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1 March 2013

Resource Consents Department
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Attention: Graeme Michie

Dear Graeme

**Central Interceptor Main Project Works**
**Section 92 RMA Response Report – Groundwater and Surface Settlement Effects**

On 2 October 2012, Auckland Council requested further information under Section 92 of the Resource Management Act 1991 (RMA). Watercare's response to that request was contained in the report titled "*Central Interceptor Main Project Works – Section 92 Response Report to Auckland Council*" dated December 2012.

The response to questions on groundwater and surface settlement is contained in the enclosed letter report prepared by Tonkin and Taylor Limited titled "*Central Interceptor Main Project Works – Groundwater and surface settlement effects assessment – Technical response to Auckland Council Section 92 queries*", dated 28 February 2013.

Five hard copies of the report are enclosed, plus 5 CDs.

Once you have reviewed the enclosed report, please can we then arrange a meeting with the groundwater technical advisors for Auckland Council and Watercare to discuss any matters requiring further clarification.

Yours sincerely

Belinda Petersen
Resource Consents Manager
**Watercare Services Limited**

# Response Report Groundwater Main Works

Tonkin & Taylor

T&T Ref: 26145.3
01 March 2013

Central Interceptor Project Team
c/- Watercare Services Limited
PO Box 4241
Shortland Street
Auckland 1140

Attention: Peter Roan

Dear Peter

# Central Interceptor Main Project Works
# Groundwater and surface settlement effects assessment
# Technical response to Auckland Council Section 92 queries

## 1 Introduction

Tonkin & Taylor Ltd (T&T) were engaged by Watercare Services Ltd (Watercare) to undertake a study of the hydro-geological conditions along the route of the Central Interceptor tunnel to support resource consent applications. That study was completed in July 2012 (Technical Report J of Part D of the Assessment of Effects on the Environment (AEE)) (Tonkin & Taylor Ltd, 2012).

As part of consent processing, the study was reviewed by Auckland Council, and a request for further information (a Section 92 request) was received by Watercare. This letter report provides further information for Watercare to assist in responding to that request. The scope of information provided in this letter is as set out in our proposal to Watercare of 19 November 2012.

### 1.1 Section 92 request

The additional information request relating to groundwater and settlement was set out in the letter "Peer review of groundwater and settlement effects of proposed Central Interceptor Wastewater Project – Effects of Tunnels on Groundwater and Surface Settlement" dated 20th of September 2012 from Earthtech Consulting Ltd to Auckland Council attached to the Auckland Council Section 92 request letter.

The scope of the additional assessment was clarified at two meetings with Auckland Council (4th October 2012 and 9th November 2012).

In summary, Earthtech requested that detailed groundwater and surface settlement modelling be carried out at two shaft sites to demonstrate that construction methodologies are available that enable the shafts to be constructed with effects expected to be no more than minor on surrounding properties and structures. The previous assessments submitted with the AEE (Tonkin & Taylor Ltd,

2012) were based on a more generic approach applied across all shaft sites. The information requested is summarised as follows:

*Detailed geotechnical investigations, analysis and specimen designs are requested at WS2 and one other shaft site to demonstrate that settlement limits can be achieved (total of two detailed investigation areas). The following is requested:*

*Detailed geotechnical investigations.*

*Groundwater modelling with and without mitigation.*

*Assessment of cumulative effects from mechanical and dewatering induced settlement, based on the proposed detailed design drawings.*

*Assessment of building locations and foundation details for all buildings located within 30 m of the shaft perimeter.*

*Detailed plans for the two specimen design sites should address a number of matters listed in the S92 letter.*

Details of example monitoring regimes to manage construction activities were included in the request.

At the meeting on 4th October 2012 it was clarified that any two shafts could be selected for analysis such that further geotechnical investigations were not required to satisfy the request, and that rather than developing specimen designs, example construction methodologies would be clearly described for the shafts.

# 2 Summary of findings

Modelling has been undertaken for two shaft sites as agreed with Earthtech - Mt Albert War Memorial Reserve (AS1) and Whitney Street (L3S3). These locations were selected on the basis of available geotechnical information and proximity to surrounding structures.

Practical construction methodologies are available that enable construction of the shafts at AS1 and L3S3 that can be expected to result in effects that are no more than minor to property or structures nearby.

On the basis of the example construction methodologies proposed and the modelling undertaken we conclude that construction of the shafts and tunnels at both sites is feasible within the applied acceptable limits for surface settlement of 50 mm vertical movement and 1:1000 angular tilt.

The magnitude of settlement estimated for these two examples using accepted numerical methods is consistent with that estimated during consenting phases for other similar (and now constructed) tunnels and shafts in the Auckland Isthmus, where construction monitoring has shown that such theoretical estimates tend to be conservative (i.e. over estimates) of the settlement that occurs in practice.

During future design stages, these example methodologies, or alternative methodologies, would be developed taking into consideration the additional information on ground and ground water conditions that will be obtained in that process and with due regard to the consent limits.

Watercare are currently investigating alternative layouts for the shafts within the Mt Albert War Memorial Reserve. The overall conclusions of this report are expected to apply to alternative layouts that position the shafts no closer to buildings than the current minimum distance to any building structure.

# 3 Study sites

In discussions with Earthtech, the Mt Albert War Memorial Reserve (AS1) and Whitney Street (L3S3) sites were selected and agreed as the two study sites.

They were selected as site investigation boreholes were available to characterise the geology at these sites, and both had residential properties and surface structures in close proximity.

The Central Interceptor Project Team has developed example construction methodologies for the two construction sites. The work undertaken and findings presented here are based on the methodologies proposed.

## 3.1 Mt Albert War Memorial Reserve Shaft AS1

Shaft AS1 is an access shaft for the main Central Interceptor Tunnel and is proposed within the Mt Albert War Memorial Reserve off Wairere Ave, Mt Albert, (refer to Drawing 26145.300 SK1 attached). Two other similar sized shafts are also proposed: (a working shaft associated with a connection from Link Sewer 2; and a drop shaft associated with a connection to the existing sanitary sewer network). All shafts are to be located in the north west of the Auckland Council reserve. Residential properties are close to the northwest and south west and to the south east are buildings and the Mt Albert YMCA located on the reserve.

### 3.1.1 Surrounding buildings

Table 3.1 summarises the details of the buildings within the vicinity of the construction site (on properties within 30 m of the shaft locations). The details were obtained from Auckland Council property files and from visual observations where possible.

In summary, the building records identify housing stock dominated by weatherboard clad houses supported on timber sub floor and shallow pile (jack stud) foundations, with some constructed with concrete slab foundations and brick veneer. The building code sets a differential settlement limit for such structures as no more than 25mm over 6m (approximately 1:250). Section 5.5 of our previous report (Tonkin & Taylor Ltd, 2012) provides a more detailed commentary on the potential effects of differential settlement, and suggests that the need to protect against aesthetic damage, (particularly in brick veneer which can develop fine cracks at 1:500) indicates that differentials in the vicinity of structures should be controlled to 1:500 to 1:750.

Similarly, for the Auckland Council and Mt Albert YMCA buildings located on the reserve (which records show have been constructed by addition over a number of years combining suspended timber floors and concrete slabs, along with timber framed walls and brick and concrete block walls) differentials in the vicinity of structures should be controlled to 1:500 to 1:750 to protect against aesthetic damage.

Table 3.1 – Surrounding properties and surface structures

| Property Address | Primary foundation type | Primary construction type | Approximate distance from shaft (m) |
|---|---|---|---|
| 21 Wairere Avenue | Timber sub floor on jack studs or shallow block piles | Timber frame and weatherboard | 70 |
| 19 Wairere Avenue | Timber sub floor on jack studs or shallow block piles | Timber frame and weatherboard | 65 |

| Property Address | Primary foundation type | Primary construction type | Approximate distance from shaft (m) |
|---|---|---|---|
| 17 Wairere Avenue | Timber sub floor on jack studs or shallow block piles | Timber frame and weatherboard | 60 |
| 15 Wairere Avenue | Timber sub floor on jack studs or shallow block piles with extensions on concrete slab on grade | Timber frame with brick veneer and plaster finish, timber frame and monolithic cladding | 60 |
| 13 Wairere Avenue | Timber sub floor on jack studs or shallow block piles | Timber frame with lathe and plaster | 72 |
| 13A Wairere Avenue | Concrete slab on hardfill and perimeter block base | Timber frame with brick veneer | 54 |
| 11 Wairere Avenue | Timber subfloor on jack studs or shallow block piles | Timber frame and weatherboard | 82 |
| 11A Wairere Avenue | Timber subfloor on jack studs or shallow block piles and Concrete slab on hardfill and perimeter block base | Timber frame and weatherboard | 62 |
| 1/9 Wairere Avenue | Timber subfloor on jack studs or shallow block piles | Timber frame and weatherboard | 74 |
| 2-4/9 Wairere Avenue | Concrete slab on hardfill and perimeter block base | Timber frame with brick veneer | 58 |
| 65A Asquith Avenue | Timber sub floor on jack studs or shallow block piles | Timber frame and plasterboard | 40 |
| 65B Asquith Avenue | Timber sub floor on jack studs or shallow block piles | Timber frame and weatherboard | 28 |
| 65C Asquith Avenue | Timber sub floor on jack studs or shallow block piles | Timber frame and weatherboard | 40 |
| Mt Albert War Memorial Reserve | | | |
| Mt Albert War Memorial Hall | Timber subfloor on jack studs or shallow block piles with perimeter block base | Brick | 150 |
| Mt Albert Bridge Club | Timber subfloor on jack studs or shallow block piles with perimeter block base | Concrete block work walls | 110 |
| Mt Albert Senior Citizens Hall | Concrete slab on hardfill and perimeter block base and suspended timber floor on jack studs | Concrete block work (lower walls) and fibrolite (upper walls) | 145 |
| Mt Albert Community and Recreation Centre Complex (consisting of): | | | |
| Frank Turner Stadium | Timber subfloor on jack studs or shallow block piles with perimeter block base and concrete slab on hardfill | Concrete block work | 170 |

| Property Address | Primary foundation type | Primary construction type | Approximate distance from shaft (m) |
|---|---|---|---|
| YMCA | Timber subfloor on jack studs or shallow block piles with perimeter block base and concrete slab on hardfill | Concrete blockwork and decorative stone | 140 |
| Playgroup and community centre | Timber subfloor on jack studs or shallow block piles with perimeter block base | Concrete block work and decorative stone | 110 |

## 3.2 Whitney Street Shaft L3S3

Shaft L3S3 is proposed within the Whitney Street road reserve immediately outside number 124 Whitney Street and close to residential properties on both the eastern and western side of Whitney Street (refer to Drawing 26145.300 SK2 attached).

From number 124, Whitney Street rises to the north, and falls to the intersection of Whitney Street and Margate Road to the south.

### 3.2.1 Surrounding buildings

Table 3.2 summarises the details of the buildings within the vicinity of the shaft site (on properties within 30 m of the shaft location). The details were obtained from Auckland Council property files.

In summary, the building records identify housing stock dominated by weatherboard clad houses supported on timber sub floor and shallow pile (jack stud) foundations or concrete slab on grade. The building code sets a differential settlement limit for such structures as no more than 25 mm over 6m (approximately 1:250).

As noted in Section 3.1.1 above, to protect against aesthetic damage for structures like these, differentials should be controlled to less than 1:500 to 1:750.

Table 3.2 – Surrounding properties and surface structures

| Property address | Primary foundation type | Primary construction type | Approximate distance from shaft (m) |
|---|---|---|---|
| 115 Whitney Street | Timber sub floor on jack studs or shallow block piles with perimeter block base | Timber frame with Firbrolite base and weatherboard | 34 |
| 120 Whitney Street | Timber sub floor on jack studs or shallow block piles | Timber frame Firbrolite base and weatherboard | 36 |
| 124 Whitney Street | Timber sub floor on jack studs or shallow block piles | Timber frame Firbrolite base and weatherboard | 26 |
| 128 Whitney Street | Reinforced concrete slabs | Timber frame Weatherboard and vertical hardiplank. | 25 |
| 56 Margate Road | Timber sub floor on jack studs or shallow block piles with perimeter block base | Timber frame and weatherboard | 30 |

## 3.3 Geology and groundwater

The geology interpreted along the tunnel alignments is described in detail in our previous report (Tonkin & Taylor Ltd, 2012), Section 3.

In summary, the geology of the main tunnel alignment can be divided to three zones:

- A Northern Zone (Western Springs to Mt Roskill, including Link Sewers 1 and 2) with East Coast Bays Formation (ECBF and also referred to as "Waitemata Group") at tunnel level and surface geology dominated by Auckland Volcanic Field (AVF) basaltic flows, together with a variable cover of tuff. Depending upon the pre eruptive topography, the AVF deposits either directly overlie the ECBF Group rocks or Tauranga Group alluvium.
- A Central Zone (Mt Roskill to Hillsborough, including Link Sewer 3) with ECBF at tunnel level and outcropping ECBF rocks and minor Tauranga Group cover at the surface.
- A Southern Zone (Manukau Harbour and Mangere, including Link Sewer 4) with ECBF as well as Kaawa and Puketoka Formation deposits at tunnel level, and surface geology dominated by AVF eruptive centres.

The Mt Albert War Memorial Reserve (AS1) site is within the Northern Zone. Borehole (BH) CI-29 (copy provided in Appendix A) was put down near the proposed construction site (refer Drawing 26145.3 SK1) as part of investigations for the tunnel alignment in 2010. The borehole was progressed to an ultimate depth of 50 m below ground level, through AVF deposits, Puketoka Formation material, and ECBF residual soils and rock.

Table 3.3 – Shaft AS1 - Summary of subsurface profile BH CI 29

| Depth below ground (m) | Geological Unit | Description |
|---|---|---|
| 0 m to 0.5m | Topsoil | Gravelly SILT |
| 0.5 m to 11.5m | Auckland Volcanic Field | Dark grey to light grey jointed vesicular BASALT |
| 11.5 m to 30.5 m | Puketoka Formation | Silty CLAYS, clayey SILTS, sandy SILTS, SANDS and occasional organic layers |
| 30.5 m to 50 m + | Waitemata Group | Interbedded SANDSTONE and SILTSTONE |

BH CI -29 was drilled some 100 m away from shaft AS1, and is expected to be representative of the geological profile at the construction site. Therefore the information has been used as an appropriate basis for developing the ground model for the shaft site. The profile identified in Table 3.3 has been adopted as the ground model for this site.

The Whitney Street (L3S3) is located within the Central Zone. BH CI-12 (a copy of the log is provided in Appendix A) was put down near the proposed shaft (refer to Drawing 26145.3 SK2) as part of investigations for the tunnel alignment. The borehole was progressed to 69m depth through Puketoka Formation materials and East Coast Bays Formation and is expected to be representative of the geological profile at the shaft site. It has been adopted as the basis for developing the ground model for this site.

Table 3.4 – Shaft L3S3 Summary of subsurface profile BH CI 12

| Depth below ground (m) | Geological Unit | Description |
|---|---|---|
| 0 to 8 | Puketoka Formation | Silty CLAYS, clayey SILTS, sandy SILTS, SANDS and occasional organic layers |
| 8 to 69m+ | Waitemata Group | Interbedded SANDSTONE and SILTSTONE |

### 3.3.1 Geotechnical parameters for modelling

Geotechnical parameters developed and adopted within our previous report (Tonkin & Taylor Ltd, 2012) have been adopted for this study (for a detailed summary of parameter development, refer to Sections 3.2.4, 4.4.1 and Appendix B of the report).

Parameters relevant to this study are repeated in Table 3-5.

Table 3.5 – Summary of geotechnical parameters adopted

| Geological unit | Bulk Unit weight **γ** [kN/m$^3$] | Modulus of Elasticity – E' [kPa] | Coefficient of volume compressibility $m_v$ [1/kPa] | Poisson's ratio v | Permeability k [m/sec] |
|---|---|---|---|---|---|
| Basalt | 24 | 1000000 | 1E-7 | 0.2 | 0.0001 |
| Puketoka Formation | 18 | 6000 | 6.7E-05 | 0.35 | 2E-7 |
| ECBF | 20 | 500000 | 2E-6 | 0.3 | 2E-7<br>$k_v/k_h$=0.1 |

### 3.3.2 Groundwater levels

Piezometers were installed in borehole CI 29 to monitor groundwater levels, and to potentially form part of a construction monitoring network. To date, the piezometers have been infrequently monitored. Consistent with previous studies (Tonkin & Taylor Ltd, 2012), the groundwater level at the site has been conservatively assumed to be hydrostatic at 1.5 m below ground level. There were no piezometers installed in borehole CI-12. Groundwater level has been conservatively adopted at 1.5 m below ground level.

## 3.4 Geologic potential for dewatering induced settlement

The subsurface investigations identify that construction of shafts at both Mt Albert War Memorial Reserve and Whitney Street will encounter potentially compressible materials (Puketoka Formation). Dewatering of these materials during construction and/or long term operation of the shaft will need to be minimised to limit the potential for groundwater drawdown induced surface settlement about the shaft. Owing to the close proximity of residential and public buildings, this surface settlement, if not adequately controlled, could lead to damage to buildings.

Dewatering of the Puketoka Formation could occur as a direct result of water flowing from unlined excavations in the Puketoka Formation or other materials that are hydraulically connected. Methodologies that address this are described in Section 3.5 below.

The Basalt and ECBF have low potential for dewatering induced settlement, relative to the Puketoka Formation.

## 3.5 Shaft construction methodology

The Central Interceptor Project Team has developed specific example construction methodologies for the two construction sites. The methodologies have been developed considering the site conditions to address the potential for surface settlement identified in Section 3.4 above. The methodologies provide the basis for numerical modelling to demonstrate that the methodologies achieve appropriate settlement limits.

### 3.5.1 Shaft AS1 example shaft construction methodology

The main tunnel access shaft at the Mt Albert War Memorial Reserve (AS1) site is currently proposed to be circular with an external diameter of 9 m (the excavation diameter is 9 m). The excavations for the other shafts are of similar size.

All three shafts could be constructed in a similar way at this site, generally as follows:

1. Provision of the three circular grout curtains through the full depth of basalt with total thickness of 5 m around each shaft to minimise groundwater flow out of the basalt as it is excavated.
2. Excavation of basalt without temporary lining (rock bolting and mesh is likely to be required to provide local face stability).
3. Installation of a secant pile wall or sheet pile retaining wall inside the shaft through the Puketoka Formation and socketed into the ECBF. This wall will provide for stability of the shaft excavation through the Puketoka Formation, and provide a relatively water tight initial lining to minimise groundwater draw down in the Puketoka Formation.
4. Excavation of the Puketoka Formation under protection of temporary lining. Final design development of such a methodology may include a requirement for ring beams to be installed as construction progresses to provide for overall stability.
5. Excavation of ECBF. Previous experience indicates that the ECBF can be successfully excavated without need for temporary support and with pattern bolting and mesh for local face stability.
6. Installation of permanent insitu concrete lining and base.

### 3.5.2 Shaft L3S3 example shaft construction methodologies

The shaft at the Whitney Street site (L3S3) is currently proposed to be circular with an external diameter of 6.5 m.

Two potential construction methodologies have been proposed by the Central Interceptor Project Team.

Methodology 1:

1. Installation of a secant pile wall or sheet pile circular retaining wall through the Puketoka Formation and socketed into the ECBF. This wall will provide for stability of the shaft excavation through the Puketoka Formation, and provide a relatively water tight initial lining to minimise groundwater draw down in the Puketoka Formation

2. Excavation of the Puketoka Formation under protection of temporary lining. Final design development of such a methodology may include a requirement for ring beams to be installed as construction progresses to provide for overall stability.
3. Excavation of ECBF. Previous experience indicates that the ECBF can be successfully excavated without need for temporary support and with pattern bolting and mesh for local face stability. Temporary recharge wells will minimise under drainage (and associated surface settlement) effects in the Puketoka formation as the ECBF is excavated.
4. Installation of permanent lining and base, and decommissioning of the recharge wells.

For this methodology to be implemented a ring of recharge wells is required to minimise surface settlement. Owing to the close proximity of this shaft to residential properties, the recharge wells would need to be located within private property. While this approach is feasible, a second methodology has been developed that does not require recharge wells.

Methodology 2:

- Construction of the entire shaft using precast concrete segmental lining progressively installed as the excavation proceeds. Excavation of the shaft would proceed in tightly defined “bites” (2 to 5m increments has been used elsewhere and 5m has been assumed for modelling), with the permanent lining installed prior to excavation of the next “bite”.

The permanent lining is expected to be reinforced concrete ring constructed by concrete segments with final permeability around $10^{-9}$ m/s as described in more detail in our previous report (Tonkin & Taylor Ltd, 2012). The base of the shaft will be protected with a concrete slab with the same permeability assumed as the permanent shaft lining.

The permeability of the temporary lining (secant pile wall/sheet pile retaining wall) is expected to be higher than the permanent lining and a value of $10^{-8}$ m/s has been adopted consistent with previous work.

# 4 Assessment of potential effects

## 4.1 Groundwater modelling

Groundwater modelling methodology used in this study is consistent with that in our earlier study (Tonkin & Taylor Ltd, 2012 - refer to Section 6). Our previous report contains a detailed description of the model set-up and implementation.

In summary, two dimensional axi-symmetric models have been set up in the software package SEEP/W to represent the two sites. The models represent the interpreted geological and groundwater conditions at each site as understood from the subsurface investigations.

Into this base model, the proposed construction methodology and sequence is introduced, with the model simulating the effect of the various construction stages on the groundwater regime through estimates of the magnitude of potential groundwater drawdown. Finally, the completed shaft is installed, and the long term effects of shaft operation assessed.

At the Mt Albert War Memorial Reserve (AS1) site (refer Drawing 26145.3 SK1) two of the three shafts are proposed to be very close together. If these shafts are constructed simultaneously, the effect on groundwater is likely to be more significant than if constructed separately after completion of the initial shaft. To assess the simultaneous excavation of the shafts, an analysis of a single larger diameter shaft has been carried out as an analogy to the two shafts. The example construction methodology otherwise assumes that the third more distant shaft (which is associated with connections to the local sanitary sewer network) would be constructed separately on completion of the other shafts and on recovery of any associated ground water draw down, such that ground water drawdown would not be additive.

### 4.1.1 Model analysis cases

Three key analysis cases are presented here to assist in understanding the potential for groundwater drawdown effects:

1. A theoretical case for the shaft constructed with a very leaky liner or temporary support. In the modelling the drawdown associated with the "leaky" shaft construction is allowed to reach a steady state. This model represents the upper bound for groundwater drawdown at the site, but does not represent a credible construction methodology. It is presented to allow an assessment of the degree to which credible construction methodologies mitigate this potential magnitude of effects.
2. The credible construction methodology (or, in the case of shaft L3S3, two different methodologies) case that results in surface settlement estimates which would not be expected to result in adverse effects on nearby properties.
3. A case representing long term operation of the shaft to assess the potential for long term development of groundwater drawdown effects at the site.

All modelled cases are summarised for the two sites in the following Table 4.1.

Table 4.1 – Summary of model cases

| Shaft no. / Case no. | Analysed case | Purpose |
|---|---|---|
| AS1 / 1 | Steady state with very leaky temporary support in Puketoka soil | Analysis to assess the upper bound of potential groundwater drawdown to develop estimates of unmitigated settlement hazard. |
| AS1 / 2 | Steady state with temporary lining in Puketoka soil | Analysis to assess effect of the chosen construction methodology (described in Section 3.5) on long term groundwater drawdown |
| AS1 / 3 | Steady state with permanent lining | Analysis to assess effect of the final shaft construction on long term groundwater drawdown |
| L3S3 / 1 | Steady state with very leaky temporary support in Puketoka soil | Analysis to assess the upper bound of potential groundwater drawdown to develop estimates of unmitigated settlement hazard. |
| L3S3/ 2a | Steady state with temporary lining in Puketoka soil and presence of recharge wells | Analysis to assess effect of the chosen construction methodology (described in Section 3.5) including installation of recharge wells on long term groundwater drawdown |
| L3S3/ 2b | Placing of the precast concrete segmental lining during shaft construction | Analysis to assess effect of the chosen construction methodology with installation of the final lining during construction (described in Section 3.5) on long term groundwater drawdown |
| L3S3/ 3 | Steady state with permanent lining | Analysis to assess effect of the final shaft construction on long term groundwater drawdown |

### 4.1.2 Groundwater modelling results

Results of the groundwater modelling are presented in Table 4.2 for the Mt Albert War Memorial Reserve (AS1) site and Table 4.3 for the Whitney Street (L3S3) site. Graphical outputs are presented in Appendix B.

The rate of lowering of the phreatic surface in models for the Mt Albert War Memorial Reserve site is highly dependent on the presence of water in basalt, which is working as a "recharging" layer for Puketoka formation. The piezometer installed in BH CI-29 indicates that the ground water level remains within the basalt, and this is the basis of the models.

In the case of Whitney Street (L3S3) shaft the rate of lowering of the phreatic surface is much more dependent on the lining position as there is not an overlying basalt layer to provide recharge into the Puketoka. So either installation of recharging wells or installation of the permanent lining during shaft construction has been assumed in the example construction methodologies to minimise dewatering during construction.

Table 4.2 – Groundwater modelling results Mt Albert War Memorial Reserve (AS1)

| Model case | Max drawdown (m) | Max drawdown at nearest property boundary (m) | Max drawdown at nearest building (m) | Approximate extent of groundwater effects (m) |
|---|---|---|---|---|
| 1 Steady state with very leaky temporary support in Puketoka soil | 3 | <1 | <1 | <10 |
| 2 Steady state with temporary lining in Puketoka soil | 3 | <1 | <1 | <10 |
| 3 Steady state with permanent lining | <1 | <1 | <1 | <10 |
| 4 Steady state with temporary lining in Puketoka soil with double shaft diameter to model presence of working shaft | 3 | <1 | <1 | <10 |

Table 4-3- Groundwater modelling results Whitney Street (L3S3)

| Model case | Max drawdown (m) | Max drawdown at nearest property boundary (m) | Max drawdown at nearest building (m) | Approximate extent of groundwater effects (m) |
|---|---|---|---|---|
| 1 Steady state with very leaky temporary support in Puketoka soil | 12 | 12 | 10 | 300 |

| Model case | Max drawdown (m) | Max drawdown at nearest property boundary (m) | Max drawdown at nearest building (m) | Approximate extent of groundwater effects (m) |
|---|---|---|---|---|
| 2a Steady state with temporary lining in Puketoka soil and presence of recharge wells | 4[1] | 1.5 | 0.5 | 300 |
| 2b Placing of the precast concrete segmental lining during shaft construction | 2 | 2 | 2 | 300 |
| 3 Steady state with permanent lining | 1.5 | 1.5 | 1.0 | 200 |

1 - Maximum draw down occurs approximately 60m from shaft boundary with single ring of recharge wells 10 m from shaft.

## 4.2 Groundwater induced settlement modelling

Surface settlement analysis has been undertaken based on the changes in pore water pressure estimated in the SEEP/W models.

The settlement analysis has been undertaken using the finite element software package, SIGMA/W. SIGMA/W is a general purpose, two-dimensional geotechnical finite element package. It allows a sequentially coupled consolidation analysis to be undertaken with SEEP/W results based on the change in pore water pressure.

The settlements that might develop during shaft construction are reported in Table 4.4 for the Mt Albert War Memorial Reserve site (AS1) and Table 4.5 for the Whitney Street (L3S3) shaft.

“Steady state with permanent lining” identifies the long term settlements that might develop over the life of the shaft once the shaft is fully completed. Where groundwater has been drawn down more significantly during construction this analysis identifies the level to which groundwater might be expected to recover, and indicates that no further settlement would be expected. Where construction has tightly constrained groundwater drawdown, this represents the potential long term maximum groundwater drawdown (and surface settlement) that may develop over many years.

### Table 4.4 – Settlement modelling results Shaft AS1

| Model case[1] | Max settlement (mm)/ Max differential | Max settlement at nearest property boundary (mm)/ differential | Max settlement at nearest building (mm)/ differential | Approximate extent of settlement effects (m)[2] |
|---|---|---|---|---|
| 1 Steady state with very leaky temporary support in Puketoka soil | 60/1:1,150 | 55/1:1,400 | 50/1:1,350 | 110 |

| | | | | |
|---|---|---|---|---|
| 2 Steady state with temporary lining in Puketoka soil - construction case | 35/1:<br><1:2,000 | 30/<1:2,000 | 30/<1:2,000 | 100 |
| 3 Steady state with permanent lining - long term operation case | 10/<1:2,000 | 5/<1:2,000 | 5/<1:2,000 | 40 |
| 3 Steady state with double shaft diameter to model simultaneous excavation of two shafts | 55/1:1,400 | 50/1:1,100 | 45/1:1,500 | 130 |

1 - Refer to Section 4.1.1 for a discussion on applicability of the modelled cases

2 - Extent of settlements predicted to be greater than 5mm. Theoretical settlements of less than 5mm are unlikely to be observable or measurable with confidence.

Table 4-5- Settlement modelling results Shaft L3S3

| Model case[1] | Max settlement (mm)/ Max differential | Max settlement at nearest property boundary (mm)/ differential | Max settlement at nearest building (mm)/ differential | Approximate extent of settlement effects (m)[2] |
|---|---|---|---|---|
| 1 Steady state with very leaky temporary support in Puketoka soil | 85/1:200 | 75/1:200 | 85/1:<1:2,000 | 290 |
| 2a Steady state with temporary lining in Puketoka soil and recharge wells 10m from shaft | 35[3]/1:1,000 | 15/<1:2,000 | 15/<1:1,200 | 280 |
| 2b Placing of the precast concrete segmental lining during shaft construction-construction case | 20/1:1,600 | 20/1:1,600 | 20/<1:2,000 | 230 |
| 3 Steady state with permanent lining - long term operation case | 15/<1:2,000 | 15/<1:2,000 | 15/<1:2,000 | 165 |

1 Refer to Section 4.1.1 for a discussion on applicability of the modelled cases.

2 Extent of settlements predicted to be greater than 5mm. Theoretical settlements of less than 5 mm are unlikely to be observable or measurable with confidence.

3 Maximum settlement occurs 64m from shaft boundary.

The implications of these settlement modelling results are discussed in Section 5 below.

## 4.3 Settlement due to excavation (mechanical settlement)

During shaft excavation stresses in the ground about the shaft are expected to reduce potentially resulting in horizontal movement towards the shaft. The magnitude of the horizontal movement is highly dependent on shaft construction methodology and the stiffness of any excavation support elements. As a consequence of horizontal deformation, vertical deformation (settlement) is also caused, in addition to any settlement associated with groundwater draw down.

There are two main factors influencing the magnitude of the final settlement:

- Deflection of the structural support (related to the stiffness of the excavation support structure).
- Construction methodology.

Influence of the structural support was modelled using 2 a dimensional axi-symmetric model set up in the software package SIGMA/W. The AS1 shaft was used as an example to assess the order of magnitude of the potential settlement. The model included the structural support provided to the Puketoka Formation soils with the rest of the shaft excavated without support. Support was modelled with the parameters presented in the following Table 4.6.

Table 4.6 – Summary of support parameters adopted

| Unit | Bulk Unit weight **γ** [kN/m$^3$] | Modulus of Elasticity – E' [kPa] | Coefficient of volume compressibility $m_v$ [1/kPa] | Poisson's ratio v | Permeability k [m/sec] |
|---|---|---|---|---|---|
| Concrete lining | 25 | 10,000,000 | 5E-8 | 0.2 | 1E-9 |

### 4.3.1 Model results

The settlement estimated for the example construction methodology at AS1 is less than 5 mm (refer outputs in Appendix C).

A model representing conditions similar to L3S3 (without the stiff basalt and with deeper Puketoka) estimated maximum settlement is approximately 5mm (refer Appendix C).

# 5 Engineering implications

## 5.1 Groundwater drawdown

Groundwater drawdown in itself is unlikely to constitute an effect at the two sites. However, the potential for surface settlement to arise as a consequence of the groundwater draw down needs to be considered.

## 5.2 Surface settlement

Some settlement of the ground surface is expected as a direct result of dewatering the ground about the shaft and potentially as a result of structural deflection of temporary support structures. The nature of the settlement may range from:

- Imperceptible (i.e. settlement is within measurement error for survey methods or is masked by seasonal surface movements due to near surface soil moisture changes);
- Uniform over large areas (where the effects of groundwater changes are spread over a wide area within uniform geology);
- Locally variable (where significant changes in groundwater response occur over short distances, or where locally highly variable geology is affected by groundwater changes).

In all cases the potential for settlement to result in damage to structures depends primarily on the differential settlement, not on the total settlement.

A detailed description of the potential range of effects of surface settlement is provided in our original report (Tonkin & Taylor Ltd, 2012), Section 5.5.

### 5.2.1 Tunnelling induced settlement

The Central Interceptor Project Team advises that surface settlement associated with mechanical settlement during tunnel excavation is in the order of 5mm at the Mt Albert War Memorial Reserve (AS1) and Whitney Street (L3S3) sites, assuming that EBPM operation results in approximately 0.5% ground loss.

Our previous report (Tonkin & Taylor Ltd, 2012) identifies that for geology similar to the Mt Albert War Memorial Reserve site, tunnelling induced settlement associated with groundwater effects could be in the order of up to 20 mm with the tunnel liner installed seven days after initial excavation and without use of earth pressure balancing. At Whitney Street, for the same case, 10 mm is estimated. With use of earth pressure balancing, settlement could be controlled to less than 5 mm (theoretically settlement can be completely mitigated). Once the tunnel liner has been constructed (permeability assumed to be equivalent to 500 mm of 1e-10 m/s) groundwater is expected to substantially recover, with no further settlement resulting.

### 5.2.2 Combined effects of tunnelling and shaft construction

Construction programming is most likely to have shaft construction complete prior to tunnelling. This report assumes that this is the case, and that groundwater levels have sufficiently recovered from shaft construction at the time of tunnelling such that groundwater drawdown is not additive.

Groundwater induced settlement is therefore the maximum of that estimated for shaft or tunnel construction.

Mechanical settlement however is cumulative. At Mt Albert War Memorial Reserve the access shaft is located immediately above the tunnel, so mechanical settlements are assumed to be directly additive.

The tables below provide the estimated total settlement (mechanical and groundwater induced settlement for the tunnel and shafts combined) for the two site.

During final construction programming it could be identified that it is more desirable for tunnelling to immediately follow shaft construction. In that case the specific construction methodology employed may require a higher degree of water tightness during the construction phase to limit groundwater drawdown more significantly than assumed here.

Table 5.1 – Combined settlement results, Mt Albert War Memorial Reserve (AS1)

| Model case | Max settlement (mm)/ Max differential | Max settlement at nearest property boundary (mm) / differential | Max settlement at nearest building (mm) / differential | Approximate extent of settlement effects (m) |
|---|---|---|---|---|
| Shaft construction using example methodology | 45/<1:2,000 | 40/<1:2,000 | 40/<1:2,000 | 100 |
| Long term operation of shafts and tunnel | 20/<1:2,000 | 15/<1:2,000 | 15/<1:2,000 | 100 |

Table 5.2 – Combined settlement results at Whitney Street (L3S3)

| Model case | Max settlement (mm)/ Max differential | Max settlement at nearest property boundary (mm) / differential | Max settlement at nearest building (mm) / differential | Approximate extent of settlement effects (m) |
|---|---|---|---|---|
| Shaft construction using example methodology | 30/1:1,950 | 30/1:1,950 | 25/<1:2,000 | 230 |
| Long term operation of shafts and tunnel | 20/1:1,950 | 20/1:1,950 | 20/<1:2,000 | 165 |

### 5.2.3 Potential effect on surrounding buildings

The results identify that structural damage is unlikely to occur as a result of shaft and tunnel construction at either site for the example shaft construction methodology modelled. Total settlements, and importantly, differential settlements are indicated to be below the level which would be expected to result in damage.

The magnitude of settlement estimated is consistent with that estimated during consenting phases for other similar (and now constructed) tunnels and shafts in the Auckland Isthmus, where construction monitoring has shown estimates to be conservative (over estimates) of the settlement that actually occurs.

# 6 Monitoring

Section 11 of our previous report (Tonkin & Taylor Ltd, 2012) presents a discussion of the general concepts for monitoring and responding to changes in groundwater level and surface level as a result of shaft construction. Based on the additional example modelling carried out for this report, an example layout for a surface settlement and groundwater level monitoring network has been developed and is shown Drawings 26145.3 SK1 and SK2 for Mt Albert War Memorial Reserve and Whitney Street sites respectively.

Three groundwater monitoring bores are shown close to each shaft where effects on groundwater would be expected to be most marked. Multilevel piezometers are proposed to monitor groundwater level in each geological unit.

Monitoring of groundwater levels during construction would be referenced to triggers identified for the construction stages in the detailed modelling. Example levels have been set here based on example modelling undertaken for this report. Deviation from the expected groundwater response would trigger the need for an additional survey of settlement markers to be undertaken to confirm if the deviation was manifest as unexpected settlement. The identification of unexpected settlement would be the primary reason for contingency actions to be enacted.

Survey settlement marks have been shown surrounding the shafts and in particular attached or close to houses and buildings (subject to property owner approval) that could potentially be subject to surface settlement effects. Alternatively settlement marks would be isolated to road reserves and other public land. Example alert and alarm triggers for settlement have been identified based on the assessed range of settlement for the example construction stages. Deviation from these values, such that buildings or structures may sustain adverse effects would be a primary reason for contingency actions to be enacted.

Examples of trigger levels for monitoring effects during construction are provided below. Monitoring frequency would be set to reflect the rate of shaft excavation and construction so that monitoring would be carried out at least three times between each identified trigger.

While the sections below provide an example of how monitoring could be used to control construction, ultimately the monitoring arrangement and methodology would be directly linked to the actual construction methodology developed in detailed design, and taking into consideration the mode detailed appreciation of ground conditions that will be developed during that process. The monitoring methodology would become part of a Monitoring and Contingency Plan required by the project Consent.

### 6.1.1 Groundwater level trigger and actions - Shaft AS1

Example trigger levels are provided based on groundwater drawdown modelled for the example construction methodology for the shafts measured in the closest property mark.

Table 6.1 – Example triggers for Groundwater drawdown

| State | Piezometer | Groundwater level trigger | Action |
|---|---|---|---|
| Alert | Reflecting level in Puketoka formation | Reduction in baseline groundwater of 0.5 m | Compare observed settlements with those predicted, and re-calibrate ground model. Re-estimate likely end of construction effects and assess against acceptable criteria. |
| Action | | Reduction in baseline groundwater of 3 m | Carry out additional survey round within 48 hours. Compare observed settlements with those predicted, and re-calibrate ground model. Re-estimate likely end of construction effects and assess against acceptable criteria. |
| Alarm | | Reduction in baseline groundwater of 10 m | Halt excavation, re-check survey. Survey settlement marks within 24 hours of alarm. Assess need to enact contingency measures[1] (based on survey results) to protect buildings or structures if they are at risk of effects that are more than minor |

[1] Contingency measures could include installation of recharge wells, or more recharge wells, isolation of potential at risk structures using sheet piles, underpinning at risk structures to isolate them from ground movement, or flooding the excavation to reverse groundwater draw down.

### 6.1.2 Surface level alert triggers and actions - Shaft AS1

Example trigger levels are provided based on surface settlement modelled for the example construction methodology.

Table 6.2 – Example triggers for survey marks

| State | Marks within the closest property | | Action |
|---|---|---|---|
| | Settlement [m] | Inclination | |
| Alert | 15 | 1:2,500 | Compare observed settlements with those predicted, and re-calibrate ground model. Re-estimate likely end of construction effects and assess against acceptable criteria. |
| Action | 30 | 1:2,000 | Re-check triggered survey results. Compare observed settlements with those predicted, and re-calibrate ground model. Re-estimate likely end of construction effects and assess against acceptable criteria. |
| Alarm | 50 | 1:1,000 | Halt excavation, re-check survey. Survey settlement marks within 24 hours of alarm. Assess need to enact contingency measures[1] (based on survey results) to protect buildings or structures if they are at risk of effects that are more than minor |

1 Contingency measures could include installation of recharge wells, or more recharge wells, isolation of potential at risk structures using sheet piles, underpinning at risk structures to isolate them from ground movement, or flooding the excavation to reverse groundwater draw down.

### 6.1.3 Groundwater level trigger and actions - Shaft L3S3

Example trigger levels are provided based on groundwater drawdown modelled for the example construction methodology for the shafts measured in the closest property mark.

Table 6.3 – Example triggers for Groundwater drawdown

| State | Piezometer | Groundwater level trigger | Action |
|---|---|---|---|
| Alert | Reflecting level in Puketoka formation | Reduction in baseline groundwater of level 1.5 m | Compare observed settlements with those predicted, and re-calibrate ground model. Re-estimate likely end of construction effects and assess against acceptable criteria. |
| Action | | Reduction in baseline groundwater level of 3 m | Carry out additional survey round within 48 hours. Compare observed settlements with those predicted, and re-calibrate ground model. Re-estimate likely end of construction effects and assess against acceptable criteria. |
| Alarm | | Reduction in baseline groundwater level of 6 m | Halt excavation, re-check survey. Survey settlement marks within 24 hours of alarm. Assess need to enact contingency measures[1] (based on survey results) to protect buildings or structures if they are at risk of effects that are more than minor |

1 Contingency measures could include installation of recharge wells, or more recharge wells, isolation of potential at risk structures using sheet piles, underpinning at risk structures to isolate them from ground movement, or flooding the excavation to reverse groundwater draw down.

### 6.1.4 Surface level alert triggers and actions - Shaft AS1

Example trigger levels are provided based on surface settlement modelled for the example construction methodology.

Table 6.4 – Example triggers for Groundwater drawdown

| State | Marks within the closest property | | Action |
|---|---|---|---|
| | Settlement [m] | Inclination | |
| Alert | 15 | 1:2,500 | Compare observed settlements with those predicted, and re-calibrate ground model. Re-estimate likely end of construction effects and assess against acceptable criteria. |
| Action | 25 | 1:2,000 | Re-check triggered survey results. Compare observed settlements with those predicted, and re-calibrate ground model. Re-estimate likely end of construction effects and assess against acceptable criteria. |
| Alarm | 50 | 1:1,000 | Halt excavation, re-check survey. Survey settlement marks within 24 hours of alarm. Assess need to enact contingency measures[1] (based on survey results) to protect buildings or structures if they are at risk of effects that are more than minor |

# 7 Consent conditions

The conditions could include provisions such that, where required:

- The tunnel and shafts are designed with a low permeability liner such that long term groundwater draw down, and associated surface settlement is controlled to an acceptable level.
- The tunnel construction methodology includes the capability to pressurise the excavated face and unlined annulus where excavations pass under settlement sensitive geology. At such locations, the construction methodology should also allow for the lining to be installed within seven days of excavation
- The effects of tunnel construction on groundwater and surface settlement be monitored as the tunnel and shafts are excavated and for a period of no less than two years following lining completion.
- Prior to construction a Monitoring and Contingency Plan is prepared detailing the extent and frequency of monitoring. The plan should be targeted to respond to the actual excavation programme, and be specific to the potential settlement hazard at any location.
- Surface settlement associated with tunnel and shaft construction and operation is limited to a maximum of 50 mm total settlement and a differential no steeper than 1:1000 in developed areas.

# 8 Conclusions

Practical construction methodologies are available that enable construction of the shafts at AS1 and the shaft at L3S3 that can be expected to result in no adverse effects to property or structures nearby.

On the basis of the example construction methodologies proposed and the modelling undertaken we conclude that construction of the shafts and tunnels at both sites is feasible within acceptable limits for surface settlement of 50 mm and 1:1000.

The magnitude of settlement estimated for the shaft construction is consistent with that estimated during consenting phases for other similar (and now constructed tunnels and shafts) in the Auckland isthmus, where construction monitoring has shown estimates to be conservative (over estimates) of the settlement that actually occurs.

During final design, these example methodologies, or alternative methodologies would be developed in detail taking into consideration the additional information on ground and ground water conditions that will be obtained in that process.

Conclusions specific to the two sites follow below.

## 8.1 Shaft AS1

- Construction of two shafts simultaneously using the example construction methodology could potentially result in total settlement exceeding 50 mm at the nearest property boundary and is a worst case scenario for this assessment. At the nearest house total settlement is estimated to be 60 mm (including combined effects of tunnelling settlement). Differential settlement is however controlled to flatter than 1:1000, indicating that structural damage is unlikely.
- For individual shaft construction, the example methodology can be expected to limit total and differential settlement within properties and at structures to less than 50mm and less than 1:1,000 indicating that structural damage is unlikely to result.
- Watercare are currently investigating alternative layouts for the shafts within the Mt Albert War Memorial Reserve. The overall conclusions of this report are expected to apply to alternative layouts that position the shafts no closer to buildings than the current minimum distance to any building structure.

## 8.2 Shaft L3S3

- For the example methodology utilising recharge wells, the location of the wells is critical in controlling settlement effects. For the recharge wells located at 10 m radius from the shaft, the maximum settlement occurs some 60 – 70 m from the shaft.
- At L3S3, while the recharge methodology is a feasible one from an engineering perspective, it requires installation of recharge wells in private property.
- For the second example methodology, total settlement and differential settlement, including combined effects from tunnelling are estimated to be less than 50 mm and 1:1,000 indicating that structural damage is unlikely.

# 9 Applicability

This report has been prepared for the benefit of Watercare Services Ltd with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose without our prior review and agreement.

Tonkin & Taylor Ltd

Environmental and Engineering Consultants

| | |
|---|---|
| Report prepared by: | Authorised for Tonkin & Taylor Ltd by: |
| ............................................... | ............................................... |
| Graeme Twose | Robert Hillier |
| Senior Geotechnical Engineer | Group Manager, Geotechnical |
| and | |

pp ...............................................

Frantisek Havel

Senior Geotechnical Engineer

1-Mar-13
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# Figures

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| 0 | First Issue | | |
| | REVISION DESCRIPTION | BY | DATE |

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|---|---|---|
| DESIGNED : | DNT | Dec. 12 |
| DRAWN : | JATG | Dec. 12 |
| DESIGN CHECKED : | | |
| DRAFTING CHECKED : | | |

CADFILE : \\26 145.300–SK 1_SK4.dwg

APPROVED :
NOT FOR CONSTRUCTION
This drawing is not to be used for construction purposes unless signed as approved

NOTES :
1. All dimensions are in millimetres unless noted otherwise.

REFERENCE :

Tonkin & Taylor
Environmental and Engineering Consultants
105 Carlton Gore Road, Newmarket, Auckland
Tel. (09) 355 6000 Fax. (09) 307 0265
www.tonkin.co.nz

CLIENT, PROJECT
WATERCARE SERVICES LIMITED
watercare services limited

TITLE
CENTRAL INTERCEPTOR
Mt Albert War Memorial Reserve – AS1

SCALES (AT A1 SIZE): AS SHOWN
DWG. No.: 26 145.300–SK 1
REV.: 0

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| REVISION | DESCRIPTION | BY | DATE |

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| DESIGNED : | DNT | Dec. 12 |
| DRAWN : | JATG | Dec. 12 |
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www.tonkin.co.nz

CLIENT, PROJECT
WATERCARE SERVICES LIMITED

TITLE
CENTRAL INTERCEPTOR
Whitney Street – L3S3

SCALES (AT A1 SIZE)
AS SHOWN

DWG. No.
26 145.300–SK2

REV.
0

# Appendix A: Borehole logs

# TONKIN & TAYLOR LTD

# DRILL HOLE LOG

BOREHOLE No: CI-29
Hole Location: Selcourt Rd

SHEET 1 OF 6

PROJECT: Central Interceptor
LOCATION: Mt Albert
JOB No: 26145.206

CO-ORDINATES 6479015 mN
2664160 mE
DIRECTION: -90.00 °
ANGLE FROM HORIZ.: °

DRILL TYPE: PQ/HQ Wireline
DATUM: LINZ
R.L. GROUND: 24.68 m
R.L. COLLAR: 24.68 m

HOLE STARTED: 23/11/10
HOLE FINISHED: 26/11/10
DRILLED BY: Boart Longyear (Craig)
LOGGED BY: SRS
CHECKED:

## DESCRIPTION OF CORE

GEOLOGICAL UNIT | ROCK OR SOIL TYPE, WEATHERING, HARDNESS, STRENGTH, COLOUR, LITHOLOGICAL FEATURES (bedding, cement, foliation, mineralogy, texture, etc...); | ROCK WEATHERING (UW SW MW HW) | ROCK STRENGTH (R4 R3 R2 R1 R0) | PT LOAD / UCS TEST (MPa) | CORE LOSS / LIFT (%) (3 10 30 100) | METHOD, CORE & CASING | TEST SYMBOL | DEPTH (m) | GRAPHIC LOG

TS

Gravelly SILT, brown, organic material (roots, etc.), common disturbed fabric, basalt clasts <30mm

AUCKLAND VOLCANIC FIELD

Coarse basalt gravels (<70mm), angular to sub-angular, slightly vesicular, slightly weathered, very strong

Dark grey BASALT, moderately vesicular, strong, porphyritic texture

1.4m: Vesicle 40mm

2m: Grading to slightly vesicular

3m: Core bound
Broken up MW BASALT, very strong, sub-angular to angular, between 90-100mm
3.5m: Grading to massive (non-vesicular)

Some bands of vesicles

4.25-4.35m: Crushed zone - heavily fractured, dark grey BASALT

4.75m: moderately vesicular

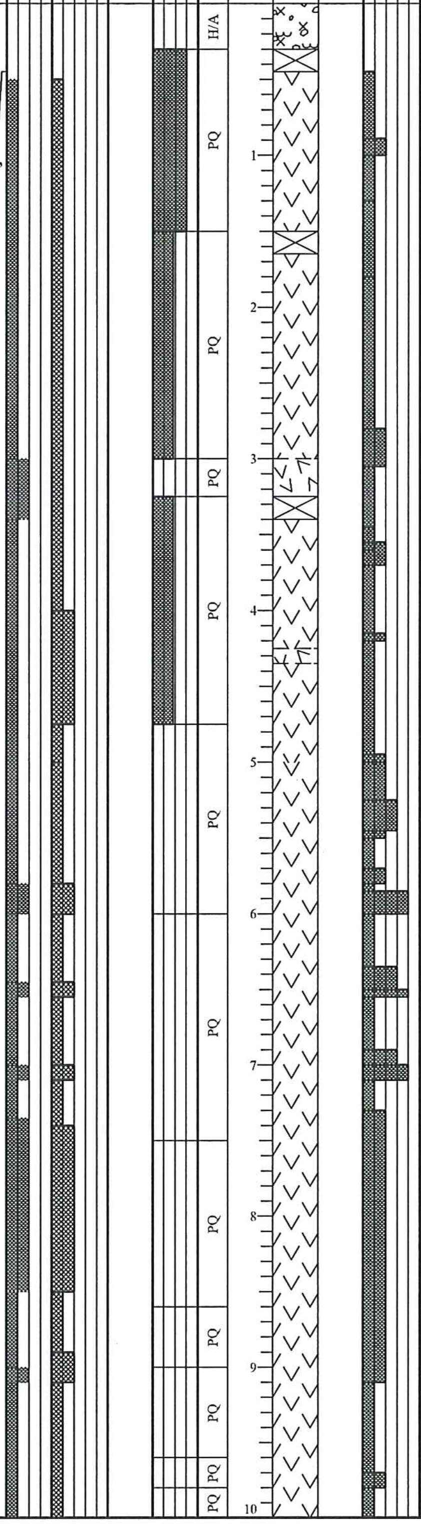
5m: very slightly vesicular to massive (non-vesicular)

5.7m: Becoming MW
5.8 and 6m: Heavily fractured contains dark lithic (olivine glass) grains ~5mm dia., angular

6.75m: Dark grey BASALT, some glass/olivine?, sub angular inclusions, low vesicularity
7.1 to 7.5m: Core bound

8m: Heavily fractured region core dropped

8.6m: "Core bound" from previous run

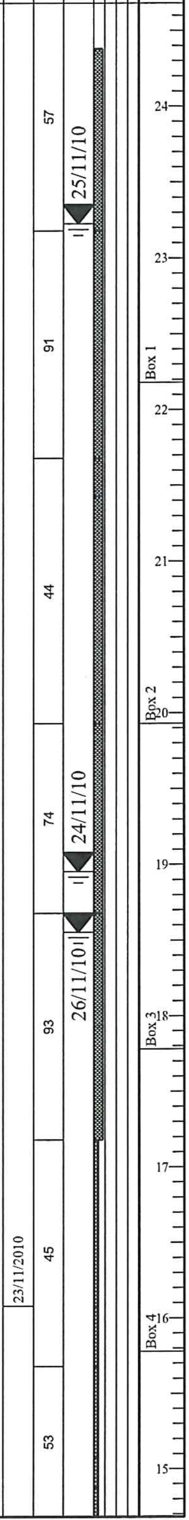


## ROCK DEFECTS

DEFECT LOG | FRACTURE LOG spacing of natural fractures (cm) (50 10 5 1) | SIGNIFICANT JOINTS, BEDDING, CRUSHED AND SHEARED ZONES/SEAMS; DEFECT TYPE, SHAPE, ROUGHNESS, APERTURE, INFILLING, SPACING; ANGLES ARE NORMAL TO CORE AXIS | DATE / DEPTH | RQD (%) | WATER | DRILL WATER LOSS (%) (25 50 75) | CORE BOX | RL (m)

0.89m: Joint 12°, slightly curved, rough, gapped, limonite coating.
1m: Joint 80°, slightly curved, rough, gapped, no coating (between 0.95 to 1.05m).
1.32m: Joint 30°, irregular, rough, open, very little limonite coating.
1.8m: Joint 28°, slightly curved, rough, gapped, limonite coating?
2.16m: Joint 5°, slightly curved, tight, rough, non coating.
2.5m: Joint 2°, planar, rough, tight, no coating.

2.9m: Joint 60°, planar, rough, open, clay coating, some clay infill.
3.1 Crushed basalt limonite staining, some clay coatings.
3.45m: Joint 80°, planar, smooth, tight, limonite coating.
3.45m: Joint 15°, curved, rough, gapped, no coating.
3.5m: Joint 5°, irregular, rough, open.
3.6m: Joint 5°, planar, open, rough.
3.7m: Joint 80°, curved, smooth, tight, limonite coating.
3.75m: Joint 10°, planar, rough, gapped.
3.85m: Joint 50°, planar, rough, gapped.
4.25m: Joint 5°, planar, rough, open, very little staining, heavily fractured.
4.35m: Heavily fractured zone, no clay or staining.
4.45m: Joint 25°, slightly curved, rough, tight.
4.55m: Joint 45°, slightly curved, rough, tight.
4.9m: Joint 5°, irregular, rough, open.
5.1m: Joint 5°, slightly curved, rough, clay gouge.
5.2m: Joint 50°, slightly curved, rough, clay gouge, some clay and Fe staining.
5.25m: Joint 50°, curved, rough, open, limonite coating.
5.3m: Joint 45°, curved, rough, open, limonite coating, some clay infill.
5.35m: Joint 20°, planar, smooth, clay gouge, no coating.
5.5m: Joint 35°, planar, smooth, clay gouge, clay staining.
5.7m: Joint 50°, planar, smooth, tight, clay infill, limonite coating.
5.8m: Joint 30°, planar, smooth, tight, clay infill, Fe stained coating.
Heavily fractured zone, parallel fracturing at 5.8-5.85m (~85°), clay infilled, Fe coating.
6.35m: Joint 35°, planar, smooth, tight, clay staining, Fe stained coating.
6.4m: Joint 55°, planar, smooth, tight, clay staining, Fe stained coating.
6.5m: Fractured zone (multiple fractures), limonite coating, clay infill.
6.65m: Joint 10°, planar, rough, gapped, limonite coating.



imz

Log Scale 1:50

# TONKIN & TAYLOR LTD

# DRILL HOLE LOG

BOREHOLE No: CI-29
Hole Location: Selcourt Rd

SHEET 2 OF 6

PROJECT: Central Interceptor
LOCATION: Mt Albert
JOB No: 26145.206

CO-ORDINATES 6479015 mN
2664160 mE
DIRECTION: -90.00 °
ANGLE FROM HORIZ.: °

DRILL TYPE: PQ/HQ Wireline
DATUM: LINZ
R.L. GROUND: 24.68 m
R.L. COLLAR: 24.68 m

HOLE STARTED: 23/11/10
HOLE FINISHED: 26/11/10
DRILLED BY: Boart Longyear (Craig)
LOGGED BY: SRS
CHECKED:

## DESCRIPTION OF CORE

GEOLOGICAL UNIT

ROCK OR SOIL TYPE, WEATHERING, HARDNESS, STRENGTH, COLOUR, LITHOLOGICAL FEATURES (bedding, cement, foliation, mineralogy, texture, etc...);

ROCK WEATHERING (UW SW MW HW)
ROCK STRENGTH (R4 R3 R2 R1 R0)
PT LOAD / UCS TEST (MPa)
CORE LOSS / LIFT (%) (3 10 30 100)
METHOD, CORE & CASING
TEST SYMBOL
DEPTH (m)
GRAPHIC LOG

AVF

10m: Light grey BASALT, slightly vesicular, porphyritic texture fractured

10.4m: Becoming moderately vesicular

11.25m: Becoming light grey BASALT, highly vesicular, with dark green staining on fracture faces
11.5m: Highly vesicular with dark green (olivine?) inclusions and some red staining
11.6m: Some glass fragments

PUKETOKA FORMATION

11.6-12m: Core loss, softer materials encountered at 11.7m

Dark brown gravelly CLAY, with clasts <50mm (Basalt gravels/fragments), firm, moist to wet

12.15 - 12.3m: Becoming orangey silty CLAY, becoming soft
12.2m: One large basalt fragment

13.95m: Orangy brown, silty CLAY, firm, basaltic gravels at top (14m) with clasts <10mm, sticky, moist
14.4m: Clayey SILT, light grey, firm to stiff, moist, moderate plasticity

15.4m: Silty CLAY, grey to brown, firm to stiff, moist, high plasticity

15.6m: Becoming clayey SILT, slightly sandy, firm to stiff, moist to wet, moderate plasticity
16m: Clayey SILT, grey, firm to stiff, wet, some dark basalt clasts (<10mm), moderate to high plasticity

16.5m: Becoming darker brown-black, organic, clayey SILT, firm, moderate plasticity

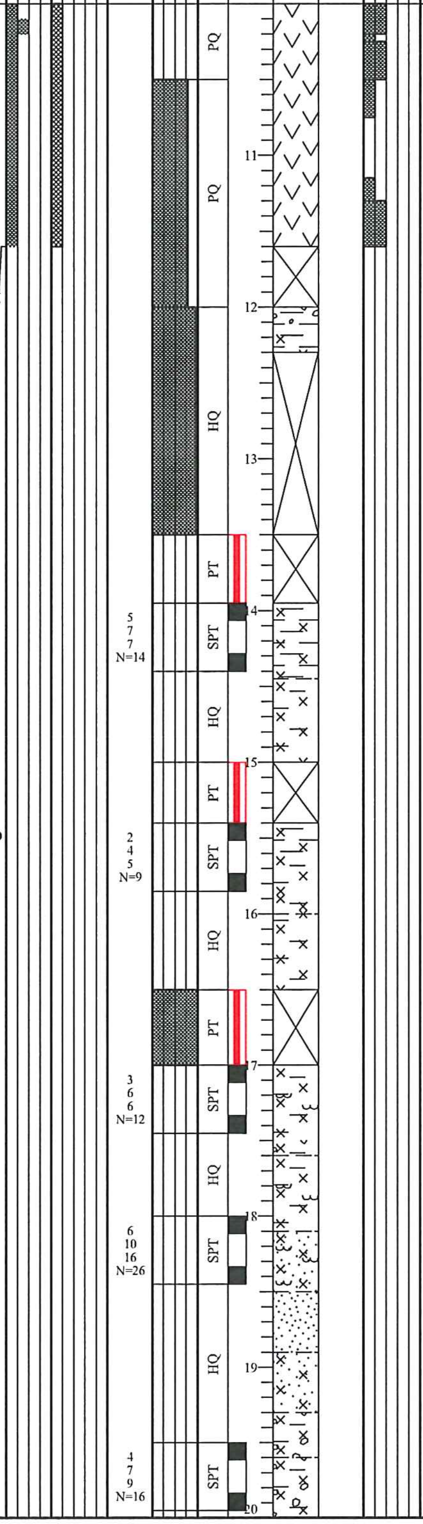
17m: Clayey SILT, some organic matter, grey, brown rootlets, moist, small basalt inclusions (size increasing with depth), firm, very sticky, low plasticity

17.5m: Dark brownish grey, some basalt clasts (<10mm), firm to soft, moderate plasticity

17.6m: Clayey SILT, light grey, firm, rootlets and organics common, contains basalt fragments <10mm throughout, moist to wet

Sandy SILT, brownish grey, stiff, moist, some rootlets, low plasticity, some green softe inclusions near 18.4m (size increasing with depth)

SAND, grey-green, stiff, predominantly green at 18.8m, moist, some rootlets, poorly graded with basalt clasts, low



## ROCK DEFECTS

DEFECT LOG

FRACTURE LOG spacing of natural fractures (cm) (50 10 5 1)

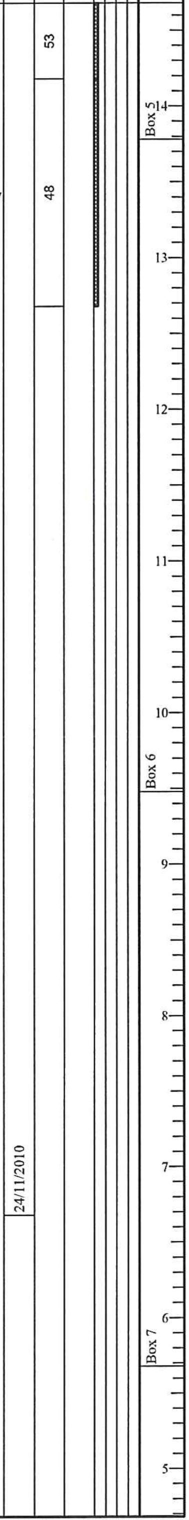
SIGNIFICANT JOINTS, BEDDING, CRUSHED AND SHEARED ZONES/SEAMS

DEFECT TYPE, SHAPE, ROUGHNESS, APERTURE, INFILLING, SPACING

ANGLES ARE NORMAL TO CORE AXIS

DATE / DEPTH
RQD (%)
WATER
DRILL WATER LOSS (%) (25 50 75)
CORE BOX
RL (m)

6.9m: Joint 65°, planar, smooth, tight, limonite coating, clay staining.
6.95m: Joint 50°, slightly curved, tight, limonite coating, clay staining.
Heavily fractured zone, Fe staining and some clay coating on fractures.
7.35m; Joint 40°, planar, smooth, open, Fe stained coating, clay infill.
7.4m: Heavily fractured, Fe stained coating, clay infill.
Joint 85°, slightly curved, smooth, open, significant clay infill.
7.5m: Joint 50°, planar, smooth, limonite coating, clay infill.
7.75m: Joint 70°, planar, smooth, open, Fe stained coating, clay coating.
Heavily fractured zone exists between 7.75-8.35m, many high angle (~80°) parallel fracture sets exist between 8.25-8.35m, more fractures ~45°-20° exist, planar, smooth, open, clay and Fe stained coating.
8.6m: Joint 55°, irregular, rough, open, Fe staining, significant clay infill.
8.7m: Joint 30°, planar, smooth, gapped, slight Fe stain, clay infill.
Between 8.7-9mn multiple fractures, including one horizontal set. Clay and Fe stained coatings, mostly planar, smooth.
9m: Heavily fractured region, significant clay coating, planar, smooth, open.
9.1m: Joint 45°, planar, smooth, tight, tight, Fe stained coating, little clay coating.
9.2m: Joint 10°, planar, smooth, tight.
9.3m: Joint 40°, planar, smooth, tight, Fe stained coating, clay infill.
9.3m: Joint 10°, planar, smooth, tight, Fe stained coating, clay infill.
9.4m: Joint 65°, curved, smooth, gapped, Fe stained coating, significant clay infill.
9.7m: Joint 40°, planar, smooth, tight, clay coating.
9.7m: Joint 85°, curved, rough, open, clay coating.
9.9m: Joint 25°, slightly curved, smooth, tight, Fe staining.
10m: Joint 15°, curved, rough, open, Fe stained coating, clay infill.
10.1m: Joint 5°, planar, rough, open, Fe stained coating, clay coating.
10.1m: Joint 45°, planar, rough, open, Fe stained/clay coating.
10.1m: Joint 50°, planar, smooth, tight, Fe stained/clay coating.
Between 10.1-10.25m: Crushed zone, angular to sub-angular particles <70mm, Fe stained coatings and some clay infill on fracture surfaces.
10.3m: Joint 15°, planar, smooth, tight, Fe stained and clay coating.
10.35m: Joint 35°, slightly curved, rough, open, Fe stained coating.
10.5m: Joint 55°, curved, rough, open, Fe stained coating.
10.55m: Joint 30°, planar, rough, tight, Fe stained coating, some clay coating.
10.7m: Joint 30°, planar, rough, tight, Fe stained coating, some clay coating.



# TONKIN & TAYLOR LTD

# DRILL HOLE LOG

BOREHOLE No: CI-29
Hole Location: Selcourt Rd

SHEET 3 OF 6

PROJECT: Central Interceptor
LOCATION: Mt Albert
JOB No: 26145.206

CO-ORDINATES 6479015 mN
2664160 mE
DIRECTION: -90.00 °
ANGLE FROM HORIZ.: °

DRILL TYPE: PQ/HQ Wireline
DATUM: LINZ
R.L. GROUND: 24.68 m
R.L. COLLAR: 24.68 m

HOLE STARTED: 23/11/10
HOLE FINISHED: 26/11/10
DRILLED BY: Boart Longyear (Craig)
LOGGED BY: SRS
CHECKED:

## DESCRIPTION OF CORE

GEOLOGICAL UNIT: PUKETOKA FORMATION

ROCK OR SOIL TYPE, WEATHERING, HARDNESS, STRENGTH, COLOUR, LITHOLOGICAL FEATURES (bedding, cement, foliation, mineralogy, texture, etc...);

plasticity

18.9m: Becoming sandy SILT, light grey, some basalt and green fragments, stiff, moderate to low plasticity

19.3m: Clayey SILT, grey, poorly (uniformly) graded basalt fragments (>5mm), firm, moist, moderate plasticity

19.6m: Clayey SILT, light brownish grey, some basalt fragments (no grading), moist, moderate to low plasticity

20m: Sandy SILT, firm, moist to wet, moderate to low plasticity

20.2m: Medium to coarse SAND, grey, firm to stiff, poorly cemented, low plasticity, some basalt fragments and rootlets

20.5m: Becoming darker grey, stiff

20.8m: Becoming finer to a sandy SILT, light grey, wet, moderate plasticity, some larger basalt clasts (~10mm)

21m: Medium SAND, brownish grey, moist, poorly cemented, low plasticity

21.1m: Coarse to medium SAND, grey, stiff, moist to wet, low plasticity, extremely weak

21.5m: SAND and SILT contact lined by dark thin material (organics?)

21.6m: Clayey SILT, dark grey, firm, moderate plasticity, extremely weak, contains dark organic material

22m: Becomes sandy SILT, greenish grey, firm, moderate to low plasticity, decreasing organic content

22.5m: Sandy SILT, grey, firm, low to moderate plasticity, brown outer coating (SPT related)

22.95-24m: Core loss

24.45m: Core loss in SPT sample

24.45m: Silty, medium to fine SAND, grey, firm, wet, low plasticity

24.8-25.1m: Dark brown ORGANIC material (root?), wet

25.2m: Silty SAND, brownish grey, speckles of organic materials/dark colouring

25m: Silty SAND, grey, firm, wet, low plasticity, poorly cemented

25.6m: Silty, medium to coarse SAND, dark grey, firm to soft, rootlets and organic material more abundant, some green soft inclusions, wet, low plasticity

25.95-26.2m: Core loss

26.2m: Sandy SILT, light grey some darker bands, firm, wet, low to moderate plasticity

26.75m: Silty, medium to fine SAND, grey, firm, moist to wet, low plasticity

27.2m: Silty, medium to fine SAND, some rootlets, dark greenish grey, moist, moderately sticky, low plasticity

27.7m: Becoming harder (firm to stiff), dark greenish grey silty SAND, still poorly cemented/crumbly (extremely weak)

| PT LOAD / UCS TEST (MPa) | METHOD, CORE & CASING | DEPTH (m) |
|---|---|---|
| | HQ | |
| 50 blows for 160mm N>50 | SPT | 21 |
| | HQ | 22 |
| 4<br>5<br>14<br>N=19 | SPT | |
| | HQ | 23 |
| 11<br>16<br>18<br>N=34 | SPT | 24 |
| | HQ | 25 |
| 7<br>11<br>12<br>N=23 | SPT | |
| | HQ | 26 |
| 6<br>8<br>9<br>N=17 | SPT | 27 |
| | HQ | |
| | HQ | 28 |
| 15<br>41<br>9 for 30mm<br>N>50 | SPT | |
| | HQ | 29 |
| | | 30 |

CORE BOX RL (m): 4, 3, Box 8, 2, 1, 0, -1, Box 9, -2, -3, -4, Box 10, -5

## ROCK DEFECTS

SIGNIFICANT JOINTS, BEDDING, CRUSHED AND SHEARED ZONES/SEAMS

DEFECT TYPE, SHAPE, ROUGHNESS, APERTURE, INFILLING, SPACING

ANGLES ARE NORMAL TO CORE AXIS

11.2m: Joint 30°, planar, rough, tight, some green coating, no clay.

11.25m: Between 11.25-11.6m: heavily fractured, broken up, angular fragments with dark green coatings on joint faces, some clay infill, fractures gaped to open.

11.6m: Increasing clay infill - less green staining.

16.5-17m: "Slipped" sample, no recovery.

imz

Log Scale 1:50

# TONKIN & TAYLOR LTD

# DRILL HOLE LOG

BOREHOLE No: CI-29
Hole Location: Selcourt Rd

SHEET 4 OF 6

PROJECT: Central Interceptor
LOCATION: Mt Albert
JOB No: 26145.206

CO-ORDINATES 6479015 mN
2664160 mE
DIRECTION: -90.00 °
ANGLE FROM HORIZ.: °

DRILL TYPE: PQ/HQ Wireline
DATUM: LINZ
R.L. GROUND: 24.68 m
R.L. COLLAR: 24.68 m

HOLE STARTED: 23/11/10
HOLE FINISHED: 26/11/10
DRILLED BY: Boart Longyear (Craig)
LOGGED BY: SRS
CHECKED:

## DESCRIPTION OF CORE

GEOLOGICAL UNIT

ROCK OR SOIL TYPE, WEATHERING, HARDNESS, STRENGTH, COLOUR, LITHOLOGICAL FEATURES (bedding, cement, foliation, mineralogy, texture, etc...);

ROCK WEATHERING (UW SW MW HW) | ROCK STRENGTH (R4 R3 R2 R1 R0) | PT LOAD / UCS TEST (MPa) | CORE LOSS / LIFT (%) (3 10 30 100) | METHOD, CORE & CASING | TEST SYMBOL | DEPTH (m) | GRAPHIC LOG

**PF**

28.2m: Silty SAND, dark greyish green, stiff to very stiff, low plasticity

28.7m: Coarse to medium SAND, greyish green, moist, low plasticity

28.9m: Becoming coarse to medium SAND, dark grey, moist

SW, sandy SILT, dark greenish grey, stiff to very stiff, moist, extremely weak, low plasticity, returns intact

29.5m: Becoming very weak (strength increasing)

29.8m: Becoming weak (strength increasing)

**WAITEMATA GROUP**

30m: Dark grey SANDSTONE

30.5m: Dark grey SANDSTONE, extremely weak

31m: Dark grey SANDSTONE, weak, returns intact, only fracturing is drilling induced

32m: Dark grey, medium to coarse SANDSTONE, weak, returns intact, grain size increasing with depth

33m: Dark grey, SANDSTONE, weak, wet, silty near 33-33.2m, returns intact

34.5m: Becoming finer

35.5m: Light grey SANDSTONE, weak, returns intact, homogeneous material

36.0 Dark grey SANDSTONE, some clay/silt infill, weak

36.3 Coarse SAND, dark grey, very weak, weakly cemented

36.5m: Light grey, coarse SANDSTONE, weak to moderately strong, well cemented,

36.8m: Dark grey, silty SAND, extremely weak, moist to wet (weak layer?), weakly to poorly cemented

36.9m: Becoming weaker (very weak)

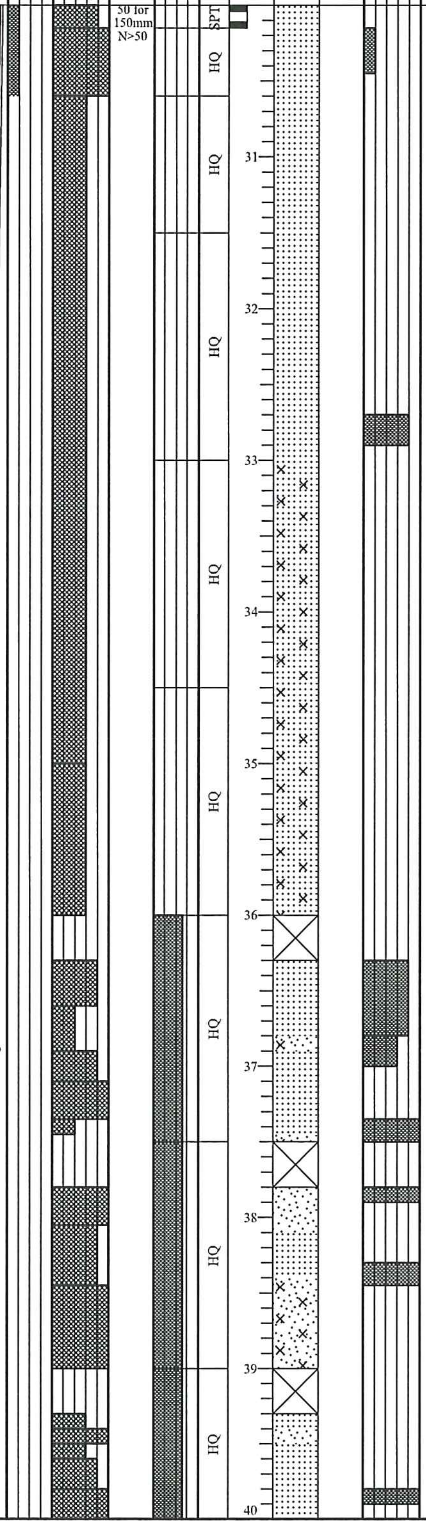
37.2m: Light grey SANDSTONE, weak to moderately strong, well cemented

Silty, medium to fine SAND, dark grey, moist, extremely weak, weakly cemented

37.8m: SAND, dark grey, moist, low to moderate plasticity, extremely weak, weakly cemented

38.1m: Dark grey SANDSTONE, very weak, well cemented

38.4m: Silty SAND, dark grey, moist, low to moderate plasticity, extremely weak, poorly cemented, some well cemented sandstone fragments within poorly cemented matrix of fine to medium sands



## ROCK DEFECTS

DEFECT LOG

FRACTURE LOG spacing of natural fractures (cm) (50 10 5 1)

SIGNIFICANT JOINTS, BEDDING, CRUSHED AND SHEARED ZONES/SEAMS

DEFECT TYPE, SHAPE, ROUGHNESS, APERTURE, INFILLING, SPACING

ANGLES ARE NORMAL TO CORE AXIS

Fractures at 30.2m and 30.4m too weak and crumbly to measure.

32.8m: Fracture 60°, curved, rough, open.
32.8m: Fracture 35°, curved, rough, open.

33.7m: Fracture 55°, curved, rough, open.

36.45m: Joint 40°, slightly curved, rough, gapped.
36.55m: Disking (~5 disking fracture), open.
36.6m: Joint 5°, slightly curved, rough, open.
36.8m: Multiple fractures in weak layer of sands.

37.5m: Disking, Multiple fractures in weak layer of sand.
37.8m: Disking.

38.4m: Disking.

39.4m: Disking, Multiple fractures in weak sand.
39.5m: Joint 50°, slightly curved, rough, open.
39.6m: Disking

DATE / DEPTH: 25/11/2010

RQD (%): 100, 100, 100, 100, 43, 27, 20

WATER

DRILL WATER LOSS (%) (25 50 75)

CORE BOX: Box 11, Box 12, Box 13

RL (m): -6, -7, -8, -9, -10, -11, -12, -13, -14, -15

jmz

Log Scale 1:50

ROCKLG 26145.206ASRS.GPJ 9/3/11

# TONKIN & TAYLOR LTD

# DRILL HOLE LOG

BOREHOLE No: CI-29
Hole Location: Selcourt Rd

SHEET 5 OF 6

| | | |
|---|---|---|
| PROJECT: Central Interceptor | LOCATION: Mt Albert | JOB No: 26145.206 |
| CO-ORDINATES 6479015 mN<br>2664160 mE | DRILL TYPE: PQ/HQ Wireline | HOLE STARTED: 23/11/10 |
| | DATUM: LINZ | HOLE FINISHED: 26/11/10 |
| DIRECTION: -90.00 ° | R.L. GROUND: 24.68 m | DRILLED BY: Boart Longyear (Craig) |
| ANGLE FROM HORIZ.: ° | R.L. COLLAR: 24.68 m | LOGGED BY: SRS CHECKED: |

## DESCRIPTION OF CORE

GEOLOGICAL UNIT: WAITEMATA GROUP

ROCK OR SOIL TYPE, WEATHERING, HARDNESS, STRENGTH, COLOUR, LITHOLOGICAL FEATURES (bedding, cement, foliation, mineralogy, texture, etc...);

39m: Light grey SANDSTONE, very weak, well cemented

39.3m: Light grey SANDSTONE, weak, well cemented

39.4m: fine to medium SAND, dark grey, moist, poorly cemented

39.5m: Light grey SANDSTONE, weak, well cemented

39.6m: Dark grey, coarse SANDSTONE, very weak, weakly to well cemented

40.1m: Dark grey, coarse to medium SANDSTONE, extremely weak, poorly cemented, moist to wet, low plasticity

40.4m: Silty, fine to medium SAND, dark grey, low to moderate plasticity, weakly to uncemented

40.8m: Dark grey medium SANDSTONE, very weak to weak

41.1m: Weak SAND layer, poorly cemented

41.4m: Dark grey SANDSTONE, very weak

Multiple disking fractures in cone (does not return intact between 40.8-42.0m)

Dark grey, coarse to medium SANDSTONE, some dark green clasts, very weak

42.5m: Grey, medium to coarse SANDSTONE, weak to moderately strong, well cemented

42.8m: Medium to fine SANDSTONE, very weak, weakly cemented

43.1m: Silty SAND infill into fractures

43.6m: Silty SAND, dark grey, extremely weak, poorly cemented

43.75m: Dark grey, sandy SILTSTONE, very weak to weak, well cemented, returns fairly intact

43.85m: Dark grey SANDSTONE, very weak

44.5m: Dark brownish grey, sandy SILTSTONE, very weak to weak, contains some organic material (dark brown staining), well cemented

44.8m: Dark brownish grey SANDSTONE, very weak, well to weakly cemented

45m: Dark grey, medium to fine SANDSTONE, weak to very weak, well cemented, no fabric

45.15m: Dark grey SILTSTONE, weak, well cemented, no apparent bedding contacts (slightly sandy Siltstone)

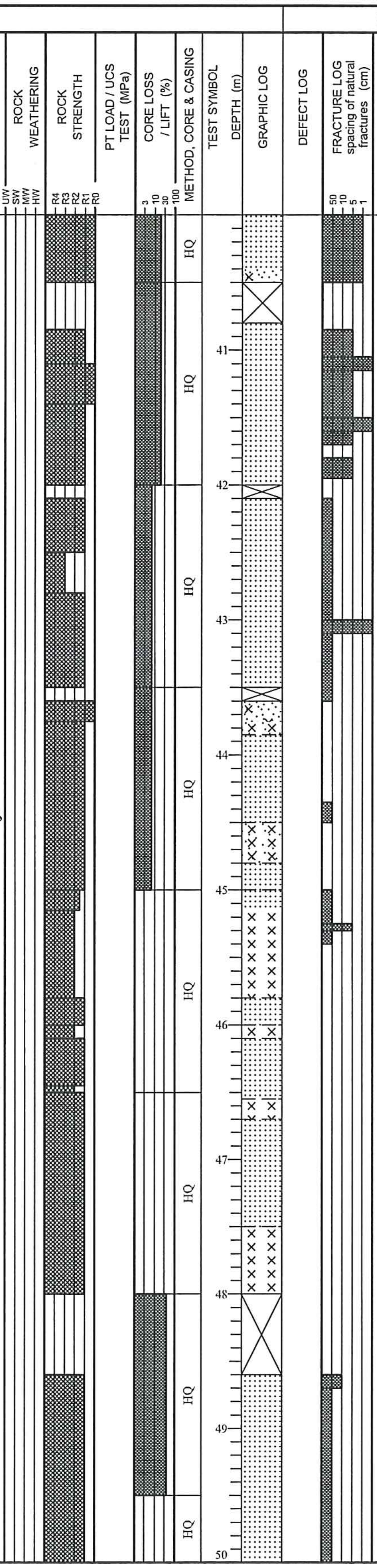
45.8m: Dark grey SANDSTONE, very weak, well to moderately cemented

46m: Dark grey SILTSTONE, weak, well cemented

46.1m: Dark grey SANDSTONE, very weak

46.4m: Dark grey SANDSTONE, weak, well cemented

46.55m: Dark grey SILTSTONE, weak to very weak, well cemented



## ROCK DEFECTS

SIGNIFICANT JOINTS, BEDDING, CRUSHED AND SHEARED ZONES/SEAMS

DEFECT TYPE, SHAPE, ROUGHNESS, APERTURE, INFILLING, SPACING

ANGLES ARE NORMAL TO CORE AXIS

39.8m: Crush zone.
Disking, Multiple fractures through 40 to 40.5m

40.9m: Disking.

41.4m: Disking.

41.6m: Disking.

41.8m: Disking.

42.2m: Joint 5°, curved, rough, open.

42.6m: Joint 10°, irregular, rough, gapped.

43.1m: Multiple fractures, infilled with silty sands, moderate plasticity, soft (fine).

43.6m: Multiple fractures.

43.75m: Siltstone and Sandstone bedding gradual.

44.35m: Joint 10°, slightly curved, rough, gapped.

44.45m: Joint 10°, curved, rough, gapped.

44.5m: Siltstone and sandstone bedding gradual.

44.8m: Siltstone and sandstone bedding gradual.

45.1m: Joint 10°, slightly curved, rough, clay gouge.

45.15m: Sandstone to siltstone.

45.25m: Joint 50°, slightly curved, rough, gapped, some silt infill.

45.3m: Joint 50°, curved, rough, gapped, slightly crushed fracture surface.

45.9m: Joint 5°, curved, rough, open.

46m: Sandstone to siltstone bedding contact gradual.

46.1m: Sandstone to siltstone bedding contact gradual.

46.6m: Bedding contact 10°, curved, rough, open, fractured contact.

46.7m: Siltstone to sandstone bedding gradual.

48.6-48.75m: Disking.

49m: Joint 2°, irregular, smooth, 20mm crushed sandstone infill.

49.3m: Joint 15°, irregular, smooth, 10mm crushed siltstone infill.

49.65m: Joint 15°, irregular, smooth.

49.9m: Joint 15°, irregular, smooth, gravels

DATE / DEPTH: 26/11/2010

RQD (%): 20, 13, 80, 87, 100, 100, 43

WATER

DRILL WATER LOSS (%): 25 50 75

CORE BOX: Box 14, Box 15, Box 16, Box 17

RL (m): -16, -17, -18, -19, -20, -21, -22, -23, -24, -25

jmz

Log Scale 1:50

# TONKIN & TAYLOR LTD

# DRILL HOLE LOG

BOREHOLE No: CI-29
Hole Location: Selcourt Rd

SHEET 6 OF 6

PROJECT: Central Interceptor
LOCATION: Mt Albert
JOB No: 26145.206

CO-ORDINATES 6479015 mN
2664160 mE
DRILL TYPE: PQ/HQ Wireline
HOLE STARTED: 23/11/10
DATUM: LINZ
HOLE FINISHED: 26/11/10
DIRECTION: -90.00 °
R.L. GROUND: 24.68 m
DRILLED BY: Boart Longyear (Craig)
ANGLE FROM HORIZ.: °
R.L. COLLAR: 24.68 m
LOGGED BY: SRS
CHECKED:

| DESCRIPTION OF CORE | | | | | | | | | | ROCK DEFECTS | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| GEOLOGICAL UNIT | ROCK OR SOIL TYPE, WEATHERING, HARDNESS, STRENGTH, COLOUR, LITHOLOGICAL FEATURES (bedding, cement, foliation, mineralogy, texture, etc...); | ROCK WEATHERING<br>UW SW MW HW | ROCK STRENGTH<br>R4 R3 R2 R1 R0 | PT LOAD / UCS TEST (MPa) | CORE LOSS / LIFT (%)<br>3 10 30 100 | METHOD, CORE & CASING | TEST SYMBOL | DEPTH (m) | GRAPHIC LOG | DEFECT LOG | FRACTURE LOG spacing of natural fractures (cm)<br>50 10 5 1 | SIGNIFICANT JOINTS, BEDDING, CRUSHED AND SHEARED ZONES/SEAMS<br>DEFECT TYPE, SHAPE, ROUGHNESS, APERTURE, INFILLING, SPACING<br>ANGLES ARE NORMAL TO CORE AXIS | DATE / DEPTH | RQD (%) | WATER | DRILL WATER LOSS (%)<br>25 50 75 | CORE BOX | RL (m) |
| | 46.7m: Dark grey SANDSTONE, very weak, well cemented, returns intact, some organic matter<br>47.5m: Dark grey SILTSTONE, very weak, well cemented, returns intact, some organic matter<br>48.6m: Grey, medium SANDSTONE, very weak, well cemented<br>**END OF BOREHOLE AT 50m.**<br>Piezometer depths at 6m, 20m, 40m. | | | | | | | 51<br>52<br>53<br>54<br>55<br>56<br>57<br>58<br>59 | | | | above, medium to coarse with clay. | | | | | | -26<br>-27<br>-28<br>-29<br>-30<br>-31<br>-32<br>-33<br>-34<br>-35 |

imz

# TONKIN & TAYLOR LTD

# DRILL HOLE LOG

BOREHOLE No: CI-12
Hole Location: Whitney Street

SHEET 1 OF 7

| | | |
|---|---|---|
| PROJECT: Central Interceptor | LOCATION: Auckland | JOB No: 26145.202 |
| CO-ORDINATES 2662605 mN<br>6475277 mE | DRILL TYPE: HQ | HOLE STARTED: 1/3/10 |
| | DATUM: | HOLE FINISHED: 3/3/10 |
| DIRECTION: ° | R.L. GROUND: 25.50 m | DRILLED BY: Boart Longyear Ltd |
| ANGLE FROM HORIZ.: -90.00 ° | R.L. COLLAR: 25.50 m | LOGGED BY: R Gulley/A O'Cleary CHECKED: KGH |

## DESCRIPTION OF CORE

GEOLOGICAL UNIT

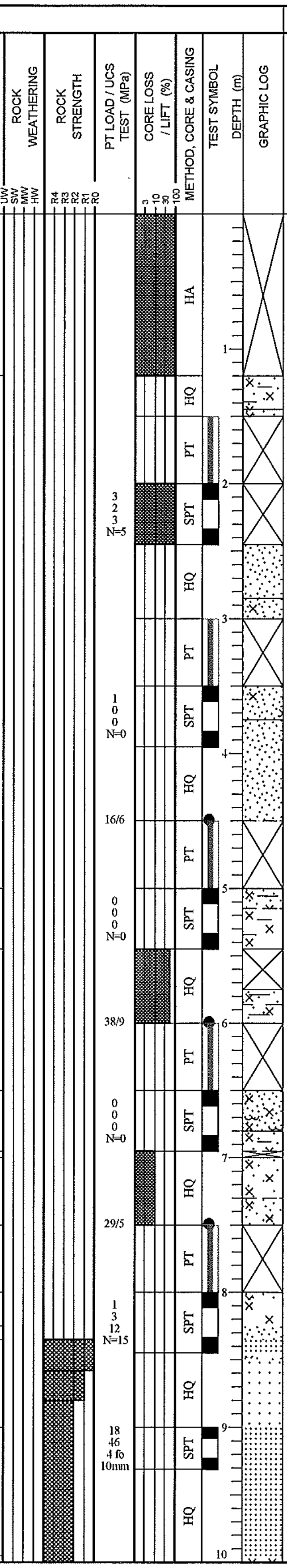
ROCK OR SOIL TYPE, WEATHERING, HARDNESS, STRENGTH, COLOUR, LITHOLOGICAL FEATURES (bedding, cement, foliation, mineralogy, texture, etc...);

**PUKETOKA FORMATION**

- GRAVELS, medium to large, dark grey overlying brown SILT some clay
- Clayey SILT, minor fine sand, grey browny-grey and orange mottle, traces of rootlets
- SILT, sandy, black topsoil?
- Push tube no recovery
- SAND, light grey, minor fine to medium black sand, very soft, wet, loosely packed.
- -some roots, firm
- SAND, brown, some silt, minor petrified wood, stiff, wet
- -silty, firm
- SAND, light grey, stiff
- - traces fine black sand
- 4.45m: firm
- SILT, sandy, light brown, some clay, minor petrified organics, black, stiff, moist
- SILT, clayey, some sand, light brown, minor petrified organics black, very stiff, moisy, moderately plastic
- CLAY, silty, brown,minor sand, fine grain, white, trace petrified wood, stiff, moist
- CLAY, silty, dark grey-brown, minor fine sand, firm, moist
- Organic, silty SAND, black, soft, wet, moderate plasticity, some wood fragments
- 6.6m: some grey sand, rootlets, stiff
- Clayey SILT, minor black fine to medium sand, grey, firm, wet
- SILT, minor white fine to medium sand, brown, soft, moist
- SILT, some sand, green-light grey, marine sediments

**ECBF**

- Sandy SILT, light brown, soft, wet
- SILT, some sand, dark green
- SAND, light brown, some black staining
- Grey, fine SANDSTONE, extremely weak
- SILT, green
- SANDSTONE, grey, well cemented. fine grained, some white grains, trace red grains
- 9m: Grey SANDSTONE, some silt, some white fines, trace of medium white fines



## ROCK DEFECTS

DEFECT LOG

FRACTURE LOG spacing of natural fractures (cm) 50 10 5 1

SIGNIFICANT JOINTS, BEDDING, CRUSHED AND SHEARED ZONES/SEAMS

DEFECT TYPE, SHAPE, ROUGHNESS, APERTURE, INFILLING, SPACING

ANGLES ARE NORMAL TO CORE AXIS

9.87m: Joint 84°, slightly curved, rough, tight.

DATE / DEPTH: 26/02/2010

RQD (%): 100

WATER: 3/3/2010

DRILL WATER LOSS (%) 25 50 75

CORE BOX: Box 1, Box 2

RL (m): 25, 24, 23, 22, 21, 20, 19, 18, 17, 16

Log Scale 1:50

ROCKLG 26145.202.GPJ 15/7/10

# TONKIN & TAYLOR LTD

# DRILL HOLE LOG

**BOREHOLE No: CI-12**
Hole Location: Whitney Street

SHEET 2 OF 7

PROJECT: Central Interceptor
LOCATION: Auckland
JOB No: 26145.202

CO-ORDINATES 2662605 mN
6475277 mE
DRILL TYPE: HQ
HOLE STARTED: 1/3/10
DATUM:
HOLE FINISHED: 3/3/10
DIRECTION: °
R.L. GROUND: 25.50 m
DRILLED BY: Boart Longyear Ltd
ANGLE FROM HORIZ.: -90.00 °
R.L. COLLAR: 25.50 m
LOGGED BY: R Gulley/A Cleary CHECKED:

## DESCRIPTION OF CORE

GEOLOGICAL UNIT: EAST COAST BAYS FORMATION

ROCK OR SOIL TYPE, WEATHERING, HARDNESS, STRENGTH, COLOUR, LITHOLOGICAL FEATURES (bedding, cement, foliation, mineralogy, texture, etc...);

Very thinly interbedded SILTSTONE, very weak, grey with SAND and large sand size grains of black carbon, extremly weak

SANDSTONE, very weak, well cemented, grey, fine to medium grain

SILTSTONE, browny grey

SANDSTONE, grey, fine to medium
11.01-11.15 SILTSTONE, browny-grey

Moderatly thin-moderatly thinkly Interbedded SILTSTONE, browny-grey and SANDSTONE, grey fine to medium grain

Fine SANDSTONE, dark grey

12.96m: medium to fine grained, moderately cemented

SILTSTONE, grey

SANDSTONE, grey, fine to medium
13.32mm: 1mm carbonate white

SILTSTONE, grey

SANDSTONE, extremely weak, poorly cemented, easily broken along sub-horizontal bedding

Interbedded SILTSTONE, grey weak, with very weak grey SANDSTONE, thin

14.41-.43m:Silty CLAY, soft

SANDSTONE, grey, fine to medium, well cemented
15m: Some medium white sand

15.2-.24m: SILTSTONE, browny grey -moderately cemented
SANDSTONE, grey thick bed 1-3mm, very poorly cemented along them cause fractures along entire length

SILTSTONE, browny-grey

SANDSTONE, grey and white fine to medium grains, with few yellow grains
16.87m: Fine to medium SANDSTONE, white and black

SILTSTONE, weak

Grey, coarse SANDSTONE, some white and green coarse sands-fine gravels, grey
17.37m: fine to medium grained
17.42m: trace fine, green gravel and large white sand

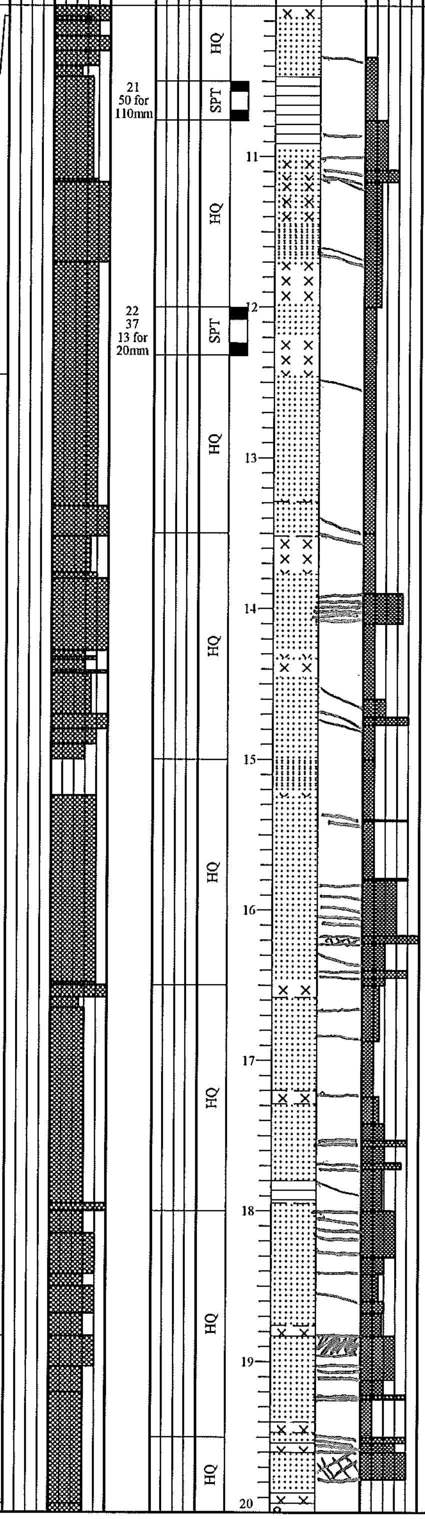
SILTSTONE, browny grey

SANDSTONE, fine to medium, grey
18m: Grey, fine to medium
SANDSTONE, weak, some medium whitish grey grains, moderately cemented
18.5m: 1.5mm wide bed SILTSTONE, 40°, carbon staining 0.01mm thick

SILTSTONE, browny grey

SANDSTONE, grey, fine to medium, moderatly cemented, heavily fractured
19.2: SILTSTONE, grey, 10mm

ROCK WEATHERING (UW, SW, MW, HW) | ROCK STRENGTH (R4, R3, R2, R1, R0) | PT LOAD / UCS TEST (MPa) | CORE LOSS / LIFT (%) (3, 10, 30, 100) | METHOD, CORE & CASING | TEST SYMBOL | DEPTH (m) | GRAPHIC LOG | DEFECT LOG | FRACTURE LOG spacing of natural fractures (cm) (50, 10, 5, 1)



## ROCK DEFECTS

SIGNIFICANT JOINTS, BEDDING, CRUSHED AND SHEARED ZONES/SEAMS

DEFECT TYPE, SHAPE, ROUGHNESS, APERTURE, INFILLING, SPACING

ANGLES ARE NORMAL TO CORE AXIS

clean.

10.34m: Joint 65°, slightly curved, smooth, tight, clean.

10.88m: Joint 72°, planar, smooth, open, 3mm broken debris.
10.93m: Joint 68°, planar, smooth, tight, clean.
11m: Joint 78°, slightly curved, rough, tight, clean.
11.09m: Joint 70°, irregular, rough, tight, clean.
11.12m: Joint 78°, curved, rough, open, 2mm silty CLAY infill.
11.17m: Joint 70°, planar, rough, 1mm CLAY infill.
11.75m: 2x Joints 62°, slightly curved, rough, tight, clean.
12.52m: Joint 70°, planar, smooth, tight, clean.
12.88m: carbon, 0.5mm.

13.43m: Joint 30°, slightly curved, smooth, tight, clean.
13.55m: Joint 70°, planar, rough, open, 3mm fine GRAVEL-large SAND in silty matrix.
13.9-14.1m: 9 x Joint 85°, irregular, rough.

14.6m: Joint 60°, planar, rough, gravels above open.
14.72 7.77m: 2 x Joint 66°, irregular, rough, medium GRAVEL-large SAND infill.

15.4m: 2 x Joint 88°, irregular, rough, tight, clean at 10mm spacing

15.79m: 2 x Joint 88°, irregular, rough, tight, clean at 10mm spacing
15.8-16.17m: 5x Joints 80°, irregular, rough.
16.17-16.22m: Heavily fractured, Joint 85°, irregular, rough, fine GRAVEL.
16.33m: Joint 65°, planar, rough, tight, silty CLAY infill.
16.4-16.45m: 3x Joints 85°, irregular, rough, tight, silty CLAY.
16.68m: Joint 88°, irregular, rough, tight, clean.
16.87m: Joint 90°, planar, smooth, SILT infill washed out.
17.24m: Joint 82°, irregular, rough.
17.42m: Joint 88°, slightly curved, rough, tight, clean.
17.53-17.57m: 3x Joints, planar, rough.
17.68-17.72m: 2x Joints 85°, irregular, rough, tight, clean.
17.85m: Joint 54°, planar, smooth, tight, clean.
18.08-.31m: 5x Joints 82°, planar, rough, open, 2mm at 50mm spacing
18.42m: 1mm silty CLAY infill.
18.6m: Joint 82°, irregular, rough, open, 4mm silty CLAY infill.
18.68m: Joint 72°, irregular, rough, tight, clean.
18.83-18.97m: Joint 82°, planar, rough, open 2mm.
19.03, .06 &.12m: 3x Joint 82°, planar, rough,

| DATE / DEPTH | RQD (%) | WATER | DRILL WATER LOSS (%) | CORE BOX | RL (m) |
|---|---|---|---|---|---|
| | 100 | | | | 15 |
| | 49 | | | Box 3 | 14 |
| | 100 | | | | 13 |
| | 71 | | | Box 4 | 12 |
| | | | | | 11 |
| | 59 | | | | 10 |
| | 95 | | | Box 5 | 9 |
| | | | | | 8 |
| | 39 | | | | 7 |
| | 81 | | | Box 6 | 6 |

# TONKIN & TAYLOR LTD

# DRILL HOLE LOG

BOREHOLE No: CI-12
Hole Location: Whitney Street

SHEET 3 OF 7

PROJECT: Central Interceptor
LOCATION: Auckland
JOB No: 26145.202

CO-ORDINATES 2662605 mN
6475277 mE
DRILL TYPE: HQ
DATUM:
HOLE STARTED: 1/3/10
HOLE FINISHED: 3/3/10
DIRECTION: °
R.L. GROUND: 25.50 m
DRILLED BY: Boart Longyear Ltd
ANGLE FROM HORIZ.: -90.00 °
R.L. COLLAR: 25.50 m
LOGGED BY: R Gulley/A O'Cleary CHECKED:

## DESCRIPTION OF CORE

GEOLOGICAL UNIT: EAST COAST BAYS FORMATION

ROCK OR SOIL TYPE, WEATHERING, HARDNESS, STRENGTH, COLOUR, LITHOLOGICAL FEATURES (bedding, cement, foliation, mineralogy, texture, etc...);

Interbedded SILTSTONE weak, grey with fine to medium SANDSTONE, grey, weak, moderately thin

Fine GRAVEL, R2, in silt matrix

Interbedded SAND (2-5mm), fine to medium and SILT (1mm) layers, grey

Green grey, medium SANDSTONE, extremely weak, moderately cemented, some fine greenish grey grains

SILTSTONE, with 4 x1-2mm clayey SILT, very stiff seams, evenly spaced

Grey SANDSTONE, very weak, 2-5mm layers with very thin silty seams

SANDSTONE, fine grain, grey, few white medium sands, poorly cemented,

GRAVEL, grey, coarse, sandstone, crushed zone?

SANDSTONE, fine to medium, grey, few white medium sands, poorly cemented

GRAVEL, grey, medium to coarse, sandstone, crushed zone?,

SANDSTONE, fine to medium, grey, few white medium sands, moderatley cemented

GRAVEL, grey, R2, sandstone, uncemented along bedding

SILTSTONE, grey

Silty SANDSTONE, grey, fine to medium, well cemented

SILTSTONE, grey

SANDSTONE, grey, fine to medium, moderately cemented

25.09m: trace pocket of carbon

Interbedded SAND, grey, fine to medium (10-20mm) and SILT, grey (1mm) layers

Grey, fine SANDSTONE, highly fractured, thinly bedded

SILTSTONE, grey

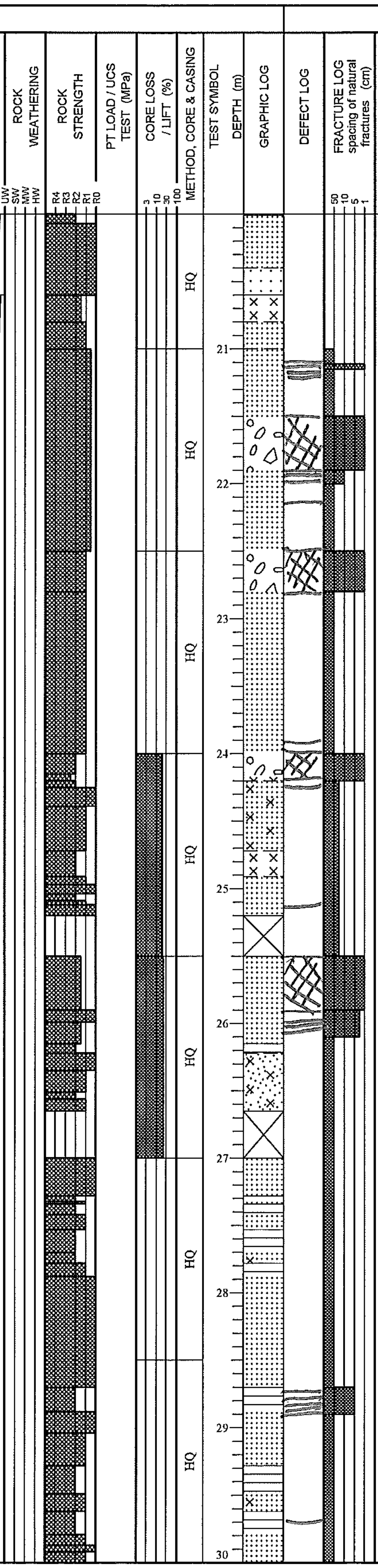
Silty SAND, poorly cemented

Grey, fine SANDSTONE, poorly cemented, trace of medium white grains

Interbedded SILTSONE, grey, weak to very weak with SANDSTONE, grey, fine to medium, very weak to extremly weak, thinly to moderately thinly bedded

Interbedded SAND (5-10mm) and SILT (1mm) layers

Interbedded SILTSONE, grey, weak to very weak with SANDSTONE, grey, fine to medium, very weak to extremly weak, moderately thinly bedded



## ROCK DEFECTS

SIGNIFICANT JOINTS, BEDDING, CRUSHED AND SHEARED ZONES/SEAMS

DEFECT TYPE, SHAPE, ROUGHNESS, APERTURE, INFILLING, SPACING

ANGLES ARE NORMAL TO CORE AXIS

open 2mm.

19.22-19.25m: 3x Joints 80°, irregular, rough, tight

19.52m: 2x Joints 74°, stepped, planar, tight, clean.

19.54m: 2x Joints 74°, stepped, planar, tight, clean.

19.6-19.78m: Joint 70°, planar, smooth, heavily fractured with some medium GRAVELS

21.11-.15m: 5xJoint 78*, planar, rough, tight, clean

21.5-.9m: Completly fractured

21.9m: Joint 80°, irregular, rough, tight, clean.

21.98m: Joint 82°, irregular, rough, tight, clean

22.16m: Joint 82°, irregular, rough, open, 2mm silt infill

22.5-22.8m: 40x Joints, planar 5-10mm thick

23.8m: Joint 72°, Slightly curved, rough, tight, clean

24-24.15m: 2mm thick laminated section.

24.25m: Joint 70°, irregular, stepped, tight, fine to medium GRAVELS.

25.12m: Joint 78°, curved, smooth, tight, SILT infill.

25.5-.9m: Highly fractured medium to large GRAVELS, some 5mm-10mm thick layers.

25.98m: 3x Joints 86°, slightly curved, rough, tight, clean, 50-100mm spacing

28.72-.88m: 5x Joint 85°, curved, smooth, 1mm clayey SILT infill.

29.74m: Joint 82°, irregular, stepped, tight,

| DATE / DEPTH | RQD (%) | WATER | DRILL WATER LOSS (%) 25 50 75 | CORE BOX | RL (m) |
|---|---|---|---|---|---|
| | 81 | | | | 5 |
| | 64 | | | | 4 |
| | | | | Box 7 | 3 |
| | 80 | | | | 2 |
| | 63 | | | | 1 |
| | | | | Box 8 | 0 |
| | 42 | | | | -1 |
| | 100 | | | | -2 |
| | | | | Box 9 | -3 |
| | 89 | | | | -4 |

Log Scale 1:50

# TONKIN & TAYLOR LTD

# DRILL HOLE LOG

BOREHOLE No: CI-12
Hole Location: Whitney Street

SHEET 4 OF 7

PROJECT: Central Interceptor
LOCATION: Auckland
JOB No: 26145.202

CO-ORDINATES 2662605 mN
6475277 mE
DIRECTION: °
ANGLE FROM HORIZ.: -90.00 °

DRILL TYPE: HQ
DATUM:
R.L. GROUND: 25.50 m
R.L. COLLAR: 25.50 m

HOLE STARTED: 1/3/10
HOLE FINISHED: 3/3/10
DRILLED BY: Boart Longyear Ltd
LOGGED BY: R Gulley/A O'Cleary CHECKED:

## DESCRIPTION OF CORE

GEOLOGICAL UNIT: EAST COAST BAYS FORMATION

ROCK OR SOIL TYPE, WEATHERING, HARDNESS, STRENGTH, COLOUR, LITHOLOGICAL FEATURES (bedding, cement, foliation, mineralogy, texture, etc...);

29.79m: 5-15mm SILT vein, carbon staining

From 31.4-31.47m: UW, dark grey, thinly laminated to laminated SILTSTONE, weak, bedding is sub-horizontal to steeply inclined, joints widely spaced, bioturbation throughout bed

From 31.47-31.55m: UW, dark grey, massive SANDSTONE, very weak

UW, dark grey, thinly laminated to laminated SILTSTONE, weak, bedding is sub-horizontal to steeply inclined, joints widely spaced, bioturbation throughout bed

UW, dark grey, massive SANDSTONE, very weak

UW, dark grey, thinly laminated to laminated SILTSTONE, weak, bedding is sub-horizontal to steeply inclined, joints widely spaced, bioturbation throughout bed

UW, dark grey, massive SANDSTONE, very weak

UW, dark grey, thinly laminated to laminated SILTSTONE, weak, bedding is sub-horizontal to steeply inclined, joints widely spaced, bioturbation throughout bed

UW, dark grey, massive SANDSTONE, very weak

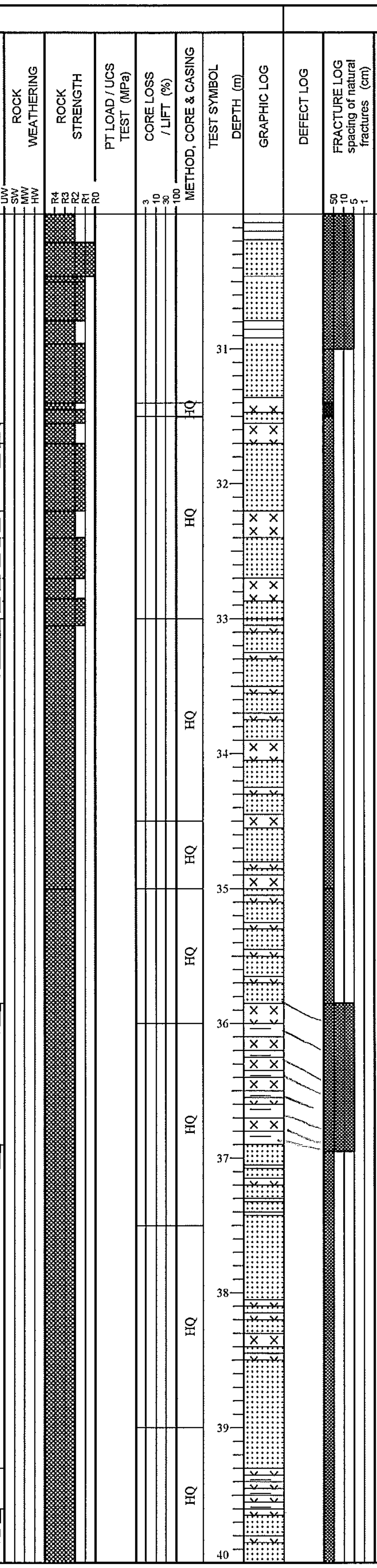
UW, dark grey SANDSTONE, weak to very weak, interbedded with laminated SILTSTONE, weak. Bedding dipping 15-20°. Rare thinly laminated clay seam, possibly drilling induced due to core spinning on itself or in-situ

UW, dark grey, laminated SILTSTONE, weak, interbedded with thinly laminated, dark grey CLAY, moist, high plasticity; SILTSTONE is moderately thin, beds are closely spaced, disseminated organics throughout unit, bedding ~10-15°, joints breaking along beddi

UW, dark grey, faintly bedded, fine to medium SANDSTONE, very weak, interbedded with UW, dark grey, laminated SILTSTONE, weak, joints widely spaced
- from 37.5m moderately thick SANDSTONE beds, very weak, moderately thin SILTSTONE beds

38.5m: UW, dark grey SANDSTONE, very weak. Joints widely spaced.

Grades to UW, dark grey, laminated SILTSTONE, weak, interbedded with thinly laminated, dark grey CLAY, moist, high plasticity; SILTSTONE is moderately



## ROCK DEFECTS

SIGNIFICANT JOINTS, BEDDING, CRUSHED AND SHEARED ZONES/SEAMS

DEFECT TYPE, SHAPE, ROUGHNESS, APERTURE, INFILLING, SPACING

ANGLES ARE NORMAL TO CORE AXIS

clean.
30.15m: Joint 72°, planar, smooth, 1mm fine GRAVEL in silt matrix infill.
30.21m: Joint 88°, stepped, planar, tight, clean.
30.46m: Joint 72°, slightly curved, planar, tight, clean.
30.56m: Joint 70°, planar, smooth, tight, clean.
30.66-.92m: 5 x Joint 82°, curved, smooth, with CLAY infill.

Joint set 5-10°, open, clean, moderately widely spaced, breaks along bedding planes.

Joints breaking along bedding.

| DATE / DEPTH | RQD (%) | WATER | DRILL WATER LOSS (%) | CORE BOX | RL (m) |
|---|---|---|---|---|---|
| 1/03/2010 | 72 | | | Box 10 | -5 |
| | 80 | | | | -6 |
| | 83 | | | Box 11 | -7 |
| | 57 | | | | -8 |
| | 57 | | | Box 12 | -9 |
| | 65 | | | Box 13 | -10 |
| | 47 | | | | -11 |
| | 67 | | | | -12 |
| | | | | | -13 |
| | | | | | -14 |

Log Scale 1:50

ROCKLG 26145.202.GPJ 15/7/10

# TONKIN & TAYLOR LTD

# DRILL HOLE LOG

BOREHOLE No: CI-12
Hole Location: Whitney Street

SHEET 5 OF 7

| | | |
|---|---|---|
| PROJECT: Central Interceptor | LOCATION: Auckland | JOB No: 26145.202 |
| CO-ORDINATES 2662605 mN<br>6475277 mE | DRILL TYPE: HQ | HOLE STARTED: 1/3/10 |
| | DATUM: | HOLE FINISHED: 3/3/10 |
| DIRECTION: ° | R.L. GROUND: 25.50 m | DRILLED BY: Boart Longyear Ltd |
| ANGLE FROM HORIZ.: -90.00 ° | R.L. COLLAR: 25.50 m | LOGGED BY: R Gulley/A O'Leary CHECKED: |

## DESCRIPTION OF CORE

GEOLOGICAL UNIT

ROCK OR SOIL TYPE, WEATHERING, HARDNESS, STRENGTH, COLOUR, LITHOLOGICAL FEATURES (bedding, cement, foliation, mineralogy, texture, etc...);

ROCK WEATHERING: UW SW MW HW

ROCK STRENGTH: R4 R3 R2 R1 R0

PT LOAD / UCS TEST (MPa)

CORE LOSS / LIFT (%): 3 10 30 100

METHOD, CORE & CASING

TEST SYMBOL

DEPTH (m)

GRAPHIC LOG

## ROCK DEFECTS

DEFECT LOG

FRACTURE LOG spacing of natural fractures (cm): 50 10 5 1

SIGNIFICANT JOINTS, BEDDING, CRUSHED AND SHEARED ZONES/SEAMS

DEFECT TYPE, SHAPE, ROUGHNESS, APERTURE, INFILLING, SPACING

ANGLES ARE NORMAL TO CORE AXIS

DATE / DEPTH

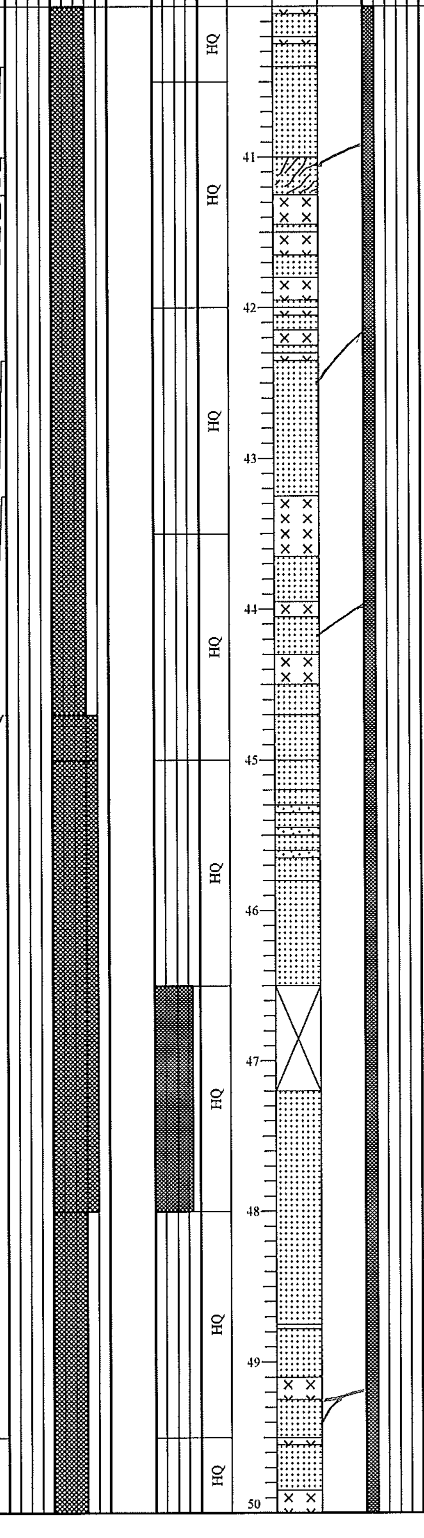
RQD (%)

WATER

DRILL WATER LOSS (%): 25 50 75

CORE BOX

RL (m)



EAST COAST BAYS FORMATION

thin, beds are closely spaced, disseminated organics throughout unit, bedding ~10-15°, joints breaking a

UW, dark grey, faintly bedded, fine to medium SANDSTONE, very weak, interbedded with UW, dark grey, laminated SILTSTONE, weak, joints widely spaced

UW, dark grey, fine to medium SANDSTONE, with disseminated organics and some coarse sand, very weak, bedding is sub-horizontal to gently inclined

Disturbed/brecciated fine to coarse SANDSTONE, and SILTSTONE, with minor clay, possible siltstone rip-up clasts and dark green, angular clasts

Moderately thin UW, dark grey, laminated SILTSTONE, weak, with thin beds of dark grey, fine to coarse SANDSTONE and disseminated organics, very weak, joints closely spaced

Disseminated organic layer 2mm thick from 45mm, with occasional organic fragments from 42 to 42.4m

UW, dark grey SANDSTONE, very weak

UW, dark grey, faintly bedded fine to medium SANDSTONE, very weak, interbedded with UW, dark grey, laminated SILTSTONE, weak, joints widely spaced

Grades to UW, dark grey, very thinly bedded SANDSTONE, very weak to weak

From 45.2m SANDSTONE with thinly laminated, clayey, fine SAND beds, extremely closely spaced

From 45.8m: No clayey SAND

48.75-48.78m: UW, dark grey SILTSTONE, weak, dipping 0-5°

49.1-49.25m: UW, dark grey SILTSTONE, weak, dipping 0-5°

Moderately thin, UW, dark grey SILTSTONE, weak, interbedded with moderately thick, UW, dark grey

Joint 25°, undulating, smooth, clean, open.

Joints to 43.2m 70°, planar, smooth, clean, open.

Joint 35°, undulating, rough, open, clean.

Joint 20°, planar, smooth, open, clean.
Joint 70°, stepped, smooth, open, clay infill 2mm.

RQD (%): 67, 85, 77, 93, 97, 100, 93, 93

CORE BOX: Box 14, Box 15, Box 16

RL (m): -15, -16, -17, -18, -19, -20, -21, -22, -23, -24

Log Scale 1:50

# TONKIN & TAYLOR LTD

# DRILL HOLE LOG

BOREHOLE No: CI-12
Hole Location: Whitney Street

SHEET 6 OF 7

PROJECT: Central Interceptor
LOCATION: Auckland
JOB No: 26145.202

CO-ORDINATES 2662605 mN
6475277 mE
DIRECTION: °
ANGLE FROM HORIZ.: -90.00 °

DRILL TYPE: HQ
DATUM:
R.L. GROUND: 25.50 m
R.L. COLLAR: 25.50 m

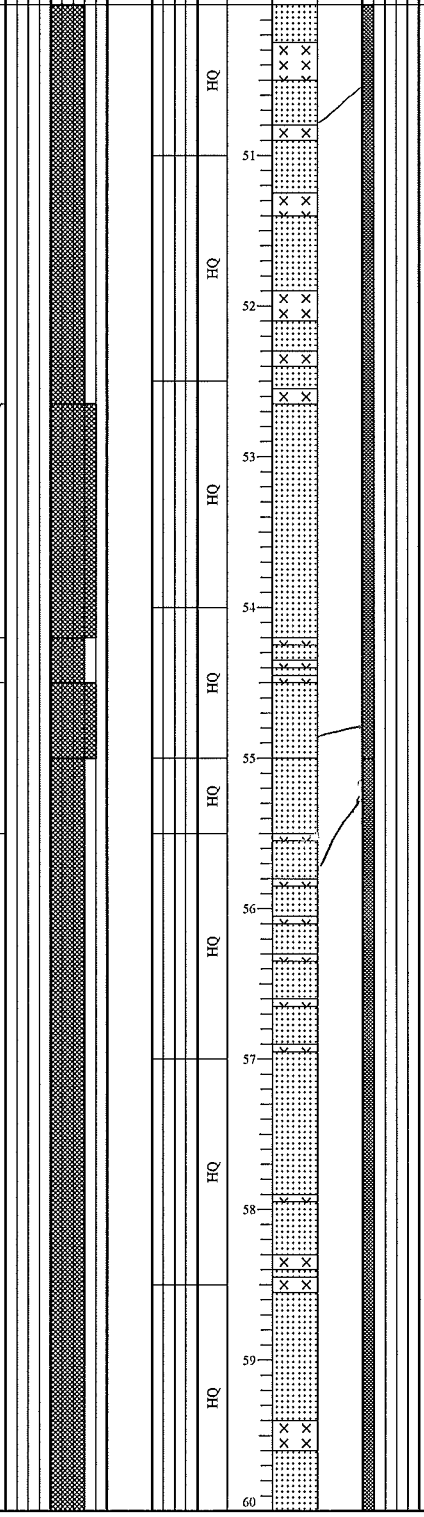
HOLE STARTED: 1/3/10
HOLE FINISHED: 3/3/10
DRILLED BY: Boart Longyear Ltd
LOGGED BY: R Gulley/A O'Leary CHECKED:

## DESCRIPTION OF CORE

GEOLOGICAL UNIT | ROCK OR SOIL TYPE, WEATHERING, HARDNESS, STRENGTH, COLOUR, LITHOLOGICAL FEATURES (bedding, cement, foliation, mineralogy, texture, etc...); | ROCK WEATHERING (UW SW MW HW) | ROCK STRENGTH (R4 R3 R2 R1 R0) | PT LOAD / UCS TEST (MPa) | CORE LOSS / LIFT (%) (3 10 30 100) | METHOD, CORE & CASING | TEST SYMBOL | DEPTH (m) | GRAPHIC LOG

## ROCK DEFECTS

DEFECT LOG | FRACTURE LOG spacing of natural fractures (cm) (50 10 5 1) | SIGNIFICANT JOINTS, BEDDING, CRUSHED AND SHEARED ZONES/SEAMS; DEFECT TYPE, SHAPE, ROUGHNESS, APERTURE, INFILLING, SPACING; ANGLES ARE NORMAL TO CORE AXIS | DATE / DEPTH | RQD (%) | WATER | DRILL WATER LOSS (%) (25 50 75) | CORE BOX RL (m)



GEOLOGICAL UNIT: EAST COAST BAYS FORMATION

SANDSTONE, very weak to weak

Disseminated organic layer dipping 20°, thinly laminated

UW, dark grey, bedded SANDSTONE, very weak, joints widely spaced

53.1 to 53.25m: Brecciated SANDSTONE with siltstone rip-up clasts

- sandstone grades to weak

SILTSTONE interbeds, laminated, weak, dipping 20°

Grades back to UW, dark grey, bedded SANDSTONE, very weak, joints widely spaced, with light greyish brown thinly laminated sandstone beds

Moderately thick UW, dark grey, bedded SANDSTONE, weak, interbedded with moderately thin bedded UW, dark grey, thinly laminated SILTSTONE, weak

From 57.9-57.95m: UW, dark grey, thinly laminated SILTSTONE, weak to moderately strong

From 58.3-58.55m: UW, dark grey, thinly laminated SILTSTONE, weak to moderately strong

59.4-59.6m: UW, dark grey, thinly laminated SILTSTONE, weak to moderately strong

Joint 40°, planar, smooth, open, clean.

Joint 20°, undulating, smooth, clean, open.

Joint 70°, undulating, smooth, open, clean.

DATE / DEPTH: 2/03/2010

RQD (%):
93
93
93
97
97
97
93
97

CORE BOX: Box 17, Box 18, Box 19, Box 20

RL (m): -25, -26, -27, -28, -29, -30, -31, -32, -33, -34

Log Scale 1:50

ROCKLG 26145.202.GPJ 15/7/10

# TONKIN & TAYLOR LTD

# DRILL HOLE LOG

BOREHOLE No: CI-12
Hole Location: Whitney Street

SHEET 7 OF 7

PROJECT: Central Interceptor
LOCATION: Auckland
JOB No: 26145.202

CO-ORDINATES 2662605 mN
6475277 mE
DIRECTION: °
ANGLE FROM HORIZ.: -90.00 °

DRILL TYPE: HQ
DATUM:
R.L. GROUND: 25.50 m
R.L. COLLAR: 25.50 m

HOLE STARTED: 1/3/10
HOLE FINISHED: 3/3/10
DRILLED BY: Boart Longyear Ltd
LOGGED BY: R Gulley/A O'Leary
CHECKED:

## DESCRIPTION OF CORE

GEOLOGICAL UNIT

ROCK OR SOIL TYPE, WEATHERING, HARDNESS, STRENGTH, COLOUR, LITHOLOGICAL FEATURES (bedding, cement, foliation, mineralogy, texture, etc...);

ROCK WEATHERING | ROCK STRENGTH | PT LOAD / UCS TEST (MPa) | CORE LOSS / LIFT (%) | METHOD, CORE & CASING | TEST SYMBOL | DEPTH (m) | GRAPHIC LOG | DEFECT LOG | FRACTURE LOG spacing of natural fractures (cm)

## ROCK DEFECTS

SIGNIFICANT JOINTS, BEDDING, CRUSHED AND SHEARED ZONES/SEAMS

DEFECT TYPE, SHAPE, ROUGHNESS, APERTURE, INFILLING, SPACING

ANGLES ARE NORMAL TO CORE AXIS

DATE / DEPTH | RQD (%) | WATER | DRILL WATER LOSS (%) | CORE BOX | RL (m)

**EAST COAST BAYS FORMATION**

UW, dark grey, massive SANDSTONE, very weak, joints widely to very widely spaced

61.2-61.3m: UW, dark grey, thinly laminated SILTSTONE, weak to moderately strong

62.55-62.9m: Interbedded UW, dark grey, massive SANDSTONE, very weak, joints widely to very widely spaced and UW, dark grey, thinly laminated SILTSTONE, weak to moderately strong, organic flecks at base of unit

Sandy CLAY, dark grey, firm, moist, low plasticity

UW, dark grey, thinly laminated SILTSTONE, weak to moderately strong

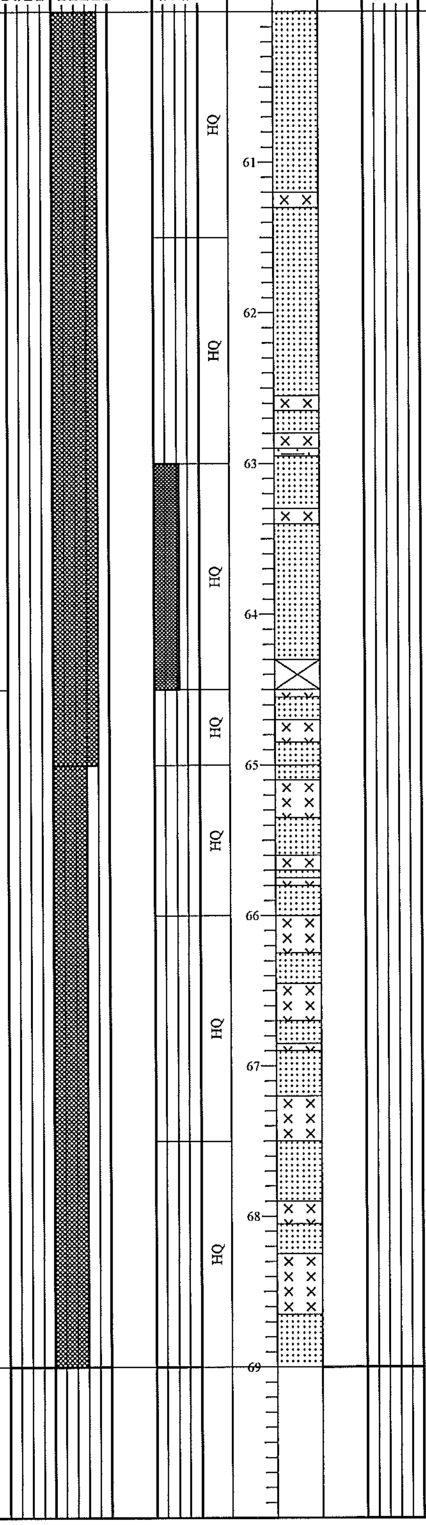
CORE LOSS

Moderately thick UW, dark grey, bedded SANDSTONE, weak, interbedded with moderately thin bedded UW, dark grey, thinly laminated SILTSTONE, weak, beds dipping 10-15°

Interbedded SANDSTONE and SILTSTONE continues, siltstone borders on moderately strong

Bedding dipping ~10-15°

**END OF BOREHOLE AT 69m.**



64.5-66m: 100mm core loss.

Joint 20°, planar, smooth, open, clean.

3/03/2010

| RQD (%) |
|---|
| 100 |
| 97 |
| 77 |
| 93 |
| 93 |
| 97 |
| 97 |

DRILL WATER LOSS (%): 25 50 75

CORE BOX: Box 21, Box 22, Box 23, Box 24

RL (m): -35, -36, -37, -38, -39, -40, -41, -42, -43, -44

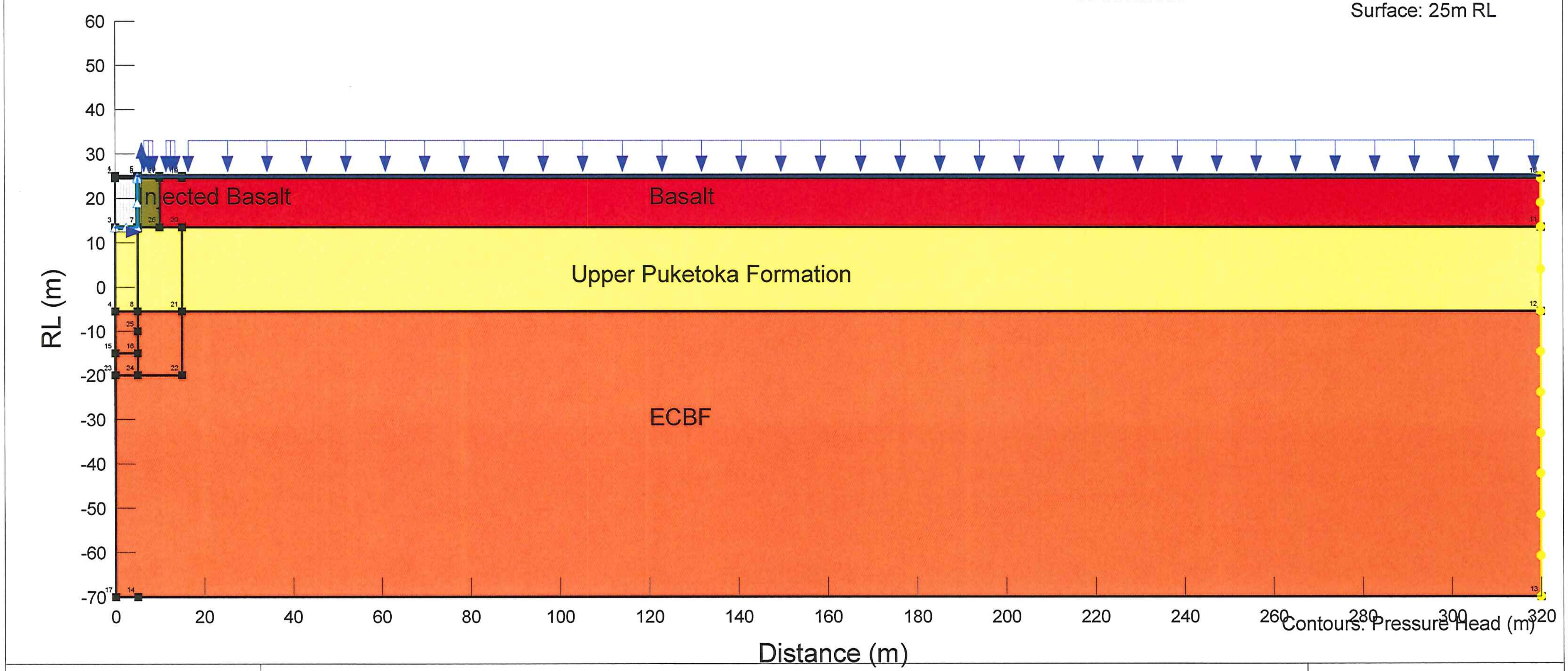
Log Scale 1:50

# Appendix B: Groundwater and settlement modelling - sample outputs

File Name: CI.GWS.AS1 axi.gsz
Type: SEEP/W
Analysis Method: Steady-State
Scale: 1:1250
Analysis View: Axisymmetric
Last Saved: 14/12/2012 12:31:21 p.m.

Surface Influx:
1e-009m/sec

Boundary Condition:
GWL: 23.2m RL
Surface: 25m RL

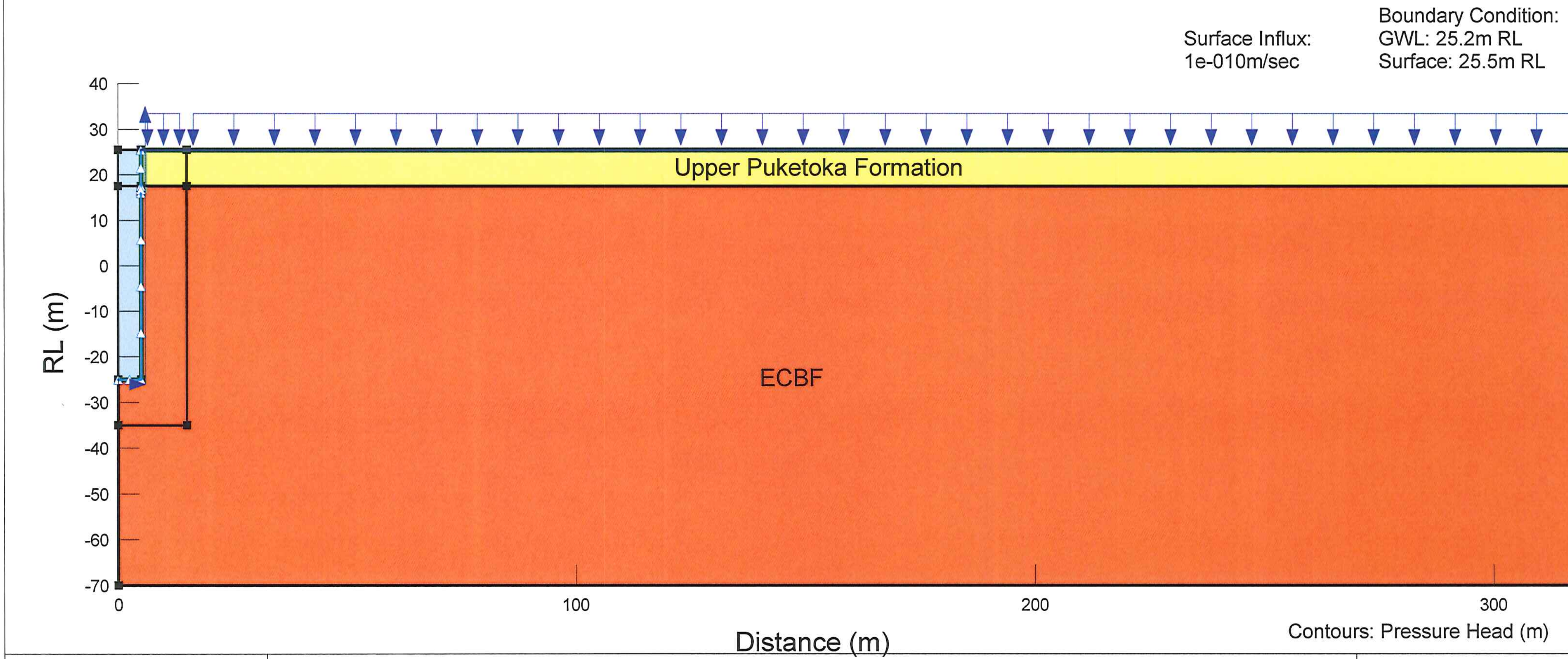


**Tonkin & Taylor**

**Central Interceptor - Groundwater and Surface Settlement Study**
Access Shaft 1
*AS1.1.2 Seep Excavation of Basalt*

Analysed : FHH
Checked:
Date: Nov 2012
Job No: 26145.300

File Name: CI.GWS.L3S3 axi.gsz
Type: SEEP/W
Analysis Method: Transient
Scale: 1:1250
Analysis View: Axisymmetric
Last Saved: 11/12/2012 4:26:48 p.m.



**Tonkin & Taylor**

**Central Interceptor - Groundwater and Surface Settlement Study**
Shaft L3S3
*L3S3.1.1.1.2 ECBF Excavation Transient*

Analysed : FHH
Checked:
Date: Nov 2012
Job No: 26145.300

File Name: CI.GWS.AS1 axi.gsz
Type: SEEP/W
Analysis Method: Steady-State
Scale: 1:1250
Analysis View: Axisymmetric
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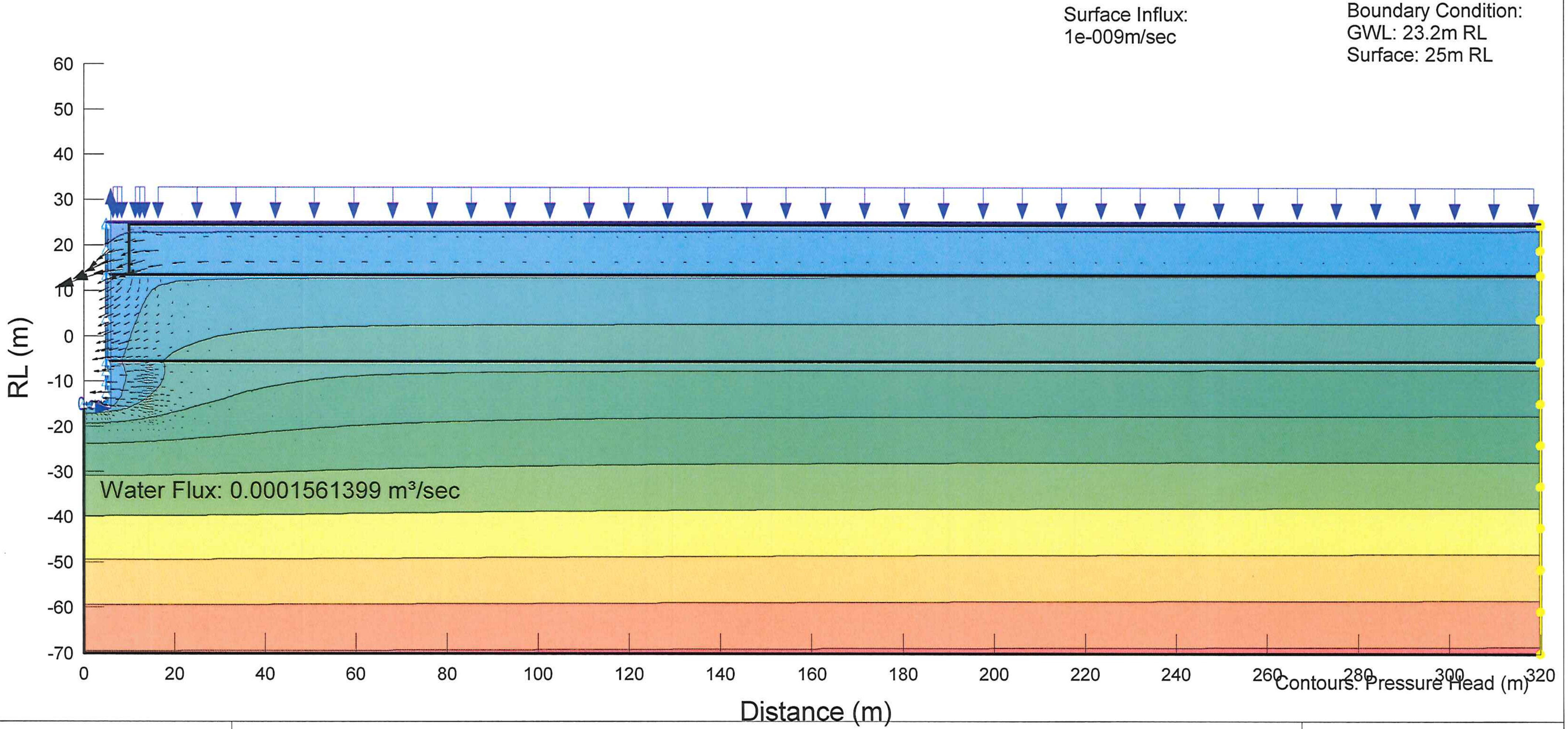


Tonkin & Taylor

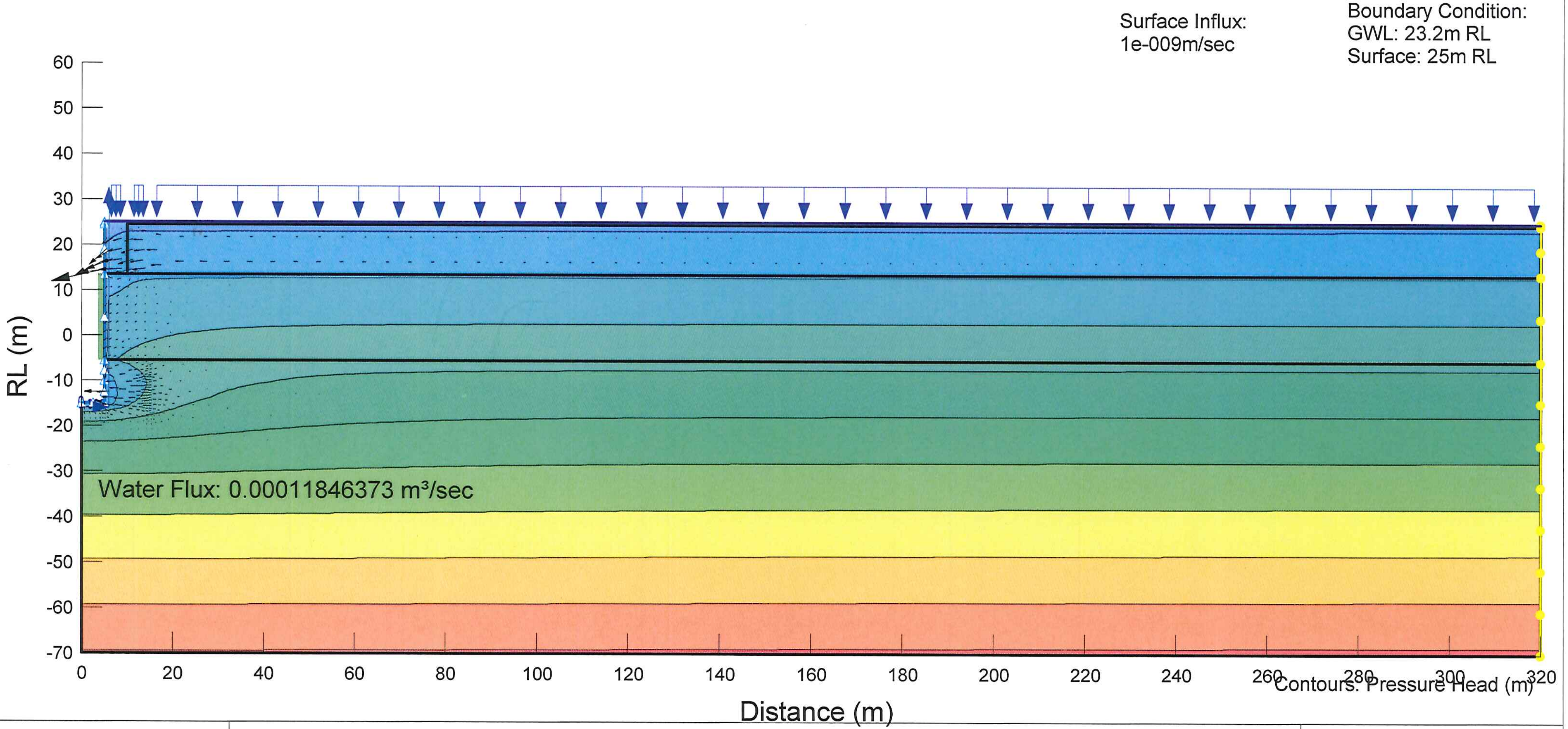
**Central Interceptor - Groundwater and Surface Settlement Study**

Access Shaft 1

*AS1.1.4 Seep Excavation of ECBF*

Analysed : FHH
Checked:
Date: Nov 2012
Job No: 26145.300

File Name: CI.GWS.AS1 axi.gsz
Type: SEEP/W
Analysis Method: Steady-State
Scale: 1:1250
Analysis View: Axisymmetric
Last Saved: 7/12/2012 3:53:26 p.m.

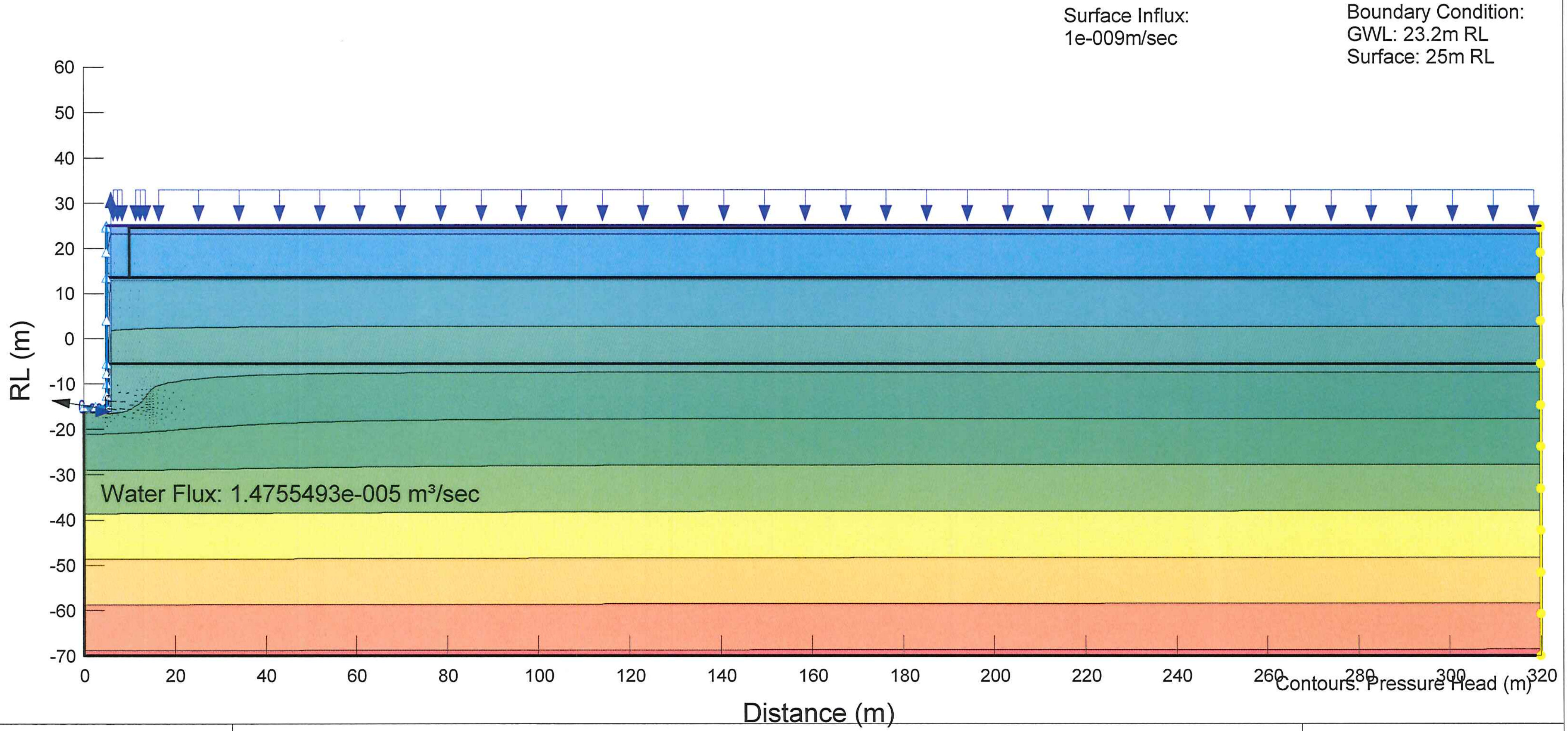


Tonkin & Taylor

**Central Interceptor - Groundwater and Surface Settlement Study**
Access Shaft 1
*AS1.1.4 Seep Excavation of ECBF*

Analysed : FHH
Checked:
Date: Nov 2012
Job No: 26145.300

File Name: CI.GWS.AS1 axi.gsz
Type: SEEP/W
Analysis Method: Steady-State
Scale: 1:1250
Analysis View: Axisymmetric
Last Saved: 7/12/2012 3:53:26 p.m.

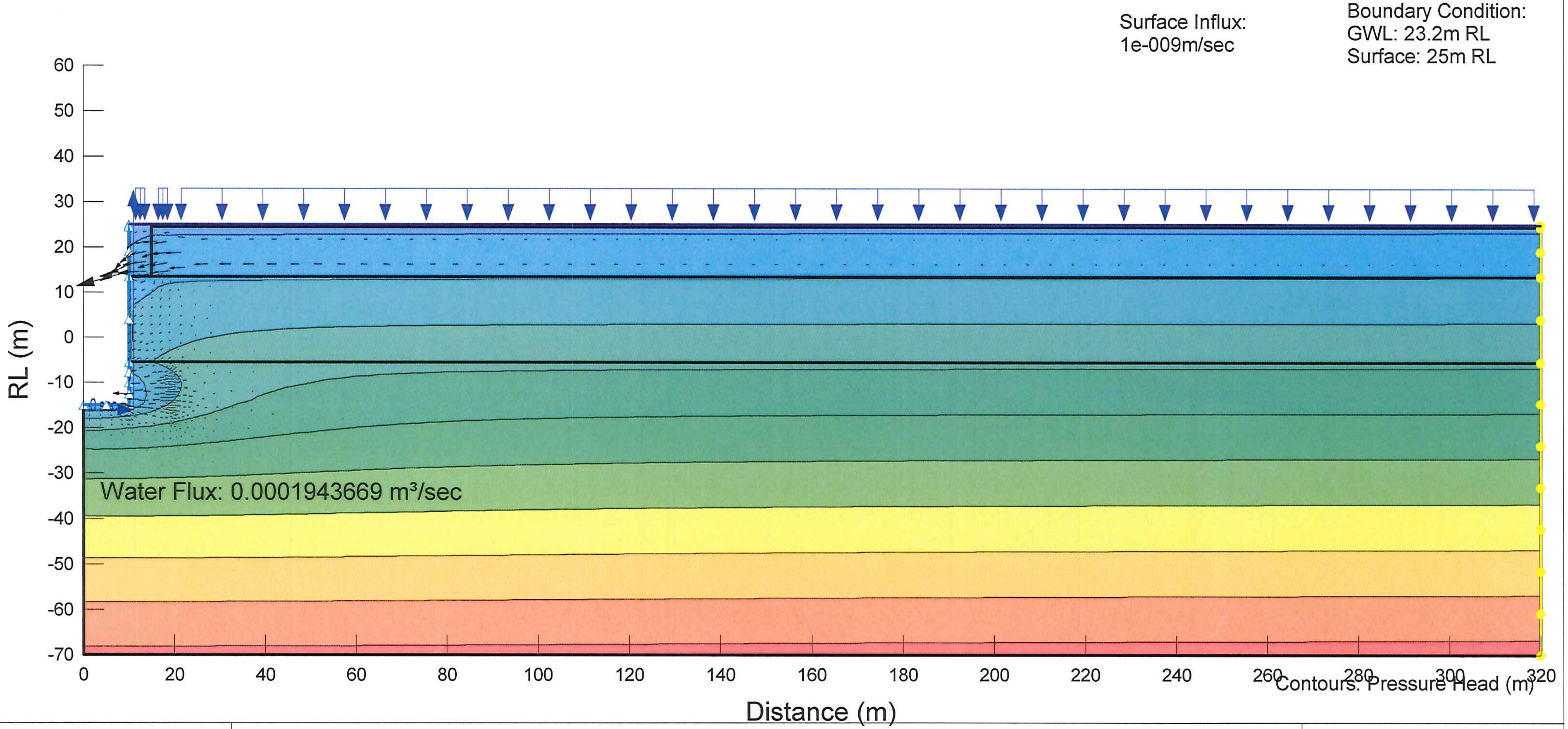


Tonkin & Taylor

**Central Interceptor - Groundwater and Surface Settlement Study**
Access Shaft 1
*AS1.1.2 Seep Total Excavation*

Analysed : FHH
Checked:
Date: Nov 2012
Job No: 26145.300

File Name: CI.GWS.AS1. bigger shaft axi.gsz
Type: SEEP/W
Analysis Method: Steady-State
Scale: 1:1250
Analysis View: Axisymmetric
Last Saved: 7/12/2012 5:15:42 p.m.

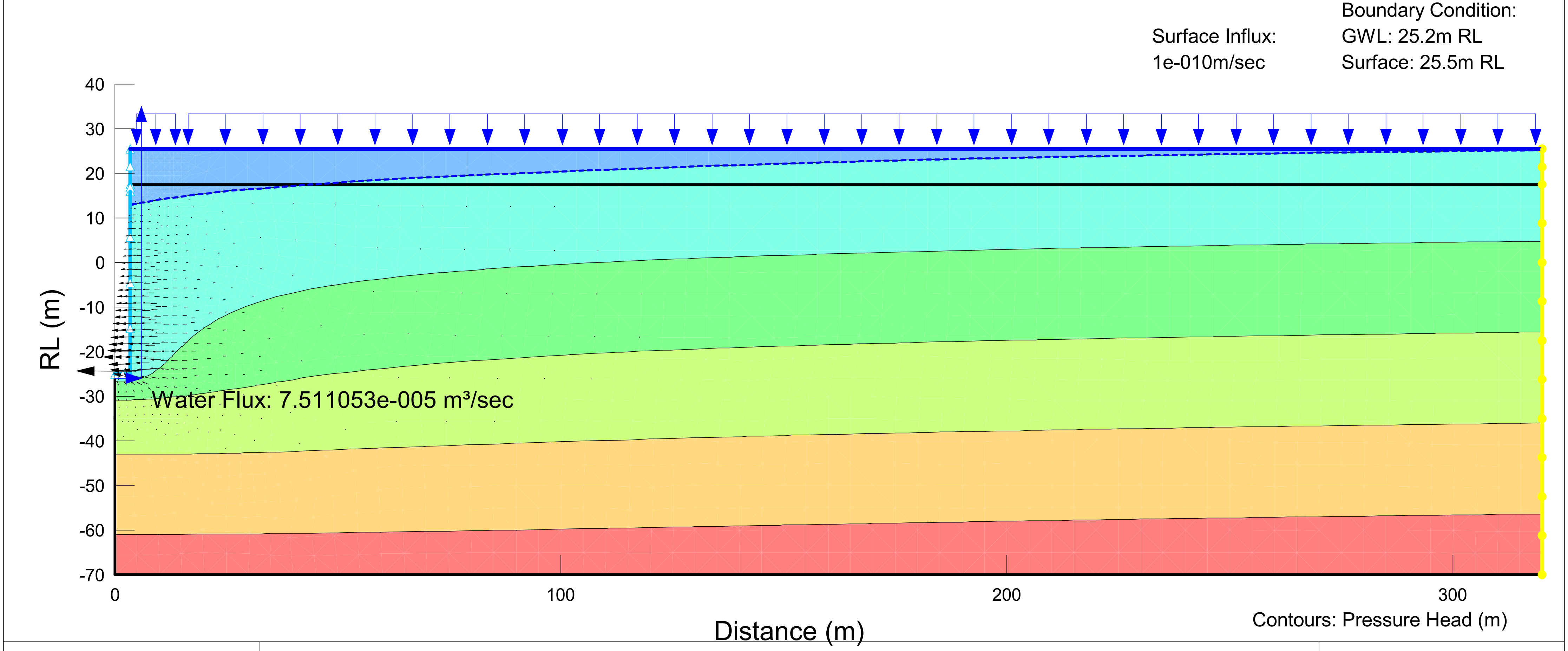


Tonkin & Taylor

**Central Interceptor - Groundwater and Surface Settlement Study**
Access Shaft 1
*AS1.1.1.4 Excavation of ECBF*

Analysed : FHH
Checked:
Date: Nov 2012
Job No: 26145.300

File Name: CI.GWS.L3S3 axi.gsz
Type: SEEP/W
Analysis Method: Steady-State
Scale: 1:1250
Analysis View: Axisymmetric
Last Saved: 25/02/2013 4:32:19 p.m.



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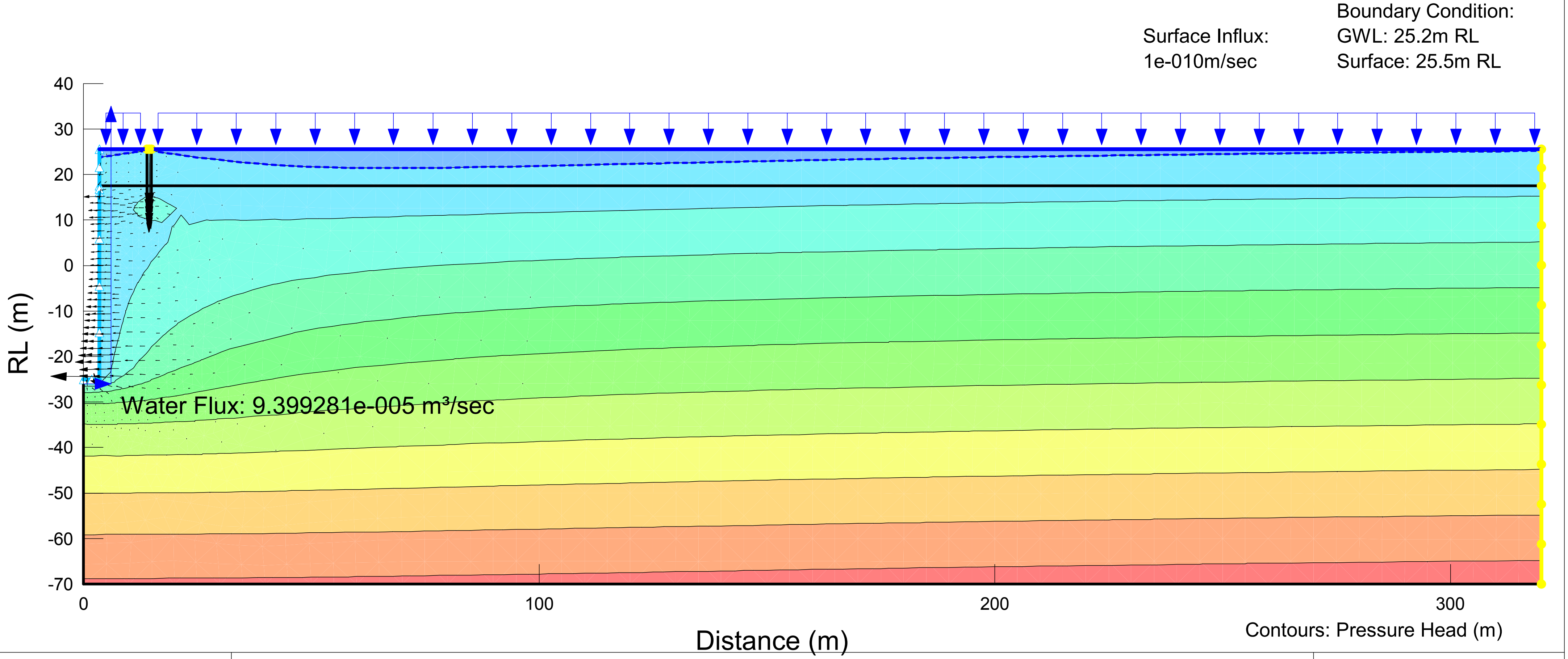
**Central Interceptor - Groundwater and Surface Settlement Study**
Shaft L3S3
*L3S3.1.1.1.2 ECBF Excavation*

Analysed : FHH
Checked:
Date: Feb 2013
Job No: 26145.300

File Name: CI.GWS.L3S3.watering 2 axi.gsz
Type: SEEP/W
Analysis Method: Steady-State
Scale: 1:1250
Analysis View: Axisymmetric
Last Saved: 25/02/2013 3:54:53 p.m.



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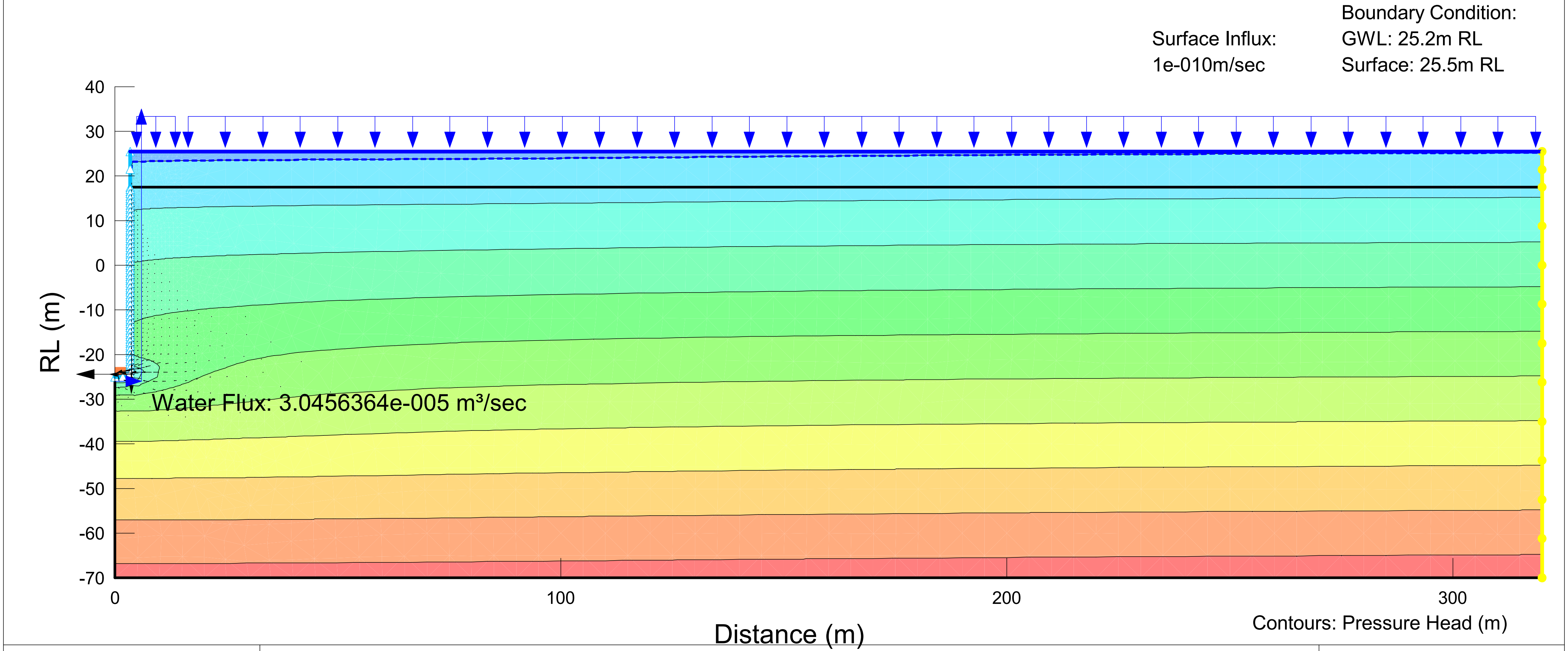
**Central Interceptor - Groundwater and Surface Settlement Study**
Shaft L3S3
*L3S3.1.1.1.2 ECBF Excavation*

Analysed : FHH
Checked:
Date: Feb 2013
Job No: 26145.300

File Name: CI.GWS.L3S3 liner ring axi.gsz
Type: SEEP/W
Analysis Method: Transient
Scale: 1:1250
Analysis View: Axisymmetric
Last Saved: 25/02/2013 4:18:04 p.m.



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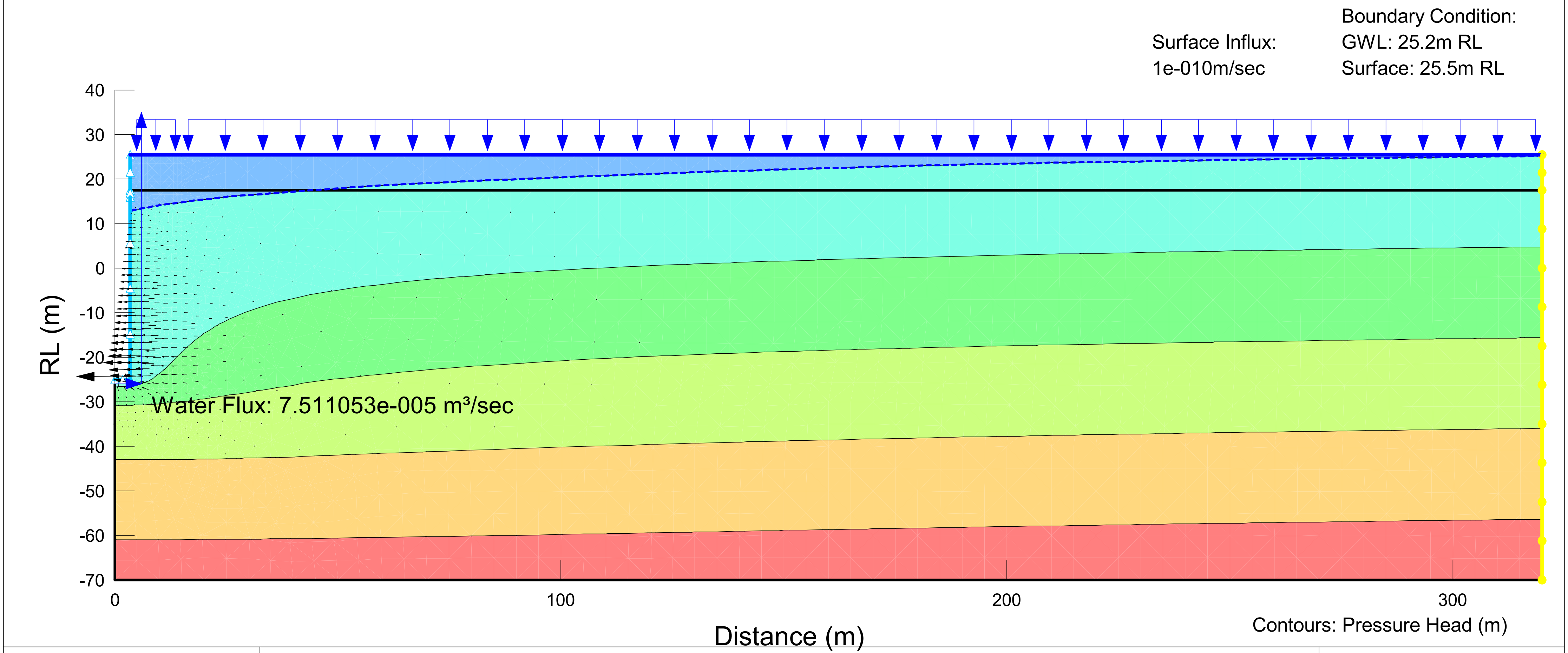
**Central Interceptor - Groundwater and Surface Settlement Study**
Shaft L3S3
*L3S3.1.1.1.2 ECBF 43 Excavation Transient*

Analysed : FHH
Checked:
Date: Feb 2013
Job No: 26145.300

File Name: CI.GWS.L3S3 axi.gsz
Type: SEEP/W
Analysis Method: Steady-State
Scale: 1:1250
Analysis View: Axisymmetric
Last Saved: 25/02/2013 4:32:19 p.m.

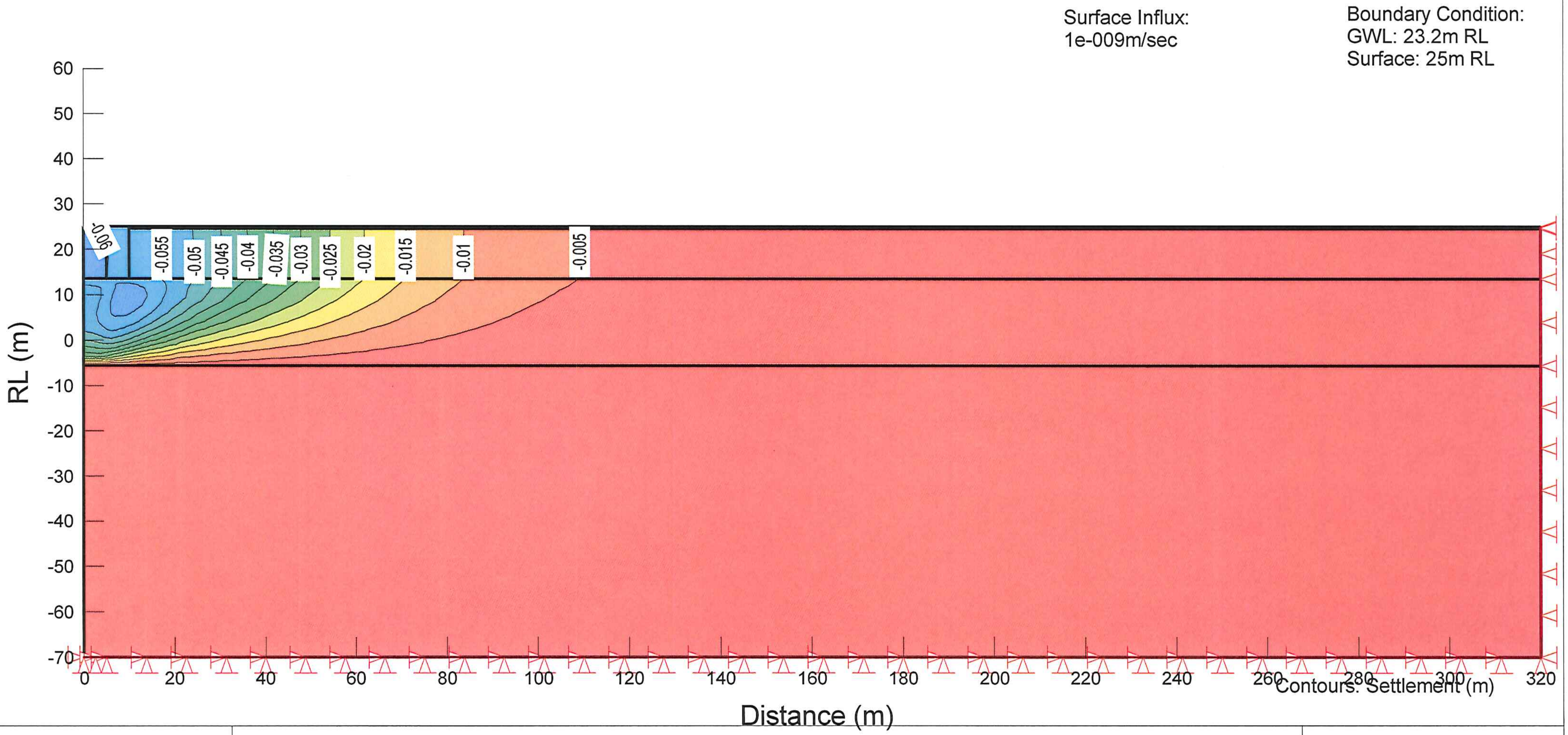


**Tonkin & Taylor**

**Central Interceptor - Groundwater and Surface Settlement Study**
Shaft L3S3
*L3S3.1.1.1.2 ECBF Excavation*

Analysed : FHH
Checked:
Date: Feb 2013
Job No: 26145.300

File Name: CI.GWS.AS1 axi.gsz
Type: SIGMA/W
Analysis Method: Volume Change
Scale: 1:1250
Analysis View: Axisymmetric
Last Saved: 11/12/2012 2:43:04 p.m.



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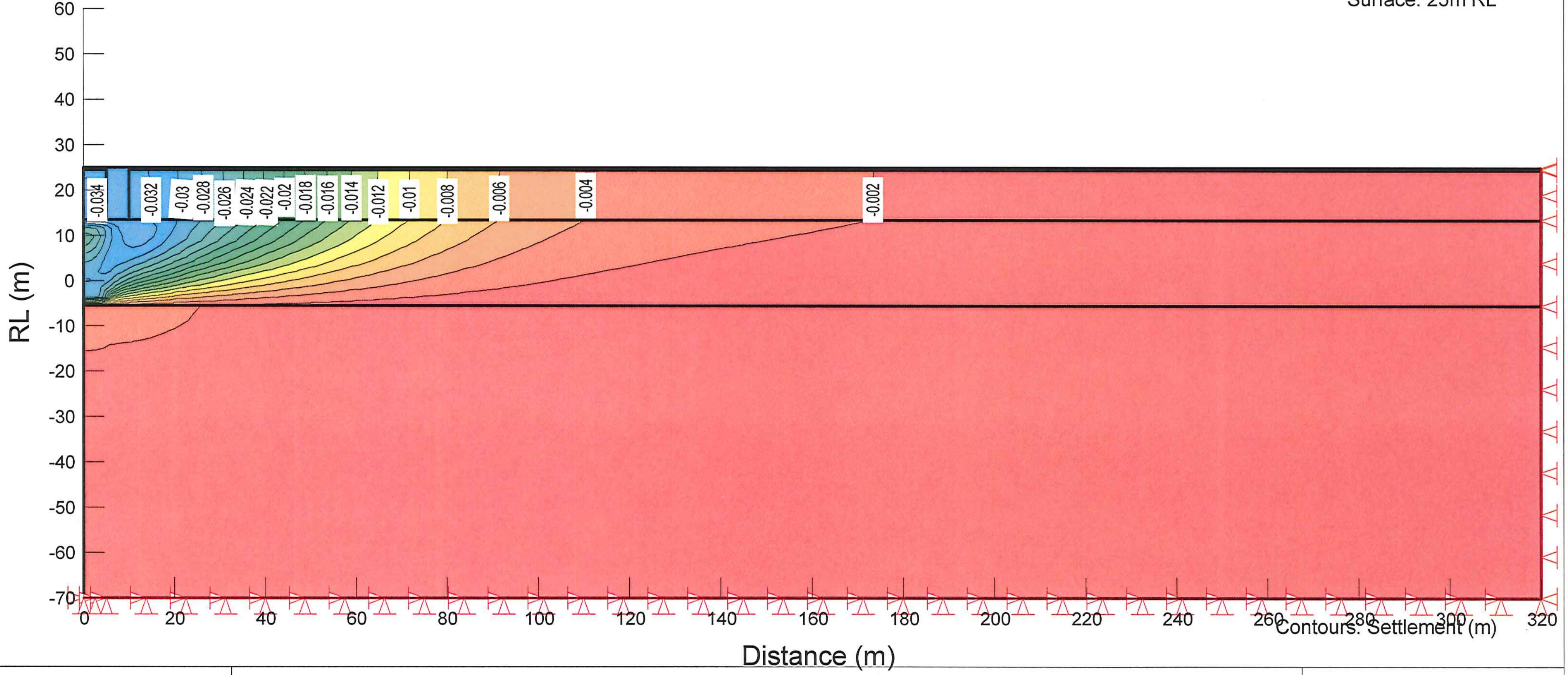
**Central Interceptor - Groundwater and Surface Settlement Study**
Access Shaft 1
*AS1.1.4.2 Excavation of ECBF*

Analysed : FHH
Checked:
Date: Nov 2012
Job No: 26145.300

File Name: CI.GWS.AS1 axi.gsz
Type: SIGMA/W
Analysis Method: Volume Change
Scale: 1:1250
Analysis View: Axisymmetric
Last Saved: 7/12/2012 3:53:26 p.m.

Surface Influx:
1e-009m/sec

Boundary Condition:
GWL: 23.2m RL
Surface: 25m RL



Tonkin & Taylor

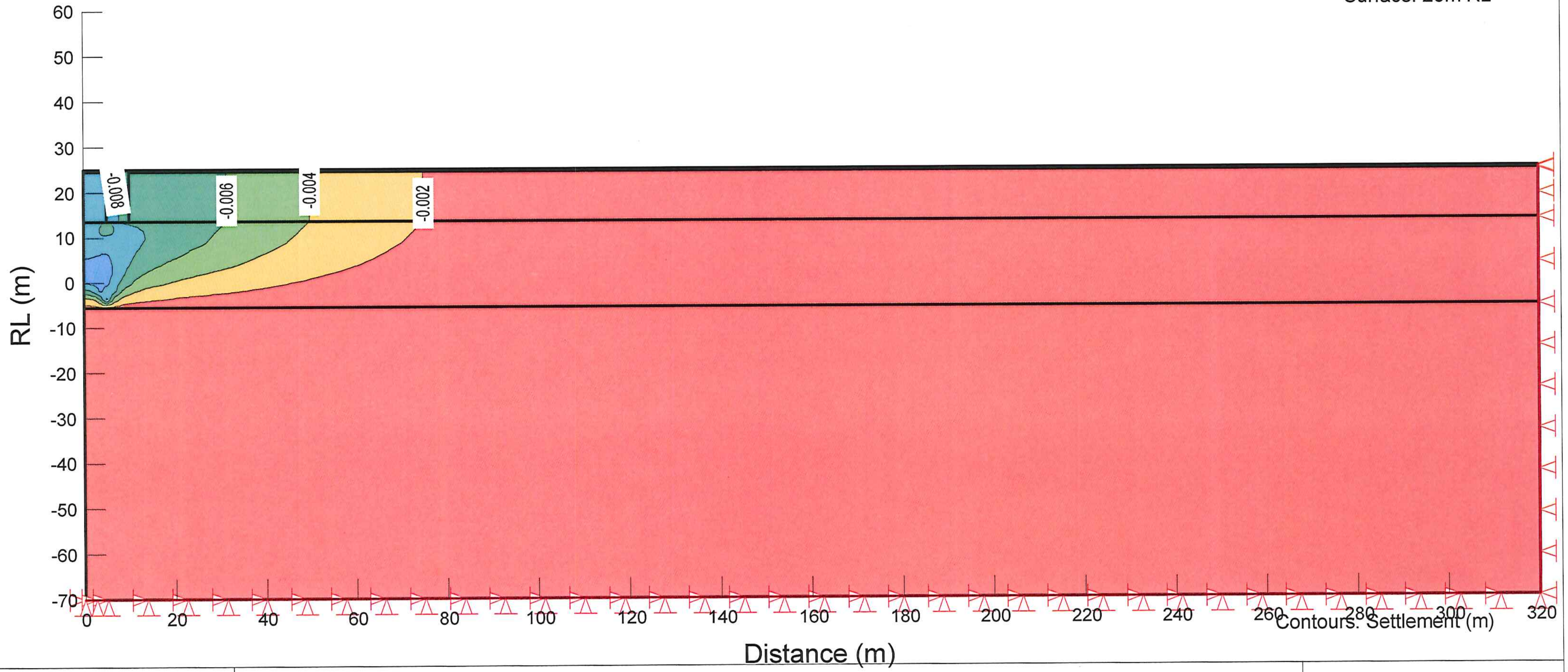
**Central Interceptor - Groundwater and Surface Settlement Study**
Access Shaft 1
*AS1.1.4.2 Excavation of ECBF*

Analysed : FHH
Checked:
Date: Nov 2012
Job No: 26145.300

File Name: CI.GWS.AS1 axi.gsz
Type: SIGMA/W
Analysis Method: Volume Change
Scale: 1:1250
Analysis View: Axisymmetric
Last Saved: 7/12/2012 3:53:26 p.m.

Surface Influx:
1e-009m/sec

Boundary Condition:
GWL: 23.2m RL
Surface: 25m RL



**Tonkin & Taylor**

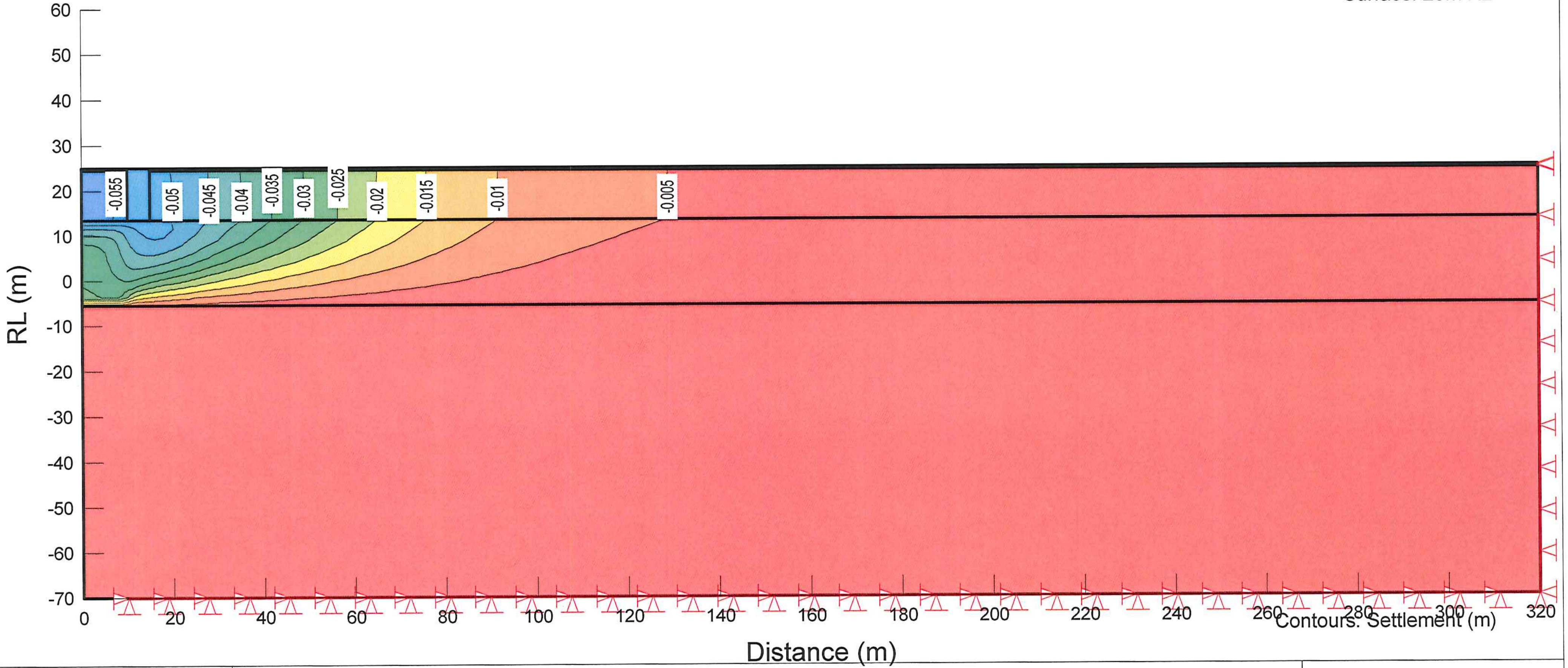
## Central Interceptor - Groundwater and Surface Settlement Study
Access Shaft 1
*AS1.1.2.2 Total Excavation*

Analysed : FHH
Checked:
Date: Nov 2012
Job No: 26145.300

File Name: CI.GWS.AS1. bigger shaft axi.gsz
Type: SIGMA/W
Analysis Method: Volume Change
Scale: 1:1250
Analysis View: Axisymmetric
Last Saved: 7/12/2012 5:15:42 p.m.

Surface Influx:
1e-009m/sec

Boundary Condition:
GWL: 23.2m RL
Surface: 25m RL



Tonkin & Taylor

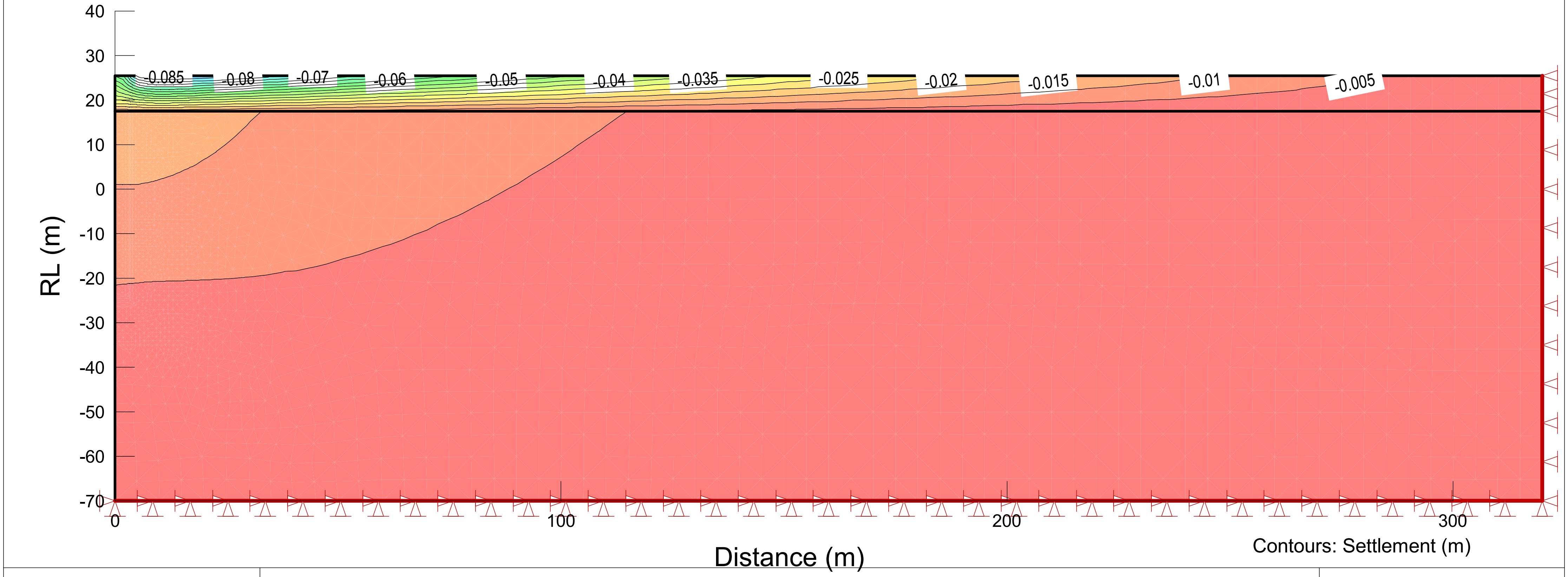
**Central Interceptor - Groundwater and Surface Settlement Study**
Access Shaft 1
*AS1.2.1.4 Excavation of ECBF*

Analysed : FHH
Checked:
Date: Nov 2012
Job No: 26145.300

File Name: CI.GWS.L3S3 axi.gsz
Type: SIGMA/W
Analysis Method: Volume Change
Scale: 1:1250
Analysis View: Axisymmetric
Last Saved: 25/02/2013 4:32:19 p.m.

Surface Influx:
1e-010m/sec

Boundary Condition:
GWL: 25.2m RL
Surface: 25.5m RL



**Tonkin & Taylor**

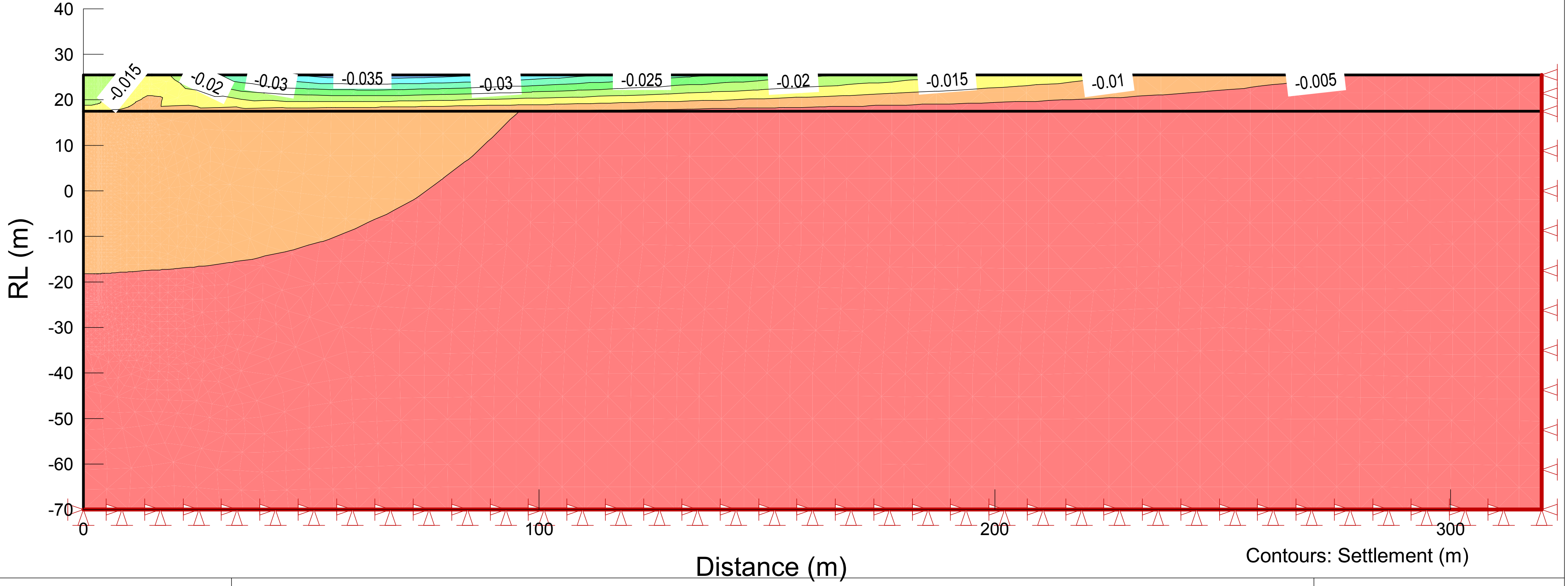
**Central Interceptor - Groundwater and Surface Settlement Study**
Shaft L3S3
*L3S3.2.1.1.2 ECBF Excavation*

Analysed : FHH
Checked:
Date: Feb 2013
Job No: 26145.300

File Name: CI.GWS.L3S3.watering 2 axi.gsz
Type: SIGMA/W
Analysis Method: Volume Change
Scale: 1:1250
Analysis View: Axisymmetric
Last Saved: 25/02/2013 3:54:53 p.m.

Surface Influx:
1e-010m/sec

Boundary Condition:
GWL: 25.2m RL
Surface: 25.5m RL

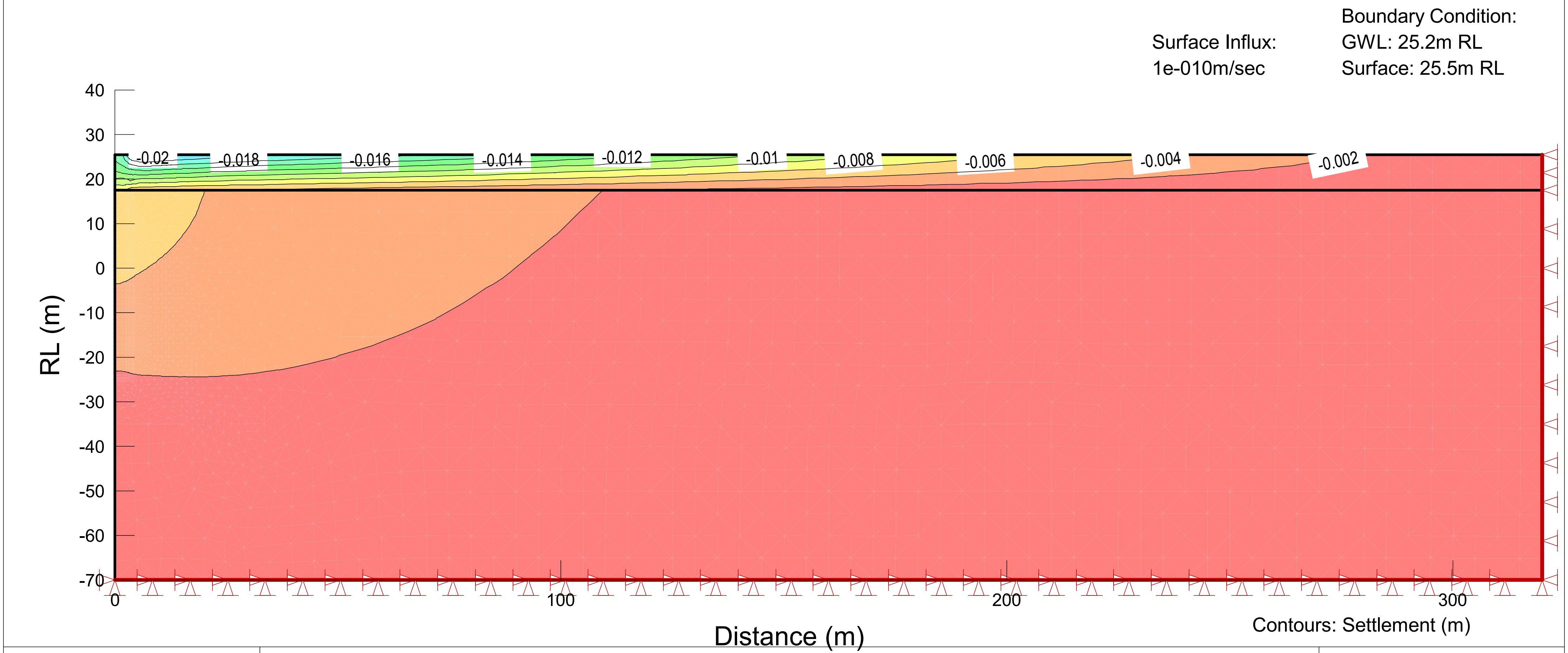


**Tonkin & Taylor**

**Central Interceptor - Groundwater and Surface Settlement Study**
Shaft L3S3
*L3S3.2.1.1.2 ECBF Excavation*

Analysed : FHH
Checked:
Date: Feb 2013
Job No: 26145.300

File Name: CI.GWS.L3S3 liner ring axi.gsz
Type: SIGMA/W
Analysis Method: Volume Change
Scale: 1:1250
Analysis View: Axisymmetric
Last Saved: 25/02/2013 4:18:04 p.m.



Tonkin & Taylor

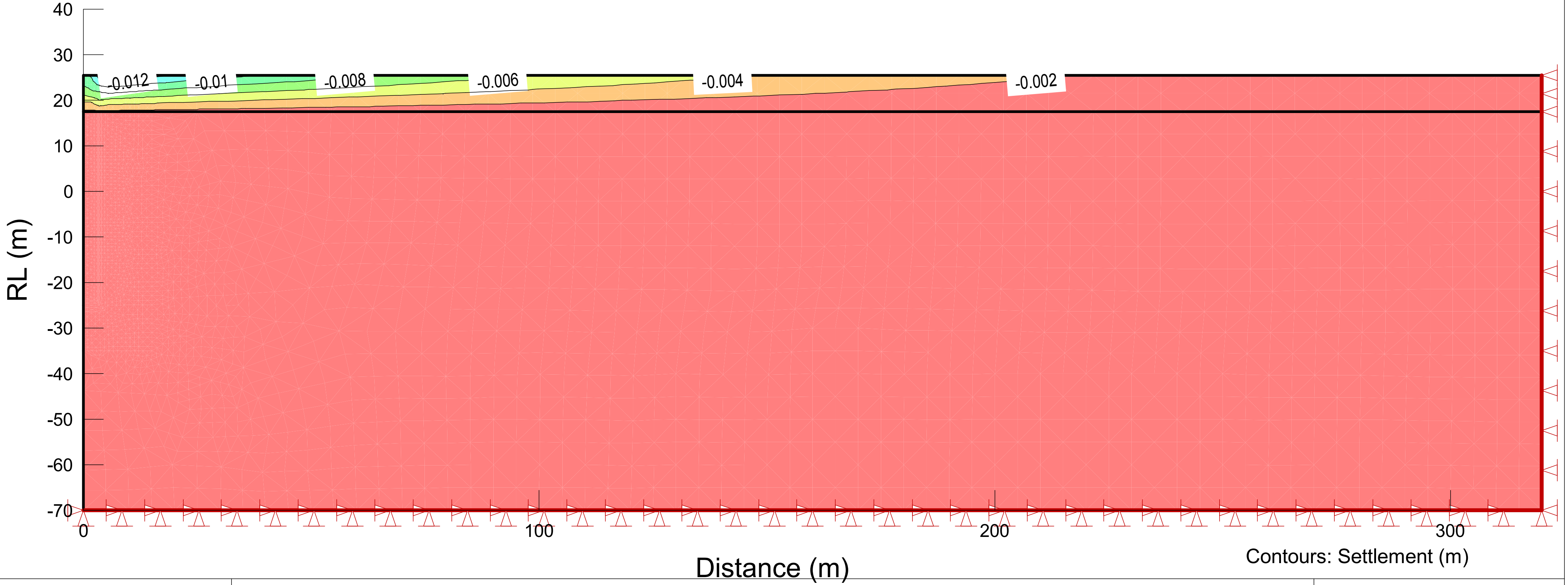
**Central Interceptor - Groundwater and Surface Settlement Study**
Shaft L3S3
*L3S3.2.1.2.2 ECBF 43 Excavation Transient*

Analysed : FHH
Checked:
Date: Feb 2013
Job No: 26145.300

File Name: CI.GWS.L3S3 axi.gsz
Type: SIGMA/W
Analysis Method: Volume Change
Scale: 1:1250
Analysis View: Axisymmetric
Last Saved: 25/02/2013 4:32:19 p.m.

Surface Influx:
1e-010m/sec

Boundary Condition:
GWL: 25.2m RL
Surface: 25.5m RL



Contours: Settlement (m)

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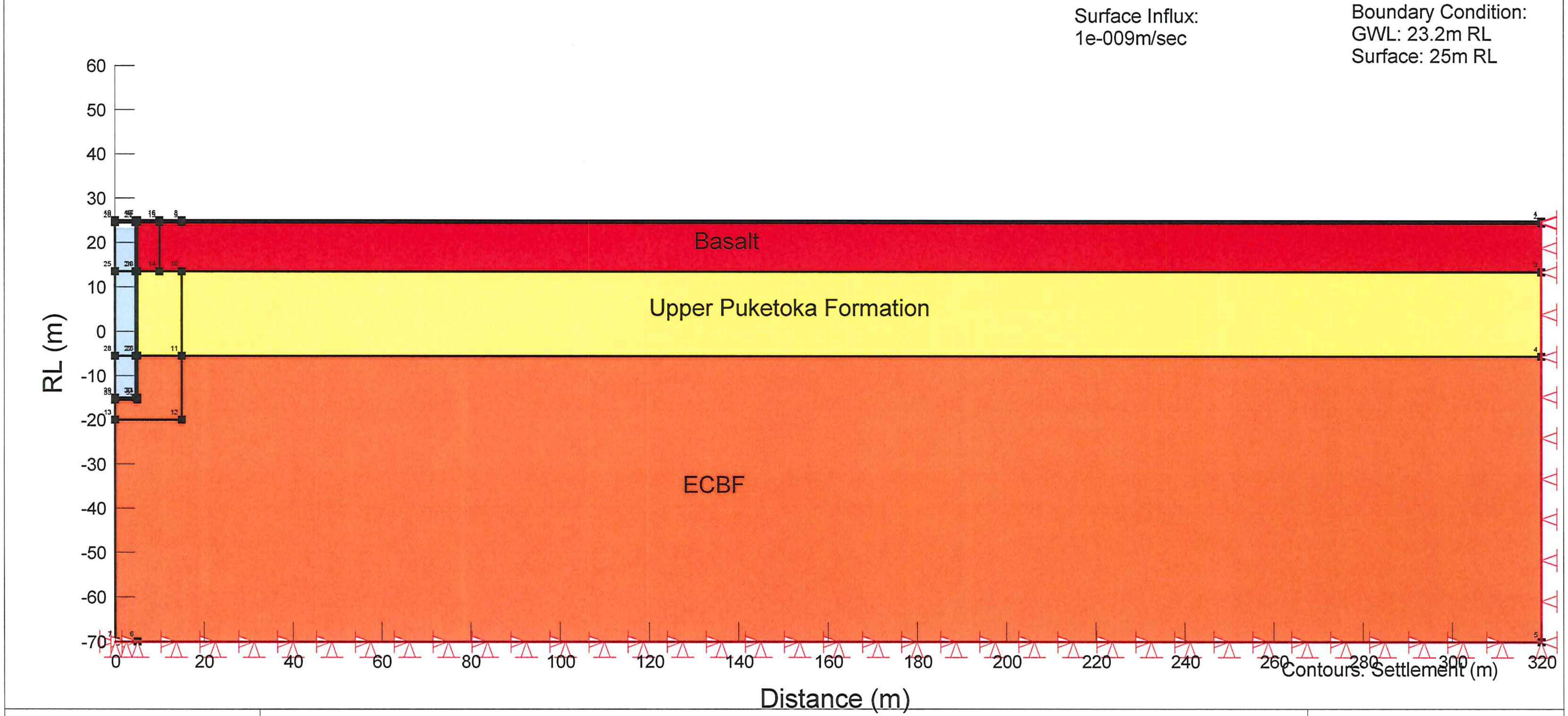
**Central Interceptor - Groundwater and Surface Settlement Study**
Shaft L3S3
*L3S3.2.4.2.1 Total Excavation*

Analysed : FHH
Checked:
Date: Feb 2013
Job No: 26145.300

# Appendix C: Mechanical settlement modelling - sample outputs

File Name: CI.GWS.AS1 axi - lining settlement.gsz
Type: SIGMA/W
Analysis Method: Load/Deformation
Scale: 1:1250
Analysis View: Axisymmetric
Last Saved: 13/12/2012 3:49:20 p.m.

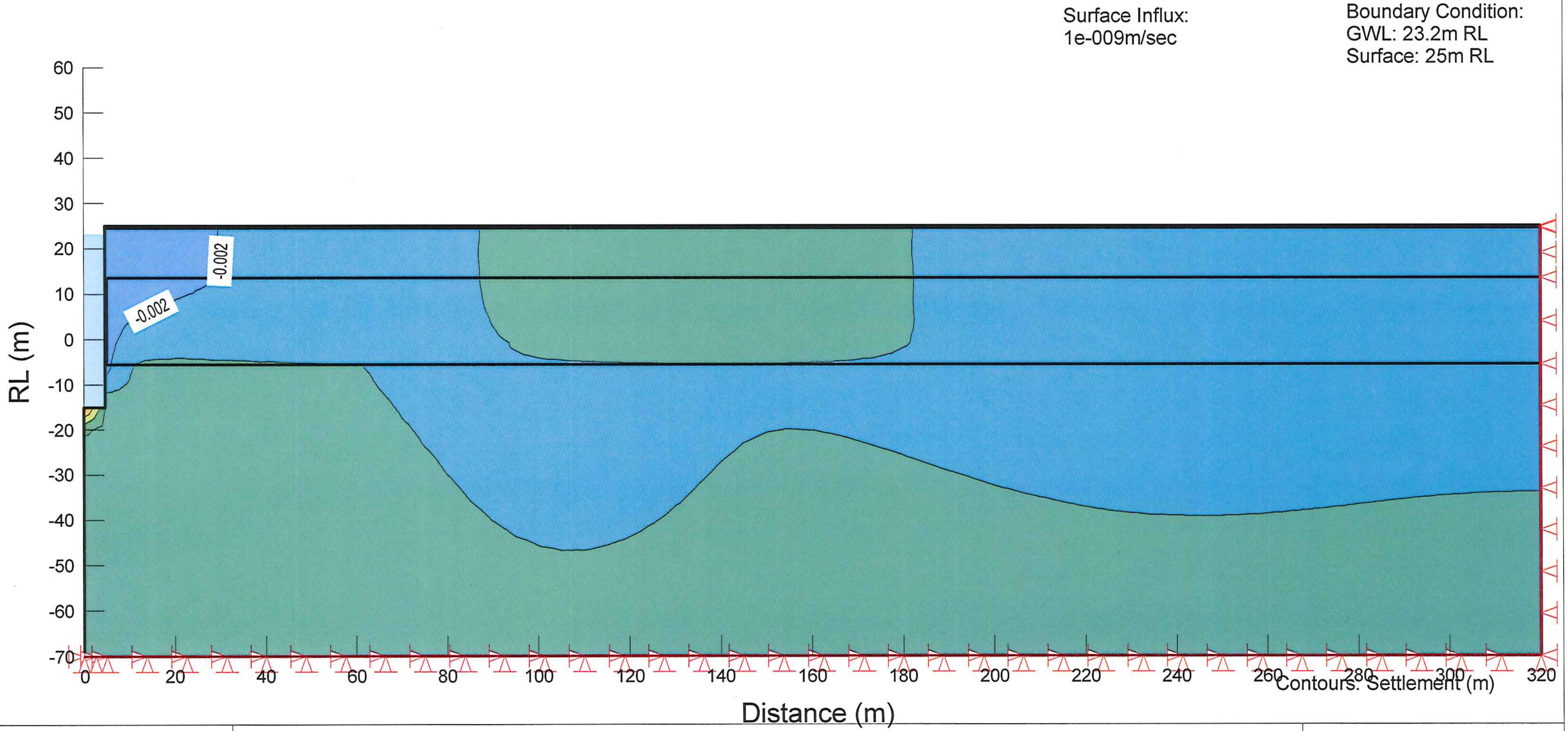


**Tonkin & Taylor**

**Central Interceptor - Groundwater and Surface Settlement Study**
Access Shaft 1
*AS1.1.3.2 Mechanical settlement*

Analysed : FHH
Checked:
Date: Nov 2012
Job No: 26145.300

File Name: CI.GWS.AS1 axi - lining settlement.gsz
Type: SIGMA/W
Analysis Method: Load/Deformation
Scale: 1:1250
Analysis View: Axisymmetric
Last Saved: 10/12/2012 6:13:24 p.m.



Tonkin & Taylor

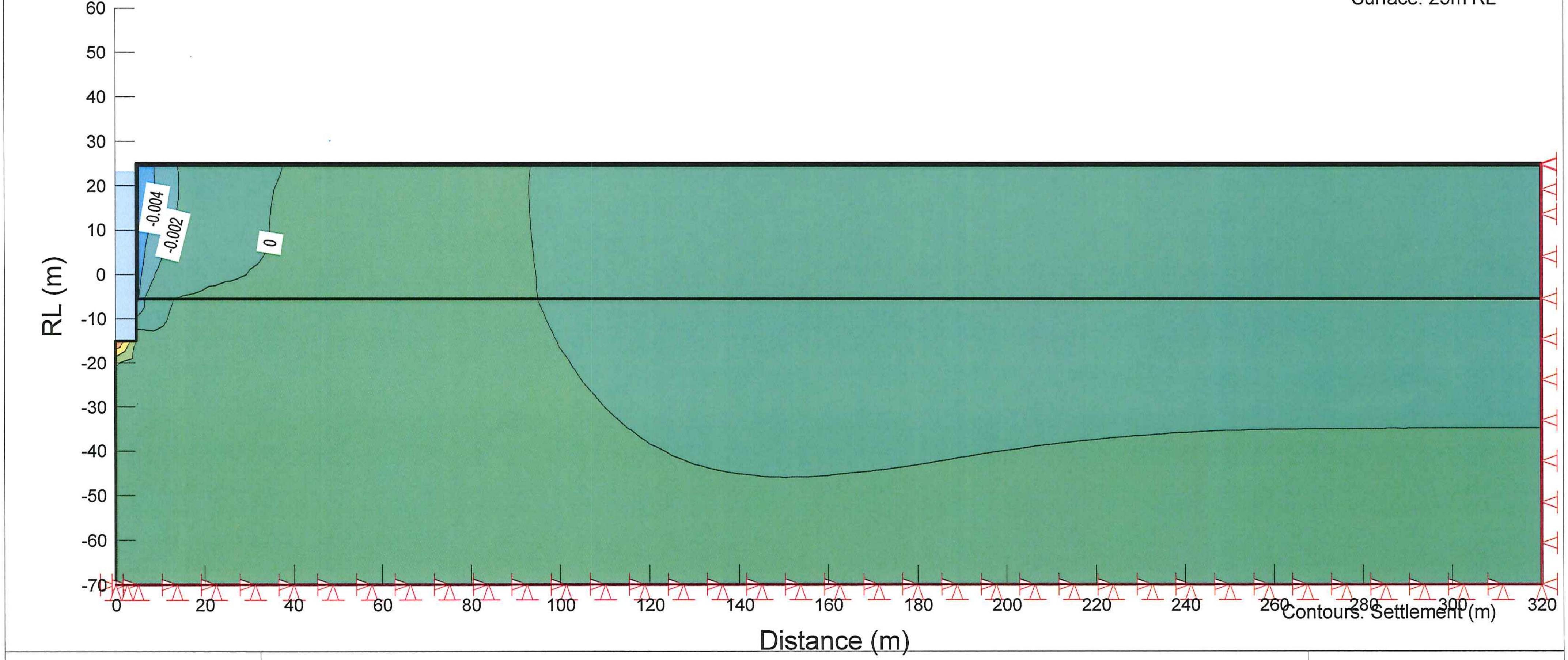
**Central Interceptor - Groundwater and Surface Settlement Study**
Access Shaft 1
*AS1.1.3.2 Mechanical settlement 2*

Analysed : FHH
Checked:
Date: Nov 2012
Job No: 26145.300

File Name: CI.GWS.AS1 axi - lining settlement.gsz
Type: SIGMA/W
Analysis Method: Load/Deformation
Scale: 1:1250
Analysis View: Axisymmetric
Last Saved: 10/12/2012 6:17:58 p.m.

Surface Influx:
1e-009m/sec

Boundary Condition:
GWL: 23.2m RL
Surface: 25m RL



**Tonkin & Taylor**

**Central Interceptor - Groundwater and Surface Settlement Study**
Access Shaft 1
*AS1.1.3.2 Mechanical settlement 2*

Analysed : FHH
Checked:
Date: Nov 2012
Job No: 26145.300