor
105 Carlton Gore Road, Newmarket, Auckland
Tel. (09) 355 6000 Fax. (09) 307 0265
www.tonkintaylor.co.nz

CLIENT, PROJECT: WATERCARE SERVICES LIMITED
NORTHERN INTERCEPTOR PROJECT

TITLE: DESIGNATION DESIGN NOR NI WAITAKERE
Geological Long Section & Mechanical Settlement Contours: Sheet 4 of 10

SCALES (AT A3 SIZE): AS SHOWN | DWG. No.: Figure 4 | REV.: 0

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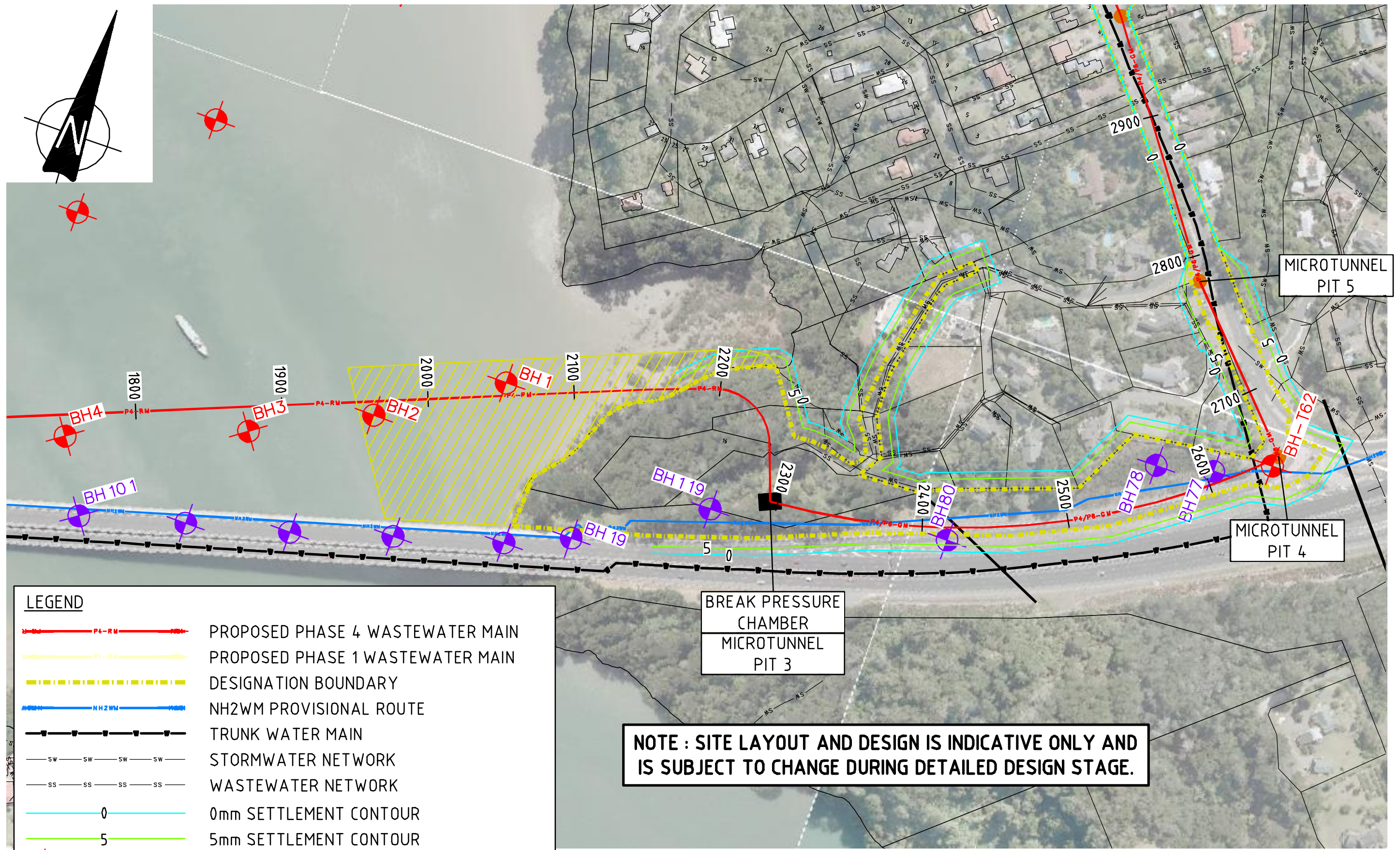
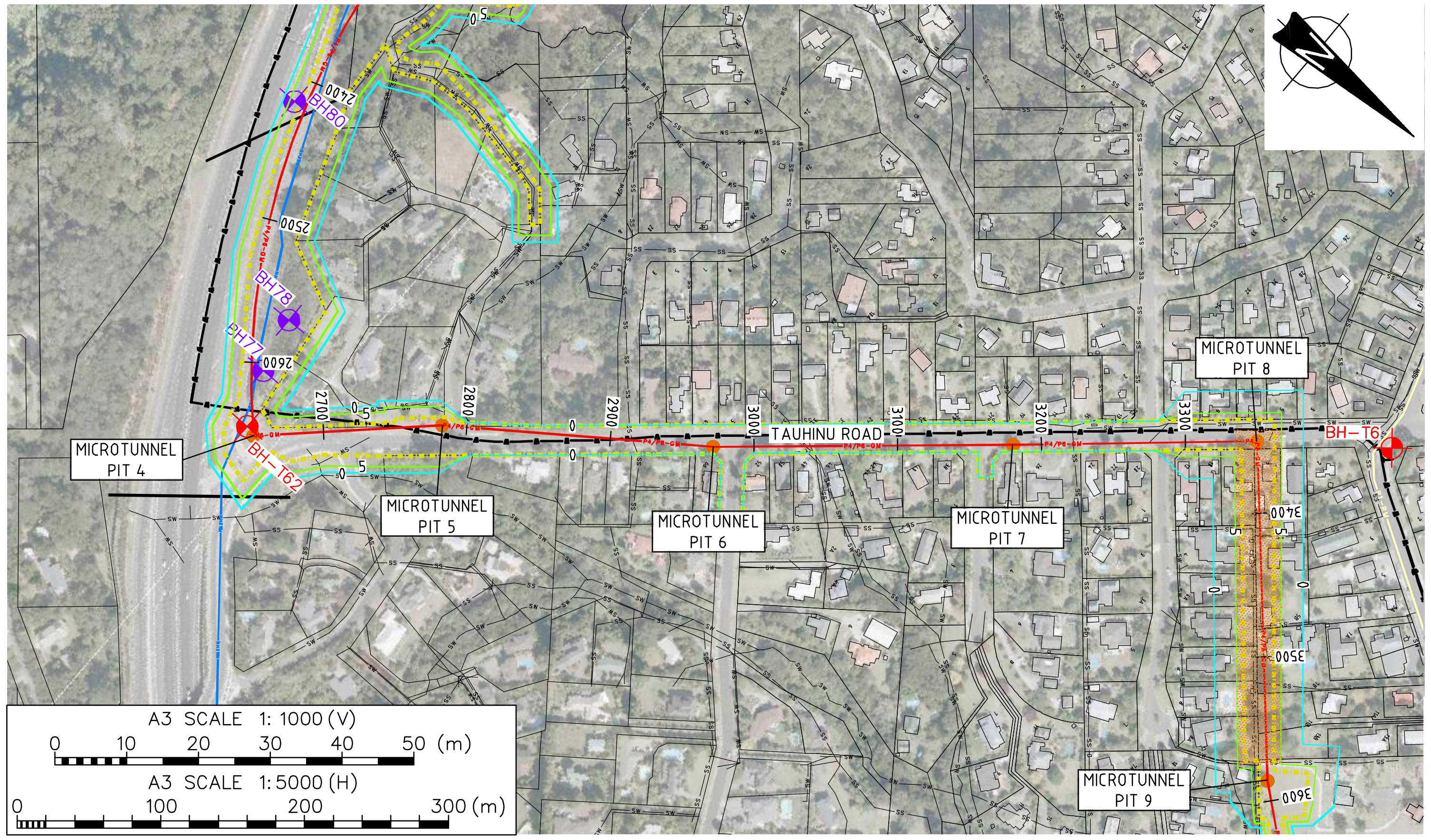


LEGEND

- PROPOSED PHASE 4 WASTEWATER MAIN
- PROPOSED PHASE 1 WASTEWATER MAIN
- DESIGNATION BOUNDARY
- NH2WM PROVISIONAL ROUTE
- TRUNK WATER MAIN
- STORMWATER NETWORK
- WASTEWATER NETWORK
- 0mm SETTLEMENT CONTOUR
- 5mm SETTLEMENT CONTOUR
- BH–T64 BOREHOLE LOCATION
- CPT–T52 CPT LOCATION
- NZTA HISTORICAL INVESTIGATION DATA
- T&T HISTORICAL INVESTIGATION
- OTHER'S HISTORICAL INVESTIGATION
- ECBF ROCK OUTCROP
- MITIGATION MEASURES MAY BE REQUIRED

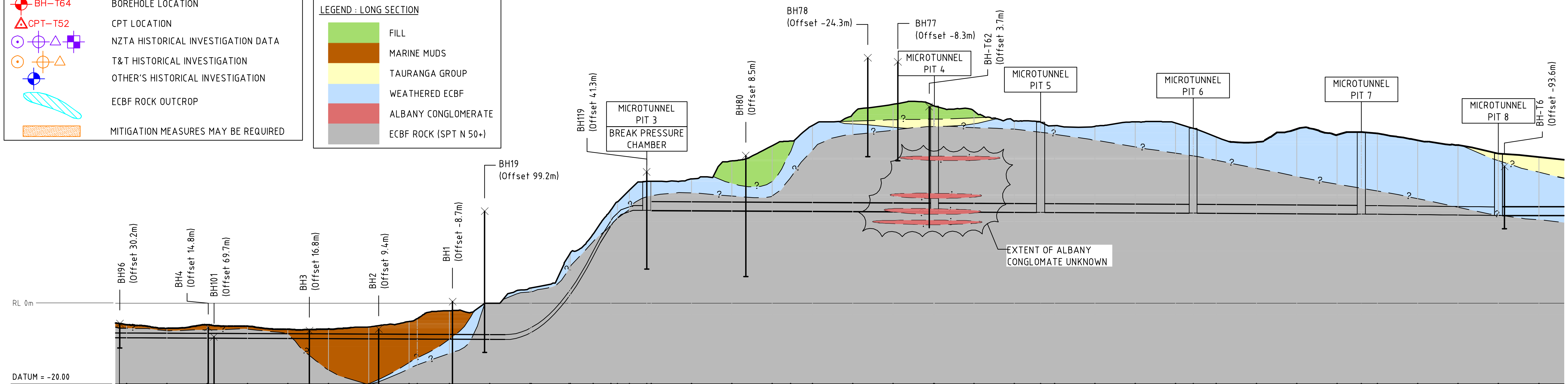
NOTE : SITE LAYOUT AND DESIGN IS INDICATIVE ONLY AND IS SUBJECT TO CHANGE DURING DETAILED DESIGN STAGE.



A3 SCALE 1: 1000 (V)
0 10 20 30 40 50 (m)
A3 SCALE 1: 5000 (H)
0 100 200 300 (m)

LEGEND : LONG SECTION

- FILL
- MARINE MUDS
- TAURANGA GROUP
- WEATHERED ECBF
- ALBANY CONGLOMERATE
- ECBF ROCK (SPT N 50+)



CHAINAGE	GROUND / SEABED PROFILE LEVEL	DEPTH TO INVERT
1650	-5.30	
1700	-6.22	
1750	-5.30	
1800	-5.71	
1850	-6.45	
1900	-6.40	
1950	-5.87	
2000	-4.52	
2010	-3.83	
2050	-1.89	
2100	0.00	
2151	3.80	
2200	12.47	
2228	17.12	
2250	23.08	
2258	25.10	
2273	27.98	
2295	30.18	
2300	30.22	7.17
2350	30.78	
2400	35.26	
2450	39.03	
2473	40.19	
2500	44.08	
2550	46.90	
2600	49.29	
2651	48.87	26.22
2700	47.65	
2750	45.14	
2783	44.84	22.32
2800	44.00	
2850	43.85	
2900	44.95	
2950	44.63	
2972	43.34	21.01
3000	41.23	
3050	39.91	
3100	43.15	
3150	41.72	
3180	42.43	20.33
3200	42.10	
3250	40.37	
3300	39.21	
3350	37.07	15.31
3400	36.23	

PIPE TYPE & SIZE: DN1200 PE RISING MAIN, MARINE TRENCH CONSTRUCTION (1650–2151); DN1200 OPEN TRENCH (2151–2300); DN2100 RCRRJ GRAVITY MAIN, MICROTUNNEL CONSTRUCTION (2300–3400)

SCALES : HOR, 1:5000 / VERT, 1:1000

DESIGNED :	RLXB	Jun. 16
DRAWN :	JC	Jun. 16
DESIGN CHECKED :	CJL	Jun. 16
DRAFTING CHECKED :	AMM	Jun. 16

CADFILE : \\28773.3420–F5_F10.dwg

APPROVED :

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REV.	REVISION DESCRIPTION	BY	DATE
0	First Issue		

NOTES :

1. All dimensions are in millimetres unless noted otherwise.
2. Layout plan and longsection supplied by MWH, reference drawing file name "2011114.005_011 – Geological Long Section" dated 11 Feb 2016.

REFERENCE :

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TITLE

DESIGNATION DESIGN NOR NI NORTHSHORE

Geological Long Section & Mechanical Settlement Contours: Sheet 5 of 10

SCALES (AT A3 SIZE): AS SHOWN

DWG. No.: Figure 5

REV.: 0

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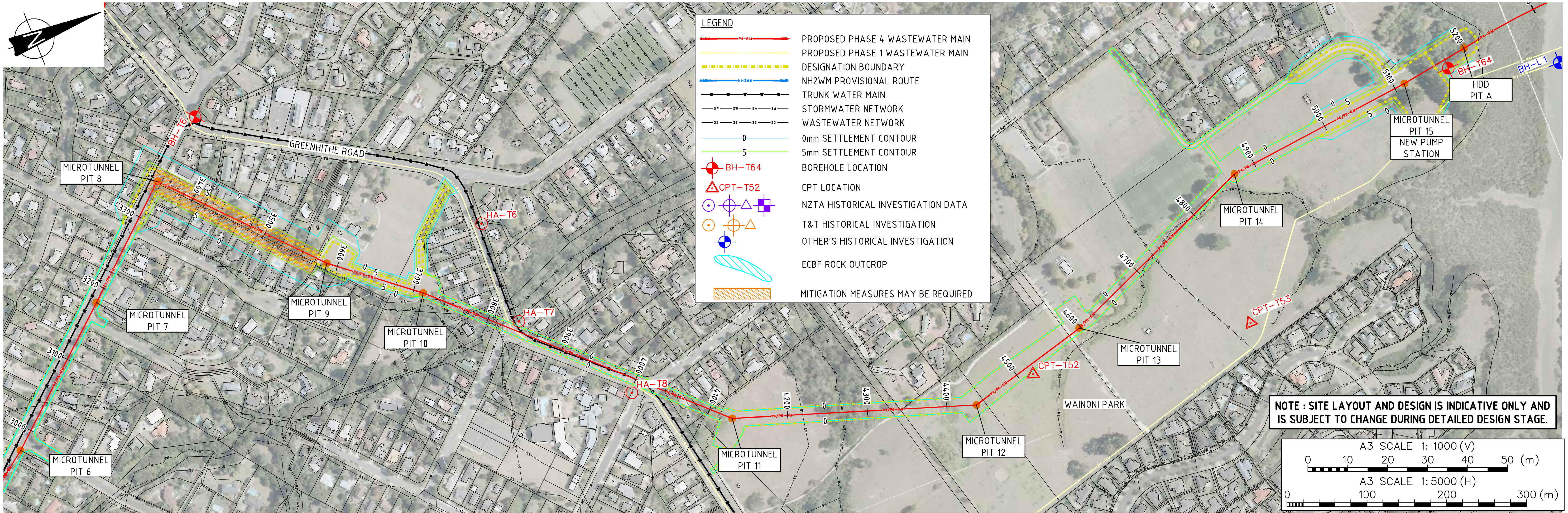

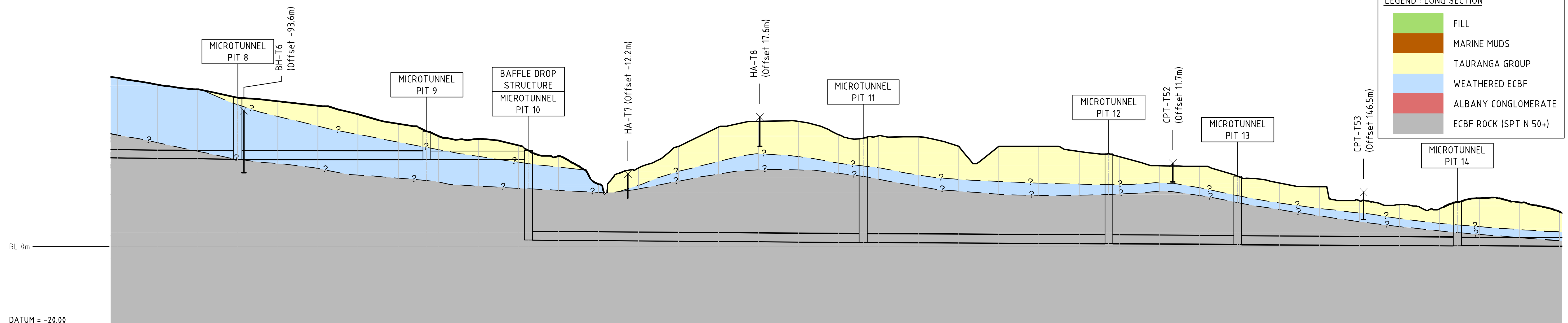

DATUM = -20.00

CHAINAGE	GROUND / SEABED PROFILE LEVEL	DEPTH TO INVERT
3200	42.10	
3250	40.37	
3300	39.21	
3350	37.07	15.31
3400	36.23	
3450	35.13	
3500	32.99	
3550	30.60	
3586	28.77	7.05
3600	27.59	
3650	26.80	
3700	25.75	2.75
3712	[illegible]	
3718	23.39	21.73
3750	22.60	
3800	15.57	
3850	19.62	
3900	25.00	
3950	29.86	
4000	31.23	
4050	31.24	
4100	27.87	
4131	27.01	25.92
4150	27.62	
4200	27.36	
4250	24.94	
4300	25.00	
4350	25.03	
4400	23.72	
4437	23.13	22.34
4450	22.42	
4500	20.16	
4550	20.01	
4600	17.42	17.06
4650	15.85	
4700	14.96	
4750	11.45	
4800	10.47	
4850	9.41	
4872	11.12	10.87
4900	12.09	
4950	11.03	
5000	8.68	

PIPE TYPE & SIZE: DN2100 RCRRJ GRAVITY MAIN, MICROTUNNEL CONSTRUCTION

SCALES : HOR, 1:5000 / VERT, 1:1000

DESIGNED :	RLXB	Jun. 16
DRAWN :	JC	Jun. 16
DESIGN CHECKED :	CJL	Jun. 16
DRAFTING CHECKED :	AMM	Jun. 16

CADFILE : \\28773.3420-F5_F 10.dwg

APPROVED :

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REVISION	DESCRIPTION	BY	DATE
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NOTES :
1. All dimensions are in millimetres unless noted otherwise.
2. Layout plan and longsection supplied by MWH, reference drawing file name "2011114.005_011 – Geological Long Section" dated 11 Feb 2016.

REFERENCE :

Tonkin+Taylor

MWH

Watercare Services
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WATERCARE SERVICES LIMITED
NORTHERN INTERCEPTOR PROJECT

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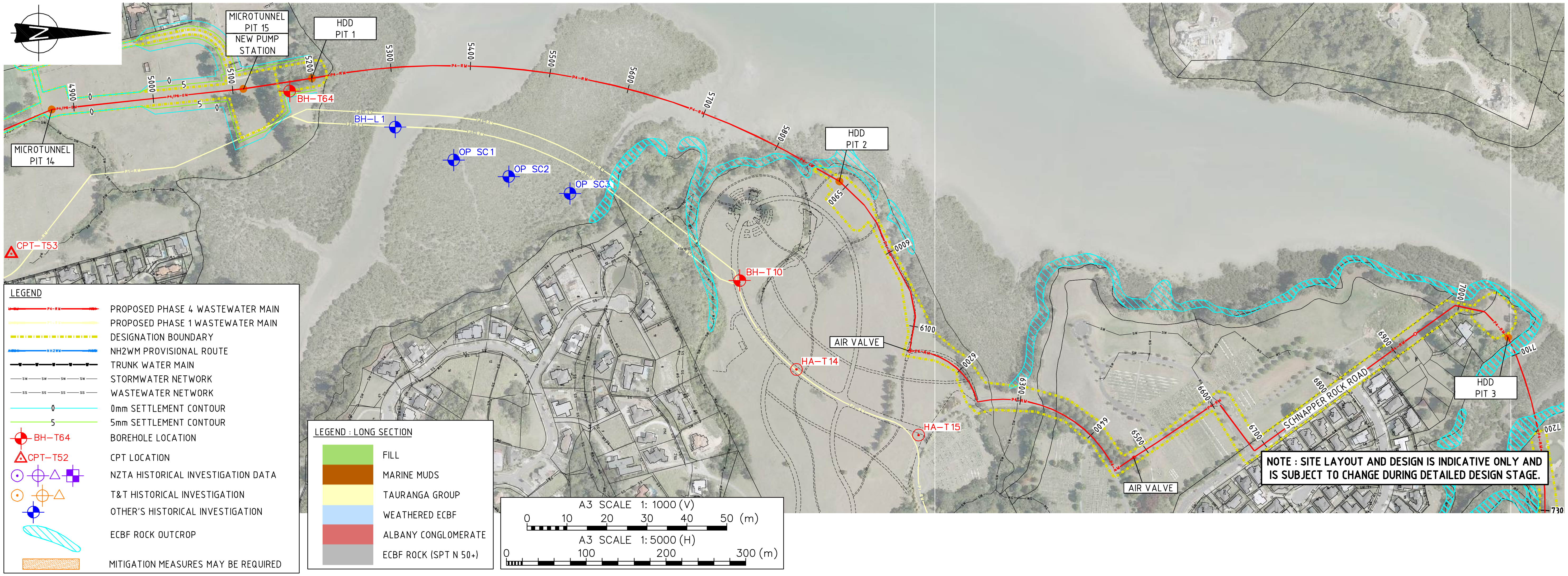
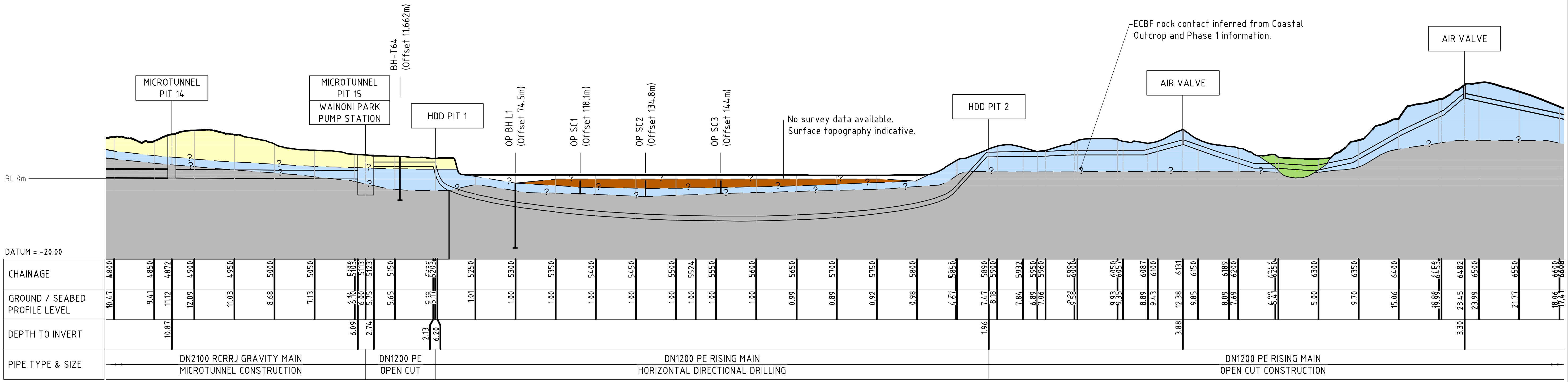
DESIGNATION DESIGN NOR NI NORTHSHORE
Geological Long Section & Mechanical Settlement Contours: Sheet 6 of 10

SCALES (AT A3 SIZE): AS SHOWN
DWG. No.: Figure 6
REV.: 0

I:\28773\28773.3420\workingmaterial\CAD\FIG\28773.3420-F5_F10.dwg, 2011114.007, 14/06/2016 12:11:09 p.m., jc





SCALES : HOR, 1:5000 / VERT, 1:1000

DESIGNED :	RLXB	Jun. 16
DRAWN :	JC	Jun. 16
DESIGN CHECKED :	CJL	Jun. 16
DRAFTING CHECKED :	AMM	Jun. 16
CADFILE : \\28773.3420-F5_F10.dwg		
APPROVED : NOT FOR CONSTRUCTION		

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REVISION	DESCRIPTION	BY	DATE
0	First Issue		

NOTES :
1. All dimensions are in millimetres unless noted otherwise.
2. Layout plan and longsection supplied by MWH, reference drawing file name "2011114.005_011 – Geological Long Section" dated 11 Feb 2016.

REFERENCE :

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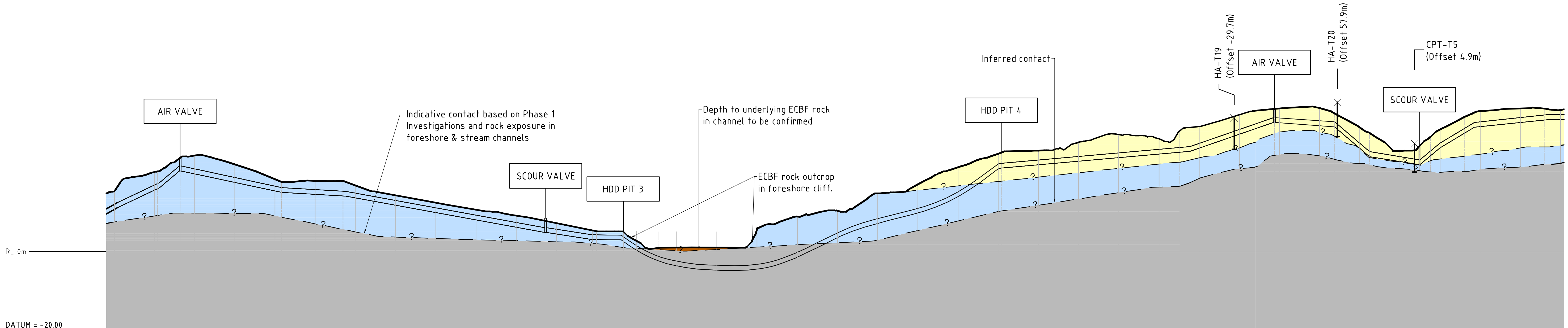
DESIGNATION DESIGN NOR NI NORTHSHORE
Geological Long Section & Mechanical Settlement Contours: Sheet 7 of 10

SCALES (AT A3 SIZE) AS SHOWN
DWG. No. Figure 7
REV. 0

NOTE : SITE LAYOUT AND DESIGN IS INDICATIVE ONLY AND IS SUBJECT TO CHANGE DURING DETAILED DESIGN STAGE.



CHAINAGE	GROUND / SEABED PROFILE LEVEL	DEPTH TO INVERT
6400	15.06	
[illegible]	[illegible]	
6453	19.99	
6482	23.45	3.30
6500	23.99	
6550	21.77	
6600	18.06	
6608	17.41	
6650	17.70	
6685	17.63	
6700	16.54	
6750	14.07	
6800	12.20	
6850	10.44	
6900	9.00	
6937	7.65	2.85
6950	7.13	
[illegible]	[illegible]	
7000	5.11	
7033	5.08	4.68
7050	5.10	
7077	5.00	
7100	5.00	
7150	5.00	
7200	5.85	
7250	8.73	
7290	10.30	
7300	10.20	
7350	14.52	
7400	16.79	
7450	21.03	
[illegible]	[illegible]	
7504	24.71	3.82
7550	25.20	
7600	27.27	
7650	29.20	
7700	28.13	
7726	30.11	
7750	31.24	
7800	34.12	
[illegible]	[illegible]	
7850	35.74	3.42
7900	35.83	
7918	34.52	
7950	30.98	
7962	29.60	
8000	25.12	
8024	26.32	4.57
8038	28.66	
8050	30.46	
8080	33.57	
8100	35.03	
8150	35.71	
8179	35.72	
8200	35.32	

PIPE TYPE & SIZE	Extent
DN1200 PE RISING MAIN – OPEN CUT CONSTRUCTION	6400 – 7033
DN1200 PE RISING MAIN – HORIZONTAL DIRECTIONAL DRILLING	7033 – 7504
DN1200 PE RISING MAIN – OPEN CUT CONSTRUCTION	7504 – 8200

SCALES : HOR, 1:5000 / VERT, 1:1000

REVISION	DESCRIPTION	BY	DATE
0	First Issue		

DESIGNED :	RLXB	Jun. 16
DRAWN :	JC	Jun. 16
DESIGN CHECKED :	CJL	Jun. 16
DRAFTING CHECKED :	AMM	Jun. 16

CADFILE : \\28773.3420–F5_F10.dwg

APPROVED :

NOT FOR CONSTRUCTION

This drawing is not to be used for construction purposes unless signed as approved

NOTES :

1. All dimensions are in millimetres unless noted otherwise.
2. Layout plan and longsection supplied by MWH, reference drawing file name "2011114.005_011 – Geological Long Section" dated 11 Feb 2016.

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TITLE
DESIGNATION DESIGN NOR NI NORTHSHORE
Geological Long Section & Mechanical Settlement Contours: Sheet 8 of 10

SCALES (AT A3 SIZE): AS SHOWN
DWG. No.: Figure 8
REV.: 0

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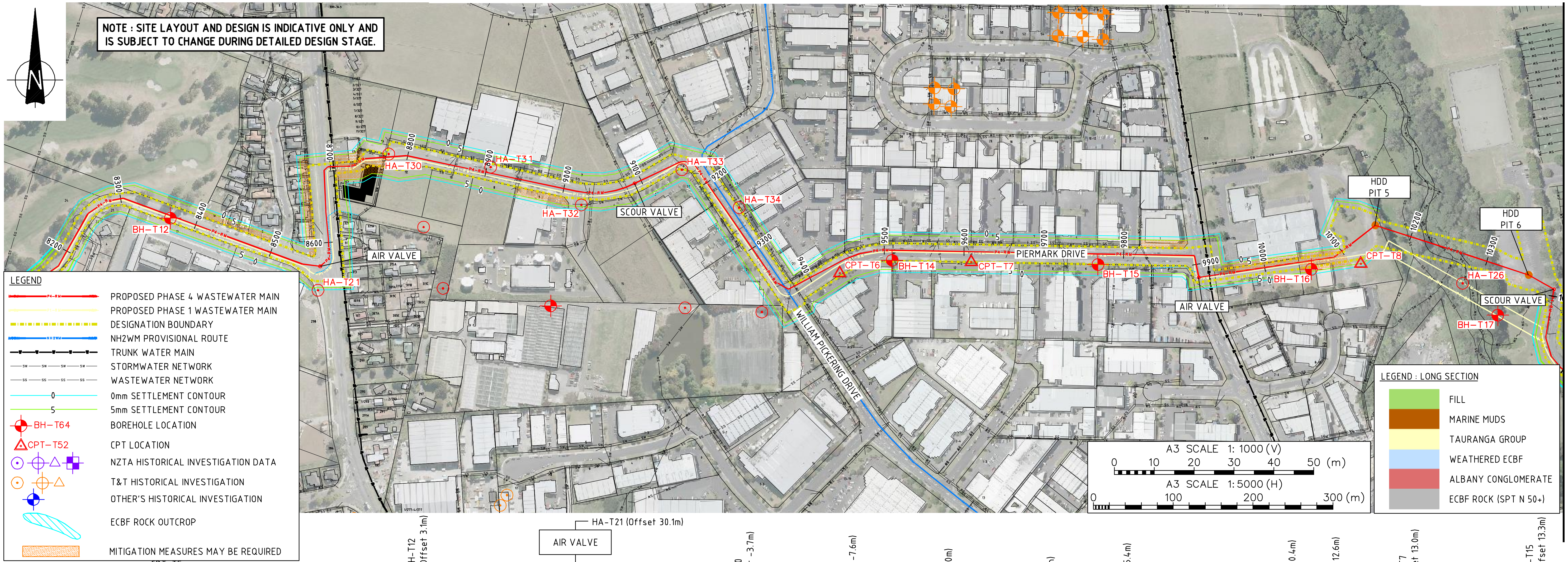

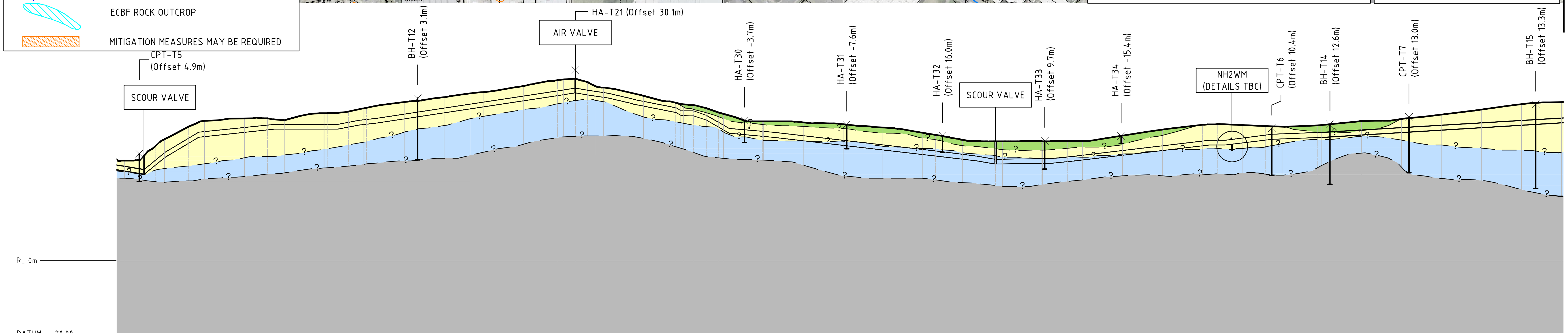

DATUM = -20.00

CHAINAGE	GROUND / SEABED PROFILE LEVEL	DEPTH TO INVERT
8000	25.12	
8024	26.32	4.57
8038	28.66	
8050	30.46	
8080	33.57	
8100	35.03	
8150	35.71	
8179	35.72	
8200	35.32	
8250	34.08	
8254	37.00	
8280	37.38	
[illegible]	[illegible]	
8303	38.35	
8350	39.80	
8400	41.02	
8450	42.26	
8500	43.83	
8542	45.25	
8550	45.46	3.54
8565	45.62	
8580	44.76	
8600	43.46	
8650	41.37	
8691	39.59	
8700	39.23	
8713	38.99	
8729	38.22	
8744	37.15	
8750	36.83	
8800	34.95	
8850	34.73	
8900	34.22	
8950	33.41	
9000	32.12	
9016	31.58	
[illegible]	[illegible]	
9053	30.19	
9091	30.00	5.71
9100	30.00	
[illegible]	[illegible]	
9150	30.00	
9165	30.00	
9181	30.00	
9200	30.00	
9250	31.38	
9300	32.89	
9350	34.09	
9370	34.27	
9400	33.99	
9429	33.73	
9450	33.63	
9495	33.96	
9500	34.06	
9550	35.01	
9600	35.54	
9650	36.67	
9700	37.92	
9750	39.28	
9800	39.81	

PIPE TYPE & SIZE: DN1200 PE RISING MAIN, OPEN CUT CONSTRUCTION

SCALES : HOR, 1:5000 / VERT, 1:1000

DESIGNED :	RLXB	Jun. 16	
DRAWN :	JC	Jun. 16	
DESIGN CHECKED :	CJL	Jun. 16	
DRAFTING CHECKED :	AMM	Jun. 16	

CADFILE : \\28773.3420-F5_F10.dwg

APPROVED :

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REVISION	DESCRIPTION	BY	DATE
0	First Issue		

NOTES :

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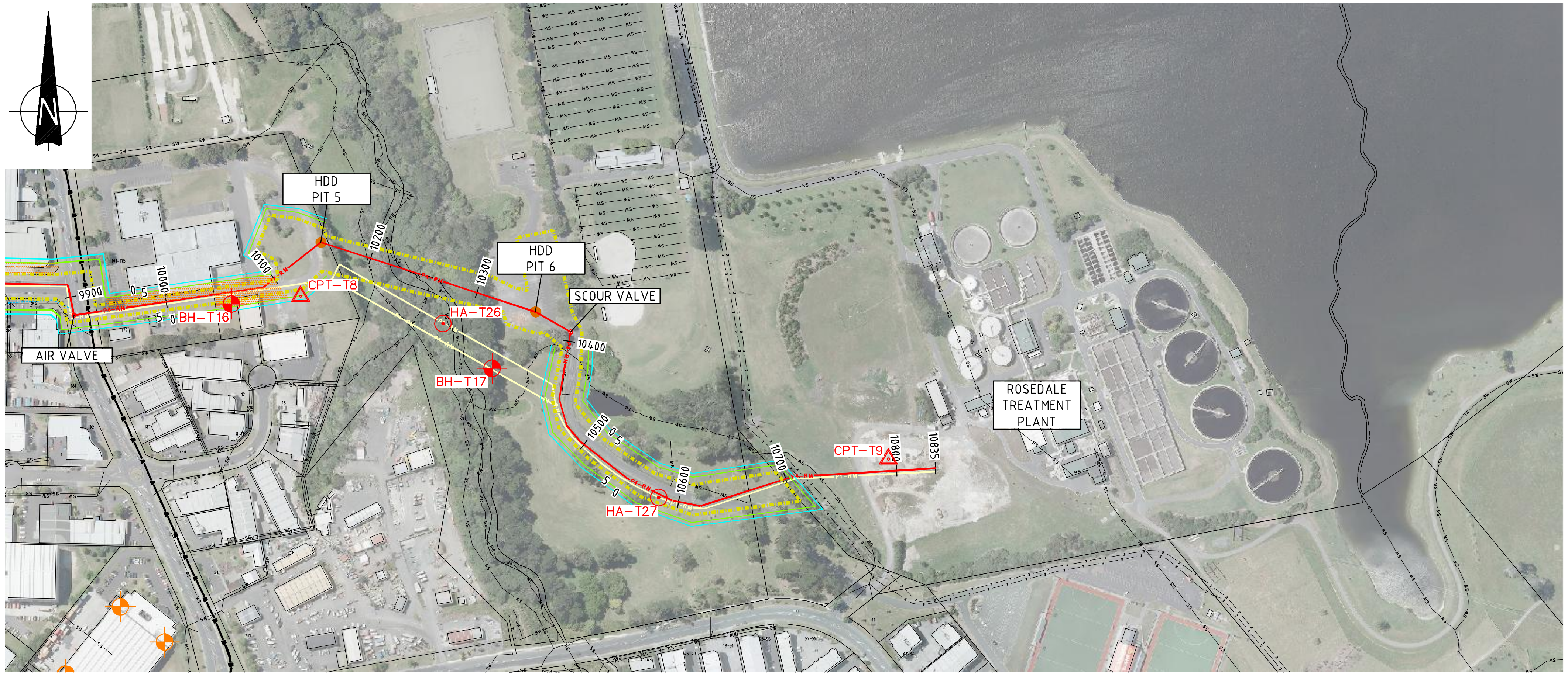
TITLE
DESIGNATION DESIGN NOR NI NORTHSHORE
Geological Long Section & Mechanical Settlement Contours: Sheet 9 of 10

SCALES (AT A3 SIZE): AS SHOWN
DWG. No.: Figure 9
REV.: 0

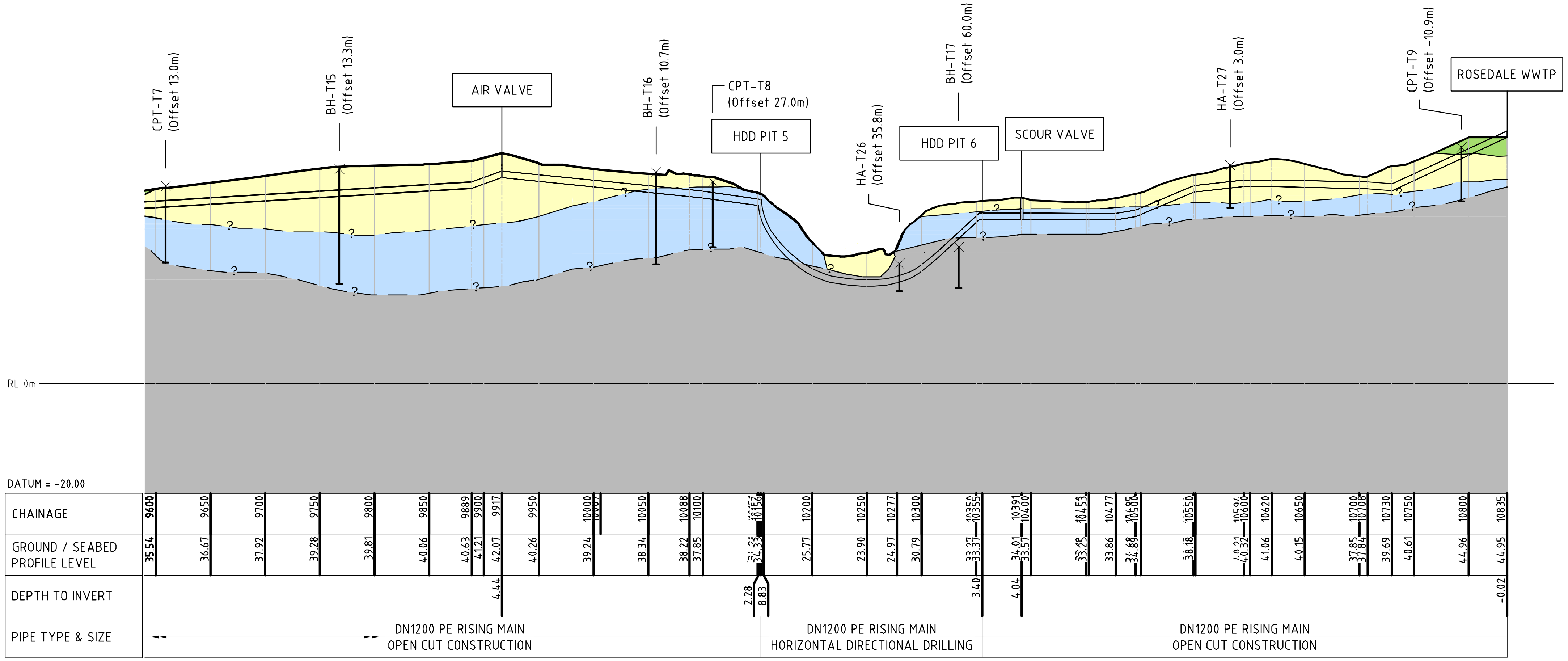


LEGEND

- PROPOSED PHASE 4 WASTEWATER MAIN
- PROPOSED PHASE 1 WASTEWATER MAIN
- DESIGNATION BOUNDARY
- NH2WM PROVISIONAL ROUTE
- TRUNK WATER MAIN
- STORMWATER NETWORK
- WASTEWATER NETWORK
- 0mm SETTLEMENT CONTOUR
- 5mm SETTLEMENT CONTOUR
- BH-T64 BOREHOLE LOCATION
- CPT-T52 CPT LOCATION
- NZTA HISTORICAL INVESTIGATION DATA
- T&T HISTORICAL INVESTIGATION
- OTHER'S HISTORICAL INVESTIGATION
- ECBF ROCK OUTCROP
- MITIGATION MEASURES MAY BE REQUIRED

NOTE : SITE LAYOUT AND DESIGN IS INDICATIVE ONLY AND IS SUBJECT TO CHANGE DURING DETAILED DESIGN STAGE.

A3 SCALE 1: 1000 (V)
0 10 20 30 40 50 (m)
A3 SCALE 1: 5000 (H)
0 100 200 300 (m)



LEGEND : LONG SECTION

- FILL
- MARINE MUDS
- TAURANGA GROUP
- WEATHERED ECBF
- ALBANY CONGLOMERATE
- ECBF ROCK (SPT N 50+)

SCALES : HOR, 1:5000 / VERT, 1:1000

DESIGNED :	RLXB	Jun. 16	
DRAWN :	JC	Jun. 16	
DESIGN CHECKED :	CJL	Jun. 16	
DRAFTING CHECKED :	AMM	Jun. 16	
CADFILE : \\28773.3420-F5_F 10.dwg			
APPROVED : NOT FOR CONSTRUCTION			

This drawing is not to be used for construction purposes unless signed as approved

REVISION	DESCRIPTION	BY	DATE
0	First Issue		

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TITLE
DESIGNATION DESIGN NOR NI NORTHSHORE
Geological Long Section & Mechanical Settlement Contours: Sheet 10 of 10

SCALES (AT A3 SIZE) AS SHOWN
DWG. No. Figure 10
REV. 0

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Appendix C: Historical ground investigations

C1 Site investigations

C1.2 Information available from other projects and sources

C1.2.1 Hobsonville wastewater pump station

T&T carried out investigations for the Hobsonville Wastewater Pump Station upgrade in 2009. The investigations included drilling of 1 No machine borehole to 19.5m depth (BH1) using rotary drilling and 3 No machine boreholes to 6m depth (BH2, BH3, BH3A) using percussion techniques. Standpipe piezometers were fitted in the boreholes and divers were installed at 5.5m b.g.l. in BH1 and at 0.8 to 4m b.g.l. in BH3. Consolidation tests for settlement estimate purposes were carried out at 4.85m and 11.4m b.g.l. in BH1.

The ground investigations also included 4 No. CPT tests with dissipation tests at selected depths. The CPTs extended between 11.9m and 13.3m b.g.l. The investigation locations are illustrated on 28773.210-F1 to F6 but are not attached to this report.

C1.2.2 SH18 and SH16 investigation data

The New Zealand Transport Agency (NZTA) commissioned ground investigation information for the approaches and pier locations for the new SH18 upgrade. Watercare and NZTA have an agreement in place to make that historic borehole information available to the Northern Interceptor project to supplement the specific ground investigation data that has been obtained as part of the marine investigation package.

The locations of historic ground investigation boreholes are illustrated in Appendix B as guidance, although that information is not collated in this document.

C 1.2.3 Schnapper Rock development

T&T was involved in the development of the Schnapper Rock sub-division and carried out numerous hand auger boreholes and construction observations across the sub-division area. The area has been subject to large scale earthworks to form level platforms for the lots.

C 1.2.4 North Shore Golf Course

The North Shore Golf Course holds an existing Consent to extract groundwater from the Waitemata aquifer. The consent allows the golf course to extract a combined total 50,500m^3/year from three boreholes. Bore 1 (ref no 32432) is located near Appleby Road and the proposed Northern Interceptor alignment, as shown on the Borehole Location plans in Appendix B.