Report

Groundwater Dewatering and Ground Settlement Effects Assessment

Review of Awakeri Wetlands Stage 1 Construction and Assessment for Stages 2 and 3

Prepared for Winton Limited

Prepared by Earthtech Consulting Limited

13 June 2024

Reference: R10015-1, Rev. B

EARTHTECH

Document Control

Groundwater Dewatering and Ground Settlement Effects Assessment

Review of Awakeri Wetlands Stage 1 Construction and Assessment for Stages 2 and 3

Client: Winton Limited

Authors: Michelle Willis, Senior Geotechnical Engineer, CMEngNZ, CPEng
michelle.willis@earthtech.co.nz

Earthtech Consulting Limited
47 West Street, PO Box 721, Pukekohe 2340
+64 9 238 3669
admin@earthtech.co.nz
www.earthtech.co.nz

Document Control			
Reference	Revision	Date	Status
R10015-1	Draft	29/04/2024	For client review
R10015-1	Draft, Rev. A	11/06/2024	Update following client feedback
R10015-1	Draft, Rev. B	13/06/2024	Update to report references
R10015-1	Final, Rev. B	13/06/2024	Finalised without further changes

Executive Summary

Stages 2 and 3 of the Awakeri Wetlands are soon to be constructed, with Stage 2 comprising a culvert under Cosgrave Road and the Watercare Waikato No. 1 pipeline, and Stage 3 extending the channel to the east and south to intersect the existing channel at Old Wairoa Road. Stages 1 to 3 are located in an area of peat extending to approximately 20*m* depth, which is well known for its high settlement potential in response to dewatering activities.

Part 1 of this report presents an assessment of the monitoring records obtained during Stage 1 construction. This shows that a groundwater mound generally between 0.3*m* to 0.7*m* (and locally up to 1*m*) in height has developed on the north-eastern side of Stage 1, attributed to the groundwater cut-off walls obstructing horizontal groundwater flow. The groundwater mound is associated with up to 60*mm* of ground settlement, which is considered to be occurring due to changes in the peat bulk density due to saturation.

Ground level monitoring also shows that the site experiences significant natural ground level movement due to the peat response to moisture changes, with settlement or heave of +/- 10*mm* to 20*mm* month-by-month, and a 40*mm* range seasonally.

These natural ground movements are mirrored in the movement of the Waikato No. 1 pipeline, with monitoring records indicating that the pipeline experiences displacement in the order of +/- 20*mm* to 40*mm*, and up to 60*mm*. These pipeline movements correspond to differential settlement gradients between 1v:300h to 1v:700h. Comparison against as-built records also indicates that the pipeline has experienced between 170*mm* to 340*mm* of permanent settlement since construction in 2006.

Part 2 of this report presents groundwater dewatering and ground settlement assessments for the construction of Stages 2 and 3, incorporating learnings from Stage 1. To define the envelope of settlement effects, an independent assessment of drawdown and ground settlement has been carried out for the Waikato No. 1 pipeline along Cosgrave Road. This has been used to define settlement effects in the vicinity of the Cosgrave Road culverts. The GHD drawdown prediction has conservatively been used to bound the envelope of effects for the Stage 2 and 3 areas.

The Cosgrave Road assessments indicate up to 1.1*m* of drawdown during construction and 0.6*m* of drawdown in the long-term, at the outside of the groundwater cut-off walls. With only the 7*m* deep groundwater cut-off walls providing drawdown mitigation, the analyses show a settlement (primary plus secondary consolidation) of 300*mm* +/- 50% over a 5*yr* period following culvert construction, with differential settlement steeper than 1v:180h. Additional mitigation in the form of screw piles has been conceptually described as a means to limit settlements effecting the pipeline to 50*mm* and flatter than 1v:200h (provisional limits, to be confirmed or modified by a pipeline specialist and agreed with Watercare).

The expected groundwater mounding on the northern side of the channel can be capped by the installation of a subsoil drain at the pre-development winter high groundwater elevation. In this area north of the subsoil drain, no drawdown or ground settlement is expected, however the area should still be monitored as part of the Groundwater and Settlement Monitoring and Contingency Plan due to uncertainty associated with the groundwater mounding mechanism.

Further mitigation options are available to ensure that damage can be avoided if settlement effects are larger than predicted.

Contents

Contents

Tables

Figures

Appendices

Groundwater Dewatering and Ground Settlement Effects Assessment

Review of Awakeri Wetlands Stage 1 Construction and Assessment for Stages 2 and 3

1. Introduction

The Awakeri Wetlands provide a stormwater conveyance channel which services areas of new residential development in eastern Takanini. Stage 1 of the channel was constructed between August 2018 to July 2020. Stages 2 and 3 are soon to be constructed, with Stage 2 comprising a culvert under Cosgrave Road and the Watercare Waikato No. 1 pipeline, and Stage 3 extending the channel to the east and south to intersect the existing channel at Old Wairoa Road. Figure 1 shows the extent of Stages 1 to 3.

Stages 1 to 3 are located in an area mapped as Holocene swamp deposits (Edbrooke, 2001), with ground conditions consisting of peat extending to approximately 20*m* depth. The peat is well known for its high settlement potential in response to dewatering activities.

This report is divided into two parts:

i. Part 1 presents an independent review of the groundwater level and ground settlement monitoring data which was collected during and after Stage 1 construction. The data is compared to the drawdown and ground settlement predictions which were made at the time of Stage 1 consenting. Part 1 includes back-analysis of the past monitoring records to help inform the ground settlement risk for Stage 2 and 3 construction.

ii. Part 2 presents groundwater dewatering and ground settlement assessments for the construction of Stages 2 and 3, incorporating learnings from Stage 1.

PART 1: Stage 1 Construction Observations

2. Stage 1 Construction Methodology and Monitoring

2.1 Stage 1 Construction

Stage 1 involved the construction of 2.1*km* of stormwater channel, extending to depths between 1.9*m* to 4*m* below original ground levels. A typical channel cross section is shown on Figure A. Full details are presented in the associated geotechnical investigation, hydrogeological, and settlement assessment reports (GHD, 2016a, b, and c).

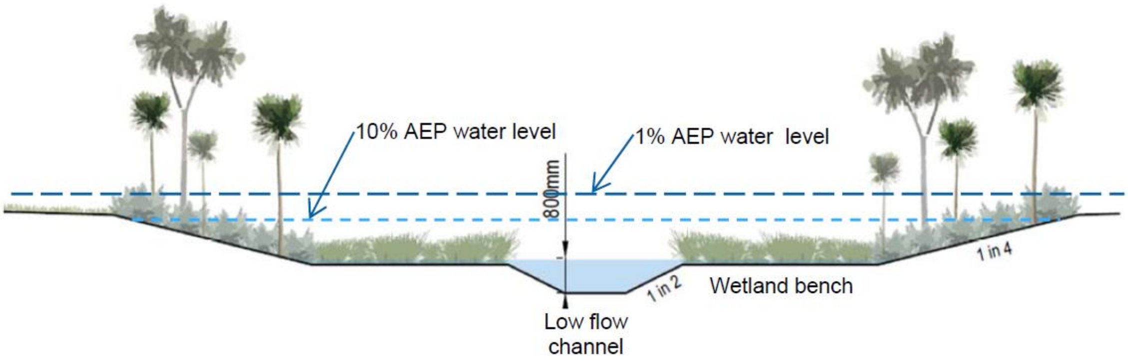


Figure A: Typical Channel Cross-section (sourced from GHD, 2016c).

A shallow unconfined aquifer is present across the site within the peat. Prior to the Stage 1 development, groundwater levels were relatively shallow at 1*m* to >1.5*m* depth in Stage 1, 1*m* to 1.5*m* depth in Stage 2, and <0.5*m* to 1*m* depth in Stage 3 (GHD, 2016c). The overall groundwater flow direction is towards the south-west, towards the existing McClennan Wetland.

Stage 1 construction involved dewatering to lower groundwater levels up to 2.6*m* below measured summer low levels during construction, with long-term drawdown up to 1.8*m* below the measured summer low levels ("measured summer low levels" based on monitoring information available at the time of Stage 1 consenting). Groundwater cut-off walls were installed to limit off-site drawdown effects. Weirs were also installed at regular intervals within the channel to maintain a minimum water depth of 0.8*m*, to limit long-term groundwater drawdown effects.

Bulk earthworks and dewatering began in August 2018, and dewatering associated with construction activities ceased in November 2019. Practical completion was achieved by 31 July 2020 following the construction of boardwalks, planting, etc.

Development of adjacent sites into subdivision (including preloading) was occurring during and after Stage 1 construction. In terms of the groundwater regime, the adjacent subdivisions are required to discharge the first 15*mm* of each rainfall event to in-ground soakage, to maintain recharge to the peat. As the majority of rainfall events are < 15*mm*, this represents a significant source of groundwater recharge which has been considered by this assessment. Overflow from rainfall events > 15*mm* is ultimately discharged into the Stage 1 wetland.

2.2 Groundwater Cut-off Walls

To limit dewatering effects, a 7*m* deep cement-bentonite groundwater cut-off wall was constructed around parts of the Stage 1 channel. Obstructions, such as the numerous buried tree trunks within the peat, were removed with an excavator mounted core barrel or over-excavated (Healthy Waters, 2024).

As-built records indicate that the 7*m* deep cut-off wall was completed to full depth without gaps, and any subsequent buried services excavations which penetrated the wall are also reported to have been sealed. With the 7*m* deep cut-off wall in place, long-term groundwater drawdowns were predicted to be < 1*m* outside of the wall (GHD, 2016b).

During initial excavations it was found that significant groundwater inflow was occurring in the upper 0.5*m* to 1*m* of soil profile, which was impractical to control by pumping. This was attributed to fibrous peat within the shallow root zone (March Construction, undated). A 3*m* deep bentonite slurry wall was constructed around the remainder of the Stage 1 excavation to cut-off the shallow groundwater inflow and control pumping volumes.

The as-built extents of the 3*m* and 7*m* deep cut-off walls are shown on Figure 1. Construction of the 7*m* deep slurry wall commenced in late 2016 and was completed by October 2017. Available records suggest that construction of the 3*m* deep slurry wall was carried out in late-2017.

2.3 Monitoring Records

Extensive groundwater level and settlement (ground, building and pipeline settlements) monitoring was carried out during Stage 1 construction and continued up to 3*yrs* after Stage 1 completion. The monitoring data was assessed by GHD, compared against consented limits, and discussed in various monitoring reports.

To provide wider context to the settlement response of the site, the main findings of the monitoring are summarised as follows (from GHD, 2022):

- The peat undergoes shrink/swell movement in response to soil moisture changes and rainfall. This indicated a settlement or heave of +/- 10*mm* to 20*mm* month-by-month, and 40*mm* range seasonally (i.e. a seasonal range of 40*mm* from peak to trough).
- Many of the ground and groundwater level monitoring baselines were set in 2017 and 2018, during a time of relatively wet weather.
- Following dewatering ceasing in November 2019, a drought occurred in the summer of 2019/2020 with the highest potential evapotranspiration deficit since record began in 1942.
- Many ground settlement alarm and groundwater level alert thresholds were triggered during the 2019/2020 and 2020/2021 summers, which were attributed to drought effects as construction dewatering had ceased. This was also supported by a wider decline in ground and groundwater levels recorded at monitoring locations distant from the Awakeri Wetlands.
- Aside from the drought condition, groundwater levels were noted to be highly responsive to rainfall, with a groundwater peak occurring generally two weeks after each significant rainfall event.
- Groundwater level seasonal variation is generally between 1*m* to 2*m*, but was noted by GHD (2016a) to be up to 5*m* for boreholes located adjacent to trees.
- Building settlement monitoring recorded numerous differential settlement triggers both during and after dewatering, which mostly occurred due to one pin heaving relative to another

pin settling at either end of the foundation. These triggers were not attributed to Stage 1 dewatering (therefore, building settlement monitoring has not been assessed by this report).

- Groundwater levels had generally stabilised by winter 2020, with a regular seasonal pattern resuming between winter 2020 to monitoring ceasing in winter 2022.
- Ground settlement monitoring was also significantly affected by preloading on the adjacent subdivision sites. Three of the ten adjacent properties were preloaded during Stage 1 construction, and an additional three had been preloaded by mid-2021. Some dewatering for buried service installation was also carried out as part of subdivision developments.
- In summary, no ground, building, or groundwater level trigger exceedances were attributed to the Stage 1 dewatering or construction activities.

The above summary indicates that there are multiple seasonal and external factors which influence groundwater drawdowns, and particularly ground settlements. Therefore, the timing of effects is imperative when reviewing the Stage 1 monitoring data. Timing has been carefully considered in the following groundwater and settlement assessments and back-analyses.

3. Groundwater Drawdown Effects

3.1 Methodology

The GHD (2022) monitoring data shows that groundwater levels are highly responsive to rainfall at the site. It is also noted that groundwater levels take time to stabilise following Stage 1 construction, as groundwater levels are permanently lowered by the new channel. Ground settlements are governed by drawdown below previous summer low groundwater levels.

This study has assessed permanent changes in groundwater levels by comparing the lowest levels measured prior to construction, against the lowest levels measured in the summer of 2020/2021 (16*mths* since dewatering ceased).

The methodology is as follows:

1. The GHD (2022) baseline groundwater levels were not used, as this assessment seeks to compare summer lows measured during seasons with similar antecedent rainfall conditions, and the baselines are known to have been set during a period of relatively wet weather.
2. The monitoring record shows that groundwater levels had stabilised by winter 2020. Therefore, the assessment to the summer of 2020/2021 (lowest levels measured in March 2021) is considered to indicate the long-term change in groundwater levels in response to Stage 1 construction. As at the summer of 2020/2021, only three of the adjacent ten subdivisions were under development, which minimises potential external effects.
3. The summer of 2021/2022 has not been used in this assessment. Although this could provide a longer monitoring record, the data has not been used due to potential external drainage influences from the adjacent subdivisions, and unavailable groundwater monitoring data at approx. one-third of the monitoring locations (cessation of monitoring following construction).

4. Pre-construction summer low groundwater levels are available for the summers of 2014/2015 (lowest levels measured in February 2015) and 2017/2018 (lowest levels measured in December 2017). The levels measured in February 2015 have been used in this assessment, with data from December 2017 substituted where earlier records are not available. It is noted that the December 2017 records may be beginning to experience the effects of the groundwater cut-off wall installation, which was completed in late 2017 – this is conservative as it means that drawdown may be over-predicted. December 2017 records were not used in the area to the north-east of Stage 1.
5. To check if the pre- and post-construction comparison is valid given the groundwater response to rainfall, the antecedent rainfall condition for each summer low is summarised in Table 1. Comments as follows:
    a. The antecedent condition has been checked in terms of both rainfall, and rainfall minus potential Penman evapotranspiration.
    b. The three-month antecedent condition is often the most appropriate when correlating groundwater levels for shallow unconfined aquifers. The one-month and six-month antecedent conditions are also included in the check, given the short groundwater response time after storm events reported by GHD (2022), and potential for longer seasonal effects.
    c. Table 1 shows that the summer of 2014/2015 is comparable to the summer of 2020/2021, particularly for the 3*mth* antecedent condition. The summer of 2017/2018 was slightly wetter but still broadly comparable, and has been used to substitute data where the earlier record is unavailable.

Table 1: Antecedent Rainfall Conditions for Groundwater Assessment
(records sourced from https://cliflo.niwa.co.nz/, for the Auckland Airport weather station)

Antecedent Condition		Summer 2014/2015 (Feb 2015)	Summer 2017/2018 (Dec 2017)	Summer 2020/2021 (March 2021)
1*mth* antecedent	Rainfall (*mm*)	13.6	23	49.2
	Rainfall minus ET (*mm*)	-167.7	-108.3	-92.3
3*mth* antecedent	Rainfall (*mm*)	137	196.8	126
	Rainfall minus ET (*mm*)	-331.1	-127.9	-381.5
6*mth* antecedent	Rainfall (*mm*)	542.6	539.2	299.6
	Rainfall minus ET (*mm*)	-166.6	114.3	-539.4

The above shows that, while it is not possible to completely remove seasonal effects from the groundwater assessment, the comparison between the pre- and post-construction groundwater levels across the 2014/2015 and 2020/2021 summers is appropriate.

3.2 Change in Groundwater Levels

Figure 2 presents a contour plot of the assessed long-term change in groundwater levels caused by Awakeri Wetlands Stage 1 construction. This shows:

- A groundwater mound is indicated on the up-gradient (north-eastern) side of the Stage 1 channels. The groundwater mound shows a rise in groundwater levels between 0.3*m* to 1*m* following Stage 1 construction.
- An area of groundwater drawdown is present at the northern tip of the Stage 1 channel. The magnitude of drawdown at 0.77*m* agrees with the channel invert level, as groundwater cut-off walls were not installed around this area.
- Areas of groundwater drawdown are present at the western and south-eastern extents of the Stage 1 channel, with drawdown generally between 0.2*m* to 0.5*m*. It is expected that these drawdowns are due to external effects and are mostly unrelated to long-term dewatering from Stage 1, as the drawdown increases with distance from Stage 1. If the drawdown was due to Stage 1, then it would reduce with distance from Stage 1.
- Overall, very little to negligible drawdown has occurred outside of the cut-off wall which is attributable to channel dewatering (with the exception of the northern tip of the channel where no cut-off walls were installed).

Similar plots were prepared to compare groundwater level changes between the pre-construction levels and the summer 2018/2019 (approx. 6*mths* into dewatering), and 2021/2022 (monitoring data for approx. one-third of boreholes unavailable). Both of these plots showed drawdown and mounding in similar areas, although the magnitudes were very different due to the different antecedent conditions. Therefore, the mounding is considered to be real and consistent, as it was observed across three summer periods.

The maximum groundwater mound height is indicated to be 1*m* above pre-construction levels. The area where the mounding is occurring has now been developed into subdivision, and the magnitude of the mound will be capped by the roading subsoil drainage.

3.3 Inferred Groundwater Mounding Mechanism

In the absence of further information, we expect that the groundwater mound has occurred due to the installation of the 3*m* and 7*m* deep groundwater cut-off walls obstructing horizontal groundwater flow. The cut-off effect of the 3*m* deep slurry wall is evident at the northern limit of the wall installation, where groundwater mounding and drawdown contours curve around the edge of the 3*m* deep wall.

This mechanism is described in Section 4.4 with respect to ground settlement.

3.4 Implications for Stages 2 to 3 Resource Consent

The groundwater mound was not predicted by GHD (2016b), as the decision to construct the 3*m* deep slurry wall was made after the GHD (2016b) analysis and resource consenting.

GHD (2016b) did predict groundwater drawdown to be less than 1*m* outside of the 7*m* deep cut-off wall. This prediction has been conservative for areas where mounding has not occurred. Monitoring records actually indicate very little to negligible drawdown outside the Stage 1 channel excavation (with the exception of the northern tip of the channel where the 3*m* cut-off wall was not constructed).

The groundwater drawdown predictions carried out by GHD (2016b) for the up-gradient (northern and north-eastern) sides of the channel are no longer applicable, as mounding is occurring in these areas. Construction of Stages 2 and 3 should consider potential mounding effects based on the Stage 1 observations. Alternatively, mounding effects can be removed by the installation of a subsoil drain on the northern and north-eastern sides of the groundwater cut-off walls.

4. Ground Settlement Effects

4.1 Methodology

As with the groundwater level assessment, efforts have been made to separate out the short-term shrink/swell rainfall responses and seasonal ground level changes in order to assess longer-term settlement effects.

This study has assessed settlement by comparing ground levels at the start of dewatering (August 2018), against ground levels in August 2020 (9*mths* after dewatering ceased). August 2020 was selected for the comparison, as only three of the adjacent subdivisions were preloaded during the period between August 2018 to August 2020. Whereas a total of six adjacent subdivisions had been preloaded by mid-2021. Adopting this time period allows external effects to be minimised.

The methodology is as follows:

1. Short term rainfall and seasonal shrink/swell effects on ground levels were minimised by visually fitting a trendline to the ground level elevation plots.
2. Ground levels were read off the trendline (not the actual monitoring data). Settlement was calculated by deducting the August 2020 trendline level from the August 2018 trendline level. Examples of the trendline analysis are shown on Figure 3.
3. Settlement was not calculated from the consent monitoring baseline ground levels, as the baselines were set at different times for different locations, and therefore have different short-term and seasonal influences. For example, heave above the baseline was indicated at the start of dewatering at most locations, which has been considered by this assessment.

It is acknowledged that at August 2020 the peat would still be undergoing primary consolidation in response to the permanent changes in groundwater levels (analyses indicate that primary consolidation takes approx. two years to complete due to the peat thickness). Groundwater levels due to Stage 1 excavation had only just stabilised in winter 2020. Therefore, this settlement assessment does not indicate long-term settlements. However, it does indicate settlement trends and areas where settlement is occurring.

4.2 Ground Settlement Effects

Figure 4 presents a contour plot of the assessed ground settlements following Stage 1 construction, as at August 2020. This shows:

- Ground settlement of 40*mm* to over 60*mm* is indicated to the north-east of the Stage 1 channel, corresponding to the area where groundwater mounding was observed. These settlements do not correspond to areas of preloading, as the subdivision developments had not yet commenced.
- A 20*mm* settlement contour line follows the southern and western sides of the channel excavation, however there is only a weak correlation to areas where groundwater drawdown was observed potentially due to the overprint of natural and external effects.
- Ground levels at all areas show an overall downwards trend across the 2*yr* study period, which applied regardless of proximity to the Stage 1 excavation or the adjacent site development and preloading. This trend continued until the monitoring ceased in mid-2022. The overall downwards trend is considered to indicate the natural consolidation and degradation processes which occur in the peat.

A similar plot was prepared to compare ground level changes between August 2018 to May 2022 (approx. 2.5*mths* after dewatering had ceased). Although heavily influenced by the adjacent subdivision developments and with fewer data points due to the cessation of monitoring, this plot showed a similar settlement pattern to Figure 4, with maximum settlements to the north-east of the channel. Therefore, the pattern of settlement occurring in the area of groundwater mounding is considered to be real and consistent.

4.3 Consolidation Settlement – Groundwater Drawdown

The estimated long-term groundwater drawdowns (Figure 2), and the settlement monitoring data, can be used to back-analyse the consolidation settlement parameters for the peat.

This back-analysis has been carried out at four locations: MP-44, BHMP-10, BHMP-11 and BHMP-43. These locations were selected as they are in areas with clear groundwater drawdown, and are remote from preloaded areas, therefore the full settlement monitoring record to May 2022 can be utilised in the back analysis.

Settlements have been back-analysed using the method of Leoni et al. (2008) modified to include Terzaghi one-dimensional consolidation. This incorporates elastic strain, and primary and secondary consolidation into one set of equations. Earthtech have utilised the method of Leoni et al. (2008) to back-analyse preload settlements in peats and marine muds on numerous other projects including the Tauranga Eastern Link peat preloads, and consider it appropriate for this purpose.

The Leoni et al. (2008) method is different to GHD (2016c), which adopted a modulus of compressibility (m_v) approach to predict primary consolidation. GHD (2016c) clearly states that they have used m_v to assess primary consolidation only, and secondary consolidation would be assessed separately. GHD have not assessed secondary consolidation on the basis that this calculation is usually not carried out for the adjacent subdivision developments, as foundations are designed to accommodate the estimated 1*mm* to 3*mm*/*mth* of secondary settlement. However, the Stage 2 development must consider cumulative primary plus secondary effects on the Waikato No. 1 pipeline, and secondary consolidation is known to be significant in peat. Therefore, this assessment will predict larger settlements than GHD (2016c) as secondary consolidation is included.

The Leoni et al. (2008) back-analysis is presented in Appendix A, and achieves a good match to the settlement monitoring data. The back analysed consolidation settlement parameters are presented in Table 2, with comparison to applicable published data. This shows that the back-analysed parameters are supported by wider published information.

Table 2: Back-analysed Consolidation Settlement Parameters

Parameter	Back-analysis	Comparison to Published Information
Primary Consolidation Ccε	0.10 to 0.19 (average 0.15)	• Ccε generally between 0.24 to 0.5 indicated by GHD (2016a) oedometer test data. • Ccε between 0.2 to 0.29 back analysed from Tauranga Eastern Link preload analyses. • Ccε = 0.3 back analysed from settlement data for Holocene peat in north Auckland.
Secondary Consolidation Cαε	0.1 × Ccε	• Cαε = 0.1 × Ccε back analysed from settlement data from Tauranga Eastern Link. • Cαε = 0.07 × Ccε back analysed from settlement data for Holocene peat in north Auckland. • Value of Cαε adopted by GHD (2016a) not provided in their reporting.
Over-consolidation ratio	1.4 (one monitoring location gave 1.8)	• OCR = 1.2 back analysed for Tauranga Eastern Link and Holocene peat in north Auckland. • OCR = 1.1 to 1.3 indicated for the site by comparing the inter-seasonal groundwater level ranges.
Cv (m^2/yr)	40	• *Cv* between 40 to 200m^2/yr indicated by experience with preloads in the Takanini peat (Beaumont, 2021). • *Cv* between 0.15 to 115m^2/yr indicated by site-specific oedometer test data (GHD, 2016a). • *Cv* = 12 to 20m^2/yr back analysed for Tauranga Eastern Link and Holocene peat in north Auckland

It is important to note that the back-analysis provides a range of consolidation settlement parameters. This is expected due to the variability in the peat, which is indicated by both the site-specific oedometer test data (GHD, 2016a), and other settlement studies in the area (Beaumont, 2021).

Table 2 shows that the rate of consolidation (*Cv*) is much higher in Takanini than other peat areas. Beaumont (2021) attributes this to the interlayered fibrous peat and occasional sandy ash layers, which also implies that the peat deposit has double-drainage. With the higher *Cv* input, a higher OCR and lower Ccε must be adopted to fit the settlement data, which are appropriate given that the peat is Pleistocene aged. Beaumont (2021) used a different settlement calculation method which did not require the Ccε or OCR parameters, however the settlement analysis data presented in Beaumont (2021) implies that Ccε is low.

Settlement back-analyses involve fitting trendlines with five degrees of freedom to survey data. Therefore, the solutions are non-unique, in that a different set of settlement parameters could be adopted which provide a similar fit to the survey data. The effects of the non-unique solution can be reduced when the survey data sets span a longer time period. In this case, 4*yrs* of data has been fitted, which is considered to be robust.

4.4 Consolidation Settlement – Groundwater Mounding

Consolidation settlement due to groundwater mounding is not a typical settlement triggering mechanism, and in many aspects is counter intuitive. The groundwater and settlement analyses (Figures 2 and 4) intentionally adopt time periods when development of the subdivisions had not yet commenced in the area where groundwater mounding is indicated. Therefore, in the absence of further information, the groundwater mounding and coinciding settlement are considered to be due to Stage 1 construction.

We propose a change in bulk density due to saturation coupled with permeability anisotropy concept to explain settlement occurring as a result of groundwater mounding. For this settlement to occur, the groundwater pressures in the upper part of the peat profile must be higher than the main peat body, to generate an increase in bulk density without a change in effective stress within the main peat body. This can be established as follows:

- Borehole logs indicate highly permeable fibrous peat interlayered with less-permeable amorphous peat. This results in permeability anisotropy, with vertical permeability being lower than horizontal permeability, and preferential groundwater flow in the horizontal direction through the fibrous peat.
- Anisotropy can enable a groundwater pressure differential to be established between the shallow and deeper peat layers. The slurry walls obstruct horizontal groundwater flow in the shallow fibrous peat. A mound develops in the shallow peat profile, but is not transmitted to the deeper peat as the anisotropy limits vertical groundwater movement.
- The groundwater mound generates load because of the increase in peat bulk density from partially saturated to saturated. This load in turn generates ground settlement.

- The groundwater mound is not expected to be perched (i.e. no zones of partially saturated soil between the shallow peat and main peat body). The groundwater pressure profile would be non-hydrostatic, as indicated by the on-site piezometers.
- Reports from site (March Construction, updated) provide anecdotal evidence of permeability anisotropy, and noted a shallow groundwater table at 200*mm* depth, whereas a groundwater table at 1*m* to 3*m* depth was indicated by the adjacent piezometers. This shallow groundwater table coincided with a zone of much higher permeability in the upper 0.5*m* to 1*m* of soil profile, through fibrous peat and the root zone. This supports the permeability anisotropy concept, although the groundwater table to which the mounding relates (as detected by the piezometers), is deeper than 0.2*m* below ground level.
- It is noted that the top of the groundwater cut-off walls were constructed 1*m* below original ground levels, meaning very shallow groundwater and the groundwater mound under winter conditions may overtop the cut-off walls. However, this assessment compares summer low levels which are critical in terms of ground settlement effects. Mounded summer low levels are still approx. 1.5*m* below ground level, and "retained" by the cut-off walls.
- The height of the groundwater mound is expected to be highly dependent on the relative thicknesses of the fibrous and amorphous peat (including wood fragments and interlayered sandy ash materials), which are variable across the site. This is considered to be the reason why the groundwater mound is not consistent to the north-east of Stage 1, but instead varies between 0.3*m* to 1*m* in height, with the peak sometimes occurring at a distance from the cut-off wall.

With shallow and deep groundwater partially separated in terms of groundwater pressure, settlement can be generated by the increase in soil bulk unit weight due to saturation within the depth range where the mound occurs. Laboratory testing data (GHD, 2016a) presents a range in bulk unit weights from 11kN/m^3 (saturated) to < 3kN/m^3 (dry) for the peat. Even a change from partially saturated to saturated conditions can result in a "load" in the order of 5*kPa*. Based on the back-analyses presented in Section 4.3, this load could generate the observed settlements in the order of 60*mm*, and offset the effects of the peat swelling.

Due to the variability in the thicknesses of the fibrous and amorphous peat, modelling of the groundwater mound is unlikely to provide reasonable accuracy unless a high density of geotechnical investigations are carried out. Therefore, we recommend that consenting of Stages 2 and 3 adopts mounding estimates based on Stage 1 observations.

It is acknowledged that there are many uncertainties in the groundwater mound vs settlement concept, and the full mechanism which causes the settlement may never be fully understood. It is not possible to carry out further investigations in the area, due to subdivision development and installed road subsoil drainage. In terms of the Stage 2 and 3 works, the important points are:

- A groundwater mound has developed on the up-gradient (north eastern side) of Stage 1. Therefore, there has been some impedance to horizontal groundwater flow. The most likely cause is the 3*m* and 7*m* deep cut-off walls which were installed.

- Given that the same cut-off walls would be installed for the Stage 2 and 3 areas, it is expected that a similar groundwater mound would occur on the up-gradient (northern and north-eastern) sides of Stages 2 and 3.
- Due to high variability in the ground conditions, the magnitude and extent of the groundwater mound cannot be modelled/predicted in advance with reasonable accuracy. However, it is reasonable to rely on the observations from Stage 1, which indicate a mound between 0.3*m* to 0.7*m* (locally up to 1*m*).
- Observations from Stage 1 also indicate ground settlement up to 60*mm* associated with the groundwater mound, within the first 2*yrs* of construction.

4.5 Implications for Stages 2 to 3 Resource Consent

In general terms, GHD (2016c) calculated that a drawdown of 200*mm* (approx. 2*kPa* pressure change) results in a primary consolidation ground settlement of 25*mm*. The GHD (2016c) settlement calculation is within the range initially observed on site as identified by this analysis, but only for the time period within approx. two years of channel construction. Analyses indicate that primary consolidation takes approx. two years to complete in the 20*m* thick peat deposit. The GHD analyses are expected to be non-conservative and underpredict settlement beyond approx. two years after construction, as secondary consolidation was not included and is significant in peat.

During the two years following channel construction, the GHD (2016c) settlements are slightly over-predicted in the northern part of Stage 1 and slightly underpredicted in the western part of Stage 1. This variability in the actual settlements is not unexpected, and is a result of variability in the peat.

Analysis for Stage 2 must consider both primary and secondary consolidation for the Waikato No. 1 pipeline. This means that future settlements predicted by this analysis will be larger than the GHD (2016c) equivalents.

On the up-gradient side (northern and north-eastern sides) of Stages 2 and 3, the ground settlement predictions by GHD (2016c) are no longer applicable, due to the groundwater mounding. Consenting for Stages 2 and 3 should consider potential mounding effects and associated settlements based on the Stage 1 observations.

5. Movement of Watercare Waikato No. 1 Pipeline

The Waikato No. 1 pipeline is a 1.2*m* diameter, 9.5*mm* thick steel pipe with concrete lining. The pipeline is a critical asset in terms of the Auckland water supply.

Monitoring of the Waikato No. 1 pipeline was carried out though 100*mm* diameter hydrovac excavations extending down to expose the top of the pipe, cased with 100*mm* diameter PVC seated on the top of the pipe. This method allowed the crest of the pipe to be accessed and directly surveyed. The pipeline monitoring is considered to represent true pipeline levels, as opposed to ground levels above the pipeline.

Full records are not available for most pipeline monitoring locations, as they were destroyed by roadworks. Monitoring locations WSMP2 and the latter-half WSMP6 have been excluded from this assessment as they were noted to be affected by silt build-up within the PVC access pipes, so may have reduced accuracy.

Figures B and C respectively show the pipeline movement from the baseline levels and pipeline elevations. Figure 5 shows an analysis of pipeline differential settlements at given times. These show the following:

- The pipeline has experienced movement in the order of +/- 20*mm* to 40*mm* from the baseline level, up to 60*mm* from the baseline level. These movements are consistent with the variation in peat ground levels in response to rainfall and seasonal effects, as the pipeline extends through the peat.
- The pipeline has experienced differential gradients in the order of 1v:300h to 1v:700h. Differentials may be up to 1v:94h between WSMP7 and WSMP8, although we consider this unlikely and potentially indicative that WSMP8 was not located on the crest of the pipe.
- The Waikato No. 1 pipeline was built in 2006. Comparing the 2018-2022 levels to the as-built levels shows significant permanent movement from the as-built position. For example:
    - WSMP1 as-built level = RL23.72*m*, and observed level in 2018-2022 ≈ RL23.38*m*, difference of 340*mm*.
    - WSMP7 as-built level = RL24.49*m*, and observed level in 2018-2022 ≈ RL24.28*m*, difference of 210*mm*.
    - WSMP10 as-built level = RL23.94*m*, and observed level in 2018-2022 ≈ RL23.77*m*, difference of 170*mm*.

In terms of Stage 2 and 3 construction, the Waikato No. 1 pipeline monitoring data shows that the pipeline is capable of accommodating significant movement. However, as permanent movement has already occurred, this can reduce the pipe tolerance to future movement caused by Stage 2 and 3 construction. Minimising pipeline movement requires careful consideration during Stage 2 and 3 construction, especially as the stormwater channel culverts are to extend under the pipeline.

These records also show that if Stage 2 and 3 construction "fixes" the pipeline level at any location (through temporary or permanent support or alternative pipeline foundations), this has the potential to result in significant differential settlement at the location of fixity.

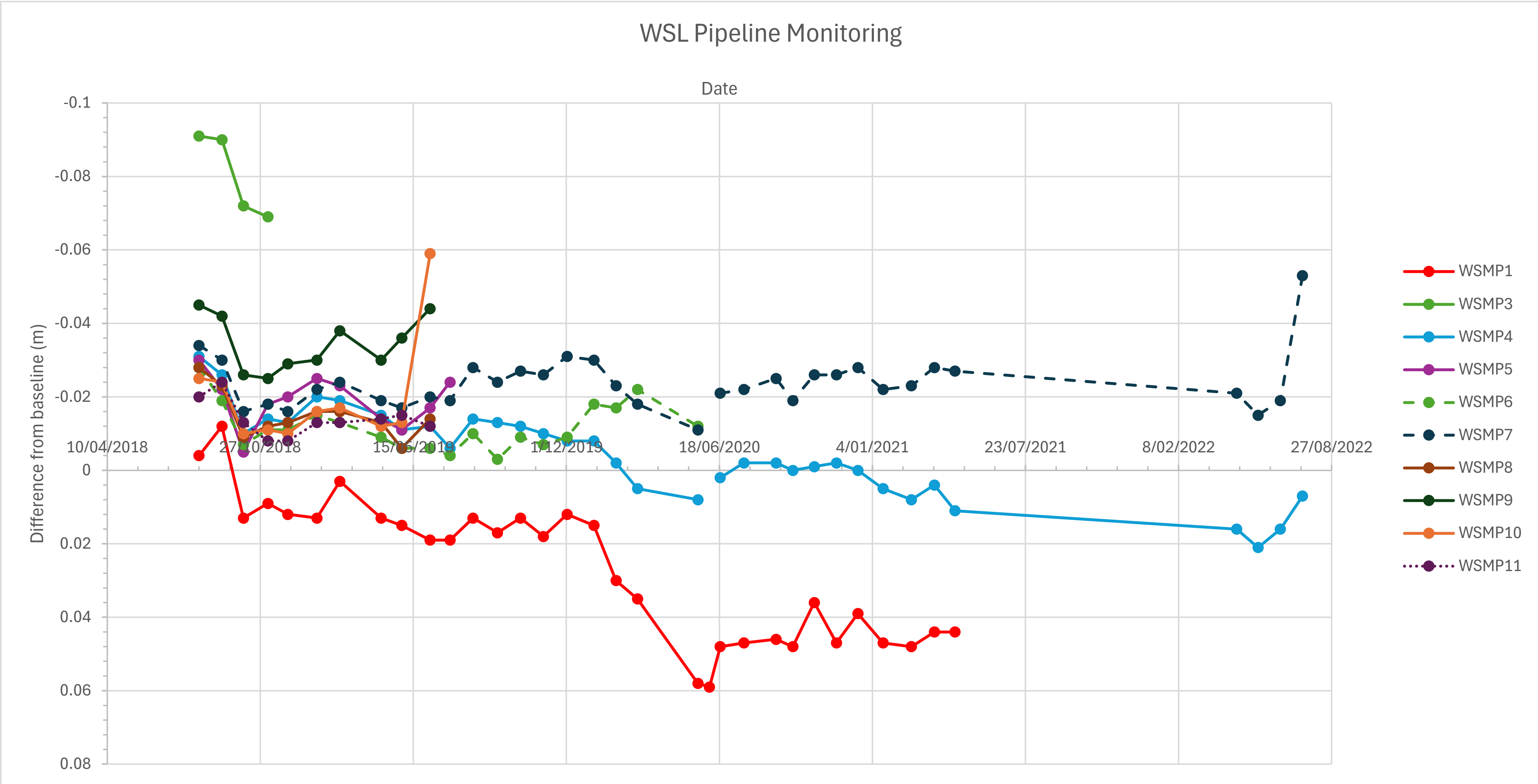


Figure B: Waikato No. 1 Pipeline Monitoring, movement from baseline levels.

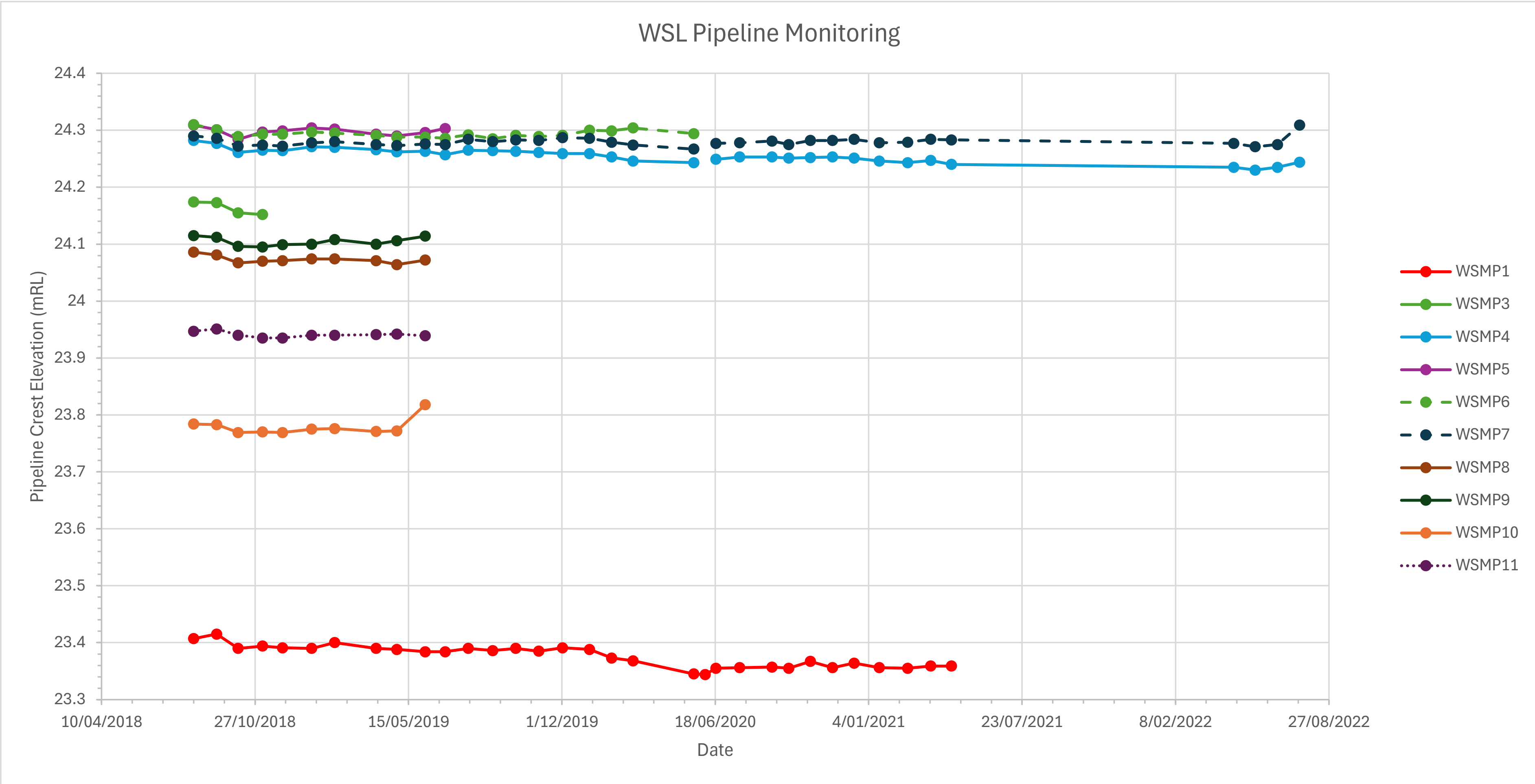


Figure C: Waikato No. 1 Pipeline Monitoring, pipeline crest elevations.

6. Groundwater Chemistry

Groundwater chemistry (pH, electrical conductivity, total suspended solids, sulphate and iron) was monitored at the Grove Road culvert during Stage 1 construction. The monitoring was carried out to check for any changes due to lowering of the groundwater table triggering acidic conditions due to oxidation of the peat.

The monitoring continued to July 2022, three years after channel completion. While natural fluctuations occurred associated with rainfall and run-off, no trends were observed in the pH or sulphate concentrations. GHD (2022) concluded that the Stage 1 channel excavation has not resulted in changes to water chemistry.

7. Summary of Effects Observed during Stage 1

Analysis of the Stage 1 construction monitoring records shows that a groundwater mound has developed on the up gradient (north-eastern) side of Stage 1, attributed to the groundwater cut-off walls obstructing horizontal groundwater flow. The groundwater mound and associated ground settlement are considered to be occurring due to increases in peat bulk density following saturation and permeability anisotropy. This mechanism is highly dependent on the variable and interlayered nature of the peat, and groundwater modelling is not considered to be an appropriate means to predict this mounding with respect to Stages 2 and 3.

Outside of the groundwater mounding area, there is very little to negligible groundwater drawdown which is attributable to channel dewatering, with a weak correlation between areas of drawdown and ground settlement potentially due to the overprint of external and natural effects. The GHD (2016b and c) analyses over-predict drawdown, but are expected to significantly underpredict ground settlement at times greater than two years following construction as secondary consolidation was not assessed and is significant.

Stage 1 monitoring data for the Waikato No. 1 pipeline indicates that it already experiences significant seasonal and permanent displacements. These movements indicate that the pipeline may have greater tolerance for movement than originally estimated during Stage 1 consenting, however the permanent displacements can also reduce the pipeline tolerance to further movement.

The excavations do not appear to have resulted in changes to groundwater chemistry.

PART 2: Stages 2 and 3 Assessment

8. Stages 2 and 3 Proposed Works

Stages 2 and 3 are to be constructed using a similar methodology to that assessed by GHD (2016b and c) and adopted during Stage 1. Proposed Stage 2 and 3 development drawings are presented by Maven (2024), and a construction methodology outline is presented by March Cato (2024) which includes temporary support of the Waikato No. 1 pipeline.

Relevant items for the dewatering assessment are summarised as follows:

1. Groundwater cut-off walls:
   - The 7*m* deep groundwater cut-off walls are to be constructed on either side of the Cosgrave Road culverts.
   - Groundwater cut-off around the culvert excavation and buried services under Cosgrave Road is to be provided by 7*m* deep sheet piles and/or cut-off walls – this will enclose the excavation, and must also include the area below the Waikato No. 1 pipeline where the pipeline enters/exits the excavation (this could be achieved by installing a fan of cement-bentonite columns at varying angles from the side of the pipeline, extending under the pipeline).
   - Based on Stage 1 experience, it is anticipated that the 3*m* deep slurry wall would be constructed around the majority of the Stage 3 works – this will be done on an as required basis at the contractor's discretion and should not be a requirement of consent.
   - The anticipated extent of the 7*m* and 3*m* deep cut-off walls are shown on Figure 6.

2. Stage 2 works:
   - The channel is to flow under Cosgrave Road in three new 1.5*m* high by 2.5*m* wide box culverts. The proposed culvert invert level is RL20.95*m*.
   - Allowing for an estimated 0.2*m* culvert floor thickness and an underlying 0.5*m* deep flowable fill or raft foundation, the maximum cut depth for Stage 2 is RL20.25*m*. This is also the maximum temporary dewatering depth during construction.
   - The maximum cut depth is approx. 4.9*m* below existing ground levels outside the road (as the road has been filled), and approx. 3.5*m* below the summer low groundwater level.
   - In the long term, the permanent water level at the culverts is RL22.25*m*, which results in a permanent drawdown of approx. 1.5*m* below the summer low groundwater level.

3. Stage 3 works:
   - Excavation of the Stage 3 channel involves cut depths ranging from 4*m* below existing ground level (cut to RL21.45*m*) at the interface with Stage 2, through to 2.4*m* below existing ground level (cut to RL23.74*m*) near Old Wairoa Road.
   - These excavations respectively result in construction drawdowns below summer low levels of 2.3*m* at the interface with Stage 2, to 0.8*m* near Old Wairoa Road.
   - In the long term, a 0.8*m* minimum permanent water depth will be maintained in the channel by the construction of weirs. This results in a permanent groundwater drawdown below summer low levels of 1.5*m* at the interface with Stage 2, grading to zero at approx. Ch520*m* half-way along the Stage 3 alignment.

4. Subsoil drainage:
   - Subsoil drainage is proposed to prevent the groundwater mound, and associated ground settlement, from developing on the northern side of the of the groundwater cut-off wall at Cosgrave Road.

- The extent of the proposed subsoil drainage is shown on Figure 6. The subsoil drainage generally does not extend through the Stage 3 area, as this land is owned by the applicant and subsoil drainage would only be installed if desired for future subdivision development.
- The subsoil drainage is proposed to consist of a 100*mm* diameter smooth-bore slotted pipe installed in geofabric wrapped drainage metal, discharging into the stormwater system.
- The subsoil drain would be installed at the winter high groundwater level, which is 0.5*m* below ground level based on available monitoring data. At this level, the subsoil drainage would not affect the pre-development summer low or winter high groundwater levels, but would prevent any mounding above the pre-development winter high level.
- The subsoil drain would require access for rodding and flushing maintenance, with maintenance to be carried out at least every 5*yrs* or as required.

9. Predicted Groundwater Drawdown and Ground Settlement Effects

9.1 Methodology

GHD (2016b) carried out an assessment of groundwater effects due to Stage 2 and 3 construction. This included a 2D cross-section model along Cosgrave Road, and a 3D model of the Stage 1 to 3 areas. The drawdown predictions were used to assess ground settlements in GHD (2016c). We have reviewed the GHD assessments, and consider the following:

1. The GHD (2016b) drawdown predictions are conservative, in that the extent of drawdown is overpredicted. GHD (2016b) noted that their prediction was expected to be conservative due to the analysis settings which were adopted, and this is also supported by the Stage 1 observations.
2. The GHD (2016c) ground settlement prediction is considered to be non-conservative and underpredict settlement effects, as secondary consolidation has not been included. Secondary consolidation effects are significant in peat.

To define the envelope of effects for Stage 2 and 3 construction, we have carried out an independent assessment of groundwater drawdown and consolidation settlement for Stage 2 at the critical Waikato No. 1 pipeline along Cosgrave Road. We have adopted the GHD (2016b) conservative extent of drawdown (relating to the 25*mm* settlement contour) to bound the envelope of effects for the Stage 2 and 3 areas, and observations from Stage 1 confirm that adopting this boundary of potential effects is conservative.

The GHD (2016b) assessed extent of drawdown is still considered to be conservative for this application due to:

1. GHD dewatering predictions assessed a groundwater drawdown to RL19.8*m* for up to 1*yr*, during construction of the Cosgrave Road culverts. This proposal is to dewater to RL20.25*m* (drawdown is reduced), for up to three months (duration of dewatering to be confirmed).

2. Both the GHD prediction and this proposal include the same extents of 7*m* deep groundwater cut-off walls through the Stage 2 and 3 areas. This proposal also includes 3*m* deep slurry walls, and subsequent mounding effects have been addressed by the installation of a subsoil drain. No drawdown or mounding is anticipated on the northern side of the subsoil drain.
3. The Stage 3 channel depth under this proposal is approx. 0.7*m* deeper than the GHD dewatering assessments at the interface with Stage 2, however this slightly greater dewatering effect is overprinted by drawdown due to the adjacent culvert excavation. For the remainder of Stage 3, the channel depths are generally the same or within 0.2*m* of the channel depths assessed by GHD.

9.2 Waikato No. 1 Pipeline at Cosgrave Road Culverts

The Waikato No. 1 pipeline is the critical asset for Stage 2 and 3 construction. The GHD analyses are known to overpredict drawdown, but underpredict longer term ground settlement as secondary consolidation was not included.

An independent assessment of drawdown and ground settlement has been carried out where the pipeline crosses the Cosgrave Road culverts. This check utilises the finite element modelling software FEFLOW to predict groundwater drawdown, and the method of Leoni et al. (2008) and the peat consolidation settlement parameters back analysed from Stage 1 construction (described in Section 4.3) to predict ground settlement.

The assessment is presented in Appendix C, with the ground settlement results summarised in Table 3 for the current proposal (7*m* deep cut-off walls only). This shows that consolidation settlements at the outside of the cut-off wall are estimated to be approx. 300*mm* over the 5*yr* period following culvert construction – this is within the range of permanent movement already experienced by the pipeline (between 170*mm* to 340*mm* of permanent movement already experienced), but is unlikely to be acceptable in terms of potential cumulative damage to the pipeline. We also recommend that a factor of +/- 50% is incorporated into consolidation settlement predictions due to long-term uncertainty and variability in the peat.

Based on the above and Table 3, further mitigation in addition to the cut-off walls is necessary to ensure that dewatering settlements effecting the pipeline remain within acceptable limits.

The maximum allowable settlements on the Waikato No. 1 pipeline should be specified by a pipeline specialist and agreed with Watercare, considering the pipe material, seasonal and permanent movement already experienced by the pipeline, and that critical differentials may occur where the pipe enters/exits the cut-off wall above the culverts. The maximum allowable limits adopted for the Waikato No. 1 pipeline during Stage 1 were 50*mm* total settlement and 1v:200h differential settlement (GHD, 2018), and it is anticipated that the limits for Stages 2 and 3 would be similar.

Table 3: Check of Ground Settlements, Waikato No. 1 Pipeline at Cosgrave Road Culverts, without further Mitigation other than 7m deep Cut-off Walls[1]

Time	Groundwater drawdown at outside of cut-off wall	Best estimate settlement	Best estimate differential settlement[4]
During construction: at 3*mths* dewatering	1.1*m*	55*mm*	Flatter than 1v:700h
After construction: 2*yrs* (approx. t_{90}) [2]	0.6*m*	165*mm*	1v:300h
After construction: 5*yrs* [2, 3]	0.6*m*	300*mm*	1v:180h (potentially 1v:120h within 10*m* of the cut-off wall)

[1] A factor of +/- 50% should be incorporated into designs which utilise settlement predictions.

[2] Settlement already includes cumulative effect of construction dewatering.

[3] Time of 5*yrs* selected as this is when other Watercare pipelines are expected to have been commissioned, and the Waikato No. 1 pipeline can be brought offline.

[4] Differential outside of the cut-off wall, does not include where the pipeline enters/exits the cut-off wall.

A conceptual option to mitigate pipeline settlements to within 50*mm* and flatter than 1v:200h is as follows:

1. Within the cut-off wall: the culvert structures and EPS fill under the pipeline will provide a rigid structure to bridge settlements which occur within the groundwater cut-off wall. The culverts could be structurally tied to the cut-off walls to minimise differential settlement between the cut-off walls. Without this mitigation settlements within the cut-off wall are expected to be greater than Table 3 values, as 1.5*m* of long-term drawdown occurs within the cut-off wall (potentially resulting in over 700*mm* of settlement across the culverts).
2. Where the pipeline enters/exits the cut-off wall: permanent screw piles could be installed outside the cut-off wall founding in the peat at 7*m* depth, which is the same depth as the cut-off wall. With potential additional reinforcing on the outside of the pipeline, the pipeline inside and immediately outside the cut-off wall could be encouraged to settle together, reducing differential settlement where the pipeline enter/exits the cut-off wall.
3. To the north and south of the cut-off wall: ground settlements reduce with distance and will progressively become less than Table 3 values. Differential settlements can be reduced by the provision of permanent screw pile supports which found in the peat and have a founding depth which reduces with distance from the cut-off walls.

The above mitigation could potentially be combined with the temporary pipeline support during construction.

With further mitigation, settlements effecting the Waikato No. 1 pipeline can be limited to within 50*mm* total settlement and 1v:200h differential. Conceptual design of the mitigation works must be carried out by the project geotechnical and structural engineers, and confirmed as part of detailed design.

9.3 Further Effects within Zone of Drawdown

Figure 6 presents long-term groundwater drawdown contours. Figure 7 presents ground settlement contours resulting from the long-term drawdown. Mechanical settlement at the Cosgrave Road culvert excavation must be included in the settlement prediction once this is known, and is only expected to influence a small area within say 5*m* of the culverts during construction.

As with the GHD (2016c) approach, a ground settlement of 25*mm* is used to bound the envelope of effects. This is considered to be appropriate as Part 1 of this report shows that natural ground movements are much larger than 25*mm*. The envelope of effects is used to define the extent of monitoring under the Groundwater and Settlement Monitoring and Contingency Plan (GSMCP). The GSMCP is provided separately to this report.

In terms of the nearby residential development, Figure 7 and Table 3 indicate that there are 16 residential properties which may experience settlements greater than 50*mm* and differential gradients steeper than 1v:500h (differential limit typically adopted for structures). The type of foundation of these buildings is expected to provide significant benefit in terms of preventing damage. However, the building tolerances should be established in conjunction with a detailed building assessment as part of detailed design. These buildings are highlighted on Figure 7, and have also been flagged for detailed condition surveys in the associated GSMCP.

GHD (2016b and c) also present an assessment of effects in terms of surface water, nearby groundwater users, and groundwater chemistry, which is not repeated herein.

Appendix B includes an assessment of the proposed Stage 2 and 3 construction against the provisions of the Auckland Unitary Plan Chapter E7.

10. Monitoring and Mitigation Options

There remains a risk that ground conditions are not as they have been evaluated, and variability within the peat has been noted (Sections 4.3 to 4.5 of this report). We consider that the variability in the peat can be managed through implementation of a GSMCP. As the mechanism causing settlement in the groundwater mounding area is not well understood, the GSMCP has also been scoped to include monitoring on the northern side of the channel, although no drawdown or ground settlement is anticipated in this area due to the potential mounding and subsoil drain installation.

The proposed resource consent design already includes methods to mitigate groundwater drawdown and ground settlement effects, such as the construction of the 7*m* deep groundwater cut-off walls, sheet piles/cut-off walls around the Cosgrave Road culvert excavation, the subsoil drain to prevent groundwater mounding, and recommendations for further support to the Waikato No. 1 pipeline.

Should settlement effects be larger than anticipated, additional mitigation options include:

- Extending or increasing the depth of the groundwater cut-off walls.
- Installation of additional subsoil drains in the case of groundwater mounding.
- Additional or alternative temporary or permanent support to the Waikato No. 1 pipeline. Supports may extend some distance from the Cosgrave Road culverts, to mitigate long-term differential settlement effects and avoid creating isolated points of fixity at the pipeline.
- Casting a low permeability floor in the base of the Cosgrave Road excavation (i.e. under the culverts), to provide further cut-off to groundwater inflow while the culverts are constructed.
- Providing groundwater recharge wells.
- Temporarily flooding or backfilling the excavations.

11. Summary of Effects for Stages 2 and 3

To define the envelope of settlement effects, an independent assessment of drawdown and ground settlement has been carried out for the Waikato No. 1 pipeline along Cosgrave Road. This has been used to define settlement effects in the vicinity of the Cosgrave Road culverts. The GHD (2016b) drawdown prediction has conservatively been used to bound the envelope of effects for the Stage 2 and 3 areas.

The Cosgrave Road assessments indicate up to 1.1*m* of drawdown during construction and 0.6*m* of drawdown in the long-term, at the outside of the groundwater cut-off walls. With only the 7*m* deep groundwater cut-off walls providing drawdown mitigation, the analyses show a settlement (primary plus secondary consolidation) of 300*mm* +/- 50% over a 5*yr* period following culvert construction, with differential settlement steeper than 1v:180h. Additional mitigation in the form of screw piles has been conceptually described as a means to limit settlements effecting the pipeline to 50*mm* and flatter than 1v:200h (provisional limits, to be confirmed or modified by a pipeline specialist and agreed with Watercare).

The expected groundwater mounding on the northern side of the channel can be capped by the installation of a subsoil drain at the pre-development winter high groundwater elevation. In this area north of the subsoil drain, no drawdown or ground settlement is expected, however the area should still be monitored as part of the GSMCP due to uncertainty associated with the groundwater mounding mechanism.

Further mitigation options are available to ensure that damage can be avoided if settlement effects are larger than predicted.

12. References

Beaumont, J. (2021) *Settlement Performance of Dwellings Constructed on Takanini Peats*. NZGS 21st Symposium, 24-26 March 2021, Dunedin.

Edbrooke, S. W. (2001) *Geology of the Auckland Area*. Geological Map 3, Scale 1:250,000. Institute of Geological and Nuclear Sciences, Wellington.

GHD (2016a) *Takanini Stormwater Conveyance Channel, Geotechnical Investigation Report, Technical Report C*. Prepared for Auckland Council. Dated December 2015.

GHD (2016b) *Takanini Stormwater Conveyance Channel, Hydrogeology Assessment of Effects, Technical Report D*. Prepared for Auckland Council. Dated February 2016.

GHD (2016c) *Takanini Stormwater Conveyance Channel, Geotechnical and Ground Settlement Effects Report, Technical Report E*. Prepared for Auckland Council. Dated February 2016.

GHD (2018) *Takanini Stormwater Conveyance Channel Stage 1 – Groundwater and Settlement Monitoring and Contingency Plan*. Prepared for Auckland Council, reference 51/33411/07, Rev. F, dated July 2018.

GHD (2022) *Awakeri Wetlands, Completion of Construction Condition Survey Report*. Prepared for Auckland Council, rev. 0, dated 3 October 2022.

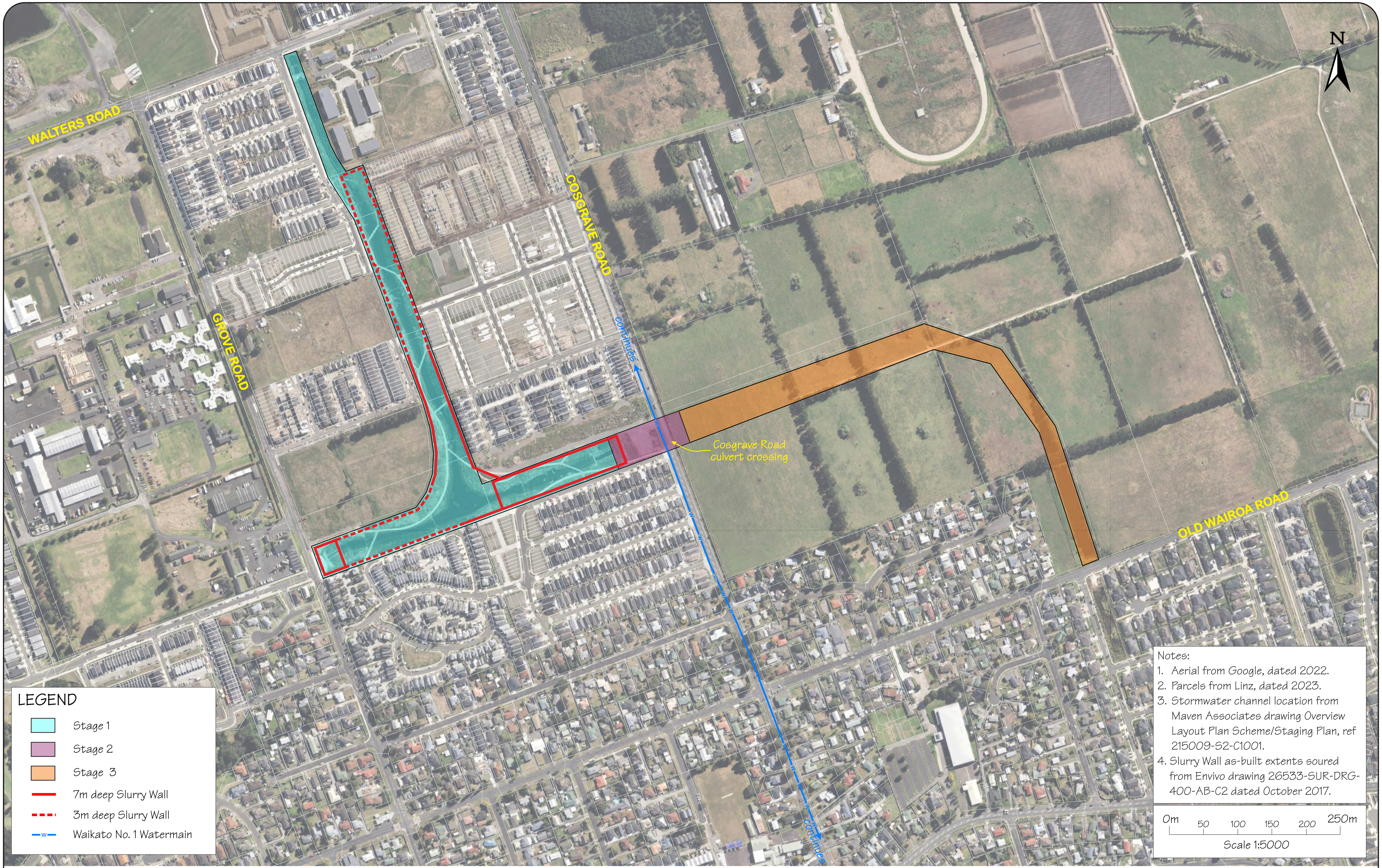
Healthy Waters (2024) *RE: Awakeri Wetlands - groundwater cutoff wall as-builts*. Email from Jesse Peeters of Auckland Council Healthy Waters to David Osborne and Michelle Willis, dated 15 March 2024.

Leoni, M., Karstunen, M., Vermeer, P. A. (2008)
Anisotropic creep model for soft soils. Geotechnique 58(3), pgs. 215 – 226.

March Cato (2024) *Indicative Construction Methodology for Awakeri Wetlands Stage 2: Cosgrave Road Stormwater Culverts*. Prepared May 2024.

March Construction *Groundwater Issues Report, 41053 – 91-99 Grove Road, Slurry Wall Investigation on the Impact of Groundwater*. Letter not dated.

Maven (2024) *Awakeri Wetlands Stage 2* set of 24 drawings, and *Awakeri Wetlands Stage 3* set of 68 drawings. Prepared for Winton Land Limited, dated February 2024. Issue for Resource Consent.



Notes:
1. Aerial from Google, dated 2022.
2. Parcels from Linz, dated 2023.
3. Stormwater channel location from Maven Associates drawing Overview Layout Plan Scheme/Staging Plan, ref 215009-S2-C1001.
4. Slurry Wall as-built extents soured from Envivo drawing 26533-SUR-DRG-400-AB-C2 dated October 2017.

FOR INFORMATION

Note: All drawings are to be approved (initialled) before final issue.

EARTHTECH
Earthtech Consulting Ltd.
P.O. Box 721, Pukekohe
Phone: 64 9 238 3669
Email: admin@earthtech.co.nz

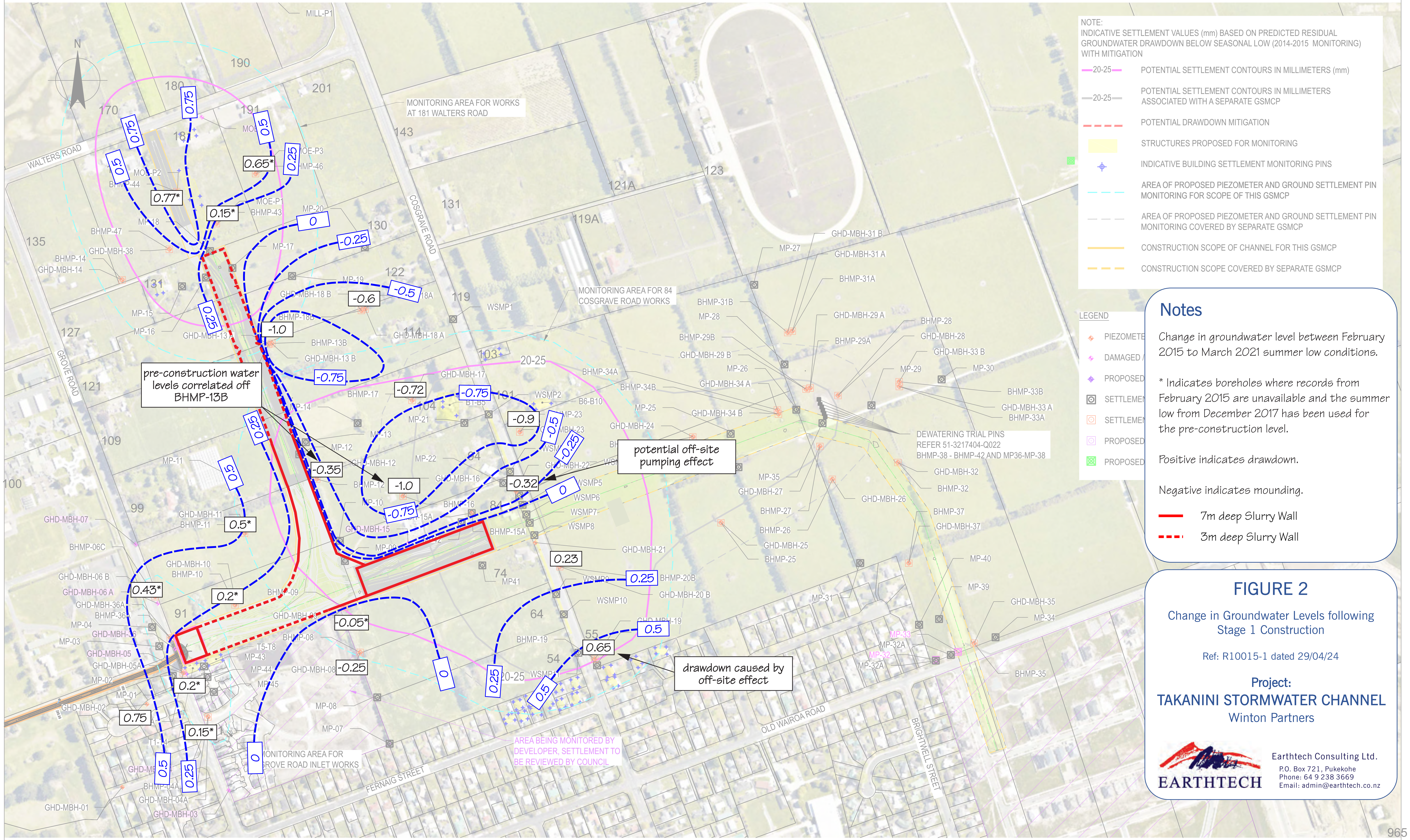
TAKANINI STORMWATER CHANNEL

Winton Partners

Site Plan

REV	DATE	AMENDMENT/ISSUE	DRAWN BY	CHECKED	TRACED BY	APPROVED BY
A	29-04-24	ISSUE FOR R10015-1	M.W	A.N	S.SW	MLW

DRAWING NO.: FIG. 1
REF: 10015
SCALE: 1:5000
CRS: NZTM
DATUM: N/A



DRAFT

No	Revision	Drawn	Job Manager	Project Director	Date
E	UPDATED STAGING	JP	AK	ER	10/17
D	UPDATED WITH NEW PINS	JP	AK	ER	07/17
C	UPDATED WITH STAGING	JP	JG		05/17
B	UPDATE FOLLOWING CONDITIONS MEETING	JP			08/16
A	SCHEME DESIGN	JP	JG		07/16

Note: * indicates signatures on original issue of drawing or last revision of drawing

0 50 100 150m
SCALE 1:5000 AT ORIGINAL SIZE

Auckland Council
Te Kaunihera o Tāmaki Makaurau

GHD
Level 3, GHD Centre
27 Napier Street, Freemans Bay, Auckland 1011 New Zealand
T 64 9 370 8000 F 64 9 370 8001
E auckland@ghd.com W www.ghd.com

DO NOT SCALE

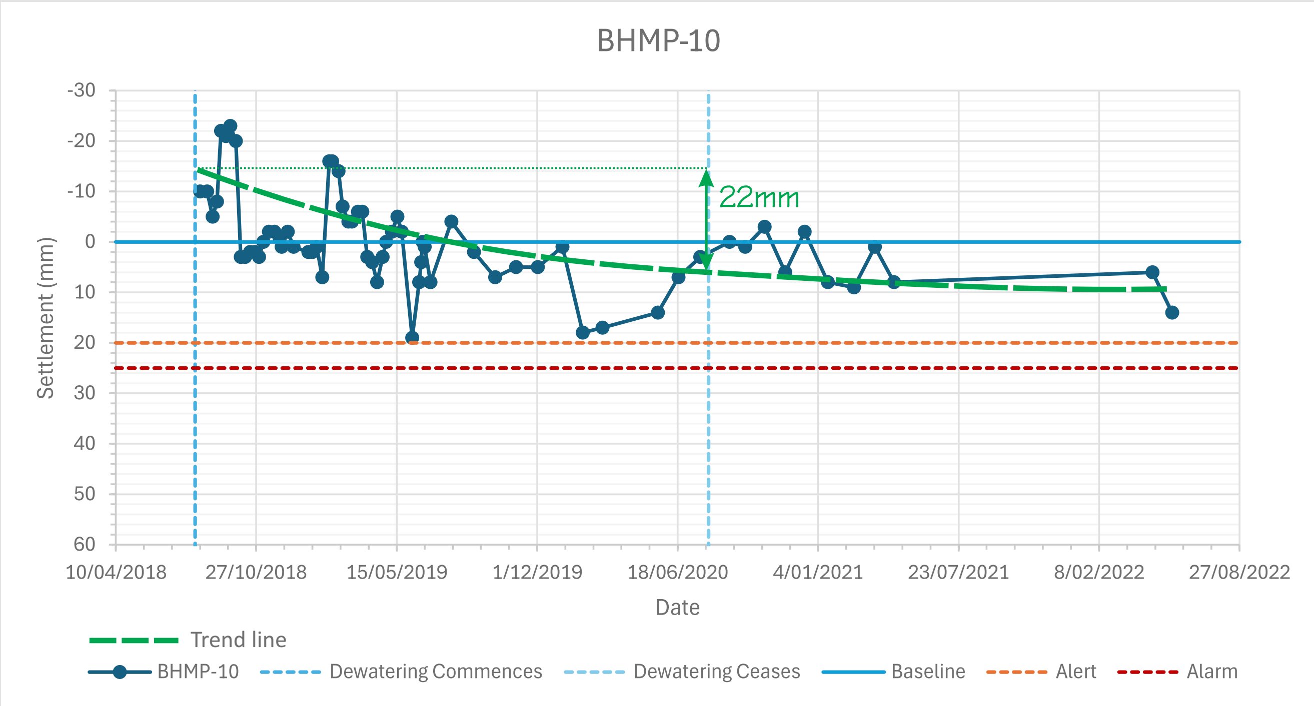
Drawn J PEETERS
Designer J PEETERS
Drafting Check
Design Check J GORINAS
Approved (Project Director)
Date
Scale 1:5000

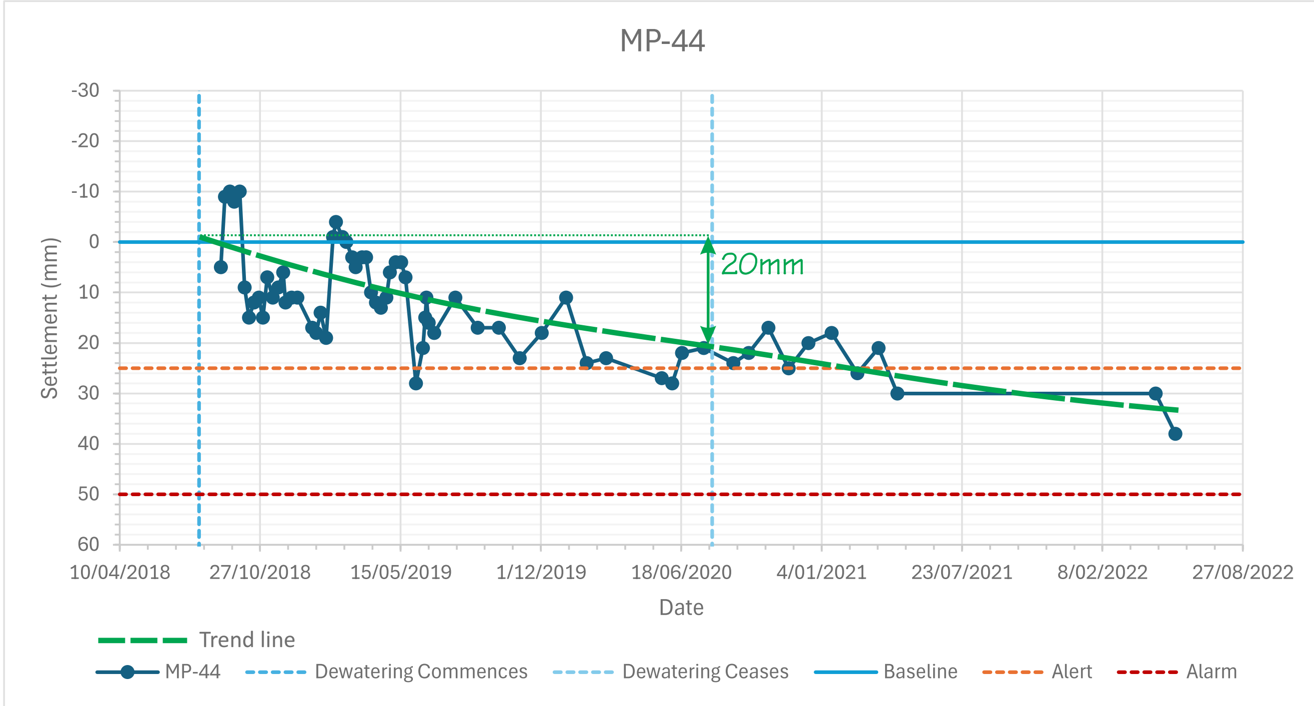
This Drawing must not be used for Construction unless signed as Approved

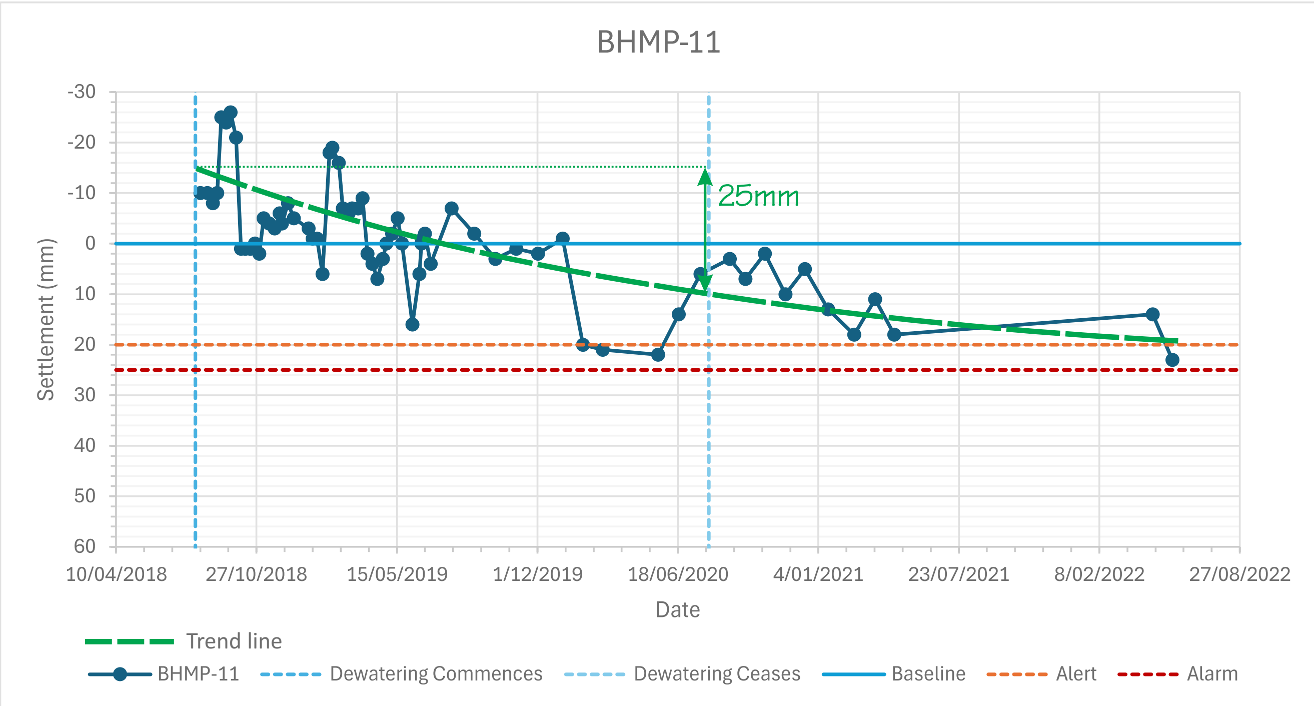
Client AUCKLAND COUNCIL
Project TAKANINI STORMWATER CONVEYANCE CHANNEL
Title GEOTECHNICAL GROUNDWATER & SETTLEMENT STAGE 1 TSCC - MONITORING PLAN

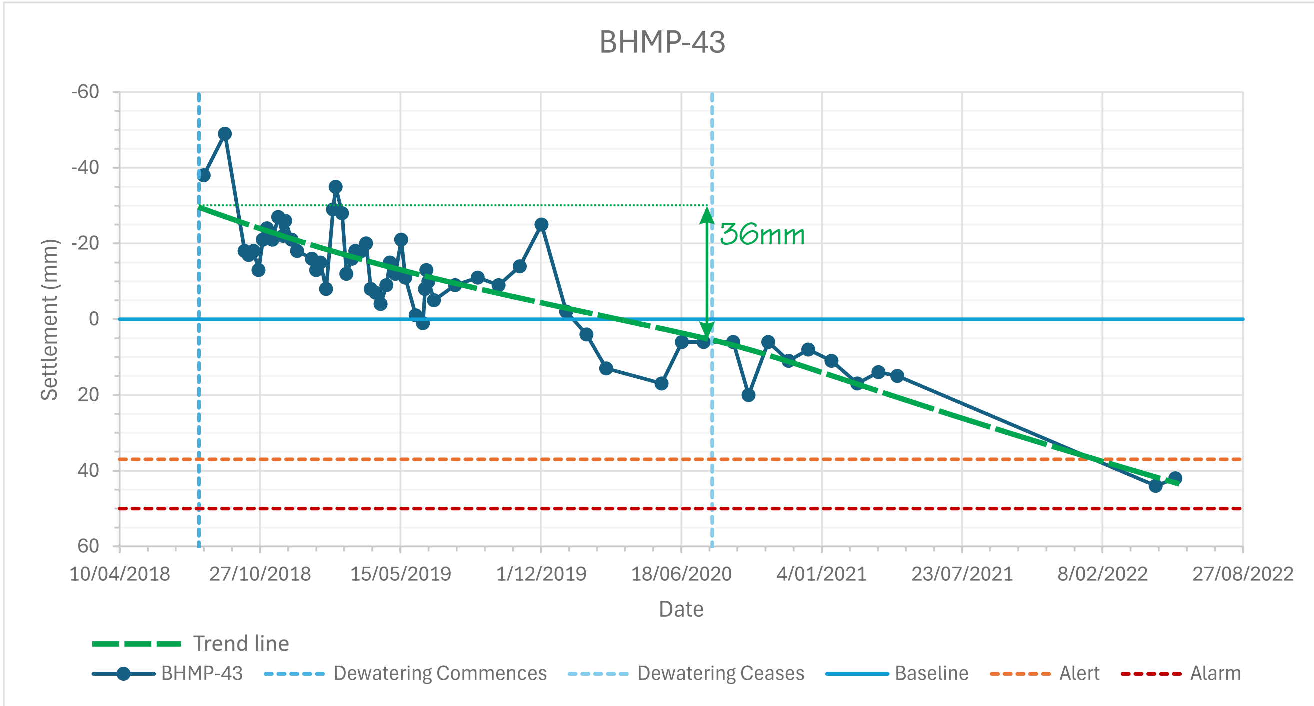
Original Size A3
Drawing No: 51-3217404-Q081
Rev: E

Plot Date: 12 October 2017 - 4:08 p.m. Plotted By: Jesse Peeters Cad File No: G:\51\32174\03 Takanini\14 CAD\Drawings\51-3217404-Q081.dwg









FOR INFORMATION

Note: All drawings are to be approved (initialled) before final issue.

EARTHTECH

Earthtech Consulting Ltd.
P.O. Box 721, Pukekohe
Phone: 64 9 238 3669
Email: admin@earthtech.co.nz

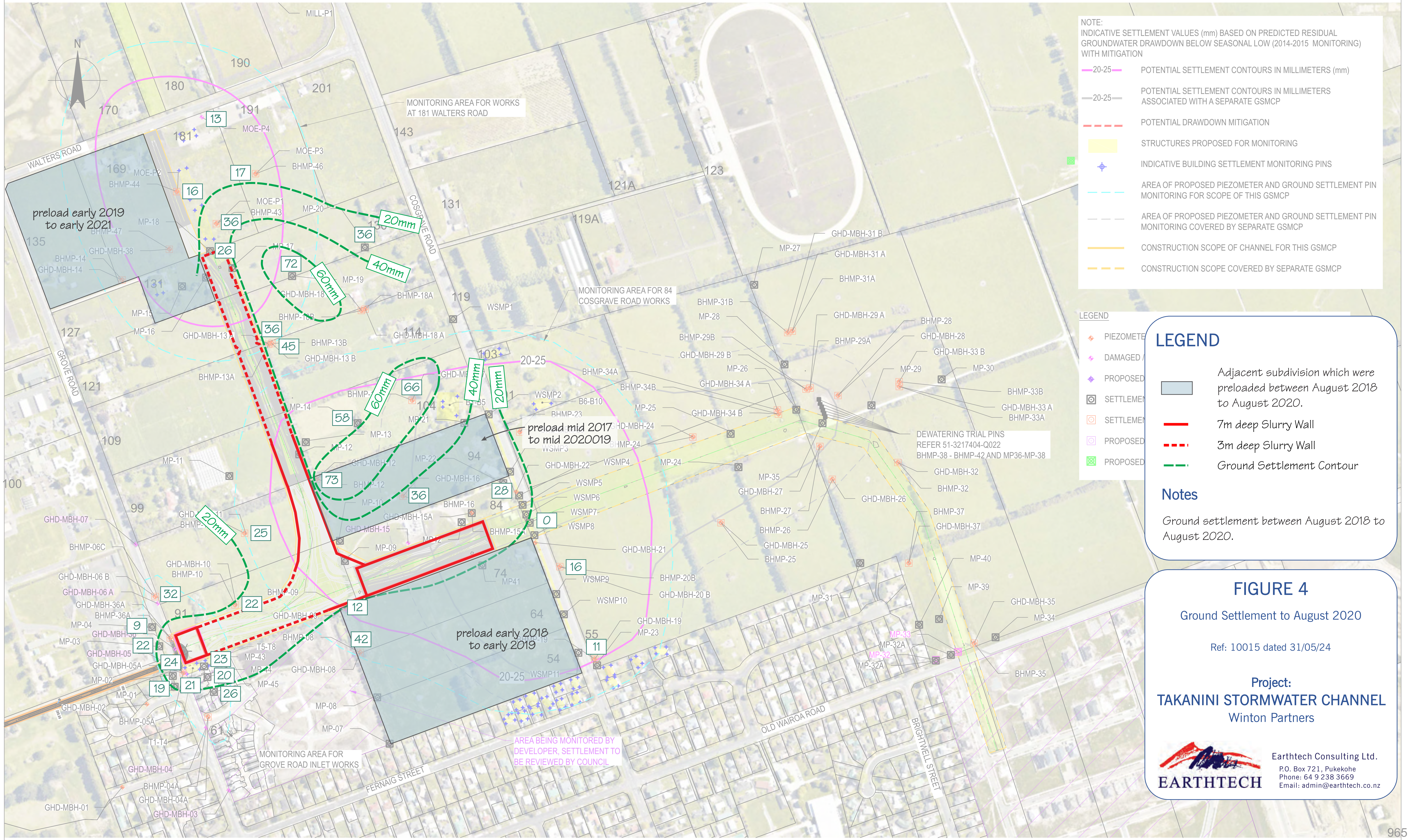
TAKANINI STORMWATER CHANNEL

Winton Partners

Examples of Trendline Analyses

REV	DATE	AMENDMENT/ISSUE	DRAWN BY	CHECKED	TRACED BY	APPROVED BY
A	29-04-24	ISSUE FOR R10015-1	M.W	A.N	M.W	MLW
B	31-05-24	UPDATE ON LEGENDS	M.W	A.N	M.W	MLW

DRAWING NO.: FIG. 3
REF: 10015
SCALE: N/A
CRS: N/A
DATUM: N/A



No	Revision	Drawn	Job Manager	Project Director	Date
E	UPDATED STAGING	JP	AK	ER	10/17
D	UPDATED WITH NEW PINS	JP	AK	ER	07/17
C	UPDATED WITH STAGING	JP	JG		05/17
B	UPDATE FOLLOWING CONDITIONS MEETING	JP			08/16
A	SCHEME DESIGN	JP	JG		07/16

Note: * indicates signatures on original issue of drawing or last revision of drawing

0 50 100 150m
SCALE 1:5000 AT ORIGINAL SIZE

Auckland Council
Te Kaunihera o Tāmaki Makaurau

GHD
Level 3, GHD Centre
27 Napier Street, Freemans Bay, Auckland 1011 New Zealand
T 64 9 370 8000 F 64 9 370 8001
E auckland@ghd.com W www.ghd.com

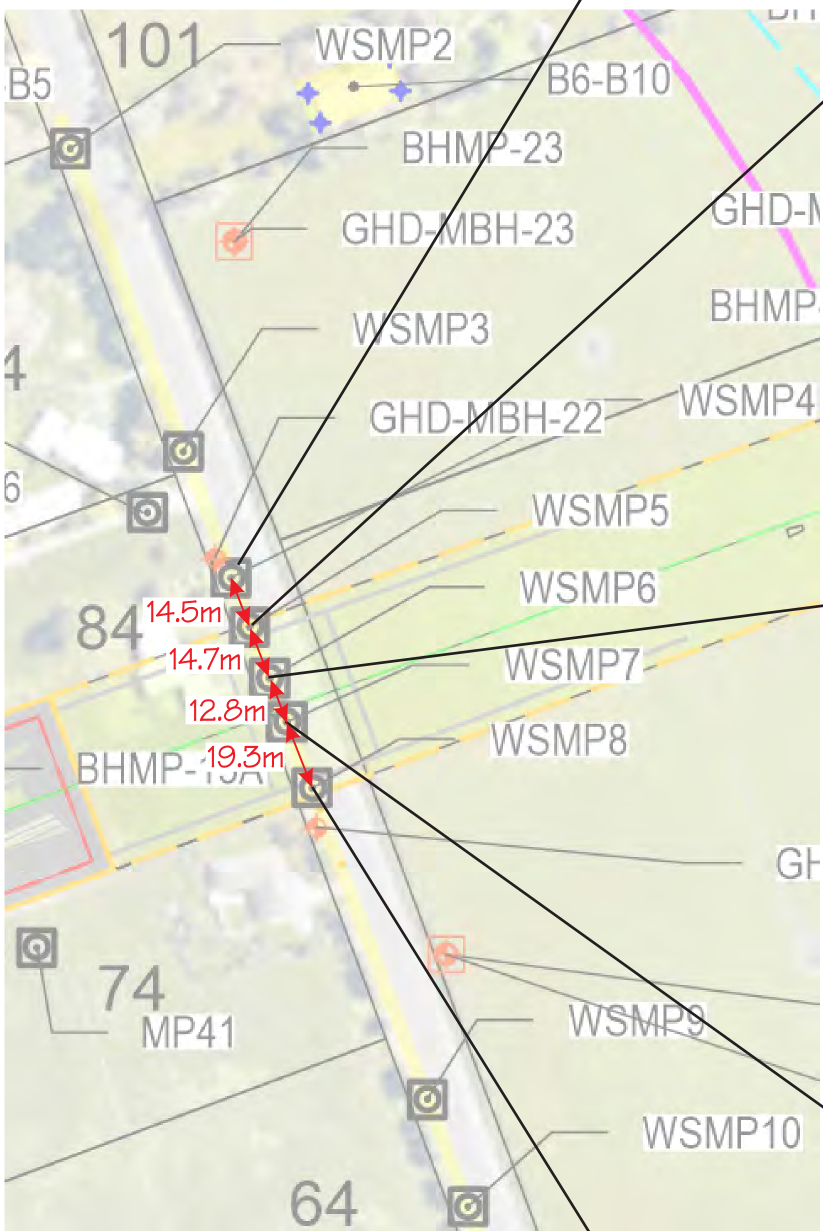
DO NOT SCALE

GHD Limited
Conditions of Use.
This document may only be used by GHD's client (and any other person who GHD has agreed can use this document) for the purpose for which it was prepared and must not be used by any other person or for any other purpose.

Drawn J PEETERS
Designer J PEETERS
Drafting Check
Design Check J GORINAS
Approved (Project Director)
Date
Scale 1:5000
This Drawing must not be used for Construction unless signed as Approved

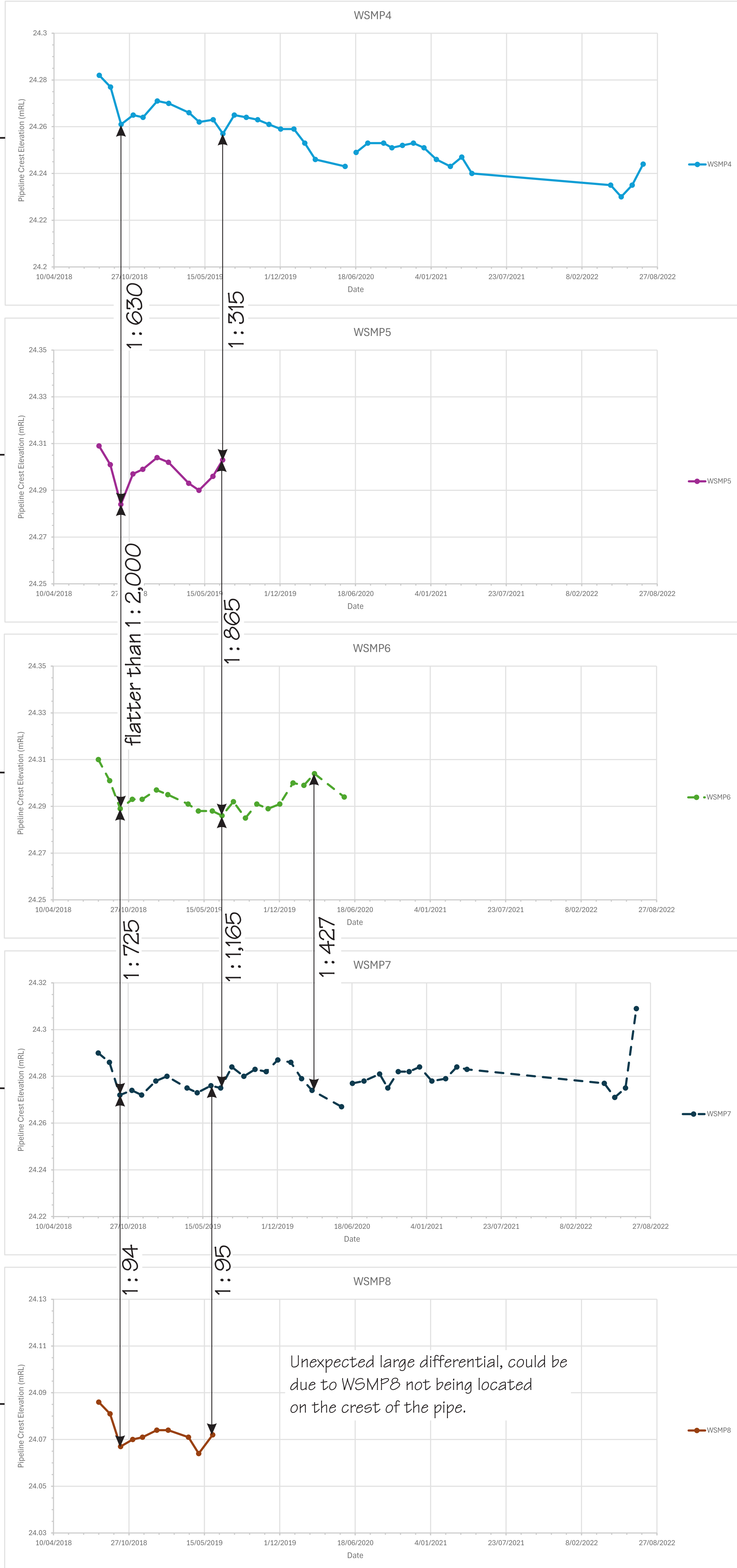
Client AUCKLAND COUNCIL
Project TAKANINI STORMWATER CONVEYANCE CHANNEL
Title GEOTECHNICAL GROUNDWATER & SETTLEMENT STAGE 1 TSCC - MONITORING PLAN
Original Size A3
Drawing No: 51-3217404-Q081
Rev: E

Plot Date: 12 October 2017 - 4:08 p.m. Plotted By: Jesse Peeters Cad File No: G:\51\32174\03 Takanini\14 CAD\Drawings\51-3217404-Q081.dwg



Exerpt from GHD drawing "Geotechnical Groundwater and Settlement Stage 1 TSCC - Monitoring Plan", Drawing no. 51-3217404-Q081, Rev. E, dated Oct 2017

Distances between monitoring points have not been provided, so have been scaled off the drawing at the distances shown in red above.



FOR INFORMATION

Note: All drawings are to be approved (initialled) before final issue.

Earthtech Consulting Ltd.
P.O. Box 721, Pukekohe
Phone: 64 9 238 3669
Email: admin@earthtech.co.nz

EARTHTECH

TAKANINI STORMWATER CHANNEL
Winton Partners

Waikato No. 1 Pipeline Settlement Data

REV	DATE	AMENDMENT/ISSUE	DRAWN BY	CHECKED	TRACED BY	APPROVED BY
A	29-04-24	ISSUE FOR R10015-1	M.W	P.K	M.W	MLW

DRAWING NO.: **FIG. 5**
REF: 10015
SCALE: n/a
CRS:
DATUM:

FOR INFORMATION

Note: All drawings are to be approved (initialled) before final issue.

EARTHTECH
Earthtech Consulting Ltd.
P.O. Box 721, Pukekohe
Phone: 64 9 238 3669
Email: admin@earthtech.co.nz

TAKANINI STORMWATER CHANNEL

Winton Partners

Predicted Long-term Groundwater Drawdown

REV	DATE	AMENDMENT/ISSUE	DRAWN BY	CHECKED	TRACED BY	APPROVED BY
A	11-06-24	ISSUE FOR R10015-1	M.W	A.N	S.SW	MLW

DRAWING NO.: FIG. 6

REF: 10015

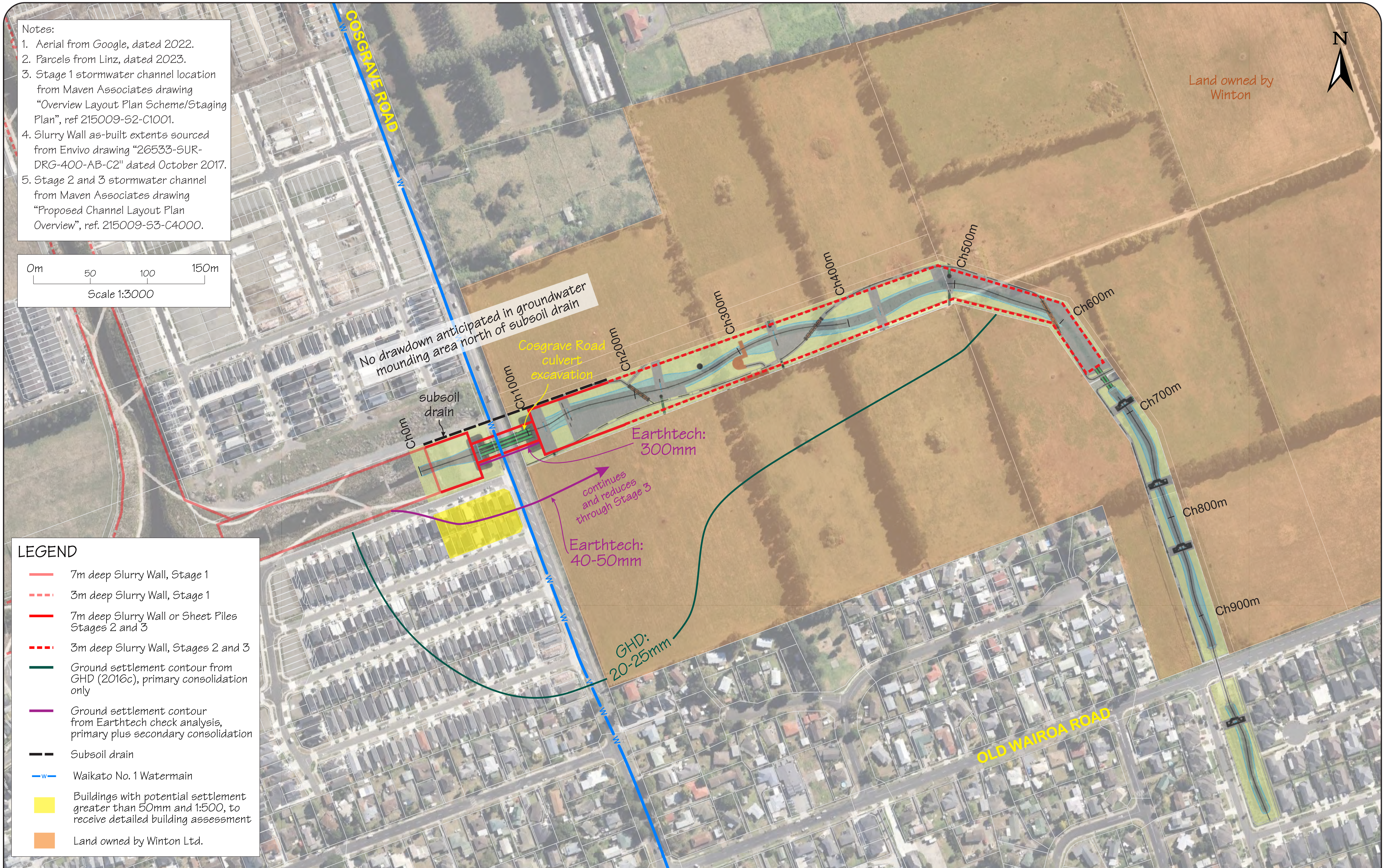
SCALE: 1:5000

CRS: NZTM

DATUM: N/A

Notes:
1. Aerial from Google, dated 2022.
2. Parcels from Linz, dated 2023.
3. Stage 1 stormwater channel location from Maven Associates drawing "Overview Layout Plan Scheme/Staging Plan", ref 215009-S2-C1001.
4. Slurry Wall as-built extents sourced from Envivo drawing "26533-SUR-DRG-400-AB-C2" dated October 2017.
5. Stage 2 and 3 stormwater channel from Maven Associates drawing "Proposed Channel Layout Plan Overview", ref. 215009-S3-C4000.

0m 50 100 150m
Scale 1:3000



LEGEND

- 7m deep Slurry Wall, Stage 1
- 3m deep Slurry Wall, Stage 1
- 7m deep Slurry Wall or Sheet Piles Stages 2 and 3
- 3m deep Slurry Wall, Stages 2 and 3
- Ground settlement contour from GHD (2016c), primary consolidation only
- Ground settlement contour from Earthtech check analysis, primary plus secondary consolidation
- Subsoil drain
- Waikato No. 1 Watermain
- Buildings with potential settlement greater than 50mm and 1:500, to receive detailed building assessment
- Land owned by Winton Ltd.

FOR INFORMATION

Note: All drawings are to be approved (initialled) before final issue.

EARTHTECH

Earthtech Consulting Ltd.
P.O. Box 721, Pukekohe
Phone: 64 9 238 3669
Email: admin@earthtech.co.nz

TAKANINI STORMWATER CHANNEL

Winton Partners

Predicted Ground Settlement

REV	DATE	AMENDMENT/ISSUE	DRAWN BY	CHECKED	TRACED BY	APPROVED BY
A	11-06-24	ISSUE FOR R10015-1	M.W	A.N	S.SW	MLW

DRAWING NO.: FIG. 7
REF: 10015
SCALE: 1:5000
CRS: NZTM
DATUM: N/A

Groundwater Dewatering and Ground Settlement Effects Assessment

Review of Awakeri Wetlands Stage 1 Construction and Assessment for Stages 2 and 3

Appendix A

Consolidation Settlement Back-analysis, Groundwater Drawdown

Settlement response using the approach of Leoni coupled with Terzaghi's one-dimensional consolidation theory

STEP 2 - Set OCR and Surcharge Parameters

** Ref. Leoni, M, Karstunen, M, Vermeer, PA, Anisotropic Creep Model for Soft Soils, Geotechnique, Vol.58, No.3, 215-226,(2008)*

** This sheet also uses constant c_v and leveraged Δt. h represents the longest drainage path. No surcharge removal gives the expected settlement history for constant load p_0.*

** h represents the longest drainage path. Make sure h is doubled in the calculation for settlement in Step 2 if the deposit is doubly drained.*

** Site: Awakeri Wetlands, BHMP-10*

2 Drainage (1 = single, 2 = double)

Input Data in Yellow Total thickness 14.9 m

30 d Time fill placement completed

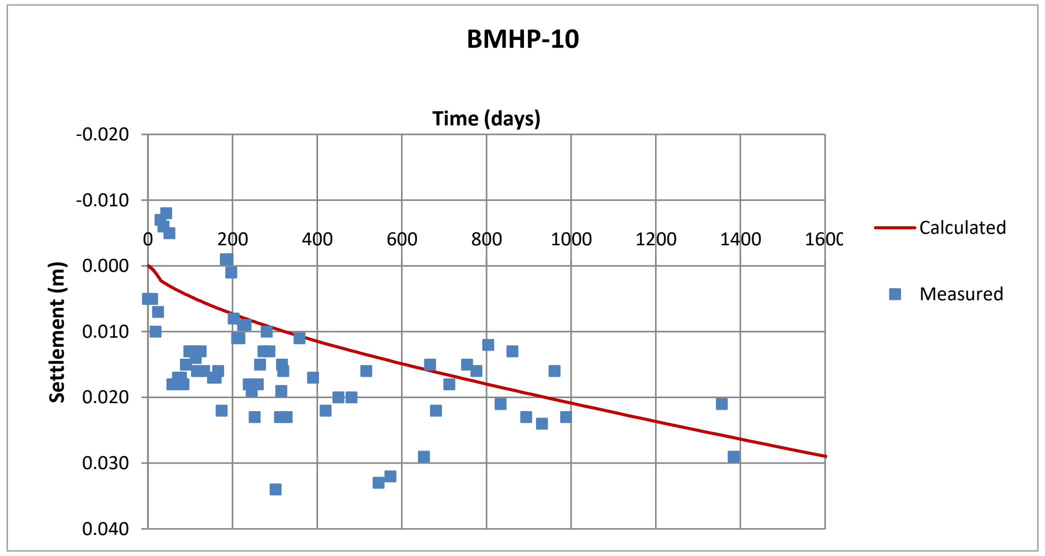
τ	1.3263	yr	c_{v0}	40	m^2/yr	p_0	1.67	kPa	$C_{\alpha\varepsilon}$	0.014	
β	8.50		h	7.45	m	p_1	1.67	kPa	$C_{s\varepsilon}$	0.021	
Leverage	1.025		h^2/c_{v0}	1.388	yr	σ'_0	32.7	kPa	$C_{c\varepsilon}$	0.14	
t_1	1.2	yr	OCR_0	1.40		σ'_{p0}	45.8	kPa	M_0	540	kPa

t1 is time since fill placement commenced

Results

Degree of primary consolidation at time t_1	90.2	percent		
Settlement at time t_1	0.012	m		
Residual settlement 3 years after t_1	0.016	m	OCR at 3 years	1.37
Residual settlement 50 years after t_1	0.128	m	OCR at 10 years	1.42
Residual settlement 100 years after t_1	0.178	m	OCR at 25 years	1.50

t (days)	p/p0	n	t (yr)	Time Factor T	Degree of Consolidation U	σ' (kPa)	σ'* (kPa)	σ'/σ'_{p0}	M/M_0	ε^e_n	ε^c_n	σ'_{pn}	OCR	ε_n	Settlement
0	0	1	0	0.000000	0.000000	32.700	32.700	0.7143	6.640	0.000000	0.000000	45.780	1.400	0.000000	0.000000
0.0365	0.001217	2	0.0001	0.000072	0.000000	32.700	32.700	0.7143	6.640	0.000000	0.000000	45.780	1.400	0.000000	0.000000
0.037413	0.001247	3	0.000103	0.000074	0.000029	32.700	32.700	0.7143	#DIV/0!	0.000000	0.000000	45.780	1.400	0.000000	0.000001
0.038348	0.001278	4	0.000105	0.000076	0.000030	32.700	32.700	0.7143	6.332	0.000000	0.000000	45.780	1.400	0.000000	0.000001
0.039307	0.00131	5	0.000108	0.000078	0.000031	32.700	32.700	0.7143	2.299	0.000000	0.000000	45.780	1.400	0.000000	0.000001
0.040289	0.001343	6	0.00011	0.000080	0.000031	32.700	32.700	0.7143	2.303	0.000000	0.000000	45.780	1.400	0.000000	0.000001
0.041296	0.001377	7	0.000113	0.000082	0.000032	32.700	32.700	0.7143	2.307	0.000000	0.000000	45.780	1.400	0.000000	0.000001
0.042329	0.001411	8	0.000116	0.000084	0.000033	32.700	32.700	0.7143	2.311	0.000000	0.000000	45.780	1.400	0.000000	0.000001
0.043387	0.001446	9	0.000119	0.000086	0.000034	32.700	32.700	0.7143	2.315	0.000000	0.000000	45.780	1.400	0.000000	0.000001
0.044472	0.001482	10	0.000122	0.000088	0.000035	32.700	32.700	0.7143	2.319	0.000000	0.000000	45.780	1.400	0.000000	0.000001
0.045583	0.001519	11	0.000125	0.000090	0.000036	32.700	32.700	0.7143	2.324	0.000000	0.000000	45.780	1.400	0.000000	0.000001
0.046723	0.001557	12	0.000128	0.000092	0.000037	32.700	32.700	0.7143	2.328	0.000000	0.000000	45.780	1.400	0.000000	0.000001
0.047891	0.001596	13	0.000131	0.000095	0.000038	32.700	32.700	0.7143	2.333	0.000000	0.000000	45.780	1.400	0.000000	0.000001
0.049088	0.001636	14	0.000134	0.000097	0.000039	32.700	32.700	0.7143	2.337	0.000000	0.000000	45.780	1.400	0.000000	0.000001
0.050316	0.001677	15	0.000138	0.000099	0.000040	32.700	32.700	0.7143	2.342	0.000000	0.000000	45.780	1.400	0.000000	0.000001
0.051574	0.001719	16	0.000141	0.000102	0.000041	32.700	32.700	0.7143	2.347	0.000000	0.000000	45.780	1.400	0.000000	0.000001
0.052863	0.001762	17	0.000145	0.000104	0.000042	32.700	32.700	0.7143	2.352	0.000000	0.000000	45.780	1.400	0.000000	0.000001
0.054184	0.001806	18	0.000148	0.000107	0.000043	32.700	32.700	0.7143	2.357	0.000000	0.000000	45.780	1.400	0.000000	0.000001
0.055539	0.001851	19	0.000152	0.000110	0.000044	32.700	32.700	0.7143	2.362	0.000000	0.000000	45.780	1.400	0.000000	0.000001
0.056928	0.001898	20	0.000156	0.000112	0.000045	32.700	32.700	0.7143	2.367	0.000000	0.000000	45.780	1.400	0.000000	0.000001
0.058351	0.001945	21	0.00016	0.000115	0.000047	32.700	32.700	0.7143	2.373	0.000000	0.000000	45.780	1.400	0.000000	0.000001
0.05981	0.001994	22	0.000164	0.000118	0.000048	32.700	32.700	0.7143	2.378	0.000000	0.000000	45.780	1.400	0.000000	0.000001
0.061305	0.002043	23	0.000168	0.000121	0.000049	32.700	32.700	0.7143	2.384	0.000000	0.000000	45.780	1.400	0.000000	0.000001
0.062837	0.002095	24	0.000172	0.000124	0.000050	32.700	32.700	0.7143	2.390	0.000000	0.000000	45.780	1.400	0.000000	0.000001
0.064408	0.002147	25	0.000176	0.000127	0.000052	32.700	32.700	0.7143	2.395	0.000000	0.000000	45.780	1.400	0.000000	0.000001
0.066018	0.002201	26	0.000181	0.000130	0.000053	32.700	32.700	0.7143	2.401	0.000000	0.000000	45.780	1.400	0.000000	0.000001
0.067669	0.002256	27	0.000185	0.000134	0.000055	32.700	32.700	0.7143	2.408	0.000000	0.000000	45.780	1.400	0.000000	0.000001
0.069361	0.002312	28	0.00019	0.000137	0.000056	32.700	32.700	0.7143	2.414	0.000000	0.000000	45.780	1.400	0.000000	0.000001
0.071095	0.00237	29	0.000195	0.000140	0.000058	32.700	32.700	0.7143	2.420	0.000000	0.000000	45.780	1.400	0.000000	0.000001
0.072872	0.002429	30	0.0002	0.000144	0.000059	32.700	32.700	0.7143	2.427	0.000000	0.000000	45.780	1.400	0.000000	0.000001
0.074694	0.00249	31	0.000205	0.000147	0.000061	32.700	32.700	0.7143	2.433	0.000000	0.000000	45.780	1.400	0.000000	0.000001
0.076561	0.002552	32	0.00021	0.000151	0.000063	32.700	32.700	0.7143	2.440	0.000000	0.000000	45.780	1.400	0.000000	0.000001
0.078475	0.002616	33	0.000215	0.000155	0.000064	32.700	32.700	0.7143	2.447	0.000000	0.000000	45.780	1.400	0.000000	0.000001
0.080437	0.002681	34	0.00022	0.000159	0.000066	32.700	32.700	0.7143	2.454	0.000000	0.000000	45.780	1.400	0.000000	0.000001
0.082448	0.002748	35	0.000226	0.000163	0.000068	32.700	32.700	0.7143	2.461	0.000000	0.000000	45.780	1.400	0.000000	0.000001
0.084509	0.002817	36	0.000232	0.000167	0.000070	32.700	32.700	0.7143	2.469	0.000000	0.000000	45.780	1.400	0.000000	0.000001
0.086622	0.002887	37	0.000237	0.000171	0.000072	32.700	32.700	0.7143	2.476	0.000000	0.000000	45.780	1.400	0.000000	0.000001
0.088788	0.00296	38	0.000243	0.000175	0.000074	32.700	32.700	0.7143	2.484	0.000000	0.000000	45.780	1.400	0.000000	0.000001
0.091007	0.003034	39	0.000249	0.000180	0.000076	32.700	32.700	0.7143	2.491	0.000000	0.000000	45.780	1.400	0.000000	0.000002
0.093282	0.003109	40	0.000256	0.000184	0.000078	32.700	32.700	0.7143	2.499	0.000000	0.000000	45.780	1.400	0.000000	0.000002
0.095614	0.003187	41	0.000262	0.000189	0.000080	32.700	32.700	0.7143	2.507	0.000000	0.000000	45.780	1.400	0.000000	0.000002
0.098005	0.003267	42	0.000269	0.000194	0.000083	32.700	32.700	0.7143	2.516	0.000000	0.000000	45.780	1.400	0.000000	0.000002
0.100455	0.003348	43	0.000275	0.000198	0.000085	32.700	32.700	0.7143	2.524	0.000000	0.000000	45.780	1.400	0.000000	0.000002
0.102966	0.003432	44	0.000282	0.000203	0.000087	32.700	32.700	0.7143	2.533	0.000000	0.000000	45.780	1.400	0.000000	0.000002
0.10554	0.003518	45	0.000289	0.000208	0.000090	32.700	32.700	0.7143	2.541	0.000000	0.000000	45.780	1.400	0.000000	0.000002
0.108179	0.003606	46	0.000296	0.000214	0.000092	32.700	32.700	0.7143	2.550	0.000000	0.000000	45.780	1.400	0.000000	0.000002
0.110883	0.003696	47	0.000304	0.000219	0.000095	32.700	32.700	0.7143	2.559	0.000000	0.000000	45.780	1.400	0.000000	0.000002
0.113656	0.003789	48	0.000311	0.000224	0.000098	32.700	32.700	0.7143	2.568	0.000000	0.000000	45.780	1.400	0.000000	0.000002
0.116497	0.003883	49	0.000319	0.000230	0.000100	32.700	32.700	0.7143	2.578	0.000000	0.000000	45.780	1.400	0.000000	0.000002
0.119409	0.00398	50	0.000327	0.000236	0.000103	32.700	32.700	0.7143	2.587	0.000000	0.000000	45.780	1.400	0.000000	0.000002



Settlement response using the approach of Leoni coupled with Terzaghi's one-dimensional consolidation theory

STEP 2 - Set OCR and Surcharge Parameters

** Ref. Leoni, M, Karstunen, M, Vermeer, PA, Anisotropic Creep Model for Soft Soils, Geotechnique, Vol.58, No.3, 215-226,(2008)*

** This sheet also uses constant c_v and leveraged Δt. h represents the longest drainage path. No surcharge removal gives the expected settlement history for constant load p_0.*

** h represents the longest drainage path. Make sure h is doubled in the calculation for settlement in Step 2 if the deposit is doubly drained.*

** Site: Awakeri Wetlands, BHMP-11*

2 Drainage (1 = single, 2 = double)

Input Data in Yellow Total thickness 15.9 m; 30 d Time fill placement completed

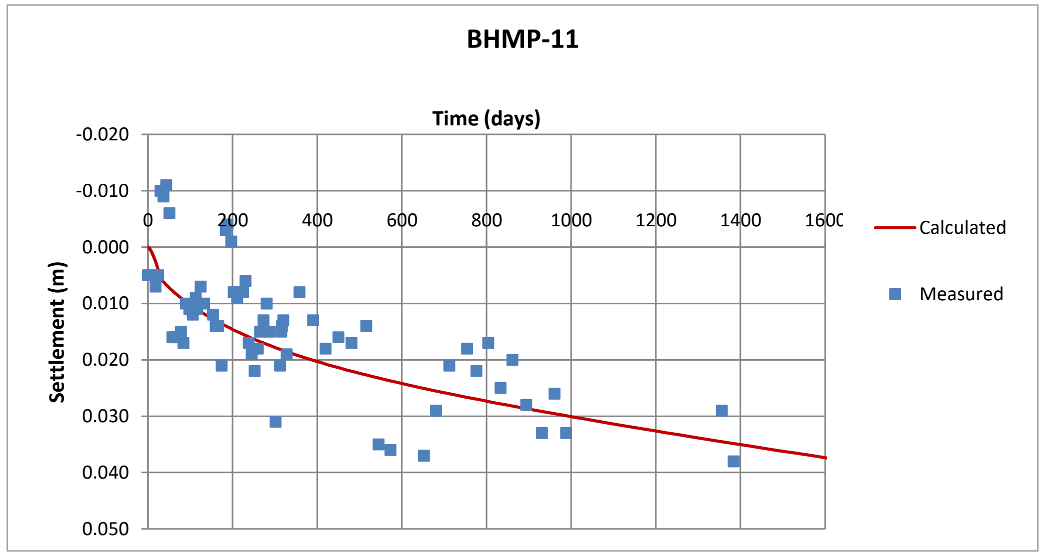
τ	0.4453	*yr*	c_{v0}	40	m^2/yr	p_0	4.71	*kPa*	$C_{\alpha\varepsilon}$	0.01	
β	8.50		h	7.95	*m*	p_1	4.71	*kPa*	$C_{s\varepsilon}$	0.015	
Leverage	1.025		h^2/c_{v0}	1.580	*yr*	σ'_0	22.4	*kPa*	$C_{c\varepsilon}$	0.1	
t_1	1.4	*yr*	OCR_0	1.80		σ'_{p0}	40.3	*kPa*	M_0	520	*kPa*

t1 is time since fill placement commenced

Results

Degree of primary consolidation at time t_1	90.6	percent		
Settlement at time t_1	0.022	*m*		
Residual settlement 3 years after t_1	0.015	*m*	*OCR at 3 years*	1.53
Residual settlement 50 years after t_1	0.107	*m*	*OCR at 10 years*	1.60
Residual settlement 100 years after t_1	0.148	*m*	*OCR at 25 years*	1.69

t (days)	*p/p0*	*n*	*t (yr)*	Time Factor *T*	Degree of Consolidation *U*	*σ' (kPa)*	*σ'* (kPa)*	σ'/σ'_{p0}	M/M_0	ε^e_n	ε^c_n	σ'_{pn}	*OCR*	ε_n	*Settlement*
0	0	1	0	0.000000	0.000000	22.400	22.400	0.5556	6.613	0.000000	0.000000	40.320	1.800	0.000000	0.000000
0.0365	0.001217	2	0.0001	0.000063	0.000000	22.400	22.400	0.5556	6.613	0.000000	0.000000	40.320	1.800	0.000000	0.000000
0.037413	0.001247	3	0.000103	0.000065	0.000029	22.400	22.400	0.5556	#DIV/0!	0.000000	0.000000	40.320	1.800	0.000000	0.000001
0.038348	0.001278	4	0.000105	0.000066	0.000030	22.400	22.400	0.5556	6.585	0.000000	0.000000	40.320	1.800	0.000000	0.000001
0.039307	0.00131	5	0.000108	0.000068	0.000030	22.400	22.400	0.5556	5.684	0.000000	0.000000	40.320	1.800	0.000000	0.000001
0.040289	0.001343	6	0.00011	0.000070	0.000031	22.400	22.400	0.5556	5.686	0.000000	0.000000	40.320	1.800	0.000000	0.000001
0.041296	0.001377	7	0.000113	0.000072	0.000032	22.400	22.400	0.5556	5.688	0.000000	0.000000	40.320	1.800	0.000000	0.000001
0.042329	0.001411	8	0.000116	0.000073	0.000033	22.400	22.400	0.5556	5.689	0.000000	0.000000	40.320	1.800	0.000000	0.000001
0.043387	0.001446	9	0.000119	0.000075	0.000034	22.400	22.400	0.5556	5.691	0.000000	0.000000	40.320	1.800	0.000000	0.000001
0.044472	0.001482	10	0.000122	0.000077	0.000035	22.400	22.400	0.5556	5.693	0.000000	0.000000	40.320	1.800	0.000000	0.000001
0.045583	0.001519	11	0.000125	0.000079	0.000035	22.400	22.400	0.5556	5.695	0.000000	0.000000	40.320	1.800	0.000000	0.000001
0.046723	0.001557	12	0.000128	0.000081	0.000036	22.400	22.400	0.5556	5.698	0.000000	0.000000	40.320	1.800	0.000000	0.000001
0.047891	0.001596	13	0.000131	0.000083	0.000037	22.400	22.400	0.5556	5.700	0.000000	0.000000	40.320	1.800	0.000000	0.000001
0.049088	0.001636	14	0.000134	0.000085	0.000038	22.400	22.400	0.5556	5.702	0.000000	0.000000	40.320	1.800	0.000000	0.000001
0.050316	0.001677	15	0.000138	0.000087	0.000039	22.400	22.400	0.5556	5.704	0.000000	0.000000	40.320	1.800	0.000000	0.000001
0.051574	0.001719	16	0.000141	0.000089	0.000040	22.400	22.400	0.5556	5.706	0.000000	0.000000	40.320	1.800	0.000000	0.000001
0.052863	0.001762	17	0.000145	0.000092	0.000041	22.400	22.400	0.5556	5.709	0.000000	0.000000	40.320	1.800	0.000000	0.000001
0.054184	0.001806	18	0.000148	0.000094	0.000043	22.400	22.400	0.5556	5.711	0.000000	0.000000	40.320	1.800	0.000000	0.000001
0.055539	0.001851	19	0.000152	0.000096	0.000044	22.400	22.400	0.5556	5.713	0.000000	0.000000	40.320	1.800	0.000000	0.000001
0.056928	0.001898	20	0.000156	0.000099	0.000045	22.400	22.400	0.5556	5.716	0.000000	0.000000	40.320	1.800	0.000000	0.000001
0.058351	0.001945	21	0.00016	0.000101	0.000046	22.400	22.400	0.5556	5.718	0.000000	0.000000	40.320	1.800	0.000000	0.000001
0.05981	0.001994	22	0.000164	0.000104	0.000047	22.400	22.400	0.5556	5.721	0.000000	0.000000	40.320	1.800	0.000000	0.000001
0.061305	0.002043	23	0.000168	0.000106	0.000049	22.400	22.400	0.5556	5.723	0.000000	0.000000	40.320	1.800	0.000000	0.000001
0.062837	0.002095	24	0.000172	0.000109	0.000050	22.400	22.400	0.5556	5.726	0.000000	0.000000	40.320	1.800	0.000000	0.000001
0.064408	0.002147	25	0.000176	0.000112	0.000051	22.400	22.400	0.5556	5.728	0.000000	0.000000	40.320	1.800	0.000000	0.000001
0.066018	0.002201	26	0.000181	0.000114	0.000053	22.400	22.400	0.5556	5.731	0.000000	0.000000	40.320	1.800	0.000000	0.000001
0.067669	0.002256	27	0.000185	0.000117	0.000054	22.400	22.400	0.5556	5.734	0.000000	0.000000	40.320	1.800	0.000000	0.000001
0.069361	0.002312	28	0.00019	0.000120	0.000056	22.400	22.400	0.5556	5.737	0.000000	0.000000	40.320	1.800	0.000000	0.000001
0.071095	0.00237	29	0.000195	0.000123	0.000057	22.400	22.400	0.5556	5.739	0.000000	0.000000	40.320	1.800	0.000000	0.000001
0.072872	0.002429	30	0.0002	0.000126	0.000059	22.400	22.400	0.5556	5.742	0.000000	0.000000	40.320	1.800	0.000000	0.000001
0.074694	0.00249	31	0.000205	0.000130	0.000060	22.400	22.400	0.5556	5.745	0.000000	0.000000	40.320	1.800	0.000000	0.000002
0.076561	0.002552	32	0.00021	0.000133	0.000062	22.400	22.400	0.5556	5.748	0.000000	0.000000	40.320	1.800	0.000000	0.000002
0.078475	0.002616	33	0.000215	0.000136	0.000064	22.400	22.400	0.5556	5.751	0.000000	0.000000	40.320	1.800	0.000000	0.000002
0.080437	0.002681	34	0.00022	0.000139	0.000065	22.400	22.400	0.5556	5.754	0.000000	0.000000	40.320	1.800	0.000000	0.000002
0.082448	0.002748	35	0.000226	0.000143	0.000067	22.400	22.400	0.5556	5.758	0.000000	0.000000	40.320	1.800	0.000000	0.000002
0.084509	0.002817	36	0.000232	0.000147	0.000069	22.400	22.400	0.5556	5.761	0.000000	0.000000	40.320	1.800	0.000000	0.000002
0.086622	0.002887	37	0.000237	0.000150	0.000071	22.400	22.400	0.5556	5.764	0.000000	0.000000	40.320	1.800	0.000000	0.000002
0.088788	0.00296	38	0.000243	0.000154	0.000073	22.400	22.400	0.5556	5.767	0.000000	0.000000	40.320	1.800	0.000000	0.000002
0.091007	0.003034	39	0.000249	0.000158	0.000075	22.400	22.400	0.5556	5.771	0.000000	0.000000	40.320	1.800	0.000000	0.000002
0.093282	0.003109	40	0.000256	0.000162	0.000077	22.400	22.400	0.5556	5.774	0.000000	0.000000	40.320	1.800	0.000000	0.000002
0.095614	0.003187	41	0.000262	0.000166	0.000079	22.400	22.400	0.5556	5.777	0.000000	0.000000	40.320	1.800	0.000000	0.000002
0.098005	0.003267	42	0.000269	0.000170	0.000081	22.400	22.400	0.5556	5.781	0.000000	0.000000	40.320	1.800	0.000000	0.000002
0.100455	0.003348	43	0.000275	0.000174	0.000083	22.400	22.400	0.5556	5.784	0.000000	0.000000	40.320	1.800	0.000000	0.000002
0.102966	0.003432	44	0.000282	0.000179	0.000086	22.400	22.400	0.5556	5.788	0.000000	0.000000	40.320	1.800	0.000000	0.000002
0.10554	0.003518	45	0.000289	0.000183	0.000088	22.400	22.400	0.5556	5.792	0.000000	0.000000	40.320	1.800	0.000000	0.000002
0.108179	0.003606	46	0.000296	0.000188	0.000091	22.400	22.400	0.5556	5.795	0.000000	0.000000	40.320	1.800	0.000000	0.000002
0.110883	0.003696	47	0.000304	0.000192	0.000093	22.400	22.400	0.5556	5.799	0.000000	0.000000	40.320	1.800	0.000000	0.000002
0.113656	0.003789	48	0.000311	0.000197	0.000096	22.400	22.400	0.5556	5.803	0.000000	0.000000	40.320	1.800	0.000000	0.000002
0.116497	0.003883	49	0.000319	0.000202	0.000099	22.400	22.400	0.5556	5.807	0.000000	0.000000	40.320	1.800	0.000000	0.000002
0.119409	0.00398	50	0.000327	0.000207	0.000101	22.400	22.400	0.5556	5.811	0.000000	0.000000	40.320	1.800	0.000000	0.000003



Settlement response using the approach of Leoni coupled with Terzaghi's one-dimensional consolidation theory

STEP 2 - Set OCR and Surcharge Parameters

** Ref. Leoni, M, Karstunen, M, Vermeer, PA, Anisotropic Creep Model for Soft Soils, Geotechnique, Vol.58, No.3, 215-226,(2008)*

** This sheet also uses constant c_v and leveraged Δt. h represents the longest drainage path. No surcharge removal gives the expected settlement history for constant load p_0.*

** h represents the longest drainage path. Make sure h is doubled in the calculation for settlement in Step 2 if the deposit is doubly drained.*

** Site: Awakeri Wetlands, BHMP-43*

2 Drainage (1 = single, 2 = double)

Input Data in Yellow Total thickness 20.3 m

30 d Time fill placement completed

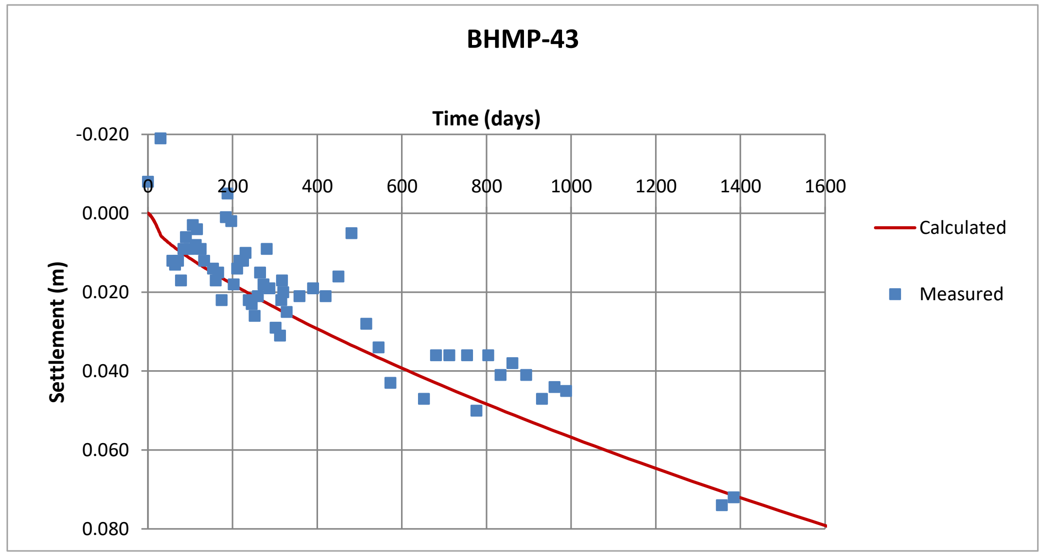
τ	1.1503	*yr*	c_{v0}	40	m^2/yr	p_0	1.57	*kPa*	$C_{\alpha\varepsilon}$	0.016	
β	8.50		h	10.15	*m*	p_1	1.57	*kPa*	$C_{s\varepsilon}$	0.024	
Leverage	1.025		h^2/c_{v0}	2.576	*yr*	σ'_0	13.2	*kPa*	$C_{c\varepsilon}$	0.16	
t_1	2.2	*yr*	OCR_0	1.40		σ'_{p0}	18.5	*kPa*	M_0	190	*kPa*

t1 is time since fill placement commenced

Results

Degree of primary consolidation at time t_1	89.7	percent		
Settlement at time t_1	0.048	*m*		
Residual settlement 3 years after t_1	0.039	*m*	*OCR at 3 years*	1.32
Residual settlement 50 years after t_1	0.263	*m*	*OCR at 10 years*	1.39
Residual settlement 100 years after t_1	0.349	*m*	*OCR at 25 years*	1.49

t (days)	*p/p0*	*n*	*t (yr)*	*Time Factor T*	*Degree of Consolidation U*	*σ' (kPa)*	*σ'* (kPa)*	σ'/σ'_{p0}	M/M_0	ε^e_n	ε^c_n	σ'_{pn}	*OCR*	ε_n	*Settlement*
0	0	1	0	0.000000	0.000000	13.200	13.200	0.7143	6.665	0.000000	0.000000	18.480	1.400	0.000000	0.000000
0.0365	0.001217	2	0.0001	0.000039	0.000000	13.200	13.200	0.7143	6.665	0.000000	0.000000	18.480	1.400	0.000000	0.000001
0.037413	0.001247	3	0.000103	0.000040	0.000028	13.200	13.200	0.7143	#DIV/0!	0.000000	0.000000	18.480	1.400	0.000000	0.000001
0.038348	0.001278	4	0.000105	0.000041	0.000029	13.200	13.200	0.7143	6.505	0.000000	0.000000	18.480	1.400	0.000000	0.000001
0.039307	0.00131	5	0.000108	0.000042	0.000030	13.200	13.200	0.7143	3.362	0.000000	0.000000	18.480	1.400	0.000000	0.000002
0.040289	0.001343	6	0.00011	0.000043	0.000030	13.200	13.200	0.7143	3.365	0.000000	0.000000	18.480	1.400	0.000000	0.000002
0.041296	0.001377	7	0.000113	0.000044	0.000031	13.200	13.200	0.7143	3.367	0.000000	0.000000	18.480	1.400	0.000000	0.000002
0.042329	0.001411	8	0.000116	0.000045	0.000032	13.200	13.200	0.7143	3.370	0.000000	0.000000	18.480	1.400	0.000000	0.000002
0.043387	0.001446	9	0.000119	0.000046	0.000033	13.200	13.200	0.7143	3.373	0.000000	0.000000	18.480	1.400	0.000000	0.000002
0.044472	0.001482	10	0.000122	0.000047	0.000034	13.200	13.200	0.7143	3.375	0.000000	0.000000	18.480	1.400	0.000000	0.000002
0.045583	0.001519	11	0.000125	0.000048	0.000035	13.200	13.200	0.7143	3.378	0.000000	0.000000	18.480	1.400	0.000000	0.000002
0.046723	0.001557	12	0.000128	0.000050	0.000036	13.200	13.200	0.7143	3.381	0.000000	0.000000	18.480	1.400	0.000000	0.000002
0.047891	0.001596	13	0.000131	0.000051	0.000036	13.200	13.200	0.7143	3.384	0.000000	0.000000	18.480	1.400	0.000000	0.000002
0.049088	0.001636	14	0.000134	0.000052	0.000037	13.200	13.200	0.7143	3.387	0.000000	0.000000	18.480	1.400	0.000000	0.000002
0.050316	0.001677	15	0.000138	0.000054	0.000038	13.200	13.200	0.7143	3.390	0.000000	0.000000	18.480	1.400	0.000000	0.000002
0.051574	0.001719	16	0.000141	0.000055	0.000039	13.200	13.200	0.7143	3.393	0.000000	0.000000	18.480	1.400	0.000000	0.000002
0.052863	0.001762	17	0.000145	0.000056	0.000040	13.200	13.200	0.7143	3.396	0.000000	0.000000	18.480	1.400	0.000000	0.000002
0.054184	0.001806	18	0.000148	0.000058	0.000041	13.200	13.200	0.7143	3.399	0.000000	0.000000	18.480	1.400	0.000000	0.000002
0.055539	0.001851	19	0.000152	0.000059	0.000043	13.200	13.200	0.7143	3.403	0.000000	0.000000	18.480	1.400	0.000000	0.000002
0.056928	0.001898	20	0.000156	0.000061	0.000044	13.200	13.200	0.7143	3.406	0.000000	0.000000	18.480	1.400	0.000000	0.000002
0.058351	0.001945	21	0.00016	0.000062	0.000045	13.200	13.200	0.7143	3.410	0.000000	0.000000	18.480	1.400	0.000000	0.000002
0.05981	0.001994	22	0.000164	0.000064	0.000046	13.200	13.200	0.7143	3.413	0.000000	0.000000	18.480	1.400	0.000000	0.000002
0.061305	0.002043	23	0.000168	0.000065	0.000047	13.200	13.200	0.7143	3.417	0.000000	0.000000	18.480	1.400	0.000000	0.000002
0.062837	0.002095	24	0.000172	0.000067	0.000048	13.200	13.200	0.7143	3.420	0.000000	0.000000	18.480	1.400	0.000000	0.000002
0.064408	0.002147	25	0.000176	0.000069	0.000050	13.200	13.200	0.7143	3.424	0.000000	0.000000	18.480	1.400	0.000000	0.000002
0.066018	0.002201	26	0.000181	0.000070	0.000051	13.200	13.200	0.7143	3.428	0.000000	0.000000	18.480	1.400	0.000000	0.000003
0.067669	0.002256	27	0.000185	0.000072	0.000052	13.200	13.200	0.7143	3.432	0.000000	0.000000	18.480	1.400	0.000000	0.000003
0.069361	0.002312	28	0.00019	0.000074	0.000054	13.200	13.200	0.7143	3.436	0.000000	0.000000	18.480	1.400	0.000000	0.000003
0.071095	0.00237	29	0.000195	0.000076	0.000055	13.200	13.200	0.7143	3.440	0.000000	0.000000	18.480	1.400	0.000000	0.000003
0.072872	0.002429	30	0.0002	0.000078	0.000057	13.200	13.200	0.7143	3.444	0.000000	0.000000	18.480	1.400	0.000000	0.000003
0.074694	0.00249	31	0.000205	0.000079	0.000058	13.200	13.200	0.7143	3.449	0.000000	0.000000	18.480	1.400	0.000000	0.000003
0.076561	0.002552	32	0.00021	0.000081	0.000060	13.200	13.200	0.7143	3.453	0.000000	0.000000	18.480	1.400	0.000000	0.000003
0.078475	0.002616	33	0.000215	0.000083	0.000061	13.200	13.200	0.7143	3.458	0.000000	0.000000	18.480	1.400	0.000000	0.000003
0.080437	0.002681	34	0.00022	0.000086	0.000063	13.200	13.200	0.7143	3.462	0.000000	0.000000	18.480	1.400	0.000000	0.000003
0.082448	0.002748	35	0.000226	0.000088	0.000064	13.200	13.200	0.7143	3.467	0.000000	0.000000	18.480	1.400	0.000000	0.000003
0.084509	0.002817	36	0.000232	0.000090	0.000066	13.200	13.200	0.7143	3.472	0.000000	0.000000	18.480	1.400	0.000000	0.000003
0.086622	0.002887	37	0.000237	0.000092	0.000068	13.200	13.200	0.7143	3.477	0.000000	0.000000	18.480	1.400	0.000000	0.000003
0.088788	0.00296	38	0.000243	0.000094	0.000070	13.200	13.200	0.7143	3.482	0.000000	0.000000	18.480	1.400	0.000000	0.000003
0.091007	0.003034	39	0.000249	0.000097	0.000072	13.200	13.200	0.7143	3.487	0.000000	0.000000	18.480	1.400	0.000000	0.000004
0.093282	0.003109	40	0.000256	0.000099	0.000074	13.200	13.200	0.7143	3.492	0.000000	0.000000	18.480	1.400	0.000000	0.000004
0.095614	0.003187	41	0.000262	0.000102	0.000076	13.200	13.200	0.7143	3.497	0.000000	0.000000	18.480	1.400	0.000000	0.000004
0.098005	0.003267	42	0.000269	0.000104	0.000078	13.200	13.200	0.7143	3.503	0.000000	0.000000	18.480	1.400	0.000000	0.000004
0.100455	0.003348	43	0.000275	0.000107	0.000080	13.200	13.200	0.7143	3.508	0.000000	0.000000	18.480	1.400	0.000000	0.000004
0.102966	0.003432	44	0.000282	0.000110	0.000082	13.200	13.200	0.7143	3.514	0.000000	0.000000	18.480	1.400	0.000000	0.000004
0.10554	0.003518	45	0.000289	0.000112	0.000084	13.200	13.200	0.7143	3.520	0.000000	0.000000	18.480	1.400	0.000000	0.000004
0.108179	0.003606	46	0.000296	0.000115	0.000086	13.200	13.200	0.7143	3.526	0.000000	0.000000	18.480	1.400	0.000000	0.000004
0.110883	0.003696	47	0.000304	0.000118	0.000089	13.200	13.200	0.7143	3.531	0.000000	0.000000	18.480	1.400	0.000000	0.000004
0.113656	0.003789	48	0.000311	0.000121	0.000091	13.200	13.200	0.7143	3.538	0.000000	0.000000	18.480	1.400	0.000000	0.000004
0.116497	0.003883	49	0.000319	0.000124	0.000094	13.200	13.200	0.7143	3.544	0.000000	0.000000	18.480	1.400	0.000000	0.000005
0.119409	0.00398	50	0.000327	0.000127	0.000096	13.200	13.200	0.7143	3.550	0.000000	0.000000	18.480	1.400	0.000000	0.000005



Settlement response using the approach of Leoni coupled with Terzaghi's one-dimensional consolidation theory

STEP 2 - Set OCR and Surcharge Parameters

** Ref. Leoni, M, Karstunen, M, Vermeer, PA, Anisotropic Creep Model for Soft Soils, Geotechnique, Vol.58, No.3, 215-226,(2008)*

** This sheet also uses constant c_v and leveraged Δt. h represents the longest drainage path. No surcharge removal gives the expected settlement history for constant load p_0.*

** h represents the longest drainage path. Make sure h is doubled in the calculation for settlement in Step 2 if the deposit is doubly drained.*

** Site: Awakeri Wetlands, MP-44*

2 Drainage (1 = single, 2 = double)

Input Data in Yellow Total thickness 13.9 m

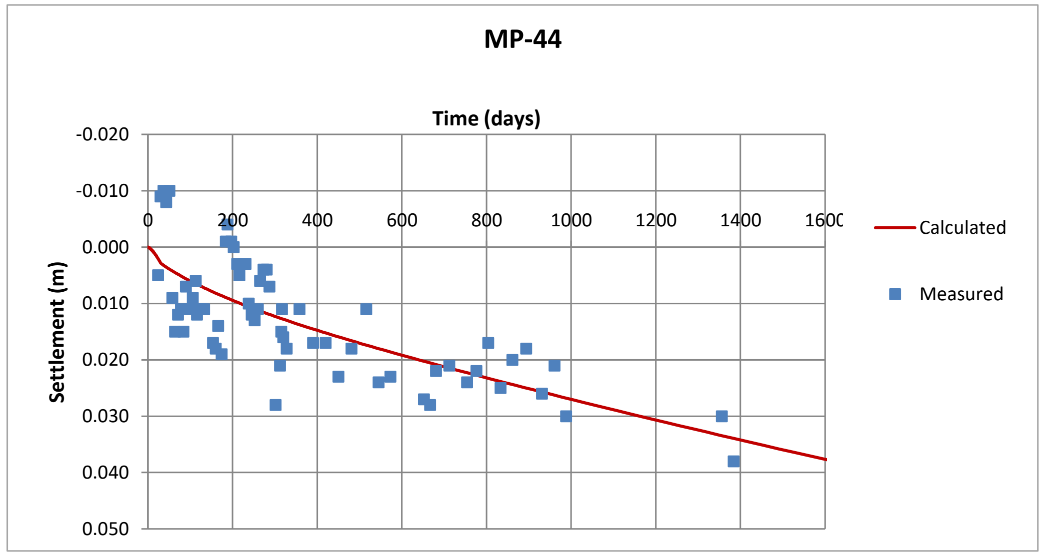
30 d Time fill placement completed

τ	1.2208 *yr*	c_{v0}	40 m^2/yr	p_0	1.28 *kPa*	$C_{\alpha\varepsilon}$	0.019
β	8.50	h	6.95 *m*	p_1	1.28 *kPa*	$C_{s\varepsilon}$	0.0285
Leverage	1.025	h^2/c_{v0}	1.208 *yr*	σ'_0	26.92 *kPa*	$C_{c\varepsilon}$	0.19
t_1	1 *yr*	OCR_0	1.40	σ'_{p0}	37.7 *kPa*	M_0	330 *kPa*

t1 is time since fill placement commenced

Results

Degree of primary consolidation at time t_1	89.0 percent		
Settlement at time t_1	0.014 *m*		
Residual settlement 3 years after t_1	0.021 *m*	*OCR at 3 years*	1.37
Residual settlement 50 years after t_1	0.168 *m*	*OCR at 10 years*	1.43
Residual settlement 100 years after t_1	0.232 *m*	*OCR at 25 years*	1.51



t (days)	*p/p0*	*n*	*t (yr)*	*Time Factor T*	*Degree of Consolidation U*	σ' *(kPa)*	σ'^* *(kPa)*	σ'/σ'_{p0}	M/M_0	ε^e_n	ε^c_n	σ'_{pn}	*OCR*	ε_n	*Settlement*
0	0	1	0	0.000000	0.000000	26.920	26.920	0.7143	6.591	0.000000	0.000000	37.688	1.400	0.000000	0.000000
0.0365	0.001217	2	0.0001	0.000083	0.000000	26.920	26.920	0.7143	6.591	0.000000	0.000000	37.688	1.400	0.000000	0.000001
0.037413	0.001247	3	0.000103	0.000085	0.000029	26.920	26.920	0.7143	#DIV/0!	0.000000	0.000000	37.688	1.400	0.000000	0.000001
0.038348	0.001278	4	0.000105	0.000087	0.000030	26.920	26.920	0.7143	6.239	0.000000	0.000000	37.688	1.400	0.000000	0.000001
0.039307	0.00131	5	0.000108	0.000089	0.000031	26.920	26.920	0.7143	2.079	0.000000	0.000000	37.688	1.400	0.000000	0.000001
0.040289	0.001343	6	0.00011	0.000091	0.000032	26.920	26.920	0.7143	2.083	0.000000	0.000000	37.688	1.400	0.000000	0.000001
0.041296	0.001377	7	0.000113	0.000094	0.000032	26.920	26.920	0.7143	2.088	0.000000	0.000000	37.688	1.400	0.000000	0.000001
0.042329	0.001411	8	0.000116	0.000096	0.000033	26.920	26.920	0.7143	2.092	0.000000	0.000000	37.688	1.400	0.000000	0.000001
0.043387	0.001446	9	0.000119	0.000098	0.000034	26.920	26.920	0.7143	2.096	0.000000	0.000000	37.688	1.400	0.000000	0.000001
0.044472	0.001482	10	0.000122	0.000101	0.000035	26.920	26.920	0.7143	2.101	0.000000	0.000000	37.688	1.400	0.000000	0.000001
0.045583	0.001519	11	0.000125	0.000103	0.000036	26.920	26.920	0.7143	2.106	0.000000	0.000000	37.688	1.400	0.000000	0.000001
0.046723	0.001557	12	0.000128	0.000106	0.000037	26.920	26.920	0.7143	2.110	0.000000	0.000000	37.688	1.400	0.000000	0.000001
0.047891	0.001596	13	0.000131	0.000109	0.000038	26.920	26.920	0.7143	2.115	0.000000	0.000000	37.688	1.400	0.000000	0.000001
0.049088	0.001636	14	0.000134	0.000111	0.000039	26.920	26.920	0.7143	2.120	0.000000	0.000000	37.688	1.400	0.000000	0.000001
0.050316	0.001677	15	0.000138	0.000114	0.000040	26.920	26.920	0.7143	2.125	0.000000	0.000000	37.688	1.400	0.000000	0.000001
0.051574	0.001719	16	0.000141	0.000117	0.000041	26.920	26.920	0.7143	2.130	0.000000	0.000000	37.688	1.400	0.000000	0.000001
0.052863	0.001762	17	0.000145	0.000120	0.000042	26.920	26.920	0.7143	2.136	0.000000	0.000000	37.688	1.400	0.000000	0.000001
0.054184	0.001806	18	0.000148	0.000123	0.000043	26.920	26.920	0.7143	2.141	0.000000	0.000000	37.688	1.400	0.000000	0.000001
0.055539	0.001851	19	0.000152	0.000126	0.000045	26.920	26.920	0.7143	2.146	0.000000	0.000000	37.688	1.400	0.000000	0.000001
0.056928	0.001898	20	0.000156	0.000129	0.000046	26.920	26.920	0.7143	2.152	0.000000	0.000000	37.688	1.400	0.000000	0.000001
0.058351	0.001945	21	0.00016	0.000132	0.000047	26.920	26.920	0.7143	2.158	0.000000	0.000000	37.688	1.400	0.000000	0.000001
0.05981	0.001994	22	0.000164	0.000136	0.000048	26.920	26.920	0.7143	2.164	0.000000	0.000000	37.688	1.400	0.000000	0.000001
0.061305	0.002043	23	0.000168	0.000139	0.000050	26.920	26.920	0.7143	2.170	0.000000	0.000000	37.688	1.400	0.000000	0.000001
0.062837	0.002095	24	0.000172	0.000143	0.000051	26.920	26.920	0.7143	2.176	0.000000	0.000000	37.688	1.400	0.000000	0.000001
0.064408	0.002147	25	0.000176	0.000146	0.000053	26.920	26.920	0.7143	2.182	0.000000	0.000000	37.688	1.400	0.000000	0.000001
0.066018	0.002201	26	0.000181	0.000150	0.000054	26.920	26.920	0.7143	2.188	0.000000	0.000000	37.688	1.400	0.000000	0.000001
0.067669	0.002256	27	0.000185	0.000154	0.000055	26.920	26.920	0.7143	2.195	0.000000	0.000000	37.688	1.400	0.000000	0.000001
0.069361	0.002312	28	0.00019	0.000157	0.000057	26.920	26.920	0.7143	2.202	0.000000	0.000000	37.688	1.400	0.000000	0.000001
0.071095	0.00237	29	0.000195	0.000161	0.000059	26.920	26.920	0.7143	2.208	0.000000	0.000000	37.688	1.400	0.000000	0.000002
0.072872	0.002429	30	0.0002	0.000165	0.000060	26.920	26.920	0.7143	2.215	0.000000	0.000000	37.688	1.400	0.000000	0.000002
0.074694	0.00249	31	0.000205	0.000169	0.000062	26.920	26.920	0.7143	2.222	0.000000	0.000000	37.688	1.400	0.000000	0.000002
0.076561	0.002552	32	0.00021	0.000174	0.000064	26.920	26.920	0.7143	2.229	0.000000	0.000000	37.688	1.400	0.000000	0.000002
0.078475	0.002616	33	0.000215	0.000178	0.000065	26.920	26.920	0.7143	2.237	0.000000	0.000000	37.688	1.400	0.000000	0.000002
0.080437	0.002681	34	0.00022	0.000182	0.000067	26.920	26.920	0.7143	2.244	0.000000	0.000000	37.688	1.400	0.000000	0.000002
0.082448	0.002748	35	0.000226	0.000187	0.000069	26.920	26.920	0.7143	2.252	0.000000	0.000000	37.688	1.400	0.000000	0.000002
0.084509	0.002817	36	0.000232	0.000192	0.000071	26.920	26.920	0.7143	2.260	0.000000	0.000000	37.688	1.400	0.000000	0.000002
0.086622	0.002887	37	0.000237	0.000197	0.000073	26.920	26.920	0.7143	2.268	0.000000	0.000000	37.688	1.400	0.000000	0.000002
0.088788	0.00296	38	0.000243	0.000201	0.000075	26.920	26.920	0.7143	2.276	0.000000	0.000000	37.688	1.400	0.000000	0.000002
0.091007	0.003034	39	0.000249	0.000206	0.000077	26.920	26.920	0.7143	2.284	0.000000	0.000000	37.688	1.400	0.000000	0.000002
0.093282	0.003109	40	0.000256	0.000212	0.000079	26.920	26.920	0.7143	2.292	0.000000	0.000000	37.688	1.400	0.000000	0.000002
0.095614	0.003187	41	0.000262	0.000217	0.000082	26.920	26.920	0.7143	2.301	0.000000	0.000000	37.688	1.400	0.000000	0.000002
0.098005	0.003267	42	0.000269	0.000222	0.000084	26.920	26.920	0.7143	2.310	0.000000	0.000000	37.688	1.400	0.000000	0.000002
0.100455	0.003348	43	0.000275	0.000228	0.000086	26.920	26.920	0.7143	2.318	0.000000	0.000000	37.688	1.400	0.000000	0.000002
0.102966	0.003432	44	0.000282	0.000234	0.000089	26.920	26.920	0.7143	2.327	0.000000	0.000000	37.688	1.400	0.000000	0.000002
0.10554	0.003518	45	0.000289	0.000239	0.000092	26.920	26.920	0.7143	2.337	0.000000	0.000000	37.688	1.400	0.000000	0.000002
0.108179	0.003606	46	0.000296	0.000245	0.000094	26.920	26.920	0.7143	2.346	0.000000	0.000000	37.688	1.400	0.000000	0.000002
0.110883	0.003696	47	0.000304	0.000252	0.000097	26.920	26.920	0.7143	2.356	0.000000	0.000000	37.688	1.400	0.000000	0.000002
0.113656	0.003789	48	0.000311	0.000258	0.000100	26.920	26.920	0.7143	2.365	0.000000	0.000000	37.688	1.400	0.000000	0.000002
0.116497	0.003883	49	0.000319	0.000264	0.000103	26.920	26.920	0.7143	2.375	0.000000	0.000000	37.688	1.400	0.000000	0.000003
0.119409	0.00398	50	0.000327	0.000271	0.000106	26.920	26.920	0.7143	2.385	0.000000	0.000000	37.688	1.400	0.000000	0.000003

Groundwater Dewatering and Ground Settlement Effects Assessment

Review of Awakeri Wetlands Stage 1 Construction and Assessment for Stages 2 and 3

Appendix B

Auckland Unitary Plan Chapter E7 Assessment

Appendix B. Assessment against Auckland Unitary Plan Chapter E7

The below presents technical information to assist with the planning determination.

	Objective/Policy	Comment
E7	**Auckland Unitary Plan (updates to 14 October 2022)**	
	E7.4.1 Activity Table	
A20	Dewatering or groundwater level control associated with a groundwater diversion authorized as a restricted discretionary activity under the Unitary Plan, not meeting permitted activity standards or is not otherwise listed	Consent is required under A20, as the proposed groundwater diversion is a restricted discretionary activity under E7.6.1.6 and E7.6.1.10.
A28	The diversion of groundwater caused by any excavation, (including trench) or tunnel that does not meet the permitted activity standards or not otherwise listed.	Consent is required under A28, as the proposed groundwater diversion is a restricted discretionary activity under E7.6.1.6 and E7.6.1.10.
	E7.6.1.6 Dewatering or groundwater level control associated with a groundwater diversion permitted under Standard E7.6.1.10, all of the following must be met:	
1	The water take must not be geothermal water;	Complies: The groundwater take will not be geothermal water.
2	The water take must not be for a period of more than 10 days where it occurs in peat soils, or 30 days in other types of soil or rock; and	Does not comply: The water take is in peat, and will exceed 10 days.
3	The water take must only occur during construction.	Does not comply: The groundwater table will be permanently lowered as part of the Awakeri Wetland construction.
	E7.6.1.10 Diversion of groundwater caused by any excavation, (including trench) or tunnel	
1	All of the following activities are exempt from the Standards E7.6.1.10(2) – (6): a) pipes cables or tunnels including associated structures which are drilled or thrust and are up to 1.2m in external diameter; b) pipes including associated structures up to 1.5m in external diameter where a closed faced or earth pressure balanced machine is used; c) piles up to 1.5m in external diameter are exempt from these standards; d) diversions for no longer than 10 days; or e) diversions for network utilities and road network linear trenching activities that are progressively opened, closed and stabilised where the part of the trench that is open at any given time is no longer than 10 days.	a) Not applicable. b) Not applicable. c) Not applicable. d) Does not comply: the groundwater diversion will exceed 10 days. e) Not applicable.

	Objective/Policy	Comment
2	Any excavation that extends below natural groundwater level, must not exceed: a) 1ha in total area; and b) 6m depth below the natural ground level.	a) Does not comply: the excavation which extends below the groundwater level is approx. 1.2ha in area. b) Complies: the maximum excavation depth is approx. 4.9m below natural ground levels.
3	The natural groundwater level must not be reduced by more than 2m on the boundary of any adjoining site.	Does not comply: the natural groundwater level will be reduced by up to 3*m* during construction, at the boundaries with Cosgrave Road. All other site boundaries comply.
4	Any structure, excluding sheet piling that remains in place for no more than 30 days, that physically impedes the flow of groundwater through the site must not: a) impede the flow of groundwater over a length of more than 20m; and b) extend more than 2m below the natural groundwater level.	a) Does not comply: the proposed 3m deep and 7m deep groundwater cut-off walls will impede the flow of groundwater over a length of approx. 970m. b) Does not comply: the proposed 7m deep groundwater cut-off walls will extend approx. 6m below the natural groundwater level.
5	The distance to any existing building or structure (excluding timber fences and small structures on the boundary) on an adjoining site from the edge of any: a) trench or open excavation that extends below natural groundwater level must be at least equal to the depth of the excavation; b) tunnel or pipe with an external diameter of 0.2 - 1.5m that extends below natural groundwater level must be 2m or greater; or c) a tunnel or pipe with an external diameter of up to 0.2m that extends below natural groundwater level has no separation requirement.	a) Complies: all existing structures (buildings) are set back greater than 5m from the excavation, and the maximum excavation depth is 4.9m at Cosgrave Road. Note roads and buried services would not comply. b) Not applicable. c) Not applicable.
6	The distance from the edge of any excavation that extends below natural groundwater level, must not be less than: a) 50m from the Wetland Management Areas Overlay; b) 10m from a scheduled Historic Heritage Overlay; or c) 10m from a lawful groundwater take.	Complies: the proposed excavation is set back more than the specified distances from these overlays.

Appendix C

Cosgrave Road Culverts,
Groundwater Drawdown and Ground Settlement Assessment

Appendix C

Cosgrave Road Culverts, Groundwater Drawdown and Ground Settlement Assessment

1. Objective and Methodology

The Waikato No. 1 pipeline is the critical asset for Stage 2 and 3 construction. The GHD analyses are known to overpredict drawdown, but underpredict longer term ground settlement as secondary consolidation was not included. Check analyses were carried out for the purpose of:

a. Obtaining a moderately conservative drawdown prediction, which is more representative of the very limited drawdown extents observed during Stage 1 construction. The model settings were adopted using moderately conservative parameters obtained from the site investigation information. Calibration against Stage 1 drawdowns was not carried out, as the check model is still expected to slightly over-predict drawdown. Visual comparison of the predicted extent of drawdown against the Stage 1 observations indicates that the model does provide a moderately conservative solution (discussed in Section 4 of this appendix).
b. Predict groundwater drawdowns at the Cosgrave Road culverts both during construction and in the long term.
c. Assessment of ground settlements resulting from the drawdown predictions, including both primary and secondary settlement.

Groundwater modelling was carried out using the finite-element software FEFLOW, which is produced by DHI in Germany. Earthtech have been using FEFLOW since 2007, and consider it suitable to predict groundwater effects due to the proposed development.

A two-dimensional cross-section model was developed for summer conditions. The method of Leoni et al. (2008) and the peat consolidation settlement parameters back analysed from Stage 1 construction (described in Section 4.3) were used to predict ground settlement.

2. Model Set-up

The FEFLOW model setup is described as follows:

1. Two-dimensional unconfined cross-section model, orientated along Cosgrave Road (approx. north-south direction).

2. Model length is 440*m*, extending 200*m* to the north and 200*m* to the south of the excavation, with a base elevation of RL5.4*m* (the base of the peat and top of the underlying Puketoka silts and clays).
3. The model left and right boundaries are set as constant head boundaries at RL23.75*m*, which is the summer low groundwater level measured in GHD-MBH-20B and 23. Note that this ignores the horizontal hydraulic gradient across the site, which was noted by GHD (2016b) to be very flat at between 0.00075 to 0.008, with flow in a south-westerly direction.
4. Base of the model is a no-flow boundary.
5. The model is entirely within the peat layer. The only other unit included in the model is the gravel bedding of the Waikato No. 1 pipeline, which was conservatively set at 200*mm* thickness, and at an elevation of RL24.0*m* which is approximately the average pipeline elevation through the model section. It is noted that since installation the pipe bedding is likely to have been contaminated by fines which would reduce the bedding permeability.
6. Adopted permeability settings are described in Table C1.

Table C1: Model Permeability Settings

Model setting	Peat	Gravel pipe bedding	Groundwater cut-off wall
Hydraulic conductivity	0.21*m/d* (geometric mean of field testing from GHD bores on section line)	8.64*m/d*	8.6e^{-5} *m/d* (equal to 1e^{-9}*m/s* achieved for Stage 1 cut-off wall)
Anisotropy	0.3 (as per GHD, 2016b)	1.0	1.0
Specific yield	0.44 (as per GHD, 2016b)	0.3	0.1
Porosity	0.91 (from lab testing data, GHD, 2016a)	0.25	0.1

7. Unconfined flow settings have been obtained from the UNSODA database for the van Genuchten model, based on the material descriptions (saturated and residual water contents, and curve fitting parameters). The peat saturated water content was verified against the lab testing data of peat samples presented in GHD (2016a).
8. Groundwater cut-off wall modelled as elements with a width of 0.4*m*.
9. Rainfall recharge of 364*mm/yr* applied to the ground surface, which is the annual recharge calculated from the average 0.827*mm* seasonal variation in groundwater levels multiplied by the peat specific yield of 0.44. It is noted that recharge in the area is high due to the flat topography,

and the adjacent subdivisions are required to discharge the first 15*mm* of each storm event to in-ground soakage which will maintain recharge.

10. Across the wider area, groundwater levels are controlled by farm drains and ditches, and the Stage 1 channel. One such drainage ditch runs along the eastern side of Cosgrave Road. To simulate these drainage effects, a constrained constant head boundary (which can only remove water from the model) was set up at the summer groundwater elevation of RL23.75*m* across the length of the model. Without this head boundary, the applied recharge causes groundwater levels in the central part of the model to rise above the observed summer low level.

The model setup is presented on Figure C1. Under pre-development conditions, the groundwater table is at RL23.75*m* throughout the model due to the applied drainage effects described in point 10 above.

3. Groundwater Drawdown due to Construction

Dewatering is proposed to RL20.25*m* during construction within the groundwater cut-off wall. A 3*mth* construction dewatering period has been assumed, and will be confirmed once the detailed construction methodology is finalised.

During construction, a drawdown of 1.1*m* is predicted at the outside of the groundwater cut-off wall. The groundwater drawdown profile is shown on Figure C2 and graphed on Figure C3.

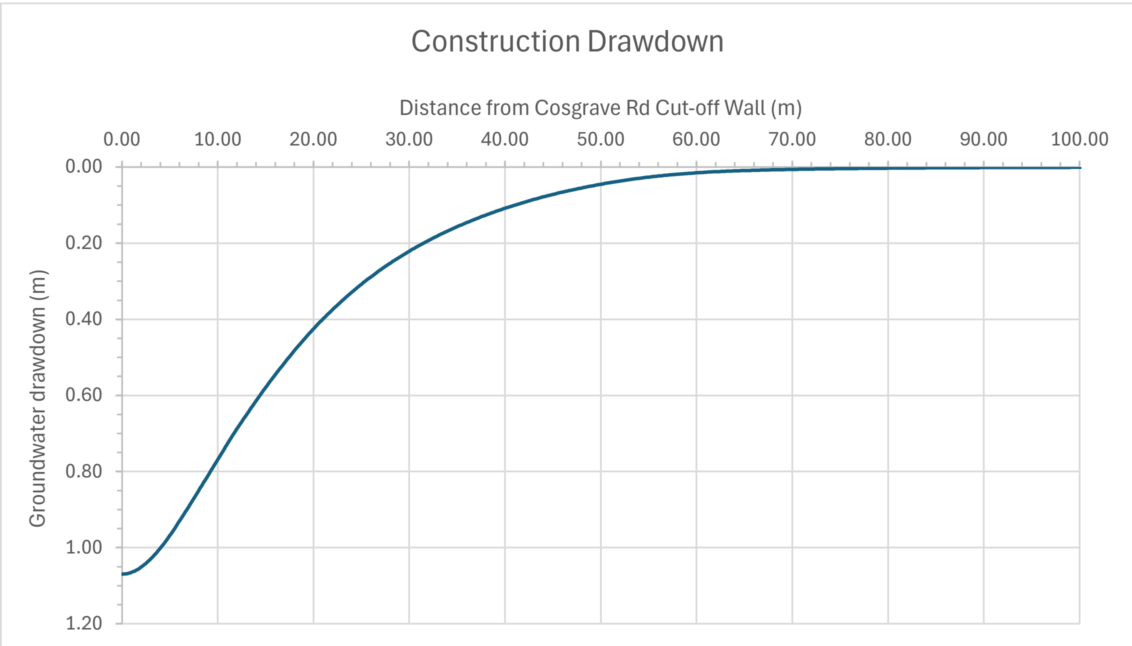


Figure C3. Estimated Construction Drawdown at t = 3mths

4. Long-term Groundwater Drawdown

In the long-term, the permanent water depth results in groundwater drawdown to RL22.25*m* within the groundwater cut-off wall.

A drawdown of 0.6*m* is predicted at the outside of the groundwater cut-off wall. The groundwater drawdown profile is shown on Figure C2 and graphed on Figure C4 below.

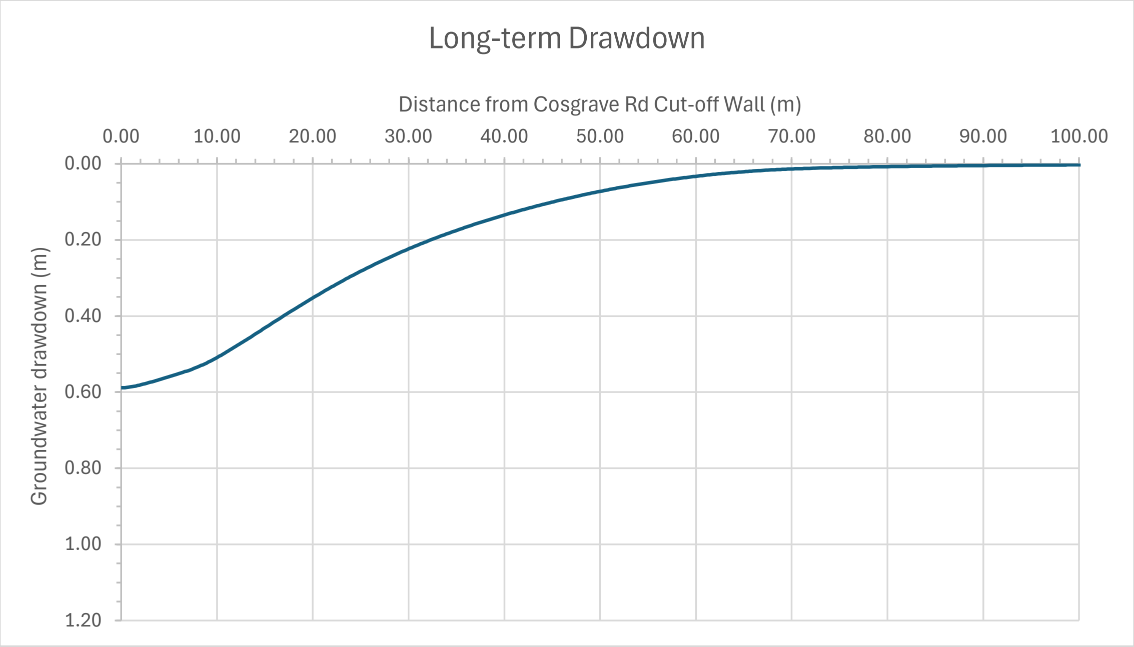


Figure C4. Estimated Long-term Groundwater Drawdown

Steady-state conditions are achieved at approx. 2*yrs* following construction.

The model indicates groundwater drawdown to extend 80*m* from the cut-off wall. This is much reduced from the GHD (2016b) prediction of approx. 200*m*, as recharge is included and various other model inputs adopt moderately conservative settings. GHD (2016b) noted that their drawdown predictions were expected to be conservative, which was appropriate given the knowledge at the time. Additionally, groundwater monitoring from Stage 1 indicates little to no long-term drawdown outside the groundwater cut-off walls, which supports the FEFLOW check model prediction.

As a rough comparison of the FEFLOW model prediction against Stage 1 observations, a long-term groundwater drawdown of 1.3*m* occurred at the eastern extent of Stage 1 adjacent to Stage 2 (similar to the 1.5*m* of drawdown at the Cosgrave Road culverts). However, Figure 2 indicates negligible groundwater drawdown on the outside of the groundwater cut-off wall. Based on this comparison, the FEFLOW model prediction is still expected to be conservative.

5. Ground Settlement due to Drawdown

The method of Leoni et al. (2008) and the peat consolidation settlement parameters back analysed from Stage 1 construction (described in Section 4.3), were used to predict ground settlement. The Leoni method includes both primary and secondary consolidation effects, and can also include the cumulative effects of two-stage loading due to higher drawdown during construction followed by the smaller long-term drawdown. Predicted settlements are presented in Table C2 and in the calculations attached.

Please note that a factor of +/- 50% should be added to designs incorporating the consolidation settlement predictions, due to uncertainty in the long-term prediction and variability in the peat.

Table C2: Check of Ground Settlements, Waikato No. 1 Pipeline at Cosgrave Road Culverts, without further mitigation other than 7m deep cut-off walls[1]

Time	Groundwater drawdown at outside of cut-off wall	Best estimate settlement	Best estimate differential settlement[4]
During construction: at 3*mths* dewatering	1.1*m*	55*mm*	Flatter than 1v:700h
After construction: 2*yrs* (approx. t_{90}) [2]	0.6*m*	165*mm*	1v:300h
After construction: 5*yrs* [2, 3]	0.6*m*	300*mm*	1v:180h (potentially 1v:120h within 10*m* of the cut-off wall)

[1] A factor of +/- 50% should be incorporated into designs which utilise settlement predictions.

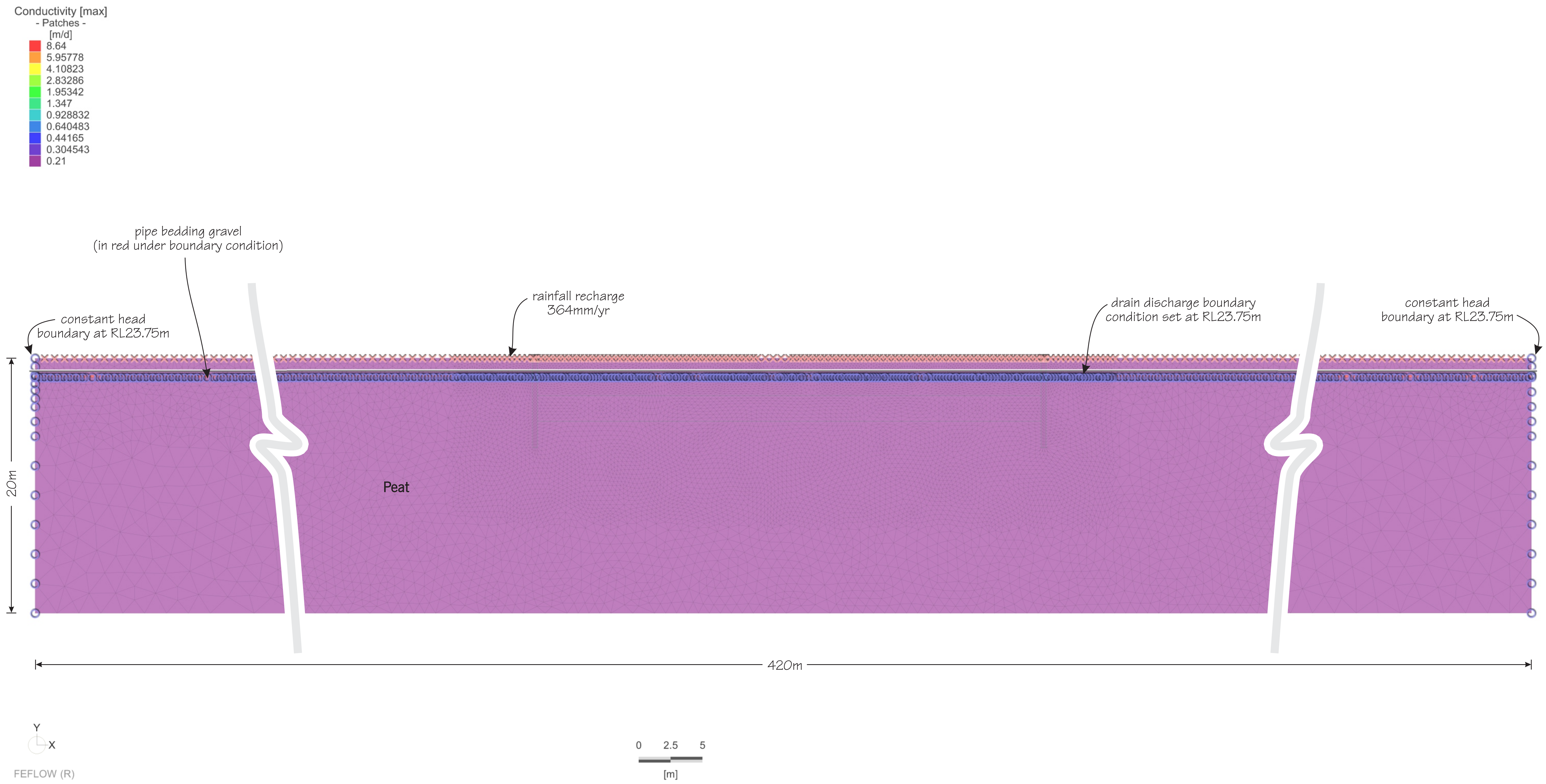
[2] Settlement already includes cumulative effect of construction dewatering.

[3] Time of 5*yrs* selected as this is when other Watercare pipelines are expected to have been commissioned, and the Waikato No. 1 pipeline can be brought offline.

[4] Differential outside of the cut-off wall, does not include where the pipeline enters/exits the cut-off wall.

From discussions with Watercare (meeting 13 March 2024), we understand that additional pipeline(s) are expected to be constructed in approx. 5*yrs*, which will duplicate and provide redundancy to the existing Waikato No. 1 pipeline. Therefore, the settlement assessment has considered secondary consolidation to 5*yrs*. At this time, it is anticipated that the Waikato No. 1 pipeline can be bought offline for maintenance if required.

It is noted that groundwater drawdowns vary slightly with depth – due to the anisotropy the maximum drawdown occurs at the base of the cut-off wall. The drawdowns presented in Table C2 have been obtained from the mid-depth between the starting groundwater table and the toe of the cut-off wall, to approximate an ‘average’ change in stress. Under steady state, there is only 0.2*m* head difference between the maximum drawdown at the toe of the cut-off wall, and the drawdown at the groundwater table, and this difference is considered to be addressed by the ‘average’ change in stress used in the calculation.



FOR INFORMATION

Note: All drawings are to be approved (initialled) before final issue.

EARTHTECH

Earthtech Consulting Ltd.

P.O. Box 721, Pukekohe
Phone: 64 9 238 3669
Email: admin@earthtech.co.nz

TAKANINI STORMWATER CHANNEL

Winton Partners

Feflow Model Setup and Boundary Conditions

REV	DATE	AMENDMENT/ISSUE	DRAWN BY	CHECKED	TRACED BY	APPROVED BY
A	11-06-24	FOR REPORT R10015-1	M.W	M.W	S.SW	MLW

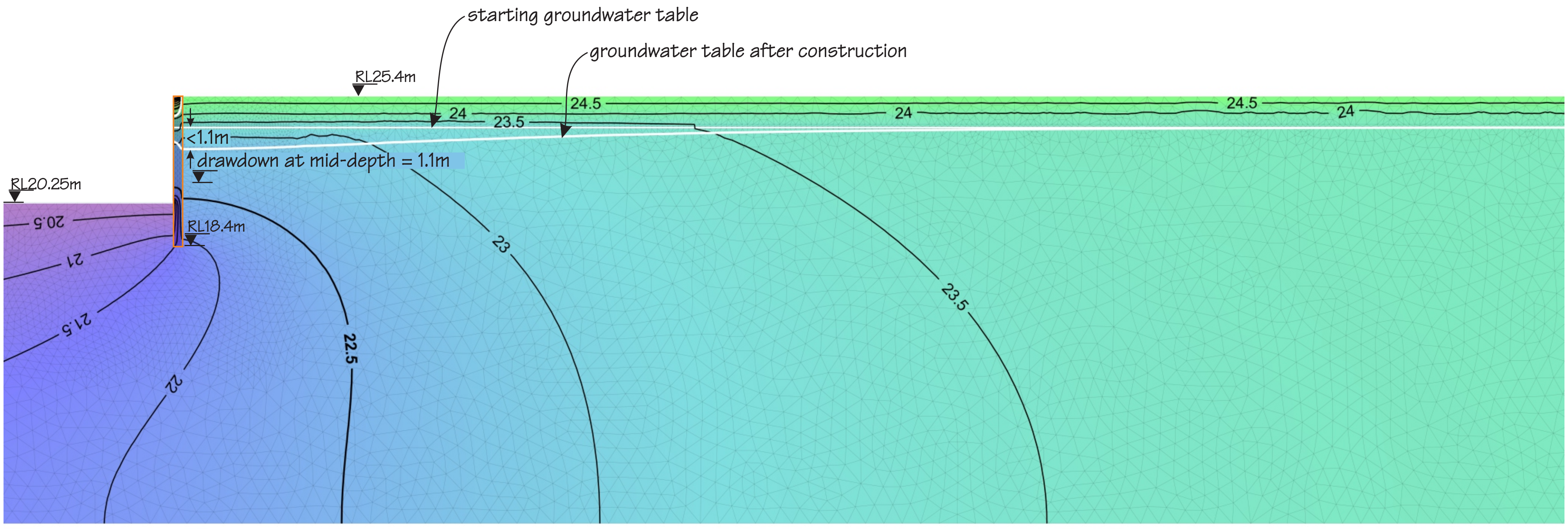
DRAWING NO.: FIG. C1

REF: 10015

SCALE: nts

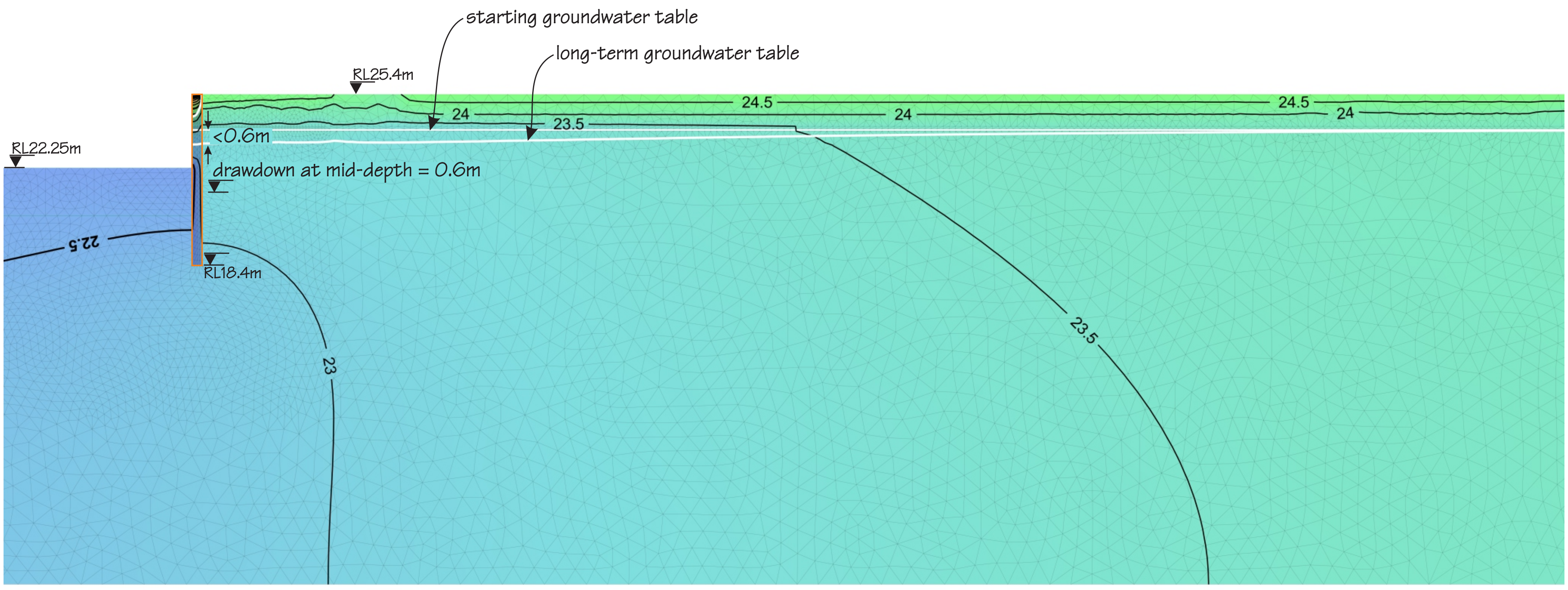
CRS:

DATUM:



Construction Drawdown, t = 3mths

Hydraulic head
- Continuous -
[m]
28
27.2
26.4
25.6
24.8
24
23.2
22.4
21.6
20.8
20



Long-Term Drawdown, t = 5yrs

Y
X
FEFLOW (R)

0 2 4
[m]

FOR INFORMATION

Note: All drawings are to be approved (initialled) before final issue.

EARTHTECH
Earthtech Consulting Ltd.
P.O. Box 721, Pukekohe
Phone: 64 9 238 3669
Email: admin@earthtech.co.nz

TAKANINI STORMWATER CHANNEL
Winton Partners

Drawdown Predictions

REV	DATE	AMENDMENT/ISSUE	DRAWN BY	CHECKED	TRACED BY	APPROVED BY
A	11-06-24	FOR REPORT R10015-1	M.W	M.W	S.SW	MLW

DRAWING NO.: **FIG. C2**
REF: 10015
SCALE: nts
CRS:
DATUM:

Settlement response using the approach of Leoni coupled with Terzaghi's one-dimensional consolidation theory

STEP 2 - Set OCR and Surcharge Parameters

** Ref. Leoni, M, Karstunen, M, Vermeer, PA, Anisotropic Creep Model for Soft Soils, Geotechnique, Vol.58, No.3, 215-226,(2008)*

** This sheet also uses constant c_v and leveraged Δt. h represents the longest drainage path. No surcharge removal gives the expected settlement history for constant load p_0.*

** h represents the longest drainage path. Make sure h is doubled in the calculation for settlement in Step 2 if the deposit is doubly drained.*

** Site: Awakeri Wetlands, Cosgrave Culvert, Best Estimate*

2 Drainage (1 = single, 2 = double)

Input Data in Yellow Total thickness 20 m

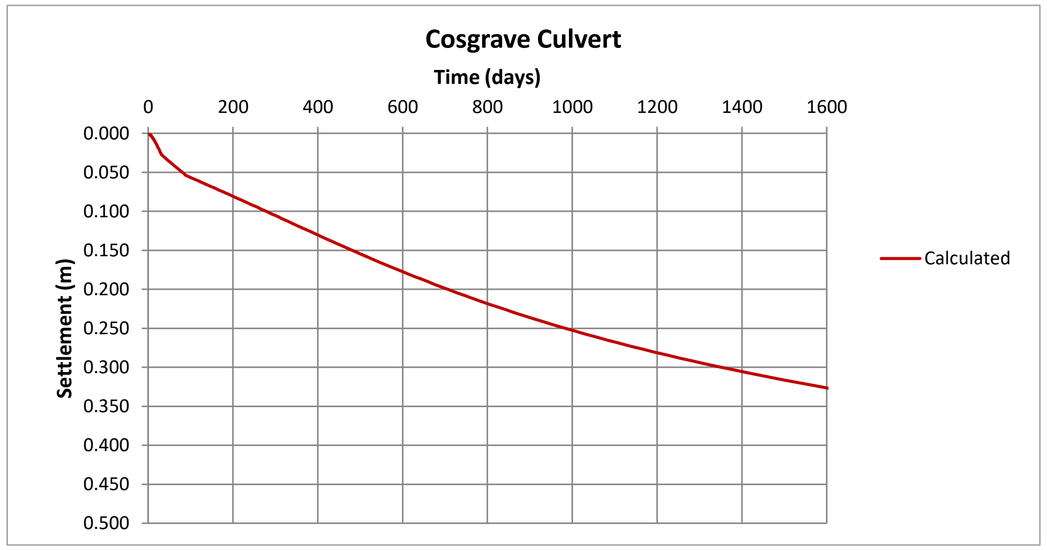
30 d Time fill placement completed

τ	0.4131 *yr*	c_{v0}	40 m^2/yr	p_0	10.5 *kPa*	$C_{\alpha\varepsilon}$	0.015
β	8.50	h	10 *m*	p_1	5.8 *kPa*	$C_{s\varepsilon}$	0.0225
Leverage	1.025	h^2/c_{v0}	2.500 *yr*	σ'_0	16.3 *kPa*	$C_{c\varepsilon}$	0.15
t_1	0.25 *yr*	OCR_0	1.40	σ'_{p0}	22.8 *kPa*	M_0	250 *kPa*

t1 is time since fill placement commenced

Results

Degree of primary consolidation at time t_1	35.3 percent		
Settlement at time t_1	0.054 *m*		
Residual settlement 2 years after t_1	0.164 *m*	*OCR at 3 years*	1.25
Residual settlement 5 years after t_1	0.298 *m*	*OCR at 10 years*	1.45
Residual settlement 100 years after t_1	0.700 *m*	*OCR at 25 years*	1.62



t (days)	*p/p0*	*n*	*t (yr)*	*Time Factor T*	*Degree of Consolidation U*	*σ' (kPa)*	*σ'* (kPa)*	*σ'/σ'p0*	*M/M0*	ε^e_n	ε^c_n	σ'_{pn}	*OCR*	ε_n	*Settlement*
0	0	1	0	0.000000	0.000000	16.300	16.300	0.7143	6.672	0.000000	0.000000	22.820	1.400	0.000000	0.000000
0.0365	0.001217	2	0.0001	0.000040	0.000000	16.300	16.300	0.7143	6.672	0.000000	0.000000	22.820	1.400	0.000000	0.000002
0.037413	0.001247	3	0.000103	0.000041	0.000028	16.300	16.300	0.7143	#DIV/0!	0.000000	0.000000	22.820	1.400	0.000000	0.000005
0.038348	0.001278	4	0.000105	0.000042	0.000029	16.300	16.300	0.7143	6.589	0.000000	0.000000	22.820	1.400	0.000000	0.000006
0.039307	0.00131	5	0.000108	0.000043	0.000030	16.300	16.300	0.7143	4.436	0.000000	0.000000	22.820	1.400	0.000000	0.000006
0.040289	0.001343	6	0.00011	0.000044	0.000031	16.300	16.300	0.7143	4.438	0.000000	0.000000	22.820	1.400	0.000000	0.000006
0.041296	0.001377	7	0.000113	0.000045	0.000031	16.300	16.300	0.7143	4.440	0.000000	0.000000	22.820	1.400	0.000000	0.000006
0.042329	0.001411	8	0.000116	0.000046	0.000032	16.300	16.300	0.7143	4.443	0.000000	0.000000	22.820	1.400	0.000000	0.000006
0.043387	0.001446	9	0.000119	0.000048	0.000033	16.300	16.300	0.7143	4.445	0.000000	0.000000	22.820	1.400	0.000000	0.000006
0.044472	0.001482	10	0.000122	0.000049	0.000034	16.300	16.300	0.7143	4.448	0.000000	0.000000	22.820	1.400	0.000000	0.000006
0.045583	0.001519	11	0.000125	0.000050	0.000035	16.300	16.300	0.7143	4.450	0.000000	0.000000	22.820	1.400	0.000000	0.000007
0.046723	0.001557	12	0.000128	0.000051	0.000036	16.300	16.300	0.7143	4.453	0.000000	0.000000	22.820	1.400	0.000000	0.000007
0.047891	0.001596	13	0.000131	0.000052	0.000036	16.300	16.300	0.7143	4.455	0.000000	0.000000	22.820	1.400	0.000000	0.000007
0.049088	0.001636	14	0.000134	0.000054	0.000037	16.300	16.300	0.7143	4.458	0.000000	0.000000	22.820	1.400	0.000000	0.000007
0.050316	0.001677	15	0.000138	0.000055	0.000038	16.300	16.300	0.7143	4.461	0.000000	0.000000	22.820	1.400	0.000000	0.000007
0.051574	0.001719	16	0.000141	0.000057	0.000039	16.300	16.300	0.7143	4.464	0.000000	0.000000	22.820	1.400	0.000000	0.000008
0.052863	0.001762	17	0.000145	0.000058	0.000040	16.300	16.300	0.7143	4.467	0.000000	0.000000	22.820	1.400	0.000000	0.000008
0.054184	0.001806	18	0.000148	0.000059	0.000042	16.300	16.300	0.7143	4.470	0.000000	0.000000	22.820	1.400	0.000000	0.000008
0.055539	0.001851	19	0.000152	0.000061	0.000043	16.300	16.300	0.7143	4.473	0.000000	0.000000	22.820	1.400	0.000000	0.000008
0.056928	0.001898	20	0.000156	0.000062	0.000044	16.300	16.300	0.7143	4.476	0.000000	0.000000	22.820	1.400	0.000000	0.000008
0.058351	0.001945	21	0.00016	0.000064	0.000045	16.300	16.300	0.7143	4.479	0.000000	0.000000	22.820	1.400	0.000000	0.000009
0.05981	0.001994	22	0.000164	0.000066	0.000046	16.300	16.300	0.7143	4.482	0.000000	0.000000	22.820	1.400	0.000000	0.000009
0.061305	0.002043	23	0.000168	0.000067	0.000047	16.300	16.300	0.7143	4.485	0.000000	0.000000	22.820	1.400	0.000000	0.000009
0.062837	0.002095	24	0.000172	0.000069	0.000048	16.301	16.300	0.7143	4.489	0.000000	0.000000	22.820	1.400	0.000000	0.000009
0.064408	0.002147	25	0.000176	0.000071	0.000050	16.301	16.300	0.7143	4.492	0.000000	0.000000	22.820	1.400	0.000000	0.000009
0.066018	0.002201	26	0.000181	0.000072	0.000051	16.301	16.300	0.7143	4.496	0.000000	0.000000	22.820	1.400	0.000000	0.000010
0.067669	0.002256	27	0.000185	0.000074	0.000052	16.301	16.300	0.7143	4.499	0.000000	0.000000	22.820	1.400	0.000000	0.000010
0.069361	0.002312	28	0.00019	0.000076	0.000054	16.301	16.300	0.7143	4.503	0.000000	0.000000	22.820	1.400	0.000001	0.000010
0.071095	0.00237	29	0.000195	0.000078	0.000055	16.301	16.300	0.7143	4.507	0.000000	0.000000	22.820	1.400	0.000001	0.000010
0.072872	0.002429	30	0.0002	0.000080	0.000057	16.301	16.300	0.7143	4.510	0.000000	0.000000	22.820	1.400	0.000001	0.000011
0.074694	0.00249	31	0.000205	0.000082	0.000058	16.301	16.300	0.7143	4.514	0.000000	0.000000	22.820	1.400	0.000001	0.000011
0.076561	0.002552	32	0.00021	0.000084	0.000060	16.301	16.300	0.7143	4.518	0.000000	0.000000	22.820	1.400	0.000001	0.000011
0.078475	0.002616	33	0.000215	0.000086	0.000061	16.301	16.300	0.7143	4.522	0.000000	0.000000	22.820	1.400	0.000001	0.000012
0.080437	0.002681	34	0.00022	0.000088	0.000063	16.301	16.300	0.7143	4.526	0.000000	0.000000	22.820	1.400	0.000001	0.000012
0.082448	0.002748	35	0.000226	0.000090	0.000065	16.301	16.300	0.7143	4.530	0.000000	0.000000	22.820	1.400	0.000001	0.000012
0.084509	0.002817	36	0.000232	0.000093	0.000066	16.301	16.300	0.7143	4.535	0.000000	0.000000	22.820	1.400	0.000001	0.000013
0.086622	0.002887	37	0.000237	0.000095	0.000068	16.301	16.300	0.7143	4.539	0.000000	0.000000	22.820	1.400	0.000001	0.000013
0.088788	0.00296	38	0.000243	0.000097	0.000070	16.301	16.300	0.7143	4.544	0.000000	0.000000	22.820	1.400	0.000001	0.000013
0.091007	0.003034	39	0.000249	0.000100	0.000072	16.301	16.300	0.7143	4.548	0.000000	0.000000	22.820	1.400	0.000001	0.000014
0.093282	0.003109	40	0.000256	0.000102	0.000074	16.301	16.300	0.7143	4.553	0.000000	0.000000	22.820	1.400	0.000001	0.000014
0.095614	0.003187	41	0.000262	0.000105	0.000076	16.301	16.300	0.7143	4.558	0.000000	0.000000	22.820	1.400	0.000001	0.000014
0.098005	0.003267	42	0.000269	0.000107	0.000078	16.301	16.300	0.7143	4.562	0.000000	0.000000	22.820	1.400	0.000001	0.000015
0.100455	0.003348	43	0.000275	0.000110	0.000080	16.301	16.300	0.7143	4.567	0.000001	0.000000	22.820	1.400	0.000001	0.000015
0.102966	0.003432	44	0.000282	0.000113	0.000082	16.301	16.300	0.7143	4.572	0.000001	0.000000	22.820	1.400	0.000001	0.000015
0.10554	0.003518	45	0.000289	0.000116	0.000084	16.301	16.300	0.7143	4.577	0.000001	0.000000	22.820	1.400	0.000001	0.000016
0.108179	0.003606	46	0.000296	0.000119	0.000087	16.301	16.301	0.7143	4.583	0.000001	0.000000	22.820	1.400	0.000001	0.000016
0.110883	0.003696	47	0.000304	0.000122	0.000089	16.301	16.301	0.7143	4.588	0.000001	0.000000	22.820	1.400	0.000001	0.000017
0.113656	0.003789	48	0.000311	0.000125	0.000091	16.301	16.301	0.7143	4.593	0.000001	0.000000	22.820	1.400	0.000001	0.000017
0.116497	0.003883	49	0.000319	0.000128	0.000094	16.301	16.301	0.7143	4.599	0.000001	0.000000	22.820	1.400	0.000001	0.000018
0.119409	0.00398	50	0.000327	0.000131	0.000096	16.301	16.301	0.7143	4.604	0.000001	0.000000	22.820	1.400	0.000001	0.000018