

EARTHWORKS FOR WATERSIDE GREEN, PENRITH, NSW, AUSTRALIA

Indra Jworchan, Tony O'Brien and Emged Rizkalla
Geotechnique Pty Ltd, Penrith, NSW

ABSTRACT

A residential and commercial subdivision, known as Waterside Green Development, in Penrith NSW, is situated in low-lying land affected by high groundwater table and the presence of saline and sodic soils. The subdivision comprises a commercial area, a residential area, internal roads and several lakes and laterals. The Development Control Plan (Penrith City Council, 2004) states that the drainage and stormwater management system across the site should be improved and future dwellings and roads should be constructed on ground higher than the 1 in 100 year flood level, without the necessity to import fill material. Therefore, earthworks for the subdivision comprised excavation of a series of lakes and laterals to improve drainage and stormwater management systems and use the materials gained from the excavations to construct fill platforms in order to raise ground levels above the 1 in 100 year flood level. This paper presents earthworks specifications and procedures for construction of fill platforms and clay liner.

1 INTRODUCTION

The residential and commercial subdivision, known as Waterside Green Development located at Penrith, NSW, Australia, contains a commercial area consisting of two to four storey commercial buildings and office blocks (16 ha), a residential area comprising 700 future dwellings and internal roads (40 ha), five lakes and several laterals (17 ha). Different components of the subdivision are shown in Figure 1.



Figure 1: Proposed Development Plan.

In order to comply with the Development Control Plan (Penrith City Council, 2004), the subdivision master plan proposes excavation of a series of lakes and laterals to improve the drainage and stormwater management systems and use materials gained from the excavation to raise ground levels above the 1 in 100 year flood level. Site works are estimated to involve movement of approximately 570,000 m³ of site material and importation of approximately 75,000 m³ of clay for lining the lakes and laterals. This paper describes soils encountered across the site and presents earthworks specifications and procedures for construction of fill platforms and clay liners.

2 SITE DESCRIPTION

The site is located at the corner of Cranebrook and Andrews Roads, Penrith, about 50 km west of Sydney CBD, and is approximately 73 ha in area. The general topography of the site is gently undulating with an overall slope of less than 4%, dipping from the east and the south towards the west and the north. Ground surface elevation across the site ranges from about RL 22.0 m AHD (Australian Height Datum) to about RL 25.0 m AHD. Natural drainage within the site is from the south east to the north and west. Poor drainage has resulted in surface water accumulation and in places the formation of swamps.

3 SUB-SURFACE PROFILES

The site is underlain by Wianamatta Group Shales of Middle Triassic Age overlain by alluvial deposits, consisting of gravel, sand, silt and clay, of variable thickness (Jones and Clark, 1987).

The sub-surface profiles across the site are generally assessed to be of two types, designated as the Clayey Profile, including Clayey Soil and Duplex Soil Groups and the Sandy Profile, comprising Sandy Soil Group (Young and Henderson, 2001). The approximate boundary between the two types of sub-surface profiles is shown in Figure 2 and detailed in Table 1.

Table 1: Types of Sub-surface Profiles.

Clayey Profile (Eastern Part)	
Soil Unit	Depth to Top of Unit (m)
Topsoil	0.0
Clay	0.1 – 0.3
Sand	2.5 – 10.5
Gravel	4.0 – 12.5
Shale	8.0 - 18.0

Sandy Profile (Western Side)	
Soil Unit	Depth to Top of Unit (m)
Topsoil	0.0
Sand	0.1 – 0.3
Gravel	2.0 – 5.4
Shale	11.0 - 16.0

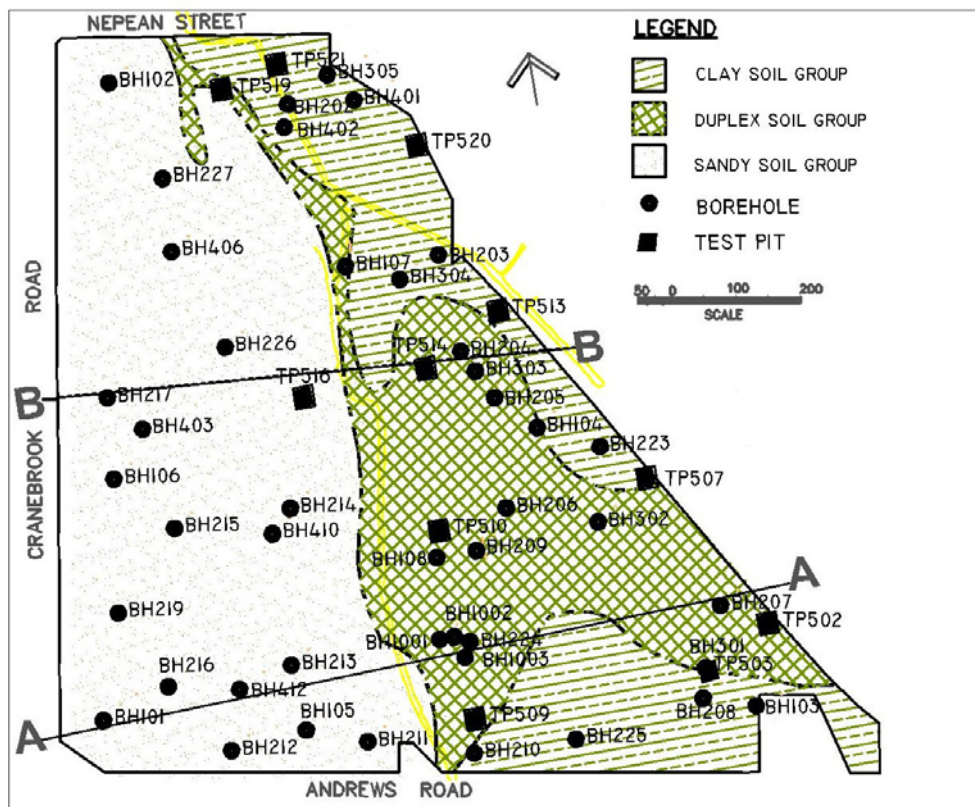


Figure 2: Types of Sub-surface Profiles.

The sandy profile in the western portion covers about 65% of the area. The clay, sand and gravel listed in Table 1 are alluvial deposits. A thin layer of residual clay was encountered between alluvium and bedrock within the clayey profile.

Depths to groundwater levels in the clayey profile range from 3.6 m-5.9 m, with approximate elevations of RL 19.0 m-20.0m AHD. In the sandy profile, the depths to groundwater range from 3.0 m-4.7 m, with elevations of about RL 18.5 m-20.5 m AHD (Geotechnique Pty Ltd, 2003).

4 SOIL PROPERTIES

The results of laboratory tests on representative alluvial soil samples are presented in Table 2.

Table 2: Soil Properties.

Soil Properties	Soils from Clayey Profile			Soils from Sandy Profile		
	Number	Maximum	Minimum	Number	Maximum	Minimum
Liquid Limit (%)	4	59	26	6	18	15
Plasticity Index (%)	4	40	15	6	5	0
Linear Shrinkage (%)	4	17	8	6	3	0.5
Maximum Dry Density (t/m ³)	14	2.19	1.50	13	2.04	1.92
Optimum Moisture Content (%)	14	24	9	13	12	8.5
California Bearing Ratio (%)	4	8	3	8	50	8
Emerson Class	5	Class 1	Class 2	6	Class 5	Class 5
Shrink/ Swell Index (%)	3	4.1	0.7	2	0.9	0.4
Percent Dispersion (%)	6	95	30	Not Tested		
Pinhole Dispersibility Class	8	PD2	ND1	8	D2	PD2
Permeability (10 ⁻⁹ m/s)	3	1.2	0.6	7	54.2	1.7
<i>In situ</i> Dry Density (t/m ³)	6	1.84	1.54	8	1.97	1.54
pH	17	8.7	4.9	8	6.4	5.1
Electrical Conductivity (mS/cm)	17	3.08	0.03	8	0.13	0.03
Exchangeable Sodium Percentage (meq%)	17	7.58	0.16	8	1.31	0.04
Sulphate (mg/kg)	9	740.0	90.0	5	280.0	5.0
Chloride (mg/kg)	9	1730.0	30.0	5	60.0	10.0
Resistivity (ohm-m)	9	100.9	1.8	5	160.5	71.7

Permeability tests were carried out on remoulded soil samples compacted to a Dry Density Ratio of 100% Standard at about Optimum Moisture Content.

Laboratory test results indicated the following:

- Soil from the Clayey Profile is generally medium to high plasticity clay, with potential for shrink/swell and slaking, dispersive to non-dispersive, firm to stiff, with California Bearing Ratio (CBR) values of 3% to 5%.
- Sand from the Sandy Profile is predominantly fine grained, potentially dispersive, loose to dense, with CBR values of 5% to 10%.
- Gravel from across the site is fine to coarse grained, rounded, dense to very dense, variably cemented in places.
- Soils from the Sandy Profile are generally non-saline (NSW Department of Land and Water Conservation, 2002). Soils from the Clayey Profile are generally slightly to highly saline. However, an exception was noted in the central portion of the clayey profile, where sub-surface soils to depths of about 1.5 m were non-saline, underlain by saline soils.
- Soils across the site were assessed to be non-aggressive to mildly aggressive towards iron/steel and concrete (Australian Standard, 1995).
- All saline soils were assessed to be sodic and most non-saline soils were assessed to be non sodic (NSW Department of Land and Water Conservation, 2002). However, sodic soils are present locally at shallower depths in the mid eastern portion of the site, where saline soils were encountered only at depths in excess of about 1.5 m.

5 MANAGEMENT OF SALINE AND SODIC SOILS

Saline soils are potentially hazardous for residential and commercial developments due to the many environmental, economic and social impacts. As soils in the eastern portion of the site are saline, environmental, economic and social impacts should be taken into consideration for the proposed residential and commercial development.

Soils in the eastern portion of the site are also sodic and dispersive and hence susceptible to erosion and piping. Therefore, earthworks for the proposed development should be carried out in accordance with an appropriate Soil Management Plan, which ensures protection from saline soils and stabilisation of dispersive soils. The basis for a Soil Management Plan is as follows.

- Dispersive soils in fill should not be exposed to water in lakes, laterals and drainage channels.
- Appropriate erosion and sediment control plans must be developed and implemented.
- Construction activities should not affect the natural flow of groundwater.
- Proposed structures are protected from saline soils and/or construction materials, and techniques suitable for a saline environment are used.

The Soil Management Plan to deal with saline and sodic soils at the site includes the following:

Lake Construction Sodic and saline soils excavated for construction of lakes and laterals are to be deposited in commercial areas and covered with a minimum of 1.0 m of non-saline, sandy capping soil. Non-saline and non-sodic clay is to be imported for use as clay liners for lakes.

Residential Areas In areas where saline soils are encountered, a minimum of 2.0 m of non-saline sandy capping soil should be provided. If proposed structures for the subdivision, including footings, building slabs, road and car park pavements, underground services etc., are to be located within 2.0 m of saline soils, construction methods and materials should be appropriate for moderately aggressive site conditions.

Commercial Areas Sodic and saline soils deposited in commercial areas should be covered with a minimum of 1.0 m of non-saline, sandy capping soils. If saline soils are to be used in fill within 1.0 m of finished building platform level, the saline soils should be encapsulated with an impermeable geomembrane.

6 SUITABILITY OF ON SITE SOILS FOR USE IN STRUCTURAL FILL

Soils obtained from excavations for the proposed lakes and laterals consist of topsoil and alluvial deposits, comprising clay, sand and gravel. Topsoil, predominantly comprising silt and sandy silt, is very difficult to compact to a state that will attain an acceptable strength (bearing capacity) and resist deformation (settlement). Furthermore, compaction of silty topsoil is very sensitive to moisture content. At higher than optimum moisture content and under the influence of vibration or traffic loading, silty topsoil could liquefy. Silty topsoil is also susceptible to surface and internal erosion (piping). Therefore, topsoil as it exists is unsuitable for use in structural fill. However, if the upper 100 mm to 200 mm thick layer of topsoil containing organic materials is stripped, the remaining portion of topsoil may be used as part of structural fill, as follows:

- Topsoil can be left where it is if the thickness of structural fill above the topsoil is more than 500 mm. If thickness of structural fill above the topsoil is less than 500 mm, the topsoil should be excavated partly or entirely and replaced with structural fill, so that there is at least 500 mm of structural fill above the topsoil.
- Topsoil may be blended with alluvial clay and sand available at the site, for use in structural fill, provided the proportion of topsoil in the blended fill does not exceed about 30% of total fill volume and the fill placement method does not allow formation of pockets and layers of topsoil within the blended fill.
- Topsoil blended fill should be used in structural fill above the groundwater table only, but is not suitable as subgrade for pavements and/or building slabs.
- Topsoil in the fill is not exposed to water. It is recommended that clayey alluvium (without topsoil) should be used in those parts of fill likely to be exposed to water, such as lakes and drainage channels.

Alluvium deposits, including clay, sand and gravel, are assessed to be suitable for use in structural fill.

7 SUITABILITY OF ON SITE SOILS FOR USE IN IMPERMEABLE LINING

The proposed lakes and laterals are up to about 5.0 m deep. Lake and lateral excavations expose clay, sand and gravel at the base and sides (shores), depending on locations and depths. Sand and gravel are widespread and relatively impermeable clayey alluvium will be encountered only in the eastern portion of the site.

At completion of development works, water levels in the lakes and laterals will be higher than groundwater levels across the site. Therefore, unless the base and shores of lakes and laterals in sand and gravel are provided with impermeable liners, water loss is likely to be considerable. The following lining options were considered (1) Clay lining, (2) Geo-membrane lining, (3) Geo-synthetic clay liner and (4) Soil Cement lining.

Based on cost and ease of construction, clay lining was the preferred option. Clay with the following properties is suitable for use as impermeable clay liners.

- Permeability = 1.0×10^{-7} m/s - 1×10^{-9} m/s.
- Particle size = Percent passing 0.075 mm \geq 50%.
- Plasticity = Low to medium
- Dispersion = Non-dispersive
- Salinity = Non-saline

Alluvial clay obtained from excavations within the site satisfies the requirements on particle size, plasticity and permeability, but does not satisfy requirements on dispersion and salinity. Dispersive clay available at the site transforms into practically non-dispersive clay, percent dispersion of about 15%, when mixed with 3% hydrated lime or gypsum. Thus, clay available at the site may be used as impervious clay liner when stabilised with 3% lime and/or gypsum. However, the use of lime/gypsum was not permitted under the development consent as it could adversely affect the salinity of the site (Penrith City Council, 2004). Therefore, clay obtained from within the site could not be used in impermeable lake and lateral liners. Site investigation and laboratory tests were carried out to identify Agnes Banks Quarry, about 20 km north of the site, as the source of clay for use in lake and lateral liners.

8 EARTHWORK METHODS

Ground level for building platforms at the proposed residential and commercial areas is to be raised above the 1 in 100 years flood level, by placing up to 5.0 m thick structural fill. Where structural fill placement is required, the bearing capacity and settlement characteristic of the site should be improved by first providing drainage (by regrading and/or construction of temporary and permanent drainage structures). Placement of structural fill was carried out as follows.

- Strip top 100 mm to 200 mm of topsoil containing organic matter. The remaining portion of topsoil was left as it was or removed and replaced.
- Undertake proof rolling of the exposed clay/sand to detect potentially weak spots. Excavate areas of localised heaving to a depth of about 300mm and replace with granular fill, compacted as described below.
- Undertake proof rolling of soft spots backfilled with granular fill, as described above. If the backfilled area shows movement during proof rolling, the subgrade should be removed to an additional depth of 300 mm.
- Place fill in horizontal layers of 200 mm to 300 mm loose thickness and compact to achieve a Minimum Dry Density Ratio (MDDR) of 95% Standard, at moisture content within 2% of Optimum Moisture Content (OMC) or Minimum Density Index (MDI) of 65% in residential areas. In commercial areas, MDDR of 98% Standard or MDI of 70% should be achieved. Fill comprises alluvium, including clay, sand and gravel, obtained from lake and lateral excavations. Topsoil mixed with alluvium was also used locally. The sizes and depths of lakes and laterals were designed in such a way that the volume of soils obtained from excavations is equal to the volume of structural fill.

Clay available at the site was not suitable for use in lake and lateral liners and so suitable clay was imported. Construction of lake and lateral liners was carried out as follows.

- Lower groundwater level at least 300 mm below base of lakes and laterals. Groundwater modelling was carried out to determine an appropriate pumping system, including locations, number and capacity of pumps (Robert Carr & Associates Pty Ltd, 2003).
- Excavate lakes and laterals to design geometry. Lake and lateral shores were designed to have slopes of 1 vertical to 4 horizontal from base to design water level and 1 vertical to 8 horizontal from design water level to finished ground surface.
- Proof roll exposed surfaces. During construction stage, the slopes of shorelines were flatter than the design slope of 1 vertical to 4 horizontal in order to ease proof rolling and compaction.
- Place imported suitable clay in horizontal layers of 200mm-300 mm loose thickness and compact to achieve MDDR of 98% Standard at moisture content within -1% to +2% of OMC. Groundwater modelling was carried out to determine the thickness of clay liners, to be in the range of 400 mm-600 mm (Robert Carr & Associates Pty Ltd, 2003).
- Cover surface of clay liner with shrubs and riprap to protect from wave action and creatures.
- Place up to about 1.5 m thick sandy soils on liners at the base of lakes and laterals to act as surcharge to prevent base heave when lakes and laterals are to be drained for maintenance purposes.

A shallow lake was excavated and lined first. Groundwater from dewatering during excavation of the first lake was partly stored in a temporary detention basin and partly sprayed across the site for infiltration into the ground. The first lake was used as storage for groundwater during excavation of the second lake and the second lake was used to store groundwater from the third lake and so on, to ensure that outflow of surface water from the site during construction was

not more than normal flow (Robert Carr & Associates Pty Ltd, 2003). Two or more previously excavated lakes were used to store water while excavating large lakes.

9 CONCLUSIONS

An engineering/geotechnical study was conducted for a proposed residential/commercial development in Penrith, Sydney. The study was to determine characteristics of soils across the site and assess the suitability of these soils for re-use as engineered fill and impermeable clay liners for lakes and laterals.

The study revealed (1) relatively saline and dispersive soils cover about 35% of the site, mainly in the eastern portion, (2) topsoil can be used as part of engineering fill after special treatment, (3) sandy and clayey alluvial soils are suitable for use as engineering fill (4) clayey soils are not suitable for use as impermeable lake and lateral liners (5) suitable clay for use in lake and lateral liners should be imported and (6) earthworks for the proposed development should be in accordance with an appropriate Soil Management Plan that deals with saline, sodic and dispersive soils.

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