REPORT

TO
SX PROJECTS PTY LTD

ON
ADDITIONAL GROUNDWATER MODELLING

FOR
PROPOSED RESIDENTIAL DEVELOPMENT

AT
CORNER LAWERENCE AND ALBERT STREETS,
FRESHWATER, NSW

27 May 2015
Ref: 22337VYrpt3rev2

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1 INTRODUCTION AND BACKGROUND

This report presents the results of our groundwater seepage analyses for a proposed mixed use development at the corner of Lawrence and Albert Streets, Freshwater. We previously completed a report for the same site and assumed that an impervious cut-off wall would be installed into sandstone bedrock and, where bedrock was encountered above Bulk Excavation level (BEL), the cut-off wall would extend a minimum of 0.5m embedment below BEL (Ref: 22337SYrpt3, Rev: 0, dated 23 May 2014). Mr Joe Battaglia of SX Group Pty Ltd commissioned this additional analysis with the purpose of assessing what the impact of terminating the cut-off wall on the sandstone bedrock above BEL on the western or uphill side of the site would be on predicted groundwater extraction rates. The cut-off is now proposed to comprise sheet piles or similar installed down to the sandstone bedrock with a 0.45m diameter contiguous pile wall installed inside the cut-off wall to 0.5m below BEL.

JK Geotechnics have previously carried out a geotechnical investigation at this site and on adjoining properties to the west (refer to report, Ref. 22337Srptrev4, dated 28 November 2013). This previous investigation comprised thirteen boreholes and three test pits. Factual subsurface information from our investigations was included in that report, together with advice on excavation conditions and methodology, groundwater, retaining wall, footing design and basement slabs. These issues are not discussed further in this report. The groundwater model used in the current analyses has been based on the subsurface conditions encountered during the previous investigation and reference should be made to our previous report for further details.

We have been provided with the following structural drawings prepared by Waterman (Project No: 24874, S001, S002, S010, S011-S013, S015, S016S020 and S030, Revision: P2, P1, P3, P3, P3, P3, P2, P2, P1 and P1, respectively. Based on these drawings, we understand that two levels of basement carpark will be constructed. This will result in a bulk excavation level (BEL) of RL9.2m with cut depths varying between about 5m to 10m below existing levels. A secant pile cut-off wall is shown on the drawings to be installed around the perimeter of the proposed excavation and will extend to about 0.5m below the proposed BEL. For the purposes of this analysis the secant pile wall will not be installed along the western boundary.

Available geotechnical information indicates that the site is underlain by sands, sandy clays/clayey sands and clays that in turn overlie shale and sandstone bedrock. The groundwater table typically varies from 1.6m to 3.6m below existing ground levels. As excavation extends to the common boundaries dewatering will be completed inside the shoring system to allow bulk excavation and the subsequent basement construction; there will be no dewatering or drainage behind the cut-off walls which will be designed for full hydrostatic pressures.

The purpose of this groundwater modelling was to address the following:

- the steady state extraction rate required per annum to maintain the basement in a drained state and
- Groundwater monitoring requirements during construction.

A full design of the dewatering system, such as locations of dewatering wells, and recharge points was outside the scope of this commission. Geotechnical review of the final layout and design of the dewatering system, monitoring of pumping rates and groundwater levels both inside and beyond the excavation will be required.

2 ANALYSIS METHODOLOGY

Steady state seepage analyses have been carried out on the sections as shown on the attached site plan (Figure 1). The sections were chosen as they represented reasonably 'typical' sections through the site in terms of proposed basement construction, boundary set-backs and subsurface conditions (See Figures 2 and 3). The seepage analyses were carried out using a 2D finite element computer program SEEP/W (from GEO-SLOPE). The overall methodology used for the seepage analyses was as follows:

- Construct the surface and subsurface model.
- Carry out steady state seepage analyses after excavation and during dewatering. On the western or uphill side of the site a sheet pile wall was installed down to the underlying bedrock. Adjacent to and on the excavation side of the sheet pile cut-off wall a 0.45m diameter contiguous pile wall with 50mm gap between piles was installed to a minimum of 0.5m below BEL. On the eastern or downslope side of the site a cut-off was installed to below BEL and socketed into the sandstone bedrock.

3 SURFACE AND SUBSURFACE MODEL

The reduced levels adopted at the ground surface of the sections analysed were interpolated from the spot levels shown on the survey plan prepared by Daw & Walton Pty Ltd (Job No: 506-07, dated 29 November 2007) and, as such should be considered as approximate. The datum is Australian Height Datum (AHD).

The subsurface model has been developed from the results of the previous investigation. In general the subsurface conditions comprise a relatively thin layer of sand that in turn overlies a silty clay or sandy clay/clayey sand layer. These soils in turn predominantly overlie sandstone bedrock, although to the west of the site some shale bands were encountered in the upper bedrock profile. Rock levels increase across the site in a north-easterly direction and vary from about RL13.8m to RL6.4m.

Total head boundary conditions have been adopted at the sides and base of the model. Infinite elements have been utilised at the sides and base of the model to represent the total head conditions beyond the model boundaries.

The subsurface profiles have been sub-divided into layers as presented in Figures 2 and 3. The saturated coefficients of permeability have been assigned to each of these layers based on soil relative density or strength inferred from the borehole logs, past experience and published correlations. These values of permeability are "typical" values, certainly not upper or lower bound and variations of one order of magnitude should not be considered unexpected. Where the contiguous pile wall extends through the sandstone bedrock the permeability values adopted for the wall have been calculated on the assumption that the walls will consist of 0.45m diameter piles with a maximum 50mm gap left between the piles. The permeability of the wall has then been calculated as a percentage of the gaps to pile in the wall (ie 0.05/0.45 = 11.1%) multiplied by the permeability of the soils adjacent of the wall. The values adopted are presented in the table presented below.

Table 1 – Typical Saturated Coefficient of Permeability of Soils and Bedrock

Strata	Typical Saturated Coefficient of Permeability for Layer (m/sec)	Ratio of Vertical to Horizontal Permeability (kv/kh)
Sand	1×10^{-3}	1
Sandy Clay/Clayey Sand	1×10^{-6}	1
Clay	1×10^{-8}	1
Shale Bedrock	1×10^{-7}	0.5
Sandstone Bedrock	1×10^{-7}	0.5
0.6m Diameter Pile Wall Installed through Sandstone Bedrock	1.11×10^{-8}	0.5

4 ANALYSIS ASSUMPTIONS

The analyses carried out have made the following assumptions:

- The shoring system around the outside of the excavation has been taken down to bedrock and a minimum of 0.5m below BEL. The type and overall stability of the shoring system has not been assessed as part of the seepage modelling. Shoring systems extending to different depths from those modelled will change the seepage results.
- On the western or uphill side of the site the shoring system has been assumed to be impervious down to the underlying sandstone bedrock and semipervious where it extends through the sandstone bedrock to 0.5m below BEL.
- On the eastern or downslope side of the site an impervious cut-off wall extends down to below BEL and is socketed 0.5m into the sandstone bedrock.
- Initial boundary groundwater levels of RL19.1m to RL11.6m (Section A-A) and RL18.5m to RL9.5m (Section B-B) have been adopted. These levels are based on the borehole results and monitoring of standpipes as reported in our report issued on 28 November 2013. These groundwater levels should be checked prior to, during and on completion of construction.
- The bulk excavation level for the basement car park is to be at RL9.2m.
- The groundwater level inside the excavation has been drawn down to RL9.2m.
- The horizontal and vertical permeability of the subsurface materials have been assumed to be equal with the exception of the shale and sandstone bedrock where the vertical permeability is assumed to be half the horizontal permeability.
- The bedrock is relatively impervious, with only occasional tight bedding and joint defects.

A number of these assumptions are unlikely to be entirely correct, for example there will be some leakage around the pile toes but the magnitude is difficult to predict and may be insignificant.

5 RESULTS OF ANALYSIS

5.1 Potential Impact of the Proposed Development on the Groundwater Regime

The water level on the outside of the shoring system is affected to some degree with drawdown on the eastern side and mounding on the western side. Drawdown on the eastern side varies up to about 2m. Based on the results of groundwater monitoring completed from 3/3/2010 to 12/1/2012, groundwater fluctuations from lowest to highest measured levels varied from 2.55m to 2.85m in Boreholes 1 and 209 respectively. Consequently, it is anticipated that the predicted drawdown of the groundwater table on the eastern side of the cut-off wall will not exceed groundwater variations historically experienced by the site.

On the eastern side of the cut-off walls the modelling indicates that mounding of the groundwater table will occur. In the case of Section B-B this mounding will result in a rise of groundwater in the order of about 2.0m while at Section A-A the mounding results in the groundwater reaching the surface. In this regard we recommend that a drain be installed on the uphill side of the cut-off wall to allow the groundwater to be directed around the excavation and discharged at the downhill sides of the site. This would result in the re-charge of the groundwater table on the eastern side of the site and reduce the predicted drawdown. In this regard allowance should be made for volumes in the order of $5.12 \times 10^{-5} m^3/s$ per meter run. This translates into 1.9 L/sec for the width of the site (ie 37m).

It should be noted that the above two-dimensional modelling makes no allowance for the three-dimensional effects that will promote the sideways shedding of the mounded groundwater around the site. Reference should be made to Figure 6 which shows a topographical plan of the site and surrounds. From this plan it can be seen that the ground surface and similarly the groundwater gradients dip to the north-east. Due to the orientation of the site with regards to the groundwater gradients the groundwater will tend to flow around the site rather than mound on the high side. Consequently, while we do expect that some mounding and drawdown will occur on the high and low sides of the site respectively, the values predicted above are conservative and over-estimate the true impact of the development on the groundwater regime.

We recommend that the groundwater levels around the site be carefully monitored during the construction period to establish exactly what effect the excavation is having and that all recommendations be reviewed by the geotechnical and hydraulic engineers and modifications made as deemed necessary.

5.2 Predicted Yearly Extraction Rates

To maintain the steady state drop in groundwater as shown in the Section A-A (Figure 4) the site must be dewatered at a rate of $2.59 \times 10^{-6} m^3/sec$ per meter run. To maintain the steady state drop in groundwater as shown in the Section B-B (Figure 5) the site must be dewatered at a rate of $1.70 \times 10^{-6} m^3/s$ per meter run. This translates into an average pump out value of 2.50 ML/annum. This in itself is a conservative value as this assumes that the cut-off wall will extend only midway along the northern and southern boundaries of the site. This is not the case with cut-off walls intended to extend for the full length of both the northern and southern site boundaries.

Note that in either case, higher pumping rates will be required initially until steady state conditions are achieved. Higher inflows would also be expected if groundwater levels in the area rise due to prolonged wet weather or if the underlying sandstone contains open bedding or joint defects.

6 COMMENTS AND RECOMMENDATIONS

The seepage analyses have been based on our assumptions of likely permeability values within the soils and bedrock and that the cut-off wall forms an impervious barrier. In reality, there will almost certainly be some variation in soil profiles and permeability while the cut-off wall may also leak to some degree. In this regard it is not uncommon for the results to be only accurate to within one order of magnitude.

The results have shown that it is unlikely that any lowering of the groundwater on the outside of the shoring system will, if all modelling assumptions are correct exceed historical levels. However this makes no allowance for the 3D effects that will reduce the predicted maximum groundwater drawdown levels. In addition, the groundwater recharge that will result from the diversion of groundwater flows from the high side of the site to the low side will also mitigate the magnitude of groundwater drawdown.

Good monitoring and control of groundwater seepage through the cut-off wall will be required during construction and dewatering to reduce the risk of lowering groundwater levels outside the shoring system and potentially causing settlement induced damage to adjoining buildings and structures. Should the cut-off wall have a high degree of permeability then it must be progressively sealed as the excavation progresses. This may mean that where piles extend below bulk excavation, sealing of leaking piles may also need to be completed by grouting behind the wall. During dewatering it is essential that the response of the monitoring wells installed outside of the excavation be regularly monitored to confirm the results of the modelling. In this regard we recommend that a number of monitoring wells be installed on both the high and low side of the site. This monitoring will be especially critical in the early stages of dewatering. While we consider that recharge wells are unlikely to be required, it is possible that they may be should excessive drawdown be noted in the monitoring wells. It is important such equipment be available for rapid deployment.

While modelling indicates that drawdown outside of a well constructed cut-off wall installed to the underlying sandstone bedrock will be within historical variations and unlikely to result in induced settlements below adjoining buildings, particular care must be taken when installing the anchors. Where anchor heads are located within sandy soils particular care will be needed as saturated sands may flow into the excavation when the cut-off wall is drilled to allow the anchor installation. If this flow is not controlled it is likely that excessive volumes of materials will be lost below adjoining structures. Such loss of material is likely to result in the settlement of the soils behind the wall and may cause damage to adjoining structures. It is also possible that similar problems could be experienced if the clayey sands and sandy clays have localised sandy bands within them or are more sandy than expected and flow when saturated. In this regard only contractors experienced in the installation of anchors in sandy soils below the water table should be considered for this project. As such it may be prudent to obtain a work method statement from the anchor contractor indicating how they will control the flow of materials into the site where the cut-off wall is penetrated to allow the installation of the anchors.

Based on the modelling it appears that average daily pumping rates will be 6849 litres. This assumes that the cut-off wall is impermeable. This will not be the case. Leakage may occur both through the wall, at the toe of the piles and from the anchor heads. Consequently, we recommend that some allowance be made for the disposal of water that seeps through the cut-off wall during excavation. It is assumed that measures will be taken to remedy water flows through the piling during excavation (should they be encountered) such that or assumption that the cut-off wall is impermeable is correct.

The offsite disposal of groundwater will require approval from the NSSW Office of Water and/or Council and/or Sydney Water. Groundwater may be sampled from boreholes and the samples despatched to a chemical laboratory for testing.

If groundwater levels on the outside of the shoring system are found to be lower than expected then dewatering may need to be turned off until a recharge system can be implemented.

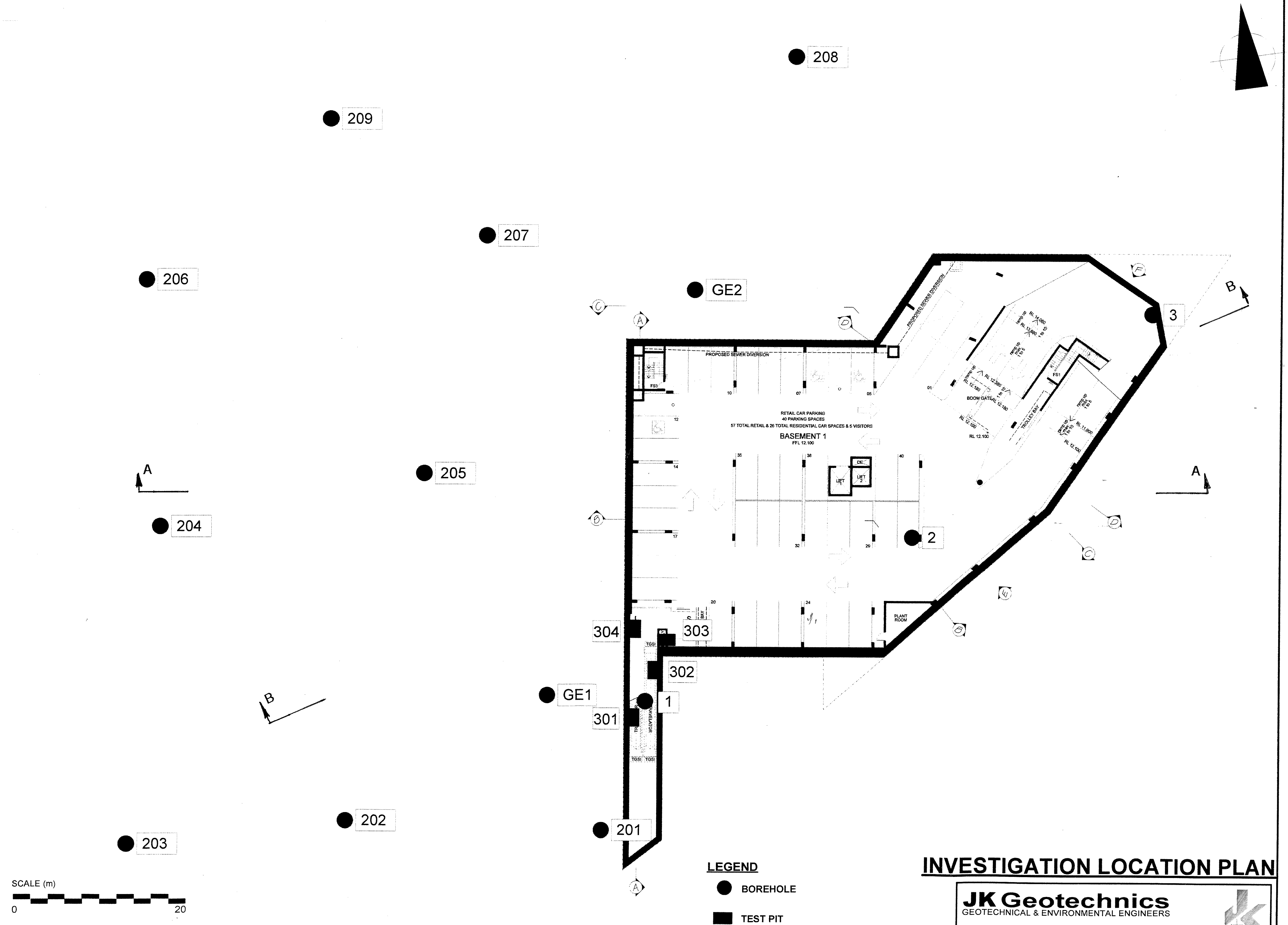
7 GENERAL COMMENTS

The recommendations presented in this report include specific issues to be addressed during the construction phase of the project. In the event that any of the construction phase recommendations presented in this report are not implemented, the general recommendations may become inapplicable and JK Geotechnics accept no responsibility whatsoever for the performance of the structure where recommendations are not implemented in full and properly tested, inspected and documented.

While all efforts have been made to check the validity of the predicted groundwater impacts numerical analysis inevitable adopts approximations to facilitate the analysis. In this regard, whilst results have been predicted to a high degree of accuracy this is to show relative differences that occur when assumptions are changed.

This report provides advice on geotechnical aspects for the proposed civil and structural design. As part of the documentation stage of this project, Contract Documents and Specifications may be prepared based on our report. However, there may be design features we are not aware of or have not commented on for a variety of reasons. The designers should satisfy themselves that all the necessary advice has been obtained. If required, we could be commissioned to review the geotechnical aspects of contract documents to confirm the intent of our recommendations has been correctly implemented.

This report has been prepared for the particular project described and no responsibility is accepted for the use of any part of this report in any other context or for any other purpose. If there is any change in the proposed development described in this report then all recommendations should be reviewed. Copyright in this report is the property of JK Geotechnics. We have used a degree of care, skill and diligence normally exercised by consulting engineers in similar circumstances and locality. No other warranty expressed or implied is made or intended. Subject to payment of all fees due for the investigation, the client alone shall have a licence to use this report. The report shall not be reproduced except in full.



INVESTIGATION LOCATION PLAN

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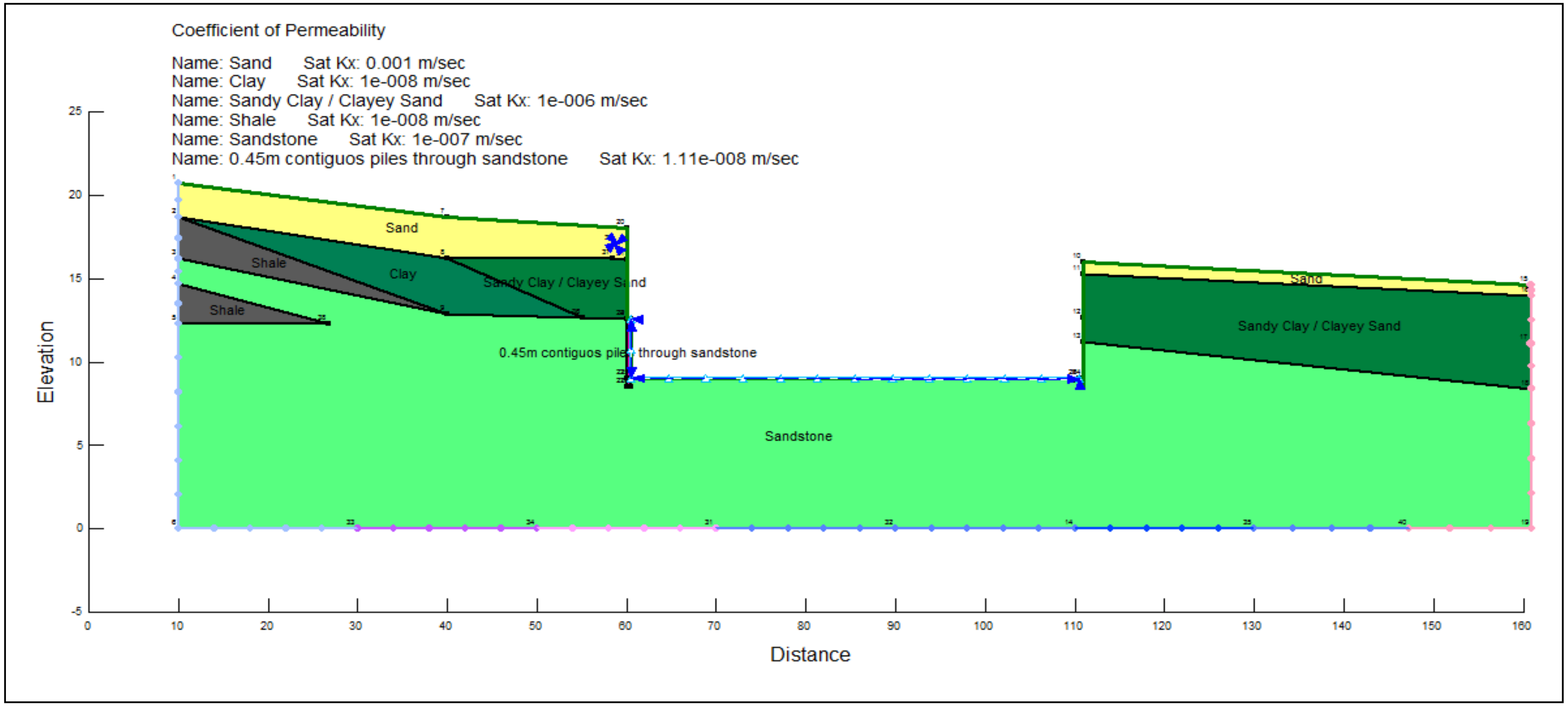
Figure No. 1



CROSS SECTION A-A

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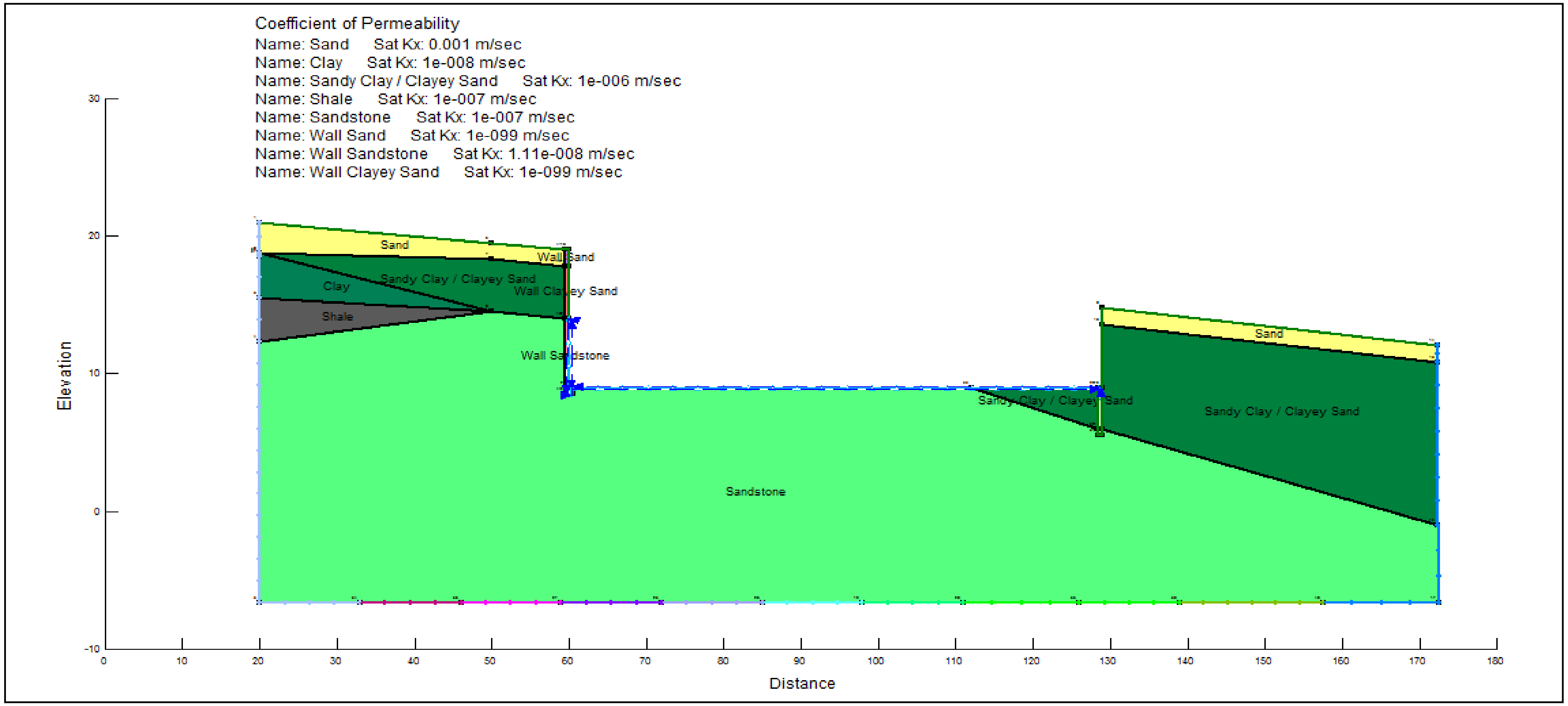
Report No. 22337SY Figure No. 2



CROSS SECTION B-B

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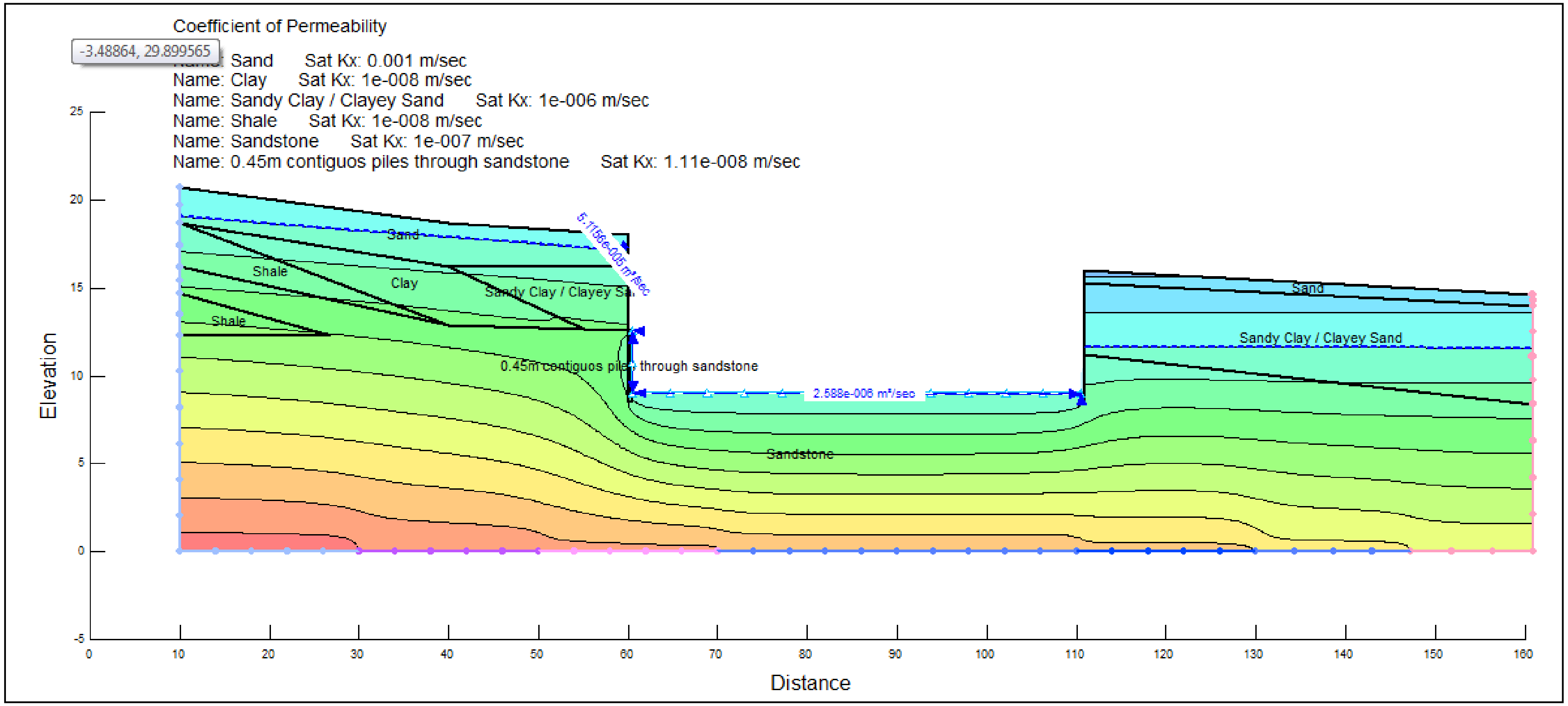
Report No. 22337SY Figure No. 3



CROSS SECTION A-A
GROUNDWATER PRESSURE HEADS

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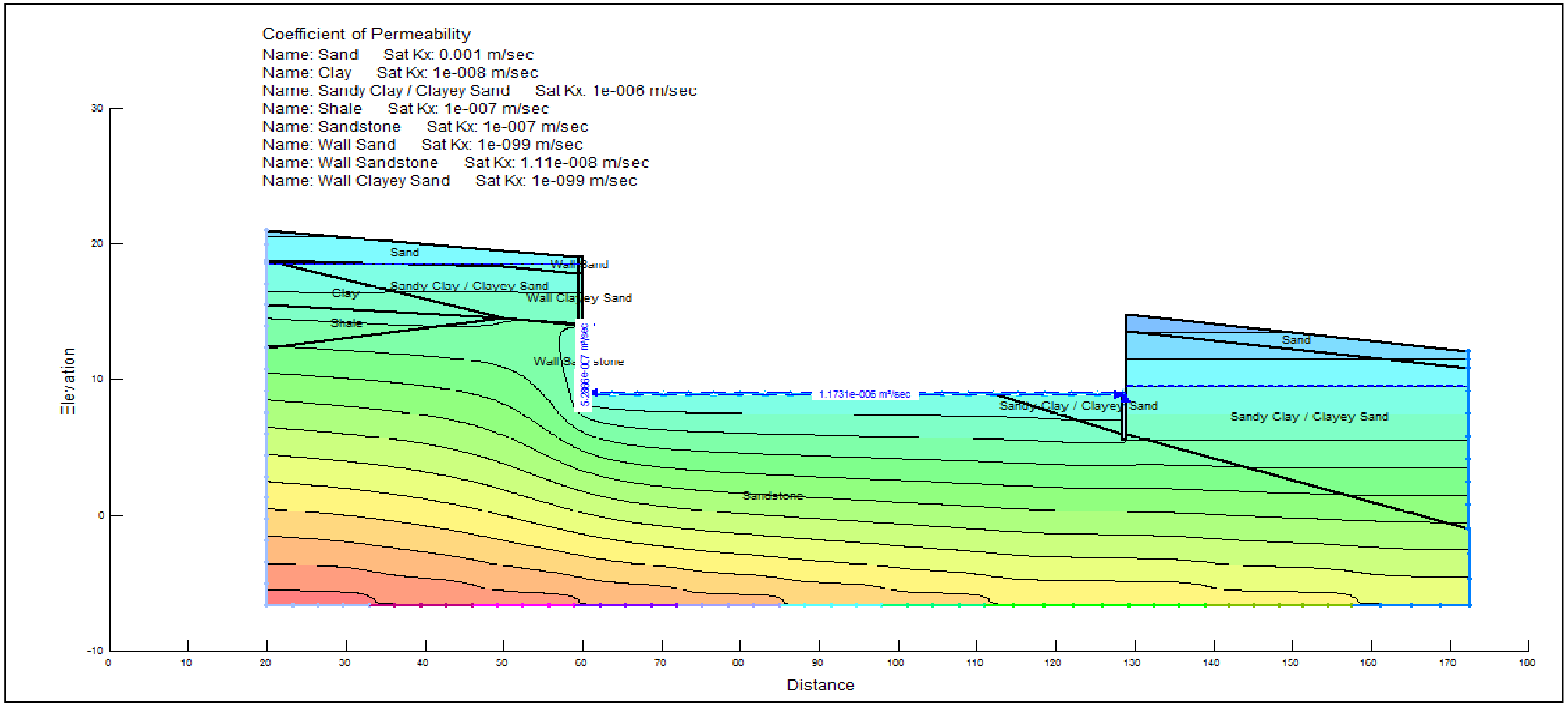
Figure No. 4



CROSS SECTION B-B
GROUNDWATER PRESSURE HEADS

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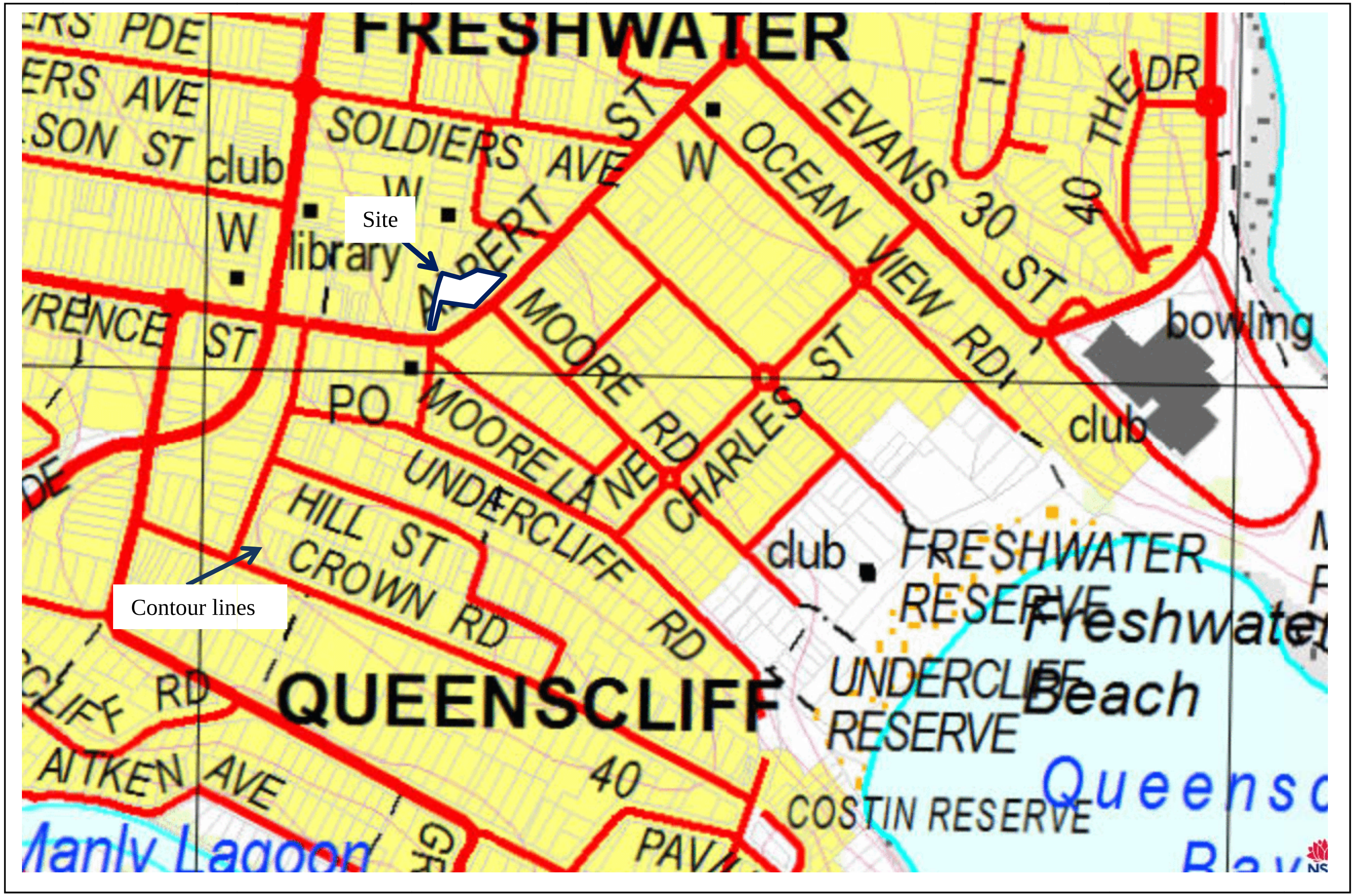
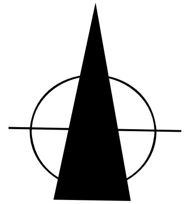
Report No. 22337SY Figure No. 5





LOCATION OF SITE WITHIN TOPOGRAPHY

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Figure No. 6