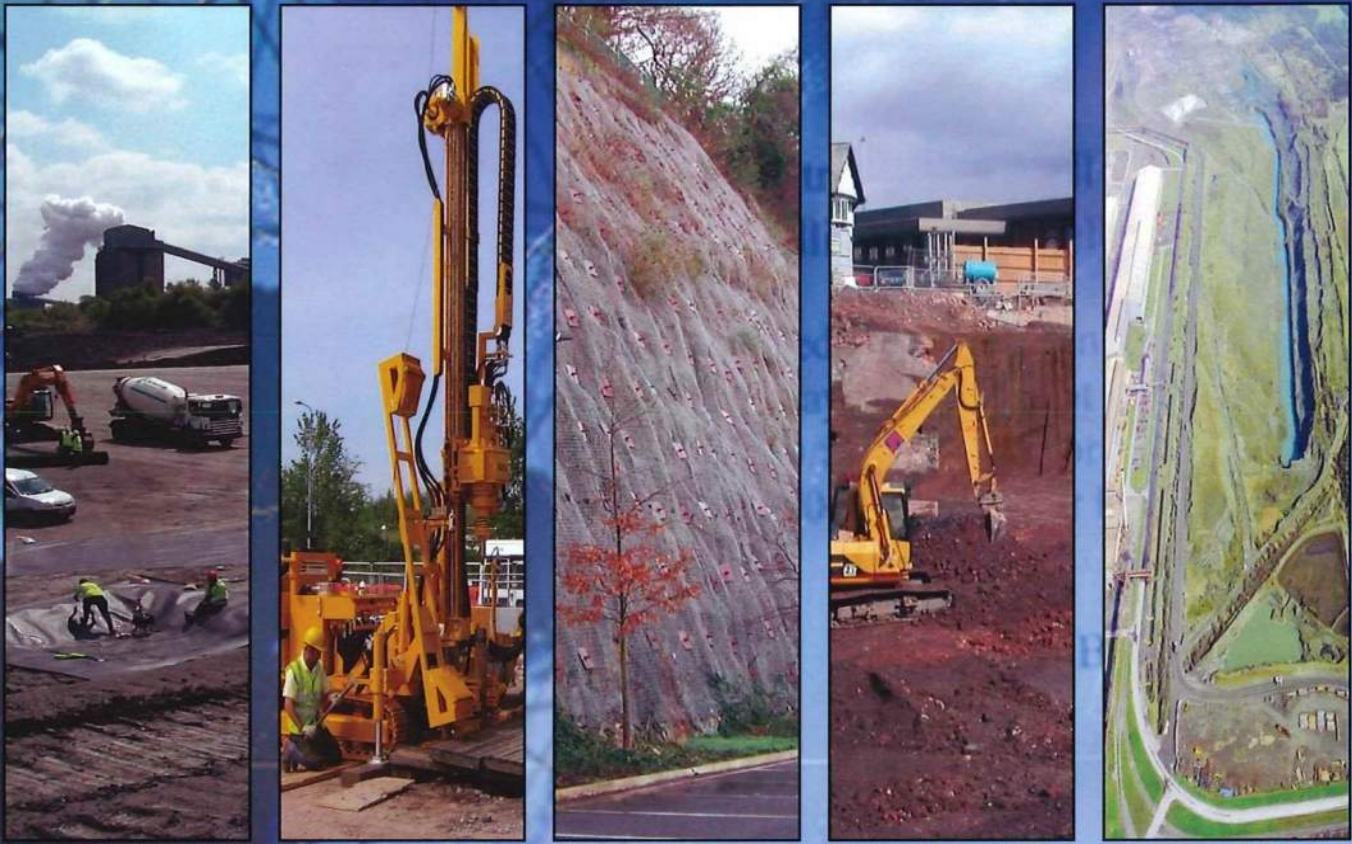

September 2019
Report No 10312-R04

GROUNDWATER PROTECTION AND HYDROGEOLOGICAL IMPACTS

WATLINGTON QUARRY- OAK FIELD

Prepared for

Mick George Limited

GROUNDWATER PROTECTION AND HYDROGEOLOGICAL IMPACTS

WATLINGTON QUARRY- OAK FIELD

September 2019

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1. INTRODUCTION

1.1 Background

This report prepared by TerraConsult Ltd on behalf of Mick George Limited presents a hydrogeological and water quality impact assessment of the potential impacts of the proposed Oak Field extraction to Watlington Quarry.

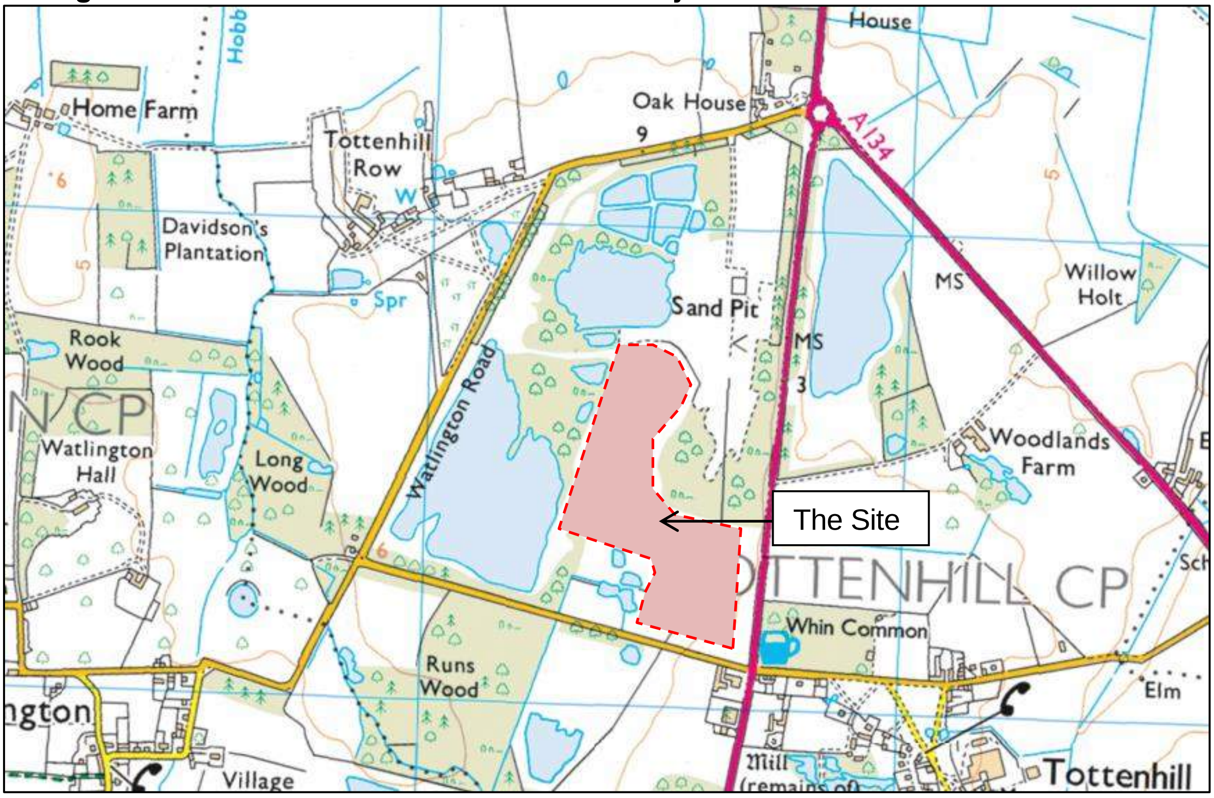
Mick George are proposing to excavate and remove an estimated 748,000 tonnes of sands, gravels and 300,000 tonnes of clay on the land identified in Figure 1 (MIN206). The site will require the importation of inert material in order to restore the site back to appropriate levels upon completion of the quarrying operations. It is expected that some 800,000 m^3 of material will be required to restore the site to a level that approximates with existing ground level.

This assessment is designed to consider the impact of the quarrying, dewatering and restoration of the extraction area with inert materials on the environment and surrounding land use. It will also consider the wider impacts on the surrounding surface water features and the regional Principal Aquifer of the Sandringham Sands to the east. The impact on water quality from the proposed operations has also been taken into account. If imported inert wastes are utilised in the restoration the requirement and specification for any pollution prevention measures will be confirmed in a future Environmental Permit application.

1.2 Site Location and History

The proposed site (hereinafter known as "the site") for the Watlington Quarry extension is 10.5 hectares, located at Watlington Quarry, between Tottenhill Row and Woodlands Farm. The site is situated approximately 6.4km to the south of King's Lynn in Norfolk at National Grid Reference TF 634 115 (Figure 1). The land is classified as Grade 3 in the Agricultural Land Classification scheme.

Figure 1 Location of Extraction Area and Adjacent Features



The site is adjacent to a previously quarried site, now a pond and the current extraction area MIN76 which are both located to the west of the site. Ponds and silt lagoons around the perimeter of the site are the restored legacy from these on-going processes and are being used as an integral component of the sand and gravel process. The current processing plant will be used which is to the north of the site.

1.3 The Development Proposal

The site is situated to the south of the main Watlington Quarry site and to the east of the current operations in the MIN76 area. The site will operate following the completion of extraction from the MIN76 area towards the end of 2020 and working of the site is not expected to start until 2021.

2. ENVIRONMENTAL SETTING

2.1 Topography

The Kimmeridge Clay acts as a natural geological barrier which is not water bearing, nor does it allow the transmission of groundwater. Consequently groundwater is only present within the Tottenhill Gravels, where it is present as a shallow (*i.e.* thin) saturated horizon immediately above the Kimmeridge Clay surface, and may be best described as a veneer of groundwater, rather than as a significant quantity of groundwater.

Watlington and the surrounding area is formed by a rise in topography towards the south above a historically reclaimed fenland where the ground rises from approximately 2mAOD up to 12mAOD. This rise is formed by the presence of the Sandringham Sands and Chalk outcrops which were not previously eroded by the fluvioglacial network which deposited the

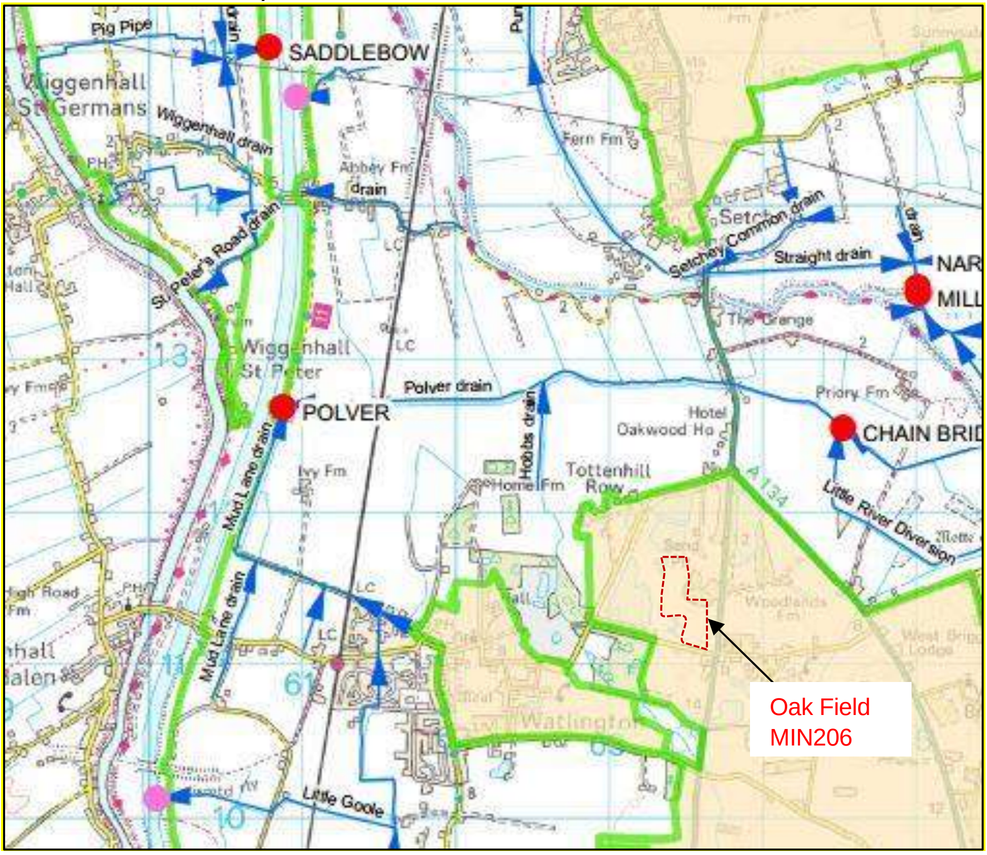
Tottenhill Gravels. The site area itself is at 10.9-8.2AOD in the north and central sections and then falls towards the south of the site to 7.5-8.5AOD with the exception of the south-east corner which rises again form 9.0-10.8AOD.

2.2 Hydrology

The site is located 1.4km south of the River Nar within the River Nar valley, an area of low lying drained land at an elevation of 2 to 3m AOD. The surface water features and groundwater elevation are controlled by the artificial drainage channels which all ultimately drain to the Polver Drain, via Hobbs Drain to the north. The site itself and the low lying area surrounding the site and around the ridge falls within the Inland Drainage Board (IDB) area of the East of Ouse, Polver and Nar IDB, as shown on Figure 2.

Hobb's Drain, located approximately 400m northwest of the site and drains a substantial catchment to the west of the site and is set in a shallow valley. Hobb's Drain flows northwards to join the Polver Drain which, in turn, flows eastwards to join with the River Great Ouse.

Figure 2 East of Ouse, Polver and Nar IDB District Plan



Green Line - IDB Drainage Board area boundaries

2.3 Geology

The geology at the site is based on BGS GeoIndex, BGS (1995) and RMC (1991) site investigations. The geological sequence in the vicinity of the site comprises

Superficial Sediments

- Alluvium (within the former fenland areas)
- Tottenhill Gravel Member
- Nar Valley Clay and Nar Valley Freshwater Beds

Bedrock

- Kimmeridge Clay

The site's geology comprises Tottenhill Gravels overlying Kimmeridge Clay (Drawing 10312-001-01 and 10312-002-01). There is alluvium to the west of the site near the Spring Pit. To the south and east of the site, the Tottenhill Gravels and Nar Valley Deposits give way to Diamicton (Glacial Till) to the south and the Sandringham Sand Formation in the east.

The Tottenhill Gravels as well as the underlying Kimmeridge Clay comprise the mineral formations to be quarried, the extracted clay will be used to supply local flood defence networks, lining of lagoons and capping of landfill sites. The British Geological Survey describes the Tottenhill Gravel Member as a complex sequence of sands and gravels, dominated by flint. In the Tottenhill area, the Tottenhill Gravel Member unconformably overlies silts and clays of the Nar Valley Clay and the Nar Valley Freshwater Beds.

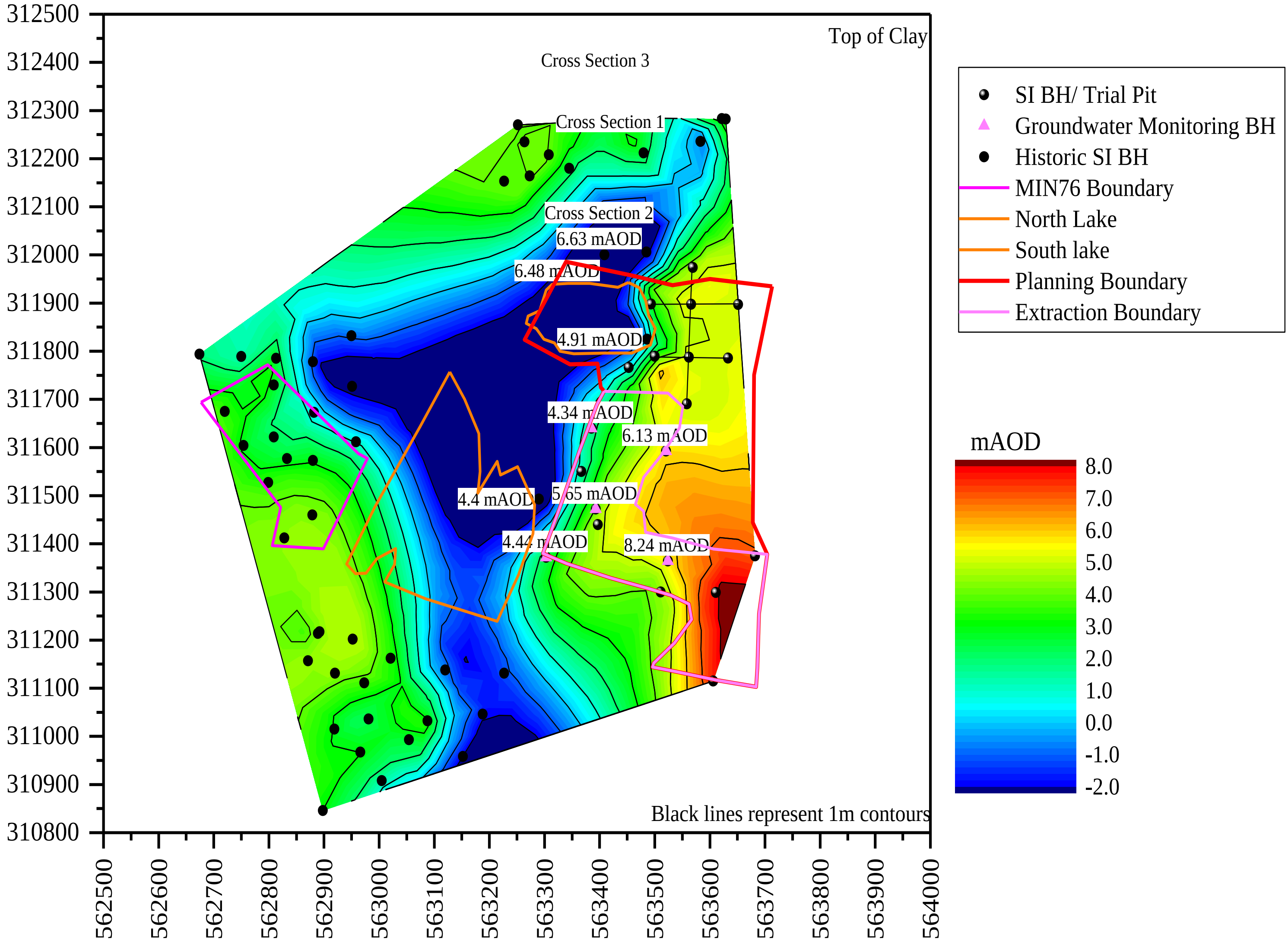
There is a sharp lithological change between the Tottenhill Gravels and the Nar Valley Formations. These comprise a succession of fluvio and marine deposits including salt marsh, peat, clay, silt and sand deposits. The Nar Valley Clay and Nar Valley Freshwater Beds are encountered sporadically across the site, but have not been identified at the extension area.

There is an equally sharp lithological change between the Tottenhill Gravels and the Kimmeridge Clay Formation. The Kimmeridge Clay Formation comprises dark brown-grey to black, organic rich, fissile mudstone with occasional hard, thin carbonate-cemented horizons.

There is a regional south easterly dip in the bedrock in which the surface of the Kimmeridge Clay would be expected to outcrop at approximately 10mAOD; however, the surface of the Kimmeridge Clay has been modified by fluvial erosion and the deposition of the Tottenhill Gravels. However, the Kimmeridge Clay does outcrop above the fenland in the order of 3 - 5mAOD.

Due to its long history as a sand and gravel resource Watlington Quarry has been subjected to extensive ground investigation in the past. The information these investigation have provided has been collated and the surface of the Kimmerage Clay has been interpolated (Figure 3). This clearly shows a fluvio-galcial channel incised into the clay surface in the area of the quarry.

Figure 3 Interpolated Kimmeridge Clay Surface within the Application Area



Site investigations have identified a rise in the Kimmeridge clay surface in the south east corner of the proposed excavation site. Adjacent to the valley feature resulting from fluvio-glacial processes immediately to the west of the site. The elevated clay surface is potentially home to a localised depression which gives rise to deeper depth of saturated mineral and higher groundwater levels as water is channelled down to the valley feature. These depressions in the surface of the Kimmeridge Clay are associated with localised thickening of the superficial deposits and may require groundwater management and dewatering as depths reach 2m in the south-easterly area around BH1.

Figure 4 Depth of Saturated Zone March 2017

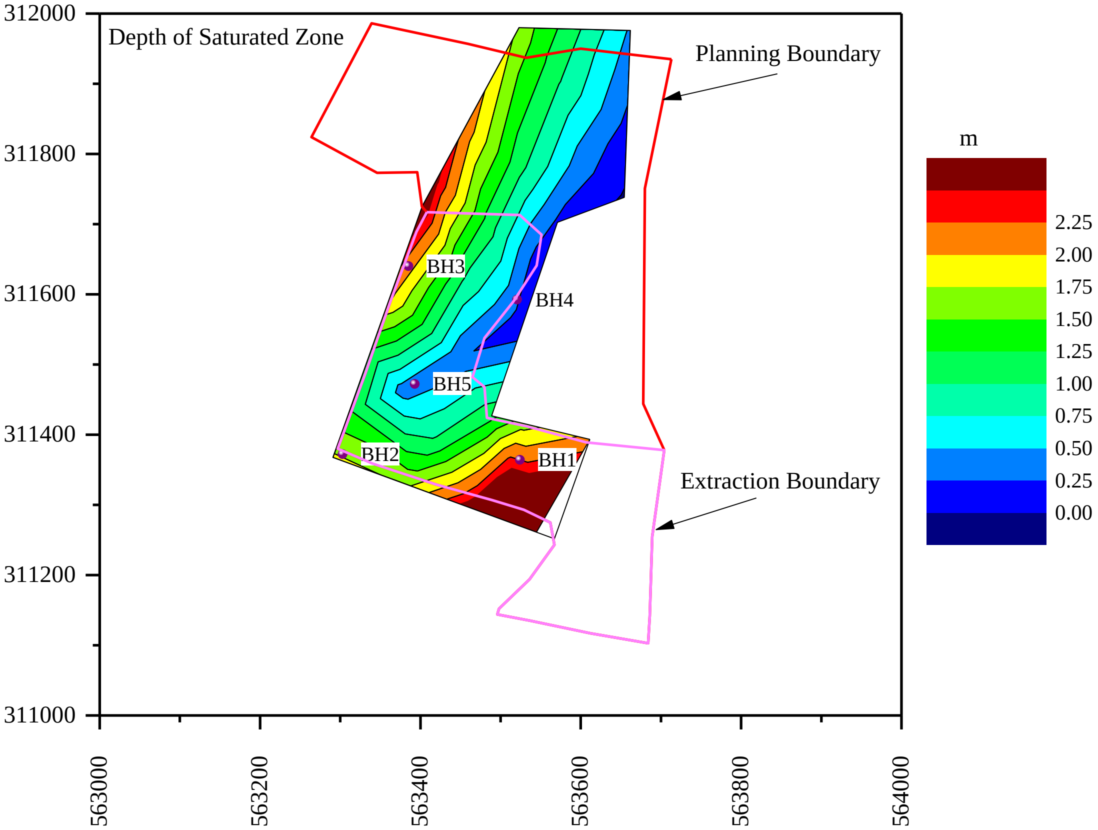


Figure 5 Depth of Saturated Zone July 2017

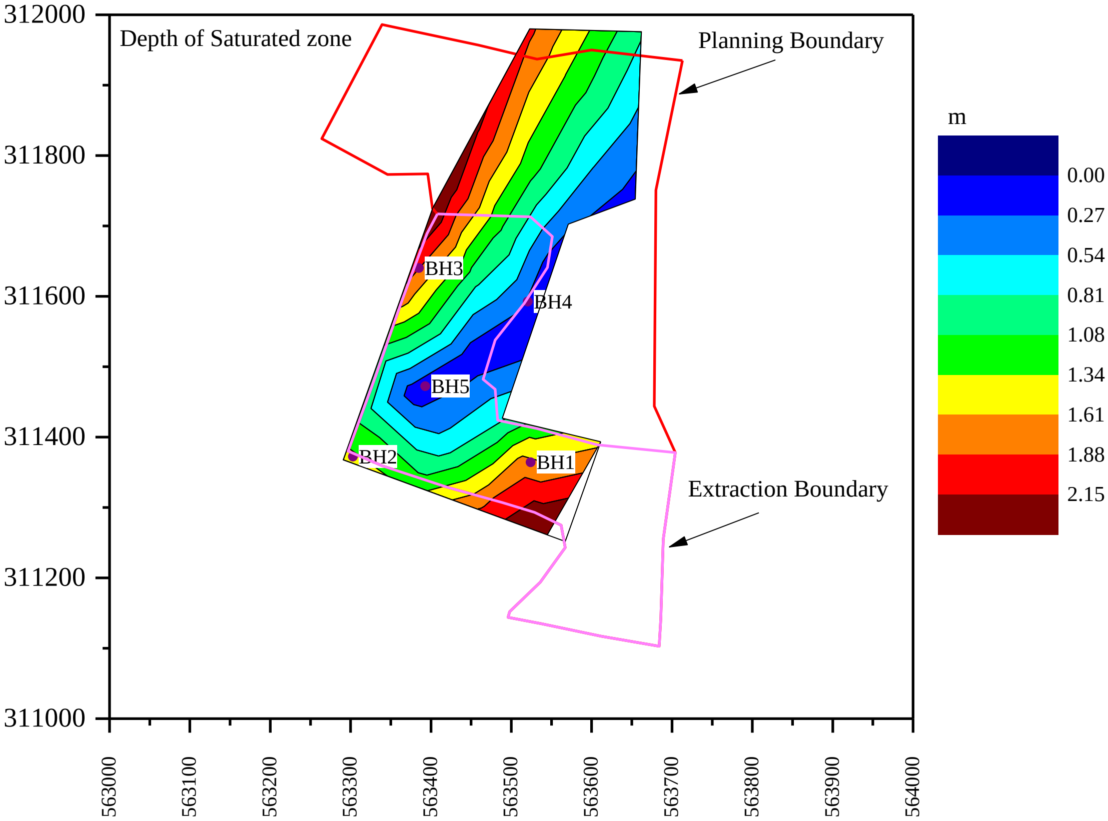
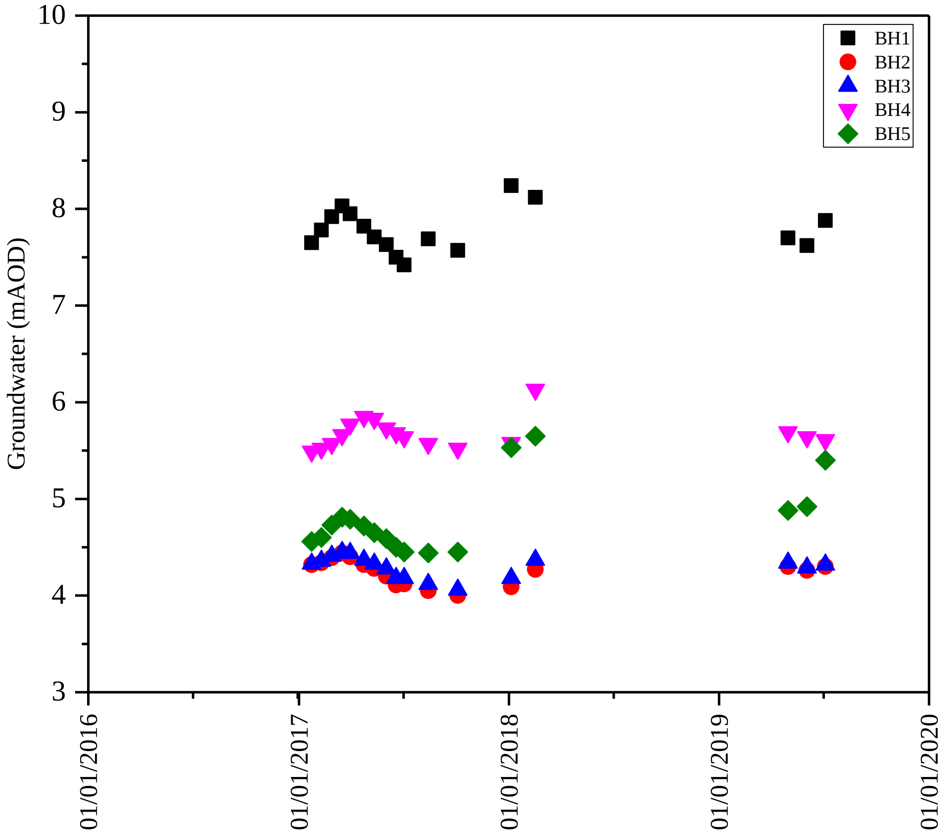


Figure 6 Groundwater levels mAOD



There is a small amount seasonal variation in groundwater levels, in the range of 50cm or so, as shown by Figure 6, with the highest groundwater levels in March as would be expected after winter recharge of groundwater. BH1 has the highest groundwater levels and is located where the clay surface is higher. Data for the depth of saturated zone was taken in March and July of 2017 as these were the annual minimum and maximum of groundwater level. The seasonal variations in depth of saturated zone (Figure 4 and Figure 5) are also minor as these are directly influenced by the top of the Kimmeridge clay surface so groundwater is confined to the sands and gravels above.

2.4 Regional Hydrogeology

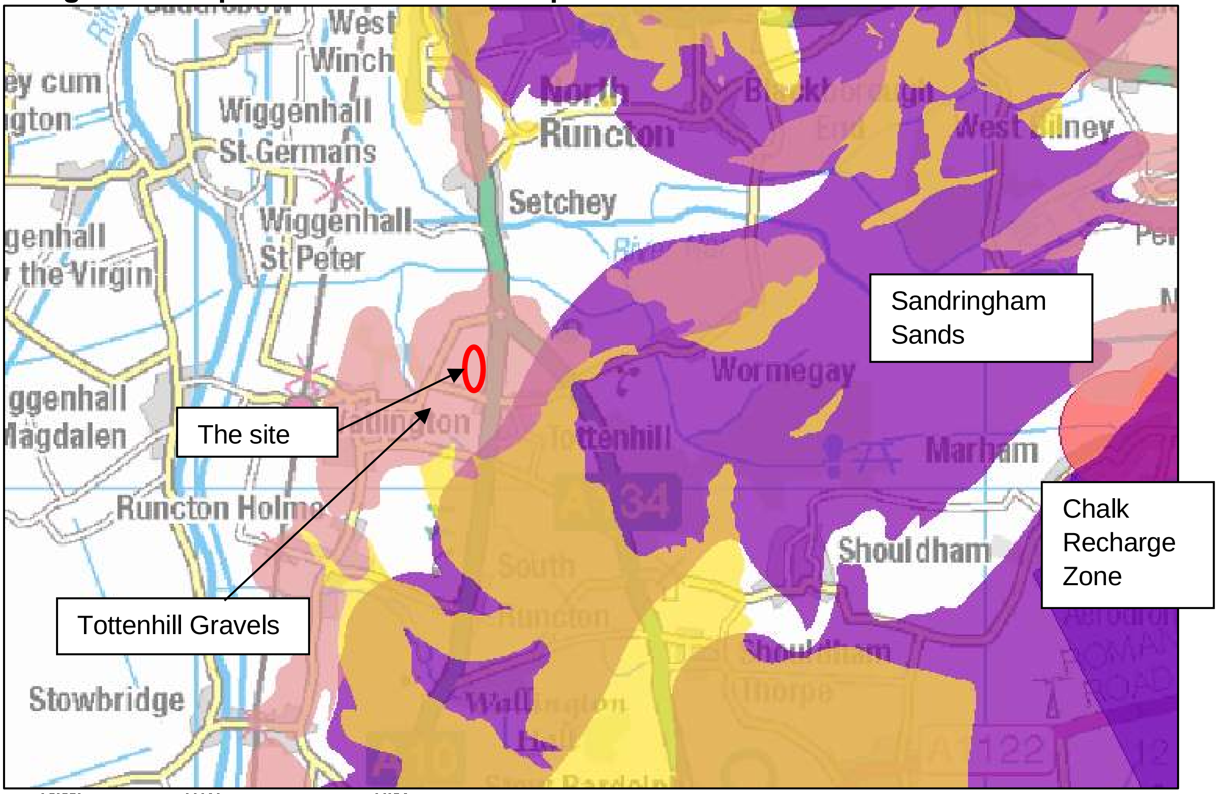
The Kimmeridge Clay and the Nar Valley sediments to the north of the site are classified as Unproductive Strata.

The Tottenhill Gravels and the Sandringham Sands Formation are classified as Secondary A and Principal Aquifers respectively (Figure 7). The site is not located within a source protection zone (SPZ), the closest of which is associated with the West Melbury Marly chalk abstraction some 8.8km to the east at Narborough. These abstraction points are physically and hydrogeologically separate from the gravel deposits (Figure 8).

Groundwater discharges to a series of spring lines where the Kimmeridge Clay surface outcrops at the surface, such as the spring at Spring Pit close to Tottenhill Row. This spring discharges via a series of ponds and ditches to Hobbs Drain.

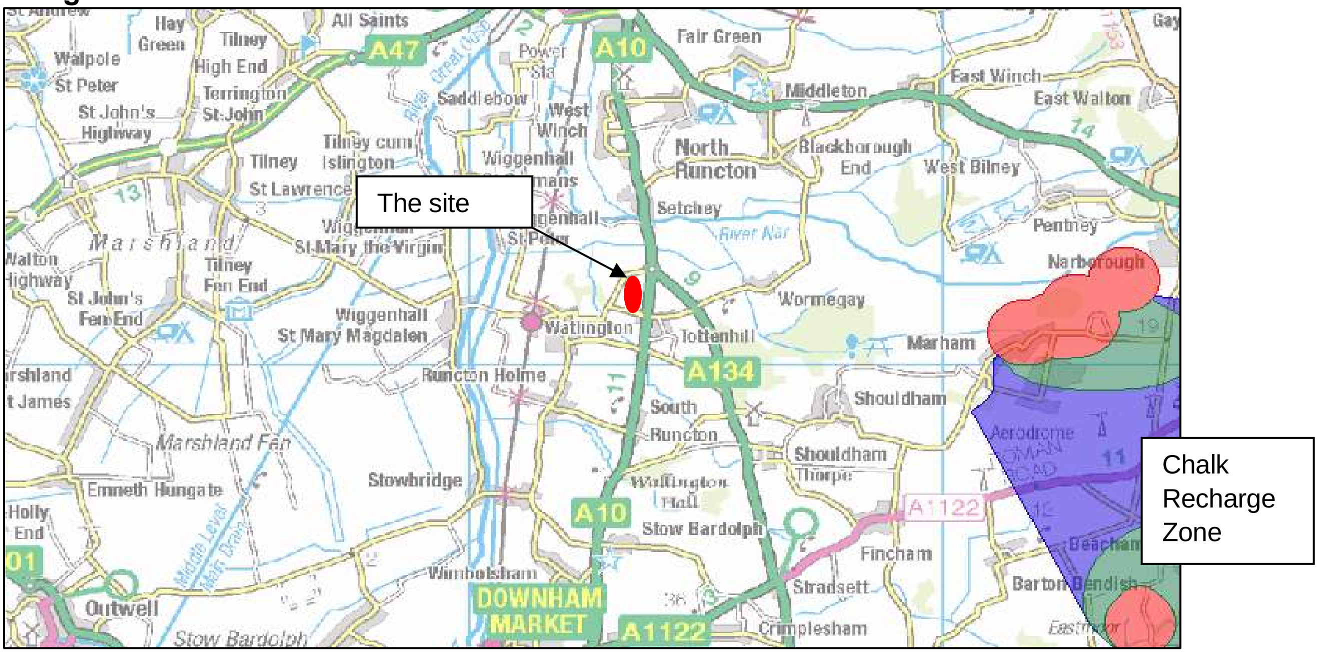
Groundwater within the Nar Valley Formation and Alluvium is within the fenland area, where the water level is artificially managed to near ground level.

Figure 7 Superficial and Bedrock Aquifer Status



Key: Principal Secondary A Secondary B Secondary (undifferentiated) Unproductive

Figure 8 Groundwater Source Protection Zones

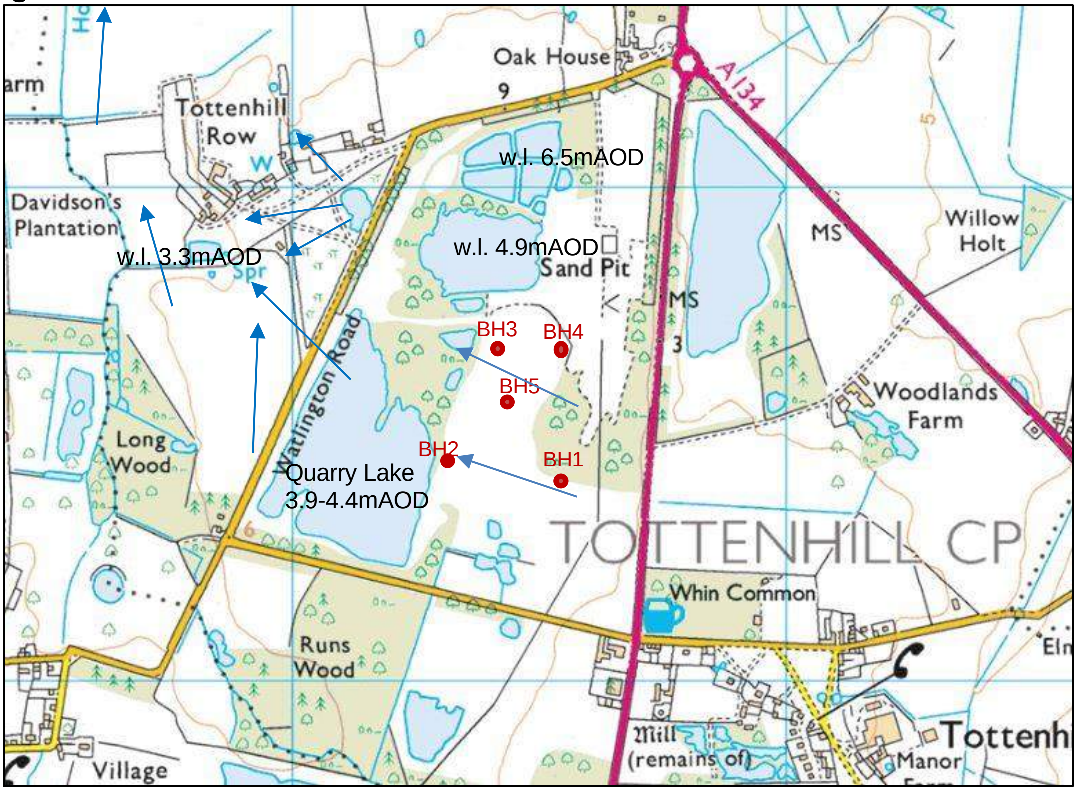


Inner zone (Zone 1) Outer zone (Zone 2) Total catchment (Zone 3)

2.5 Site Hydrogeology

The site hydrogeology is controlled by topography, the Kimmeridge Clay surface and artificial ponds associated with quarrying activities with recharge directly to the site and from the south/southeast. There is a hydraulic gradient from southeast to northwest, towards Spring Pit and possibly to the North of Oak House (Figure 6 and Figure 9). Locally the groundwater flow is controlled by the elevation and shape of the Kimmerage Clay.

Figure 9 Groundwater Flow Direction and Surface Pond Elevation



For the natural and unbunded ponds the water level will come to an equilibrium in continuity with the surrounding groundwater system in the Tottenhill Gravels. This can be seen with the quarry lake level being very similar to the groundwater levels in borehole BH2, which is adjacent to the quarry lake.

Although the overall groundwater flow across the site is from the south/southeast to the north/northwest, there may be some localised variations due to the presence of small localised depressions within the surface of the Kimmeridge Clay. Borehole BH1 shows a greater saturated thickness than BH4 or BH5 (Figure 4 and 5), suggesting groundwater flow does not move directly from BH1 to either BH4 or BH5, but potentially more towards the west or southwest first, then back in line with the general groundwater flow for the area.

The excavation itself will not affect the groundwater levels or flow. However if any dewatering is required then, without any mitigation, groundwater levels and flow are expected to be changed, especially to the west and northwest of the proposed working area. Water levels in the adjacent pond to the west of the proposed excavation at 3.9-4.4mAOD are consistent with the groundwater levels within borehole BH2, showing that the pond is most likely in continuity with the groundwater.

Groundwater recharge around the south-eastern and southern sides of the proposed excavation can therefore be readily intercepted to prevent it entering the excavations into the

Tottenhill Sands. This water would then be diverted around the existing lagoons as per the current practices without any significant change to the flow patterns thereby maintaining the same recharge to any down-gradient springs and ponds.

2.5.1 Groundwater Quality and Potential Impacts from Works

The groundwater in the Tottenhill Sands under the proposed excavation is a calcium bicarbonate solution with secondary calcium sulphate, consistent with expectations for the site setting and host geology (Table 1). Heavy metals and metalloids are negligible and typically below detection limits. Concentrations are below both Drinking Water and Environmental Quality Standards.

There is only one substance in excess of EQS and DWS, namely the agricultural fertilizer ammonium, which can be derived from both manure and artificial additions.

The mineral extraction process is not expected to discernibly change groundwater quality as the only component in the groundwater is the clay and silt fraction of the host geology through which the groundwater is already in equilibrium with. Given that the clay and silts are already derived from the host ground, then any suspended solids returned to the ground will not affect groundwater quality.

In the event that groundwater management is required, any significant impact is limited to the west and northwest of the site in the zone where the base of the Kimmeridge Clay is depressed (Figure 3)

Table 1 Groundwater Quality (May 2019)

		BH 1	BH 2	BH 3	BH 4	BH 5
pH		8.3	7.8	Dry at 4.34mAOD	7.5	8.0
Electrical Conductivity	µS/cm	540	730		530	700
Ammoniacal-N	mg/l	4.4	4.0		4.0	15
Calcium	mg/l	100	110		75	89
Magnesium	mg/l	5	5		3	6
Sodium	mg/l	15	16		13	19
Potassium	mg/l	3	3		3	9
Chloride	mg/l	9	47		10	23
Sulphate	mg/l	34	76		49	61
Alkalinity	mg/l	200	120		130	350
Iron	µg/l	130	110		94	140
Manganese	µg/l	<1	3		4	7
Zinc	µg/l	<1	3		<1	<1
Cadmium	µg/l	<0.08	<0.08		<0.08	<0.08
Chromium	µg/l	<1	<1		<1	<1
Copper	µg/l	4	3		<1	3
Nickel	µg/l	<1	2		<1	<1
Lead	µg/l	<1	<1		<1	<1
Selenium	µg/l	2	<1		<1	1
Mercury	µg/l	<0.01	<0.01		<0.01	<0.01

2.1 Radius of Influence of Dewatering

An estimation of the sphere of influence of a dewatering sump can be gained using the same methodologies used for the 2015 (MIN75) and the previous applications. The Construction Industry Research and Information Association Report number 113, '*Control of groundwater for temporary works*' provides a methodology for calculating the radius of influence of a drawdown curve during dewatering, as shown in Equation 1:

$$R = Ch\sqrt{k} \qquad \text{(Equation 1)}$$

Where: R = Radius of influence

C = dimensionless factor for type of excavation (3,000 for radial flow to pumped wells)
h = depth of dewatering (2.4-2.6m)
k = hydraulic conductivity of $5x10^{-4}$m/s for a Sand and Gravel

For a drawdown depth of 2.6m (equivalent to the maximum depth to the top of Kimmeridge Clay with the plot area), the dewatering sphere of influence extends approximately 160 - 175m from the dewatering centre:

$$R = 2.6m * \sqrt{(5x10^{-4}m/s)} *3{,}000 = 175m \qquad \text{(Equation 1)}$$

2.2 Associated Abstraction Rates

An estimated abstraction rate can be derived assuming a zone of influence of 175m using the Dupuit-Forchheimer Equation (Equation 2).

$$Q = \pi k\,(H^2 - h_w^2) / \ln(R_o / r_w) \qquad \text{(Equation 2)}$$

Where: Q = abstraction rate in m^3/s
k = hydraulic conductivity ($5x10^{-4}$m/s)
H = hydraulic head of the original water table (2.6mAOD)
h_w = hydraulic head at maximum dewatering (0mAOD)
R_o = radius of influence of point source (175m)
r_w = equivalent radius of the well (m, as per Equation 3)

To obtain an equivalent radius of the well (r_w) can be calculated from:

$$r_w = \sqrt{(ab / \pi)} \qquad \text{(Equation 3)}$$

Where: a = length of excavation in area where dewatering is expected (370m)
b = width of excavation in area where dewatering is expected (150m)

$$r_w = \sqrt{(370 x150 / \pi)} \quad ` \qquad \text{(Equation 3)}$$

The expected maximum abstraction rate for the northeast section of the site is therefore:

$$Q = \pi \times 5x10^{-4} \times (6.76 – 0) / \ln(175/133) \qquad \text{(Equation 2)}$$

Q = $0.0386m^3/s$
38.6L/s
$139m^3/hr$

It should be noted that this peak sustained abstraction rate of 38.6L/s is likely to be a significant over-estimation as it is based on the conservative assumption that the maximum groundwater depth observed during monitoring is present across the whole site. The monitoring data clearly indicates that saturated zone thicknesses across the site are much thinner than the maximum thickness. There will be little groundwater recharge due to the limited radius of recharge, at 175m. In all likelihood there will be no recharge from the east and north, with the majority of recharge coming from either up-gradient groundwater to the south, or from the lake directly to the west.

Any groundwater management will therefore only be required whilst working the sands and gravels to the northwest, southwest and southeast of the proposed excavation.

2.3 Conceptual Model

Groundwater is derived from rainfall falling on to permeable soils and strata both on the site and land up-gradient of the site. The groundwater flows across the surface of the Kimmeridge Clay within a shallow saturated horizon at the base of the Tottenhill Gravels. This flow is from the south towards the north with a component of radial flow in a westerly direction due to localised variations in the erosion surface of the Kimmeridge Clay, and ultimately discharges via a spring line where the Kimmeridge Clay surface outcrops at the point it intersects the topography. This water then enters the artificially drained fenland area.

Groundwater is artificially diverted around the restored quarry, but is otherwise unhindered in its recharge to the lower level surface water features as illustrated within Figure 10.

There is therefore minimal, if any interruption in the recharge to the various springs and surface water features.

The sand and gravels extracted will be processed as the same mineral types already managed by the facility and these works will not increase the processing throughput of the plant. Consequently there is no change in the environmental risk. Excavation of the clay will be undertaken as a dry working and this will be stockpiled for reuse or sale and does not constituent an environmental risk.

Figure 10 Schematic Conceptual Cross-Section

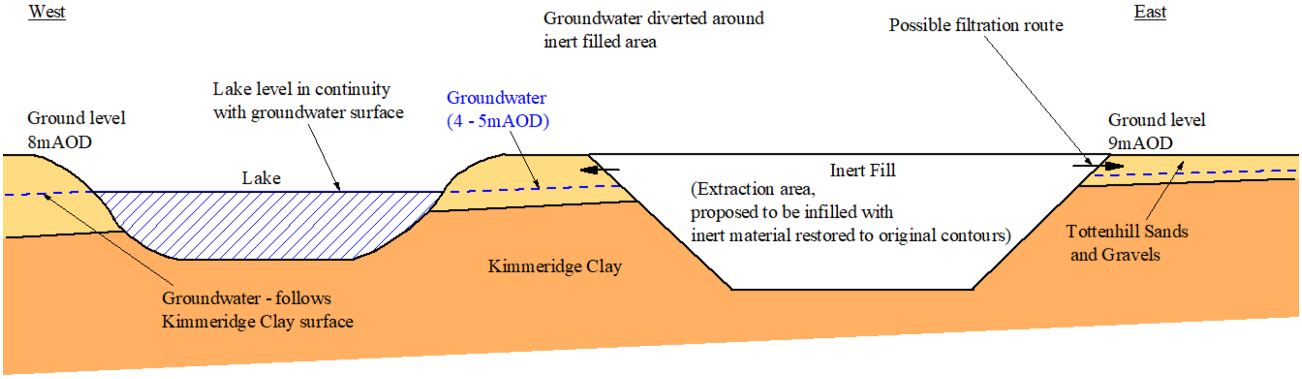
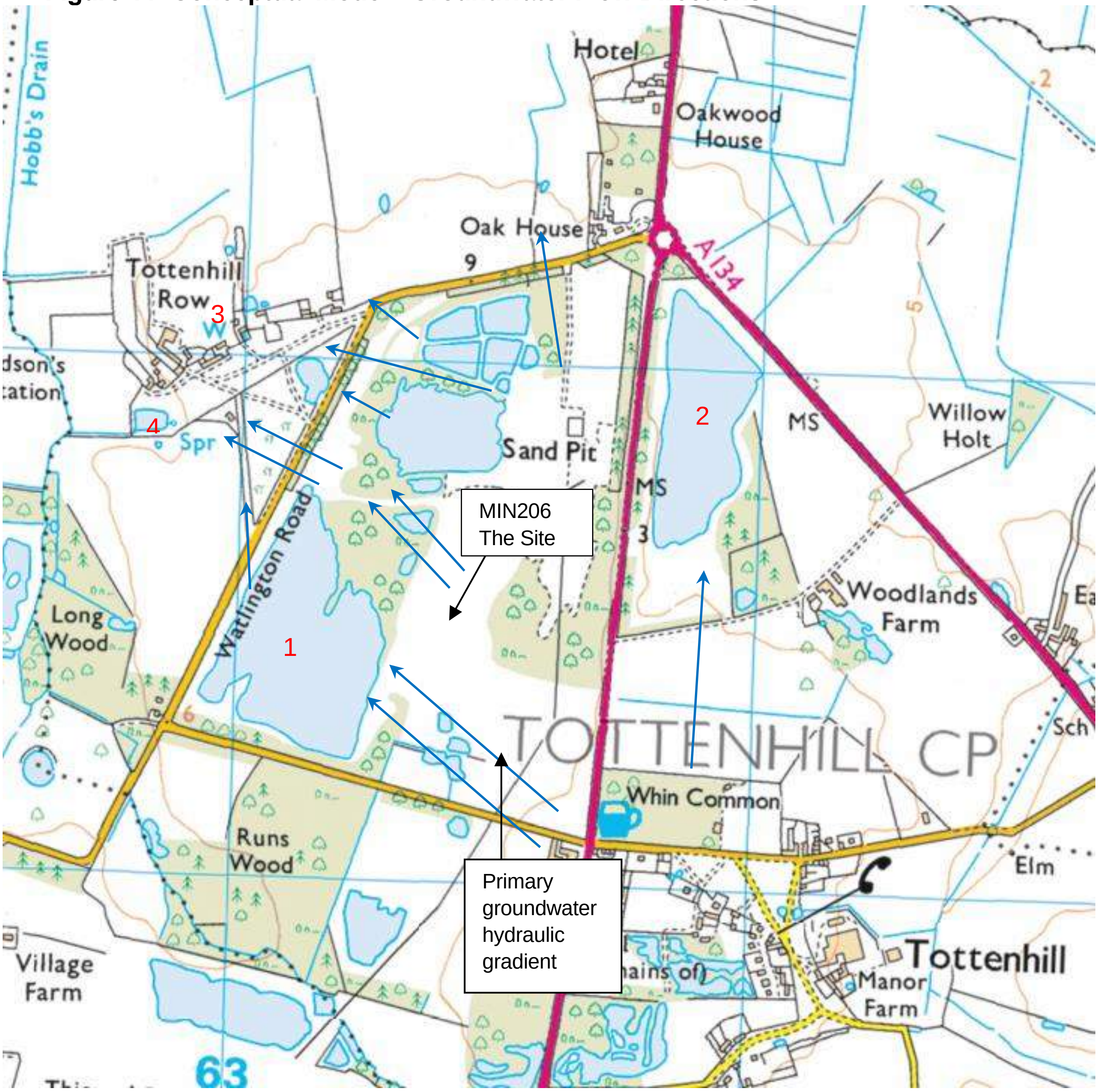


Figure 11 Conceptual Model - Groundwater Flow Directions



(Numbers refer to hydrogeologically down-gradient receptors discussed in the following section)

2.4 Hydrological and Hydrogeological Receptors

There are a number of small and large ponds hydrogeologically down-gradient of the restored quarry. However, the on-site ponds are either used within the washing process, or are just voids from previous extractions and are under the control of the operator. Consequently there are no problems with reductions of water levels in these ponds and silt lagoons. The lake to the west of the site is associated with an abstraction for agricultural uses, but as longs as suitable measures are undertaken to prevent direct ingress into the quarry void then this abstraction should be unaffected.

Notwithstanding this there are a number of potential hydrological receptors, namely the off-site ponds, springs, and streams which enter the Nar Valley artificially managed fenlands. Ponds and surface water features to the south of Watlington Road are expected to be unaffected by the proposed scheme as they are generally up-gradient of the dewatering.

There are therefore only four potential receptors (as identified in Figure 11), namely:

1) the large pond adjacent to the proposed extension, approximately 10m to the west of the proposed excavation
2) the pond 235m to the east of the proposed extension, on the east side of the A10 (Lynn Road)
3) the well on Tottenhill Row approximately 550m northwest of the proposed extension, and
4) the pond and spring line 570m to the north of the proposed lagoon across Watlington Road.

Receptor 1 is the most at risk receptor, due to its proximity to the dewatering, and the fact the dewatering will be deepest on the western side as that is where the saturated zone of the sands and gravels is thickest. It should be noted that the maximum thickness of saturated sands and gravels in the borehole nearest receptor 1 (BH2) is 1.65m, therefore the amount of dewatering will be less at this area than where the greater saturated zone thicknesses are observed (BH1 and BH3).

None of the other receptors are considered to be at risk from the excavation and dewatering, as they are all outside of the calculated radius of impact for the dewatering. Additionally, receptor 2 is considered to be across-gradient, as well as being in the same direction as borehole BH4, which has an incredibly thin saturated zone. Receptors 3 and 4 are also protected as the ponds to the north and west of the proposed mineral extraction will act as buffers to any impact from dewatering down-gradient from the dewatering.

If dewatering is required during the removal of the shallow amount of saturated gravels, the groundwater will be returned to the hydrogeological system, whilst only a small amount of Kimmeridge Clay will be required to construct a bund which can prevent continued groundwater ingress (if any does occur) from entering the excavations.

2.5 Environmental Summary

There is a shallow groundwater surface within the Tottenhill Gravels which outfalls along the spring-line to the north and west. This groundwater surface occurs as a shallow saturated / semi-saturated horizon above the Kimmeridge Clay which acts as a barrier to the continued vertical seepage of groundwater. A spring-line forms where the Kimmeridge Clay intersects with the topography at the edge of the Tottenhill Gravel outcrop to the north and west of the application area.

Surface water features to the north and west of the site are controlled by the host Kimmeridge Clay (when greater than 3mAOD) or are the regional artificially managed groundwater level at 1.5 - 2mAOD. This groundwater is physically separate from that in the gravels, although there is a likely to be a baseflow contribution from the gravels.

Localised variations in groundwater level within the application area are likely to be associated with localised variability in the Kimmeridge Clay surface. This is most apparent to the north, and south of the application area where there is an erosional feature in the top of the Kimmeridge Clay, in which the clay is sharply depressed to between 0mAOD and -1mAOD.

For the majority of the quarrying operations, groundwater management is likely to be limited to managing rainfall recharge and a small quantity of groundwater flow from both up-gradient and also from the pond to the west. Mitigation measures may be necessary to protect water levels in the pond directly to the west of the site, however no other at risk due to the buffering nature of the pond to the west of the site.

2.5.1 Licensed groundwater abstractions

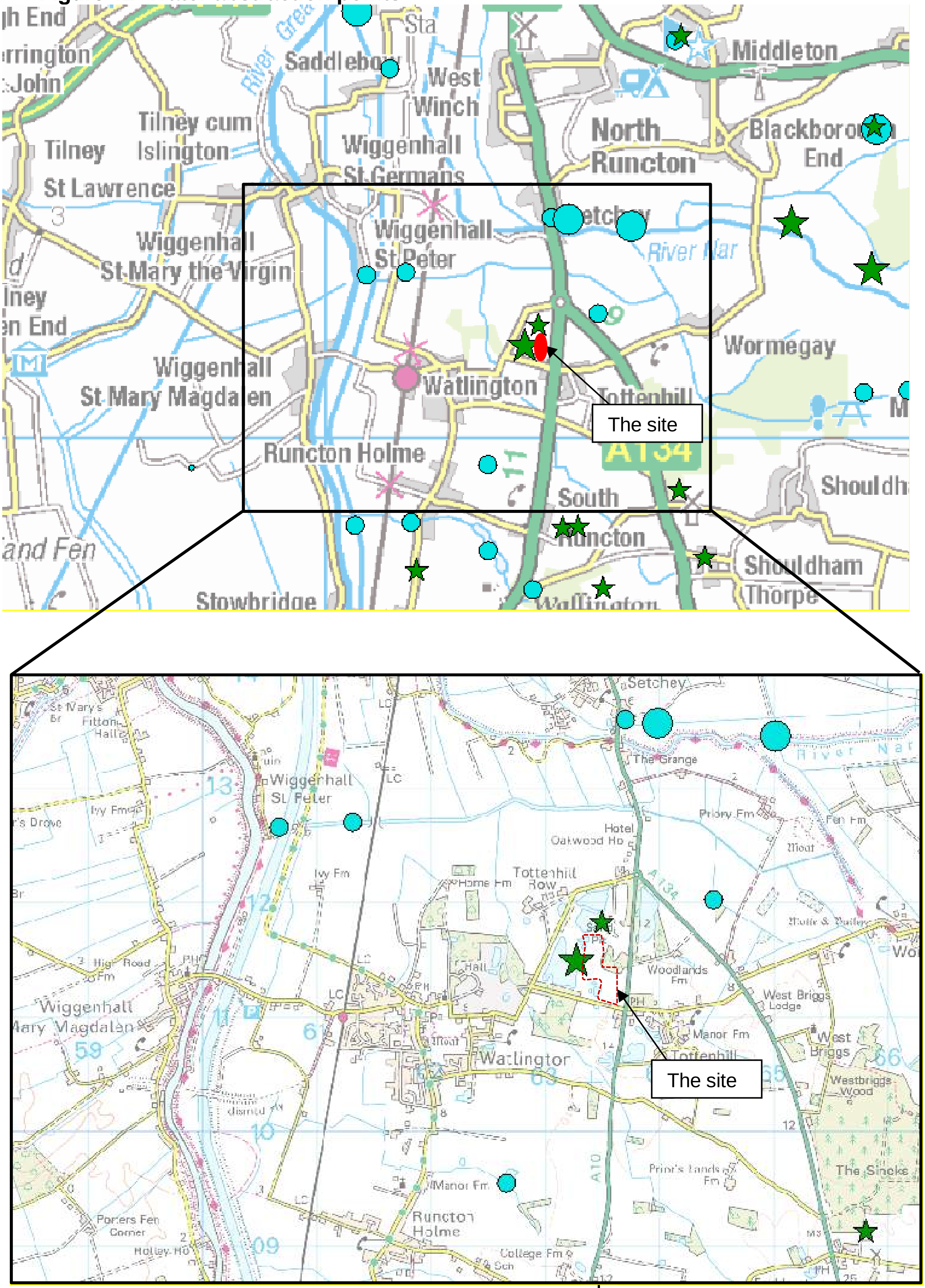
There are two groundwater abstractions located within 1km of the site; both within the wider Quarry site. One associated with Watlington Quarry and used for mineral washing and the other for spray irrigation (Figure 12) managed by Watlington Farms. The mineral washing abstraction point is located to the north of the proposed mineral extraction and is an integral part of the silt washing process. Any dewatering that does occur will be used in the silt washing process.

The spray irrigation abstraction is cross-gradient and adjacent to the proposed excavation and will likely be affected to some degree by the dewatering activities. However, as long as measures are taken to prevent the direct ingress of water from the lake to the quarry, sufficient water in the lake will be maintained for use in this irrigation. To further negate any detrimental decreases in the water level in the pond from which the spray irrigation abstraction comes from, the dewatering water can be discharged in to the pond to ensure the pond water levels remain stable.

2.5.2 Licensed surface water abstractions

There is one medium surface water abstraction point located within 1km of the site to the east north east. The next closest three are some 1.5km – 2.1km to northeast of the proposed site. The more distant surface water abstractions within the area are located 2.2-3km away from the site to the west north west and south south west. The eastern point is from a surface water drain in the alluvium below the Tottenhill gravels, and the southern from a pond constructed into the Kimmeridge Clay. There is no hydrogeological connection between theses abstraction points and the proposed area. The north eastern surface water abstraction is from the Plover Drain and therefore will be unaffected by any groundwater management as any water would be returned to this system upstream of the abstraction.

Figure 12 Water abstraction points



Groundwater Abstraction Size: Small Medium Large
Surface Water Abstraction Size: Small Medium Large

2.5.3 Private unlicensed abstractions

The Borough Council of King's Lynn & West Norfolk, report one private abstraction point registered within a 3.5km radius of the extraction area. This is from the River Nar and provides the supply for a single dwelling and is located 3km to the north west of the site at Nar Hideaway, Saddlebow, King's Lynn, Norfolk, PE34 3AP, E: 561598 N: 315364. This abstraction is to the north of the Plover Drain and is not affected by the proposed development

The historic well identified at Meadow Farm, Tottenhill Row on Ordnance Survey mapping (*e.g.* figure 1) is not registered with the Environment Agency or the Borough Council and therefore is assumed not to be in use as a source of water.

2.6 Drainage fields associated with domestic foul water disposal

Given the rural location of the area and the isolated nature of the closest residential receptors it is possible that these properties manage their foul water either by septic tanks or cess pits. The effluent from these would then drain into the groundwater.

This is a possible source of groundwater ammonium discussed in Section 2.5.1. However, as the groundwater flow regime is to remain unchanged there is no expectation of a change in groundwater quality to that occurring at present.

3. DEWATERING LOGISTICS

3.1 Dewatering of the Tottenhill Gravels

Groundwater elevations for the Tottenhill Gravels are in the order of 0 – 2.6m above the top of the Kimmeridge Clay in the proposed operational area, with the thickest saturated zones being in the southeast and northwest corners of the area. This is due the surface elevation of the Kimmeridge Clay rising in the centre, east and northeast of the working area, thus channelling the groundwater to the northwest, southwest, and southeast. Dewatering is therefore expected in these areas of the proposed excavations for the operator to work the mineral dry.

The dewatering is expected to impact the pond 10-15m directly to the west of the site, potentially lowering the pond level by up to 1.65m. As the extraction of the sands and gravels will utilise the full thickness of the strata, the excavation will dig down to the Kimmeridge Clay beneath. The Kimmeridge clay could therefore then be used as a temporary bund on the western side of the excavation to reduce the impacts of the dewatering on the pond. In addition, dewatering water can be pumped in to the pond to ensure the water level remains at a satisfactory level and allows the spray irrigation abstraction to continue unhindered.

4. WATER QUALITY

4.1 Excavation operations

Whilst the mineral is being extracted, there is only one potential impact on water quality namely fuel leakages from vehicles and machinery. However, as the works will utilise the existing quarrying machinery there is no change to the pollution risk. Consequently the existing management practices, such as the provision of spill kits is already in place.

Suspended solids could be considered as a pollution risk, however, the operation of the dewatering process will include silt traps and other measures to mitigate the discharge of suspended solids.

4.2 Restoration operations

The proposed backfilling and restoration of the resultant void created by mineral extraction shall be with site derived inert material and imported inert waste. Pollution control measures, including the necessity for any engineered lining system will be derived from specific risk assessments that will support any future Environmental Permit Application.

It is proposed that the site will be restored to approximately the pre-development level to allow the return to productive use of the land using imported inert material which may include the use of inert wastes. The material used to complete the restoration may represent a source of substances of concern that could cause elevated levels within the groundwater system. Consequently, to ascertain the level of risk posed by these materials it is necessary to understand the potential leachable substances that could be present within the imported inert fill and the likely make up of any leachates.

These leaching and total component criteria given in the Landfill Directive are set maximums for waste during testing, therefore it is highly unlikely that these concentrations will be realised for the bulk of the waste. Hence any assessment should accept that the average concentration would be substantially less. Furthermore, leaching tests performed within a laboratory are highly aggressive and will mobilise substantially more than would be available following *in-situ* leaching within any inert fill. However, it is likely that the total amount leached is representative of the total amount available of the most mobile substances over the entire '*potentially polluting*' lifespan of the site.

Leachate quality generated from inert materials can be categorised into a series of sub-groups, namely:

- Matrix salts including Na, K, Ca, Mg, Cl, SO_4, alkalinity which are non-toxic, but could be at concentrations which could increase salinity levels above typical terrestrial water drinking water standards (DWS) or Environmental Quality Standards (EQS)
- Primary products from degrading organic matter, including ammonium, BOD, COD and TOC. Of these ammoniacal-N is toxic at high concentrations and elevated BOD can cause eutrophication in surface water bodies; however, elevated BOD is a short term hydrolysis product which is only produced in significant quantities during the period taken for a microbial population to develop. Following a relatively short microbial growth phase the residual dissolved organic matter is usually biologically inert.

- The redox sensitive metals Fe and Mn, which are common metals insoluble under oxidising and reducing conditions, but soluble under anoxic (iron and manganese reducing) conditions.
- Metals, including Cd and Hg, which could be present at trace concentrations and other metals including Cr, Cu, Ni, Zn and Pb form the largest potential component of persistent pollutants within wastes
- Hazardous and non-hazardous organic compounds

The primary organic content is expected to be present as a minor component and primarily as a soil organic matter which cannot be distinguished visually or as vegetation derived cellulose or other similarly slowly degrading types. Any acceptance procedures for inert fill controlled by an Environmental Permit or via a CL:AIRE Definition of Waste Code of Practice Protocol Management Plan will also exclude green and food wastes as well as visually identified oil or contaminated materials.

Consequently, given that the proposed waste types are unlikely to contain a significant or rapidly degradable organic content, elevated ammoniacal-N and BOD is not expected to be associated with the inert fill. Similarly, solvents, refined petroleum products or other chemical spillages will be excluded from the site. With regards to metals and metalloids TerraConsult have compiled a leachate source term from a combination of reviewing leachate data from hazardous soil landfill sites over a 10 year period as well as other leaching data (Table 2). Given that the acceptance procedures for inert fill will specifically exclude hazardous soils, then this leachate source is considered to be highly conservative and above the maximum concentration range which could be expected for the proposed inert fill whether classified as waste or otherwise. The data is presented solely as an example of the limited real-world leachability of substances from worst-case waste soils which consequently produce leachate of limited concern. By extrapolation leachate produced by inert fill will have levels lower than those indicated below

Table 2 Hazardous Soil Leachate Source Study

Chemical	Sample Count	Units	Leachate concentration			DWS	MRV
			Minimum	Average	Maximum		
Hazardous Metals							
Cadmium	161	µg/l	0.025	0.29	6.7	5	0.1
Mercury	153	µg/l	0.005	0.037	0.3	1	0.01
Non-hazardous Metals & Metalloids							
Arsenic	154	µg/l	0.4	4.9	25	10	
Lead	59	µg/l	0.2	1.8	10	10	
Chromium	60	µg/l	0.25	3.1	14	50	
Copper	58	µg/l	0.5	6.2	21	2,000	
Nickel	60	µg/l	1.5	8.1	22	20	
Zinc	60	µg/l	1	45	1,600	5,000	
Organic							
PAH	15	µg/l	<1.7	n/a	<34	0.1	
Matrix Components							
Sulphate	193	mg/l	38	485	1,300	250	
Ammoniacal-N	214	mg/l	0.01	2.5	16.9	0.39	

It is noted that the majority of the metals and metalloids are expected to be below DWS at source, although maximum cadmium concentrations were determined to approximate to the 5 µg/l DWS (at 6.7 µg/l). Given that this waste source is derived from hazardous soils, then it is considered as highly conservative compared to an inert source where negligible cadmium would be present.

There are therefore two primary potential leachable components within inert materials, namely an increase in chloride or sulphate which causes an increase in an otherwise low salinity water resource to above EQS or DWS standards. However this will be limited as sulphate producing wastes will be excluded if wastes are used in the quarry restoration scheme.

4.3 Risk Assessment

The conceptual model indicates that rain which falls on the site will infiltrate through the in-situ subsoils and top soils used as restoration at the site. The water that infiltrates through these soils will reach the layer of imported inert materials.

The water that mixes with the inert materials / waste may cause leaching of substances within the infill material forming a leachate. Protection of the Tottenhill Gravels aquifer and the requirements of any pollution control engineering measures shall be determined by risk assessments prepared for any permit application.

Section 4.2 discusses the potential leachate quality produced and concludes that sulphate and chloride are the most likely substances to be leached associated with the material to be used, however as they, especially sulphates, are controlled by the acceptance criteria it is unlikely that a significant producing source will be formed. It has also been noted in research undertaken by TerraConsult discussed above that metals do not particularly leach, even from hazardous waste sources, therefore it is unlikely that any will be produced in concentrations greater than the respective DWS or EQS limits. Ultimately any leachate leaving the waste mass will contain very low concentrations of substances of environmental concern. This situation will only be improved if engineered pollution control measures are required.

In that event that leached substances percolate through the placed fill they would enter the remaining Tottenhill Gravels. If this was to occur any leachable components could disperse laterally in the groundwater towards the identified receptors in Sections 2.4 and 2.5.

As the fill will be of a lower permeability than the surrounding sand and gravel, groundwater present will flow around the site within the gravels. Mixing with groundwater will occur in/under and around the site causing dilution of any migrating leachate. Further dispersion will occur as the substances migrate to the north and northwest.

As the Tottenhill Gravels will be completely removed at the site, there will be no unsaturated zone beneath as the restored site will sit directly on the Kimmeridge Clay. Therefore any dispersion of leachate will be laterally in to the surrounding sands and gravels. The large ponds to the north and west of site are the closest receptors, however the large volumes of water should allow for greater dilution, making the risk to these receptors negligible.

5. SUMMARY

The development of the proposed mineral workings via an extension to Watlington Quarry is unlikely to result in a significant or even discernible impact on surrounding groundwater and surface water, with the exception of the pond 10-15m directly to the west of the proposed working area. The majority of the mineral resource appears to be unsaturated, with only the northwest, southwest and southeast edges having a noticeable volume of groundwater.

It is likely that dewatering along the western boundary of the site will result in noticeable impacts to the water level in the pond to the west of the site; however these impacts can be negated with suitable mitigation measures. These can be either through artificial recharge of the pond with the dewatering water, and/or using the site won Kimmeridge Clay beneath the Tottenhill Gravels to create a bund along the western boundary. Derogation of the spray irrigate abstraction licence from the pond to the west of the site can be avoided by applying the mitigation measures described previously.

The baseline conditions for the groundwater have been tentatively established this demonstrates that there are no persistent pollutants within the groundwater, although there is a background influence of an agricultural fertilizer / sewage residue, namely ammonium. Given that the mineral to be excavated sits and is derived of the same formation that will be sourced and processed throughout the historic and continuing mineral workings then there is no potential for a change or increase in the pollution risk posed by the site.

The restoration of the site using site-won material will not pose a pollution risk to groundwater receptors; however the use of imported inert fill for restoration may require the engineering of pollution prevention measures. The assessment of inert fill leachate production and the local hydrogeology indicates the risk for the receptors from leachate from the imported inert fill will be very low.

In summary, with suitable mitigation measures there is not expected to be a discernible impact on groundwater and surface resources with respect to the quantity of recharge and the quality of the groundwater.

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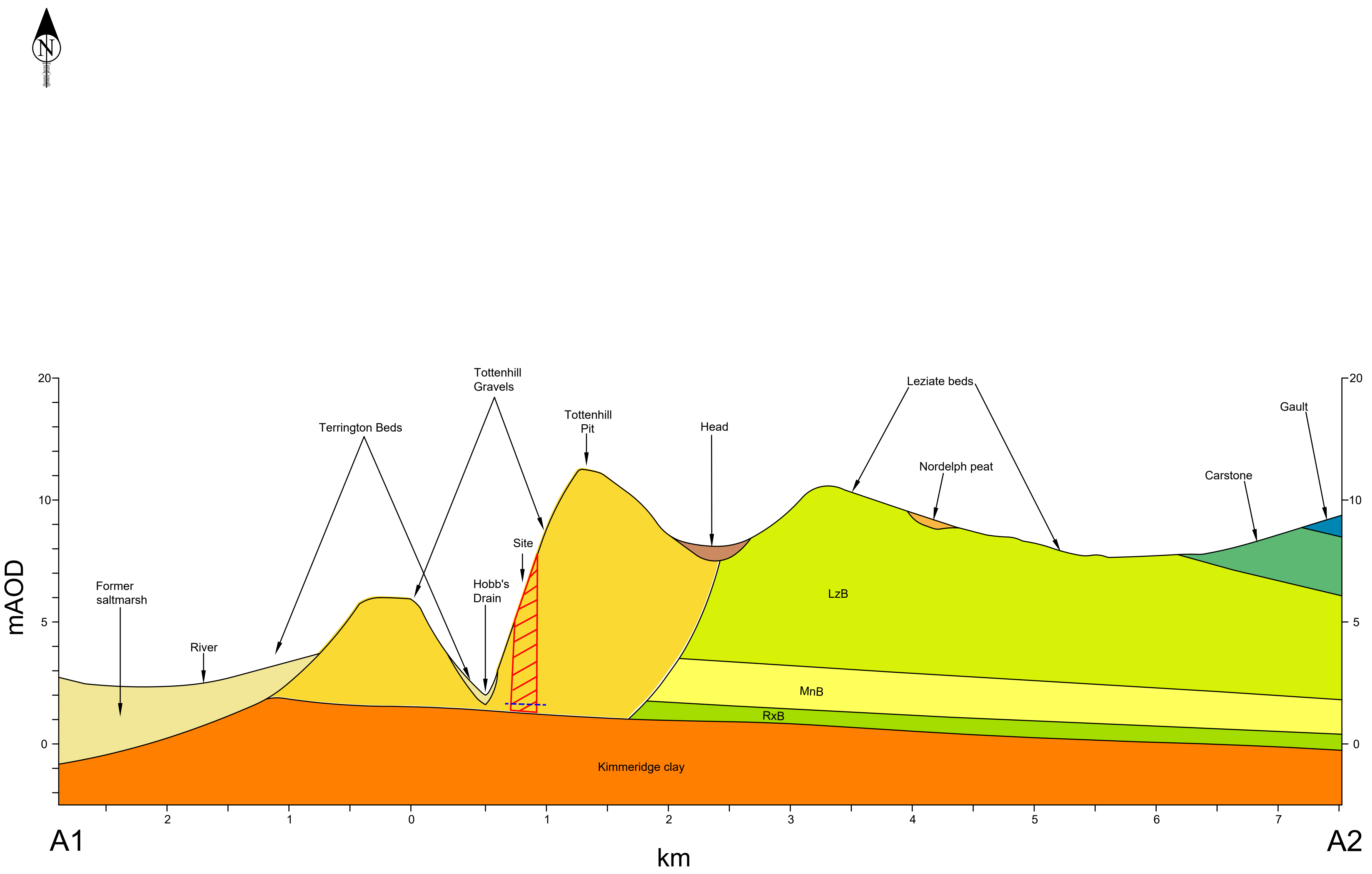
Drawings



Key

Terrington beds: younger saltmarsh and tidal creek deposits (silty clay and sandy silt)	
Tottenhill gravels: older gravels	
Kimmeridge clay (60 to 90m)	
Head	
Leziate beds (LzB) (0 to 20m)	Sandringham Sands
Mintlyn beds (MnB) (6 to 14m)	Sandringham Sands
Roxham beds (RxB) (3 to 50m)	Sandringham Sands
Nordelph peat	
Carstone (2 to 6m)	
Gault (10 to 15m)	

Note: Cross Section as shown on Drawing 10312-001-01

TerraConsult

Dugard House, Peartree Road,
COLCHESTER, CO3 0UL

Client

MICK GEORGE

Site

Watlington Quarry

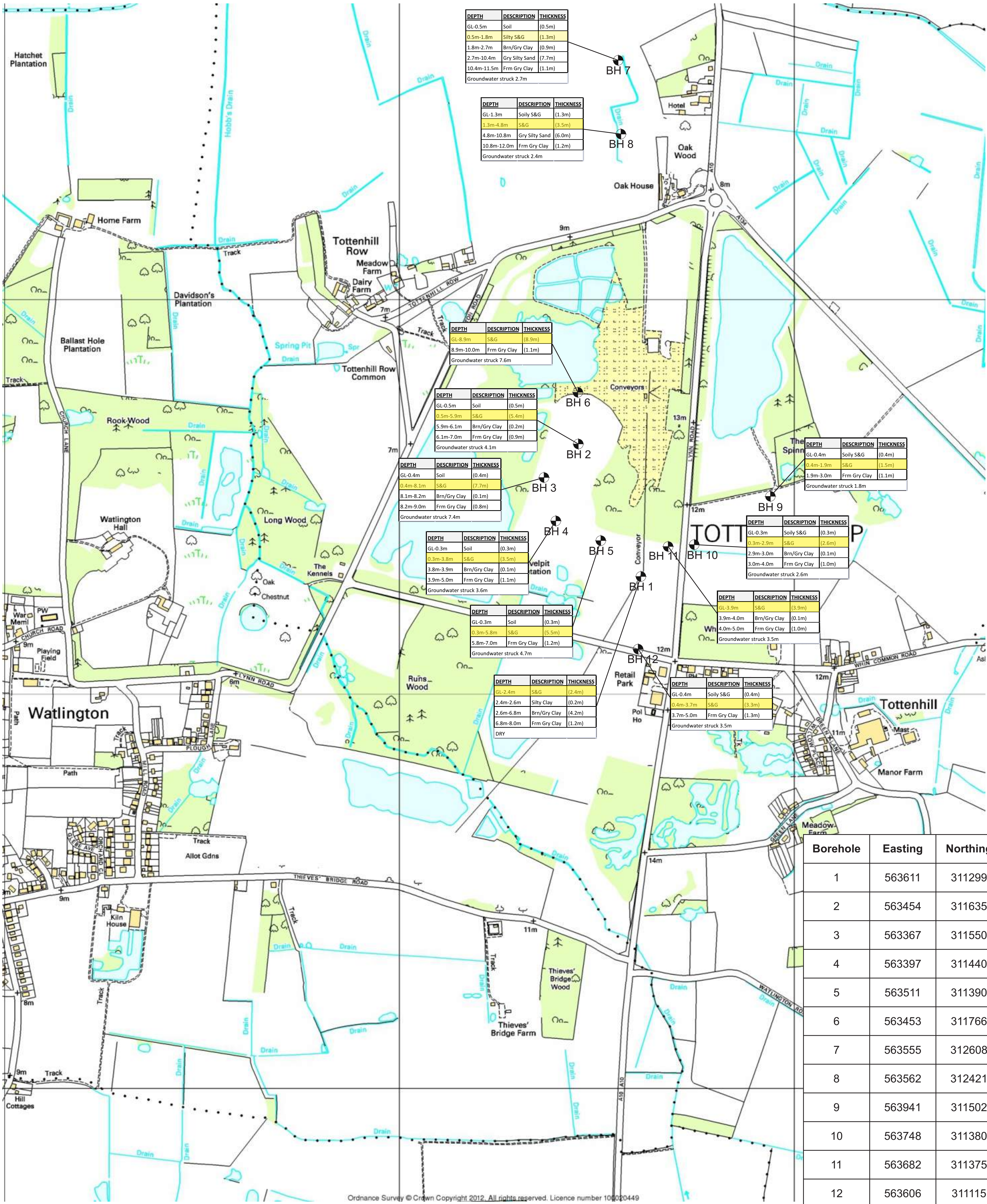
Title

Geological Cross Section
W - E

Scale	N.T.S	@ A3
Drawing No.	10312-002-01	

Rev	Date	Description

File	1031200201GeologyCrossSec.dwg		
Date	18/12/17	Engineer	CF
Drawn	ER	Checked	BK



DEPTH	DESCRIPTION	THICKNESS
GL-0.5m	Soil	(0.5m)
0.5m-1.8m	Silty S&G	(1.3m)
1.8m-2.7m	Brn/Gry Clay	(0.9m)
2.7m-10.4m	Gry Silty Sand	(7.7m)
10.4m-11.5m	Frm Gry Clay	(1.1m)
Groundwater struck 2.7m		

DEPTH	DESCRIPTION	THICKNESS
GL-1.3m	Soily S&G	(1.3m)
1.3m-4.8m	S&G	(3.5m)
4.8m-10.8m	Gry Silty Sand	(6.0m)
10.8m-12.0m	Frm Gry Clay	(1.2m)
Groundwater struck 2.4m		

DEPTH	DESCRIPTION	THICKNESS
GL-8.9m	S&G	(8.9m)
8.9m-10.0m	Frm Gry Clay	(1.1m)
Groundwater struck 7.6m		

DEPTH	DESCRIPTION	THICKNESS
GL-0.5m	Soil	(0.5m)
0.5m-5.9m	S&G	(5.4m)
5.9m-6.1m	Brn/Gry Clay	(0.2m)
6.1m-7.0m	Frm Gry Clay	(0.9m)
Groundwater struck 4.1m		

DEPTH	DESCRIPTION	THICKNESS
GL-0.4m	Soil	(0.4m)
0.4m-8.1m	S&G	(7.7m)
8.1m-8.2m	Brn/Gry Clay	(0.1m)
8.2m-9.0m	Frm Gry Clay	(0.8m)
Groundwater struck 7.4m		

DEPTH	DESCRIPTION	THICKNESS
GL-0.3m	Soil	(0.3m)
0.3m-3.8m	S&G	(3.5m)
3.8m-3.9m	Brn/Gry Clay	(0.1m)
3.9m-5.0m	Frm Gry Clay	(1.1m)
Groundwater struck 3.6m		

DEPTH	DESCRIPTION	THICKNESS
GL-0.3m	Soil	(0.3m)
0.3m-5.8m	S&G	(5.5m)
5.8m-7.0m	Frm Gry Clay	(1.2m)
Groundwater struck 4.7m		

DEPTH	DESCRIPTION	THICKNESS
GL-2.4m	S&G	(2.4m)
2.4m-2.6m	Silty Clay	(0.2m)
2.6m-6.8m	Brn/Gry Clay	(4.2m)
6.8m-8.0m	Frm Gry Clay	(1.2m)
DRY		

DEPTH	DESCRIPTION	THICKNESS
GL-0.4m	Soily S&G	(0.4m)
0.4m-1.9m	S&G	(1.5m)
1.9m-3.0m	Frm Gry Clay	(1.1m)
Groundwater struck 1.8m		

DEPTH	DESCRIPTION	THICKNESS
GL-0.3m	Soily S&G	(0.3m)
0.3m-2.9m	S&G	(2.6m)
2.9m-3.0m	Brn/Gry Clay	(0.1m)
3.0m-4.0m	Frm Gry Clay	(1.0m)
Groundwater struck 2.6m		

DEPTH	DESCRIPTION	THICKNESS
GL-3.9m	S&G	(3.9m)
3.9m-4.0m	Brn/Gry Clay	(0.1m)
4.0m-5.0m	Frm Gry Clay	(1.0m)
Groundwater struck 3.5m		

DEPTH	DESCRIPTION	THICKNESS
GL-0.4m	Soily S&G	(0.4m)
0.4m-3.7m	S&G	(3.3m)
3.7m-5.0m	Frm Gry Clay	(1.3m)
Groundwater struck 3.5m		

Borehole	Easting	Northing	
1	563611	311299	10.52mAOD
2	563454	311635	9.49mAOD
3	563367	311550	9.46mAOD
4	563397	311440	8.69mAOD
5	563511	311390	9.86mAOD
6	563453	311766	10.00mAOD
7	563555	312608	
8	563562	312421	
9	563941	311502	
10	563748	311380	
11	563682	311375	11.00mAOD
12	563606	311115	11.33mAOD

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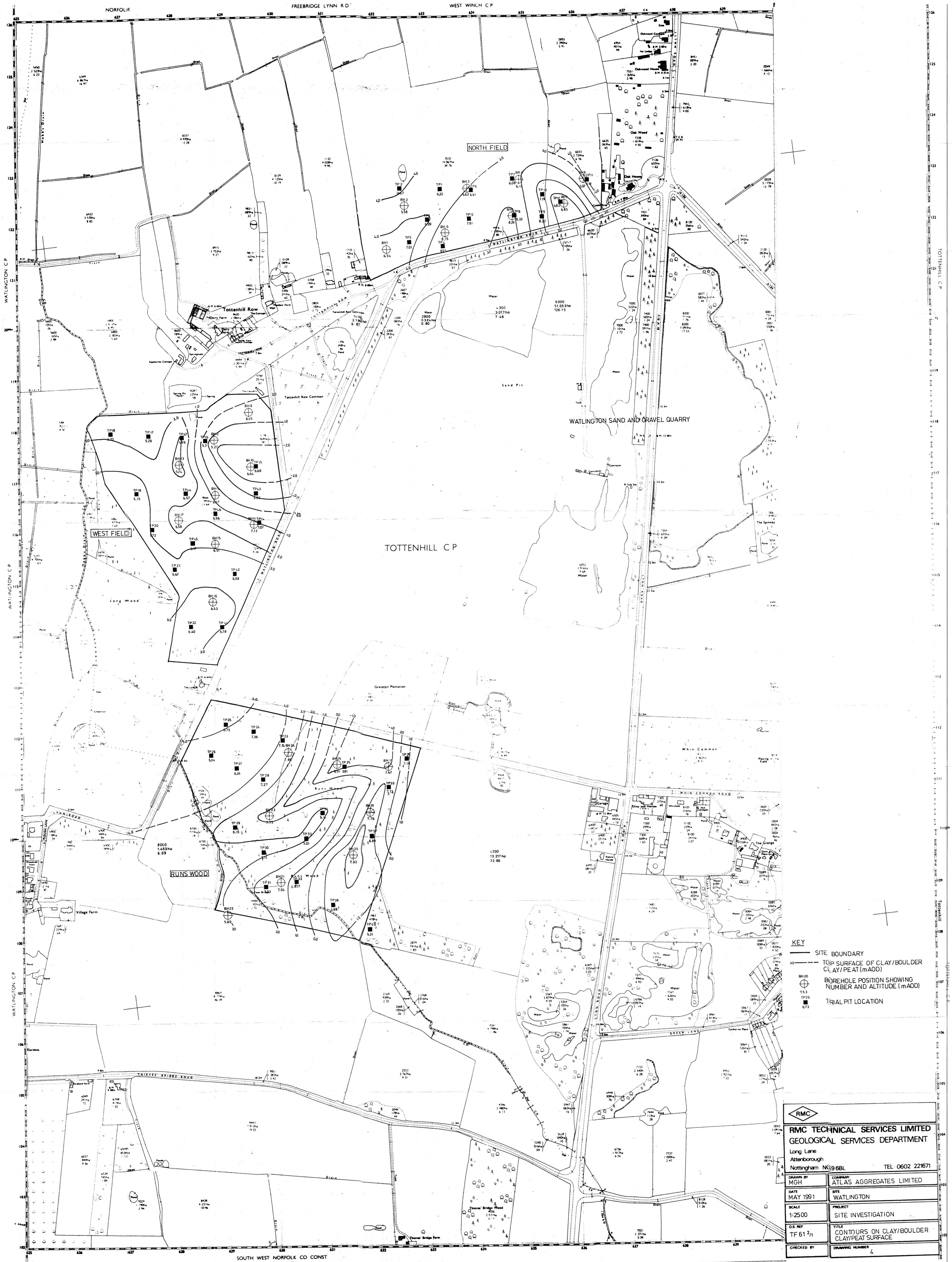
Watlington Borehole Location Plan:
Geological Investigations June 2018

Date: 29/06/2018

Scale: 1:10,000 @A3

Drawn by: PJL

Plan Ref: WAT/BH/2018/01



NORFOLK
FREEBRIDGE LYNN R D
WEST WINCH C P
NORTH FIELD
WEST FIELD
RUNS WOOD
TOTTENHILL C P
WATLINGTON SAND AND GRAVEL QUARRY
WATLINGTON C P
Tottenhill Row
SOUTH WEST NORFOLK CO CONST
KEY
SITE BOUNDARY
TOP SURFACE OF CLAY/BOULDER CLAY/PEAT (mAOD)
BOREHOLE POSITION SHOWING NUMBER AND ALTITUDE (mAOD)
TRIAL PIT LOCATION
RMC
RMC TECHNICAL SERVICES LIMITED
GEOLOGICAL SERVICES DEPARTMENT
Long Lane
Attenborough
Nottingham NG9 6BL
TEL 0602 221671
DRAWN BY MGH
COMPANY ATLAS AGGREGATES LIMITED
DATE MAY 1991
SITE WATLINGTON
SCALE 1:2500
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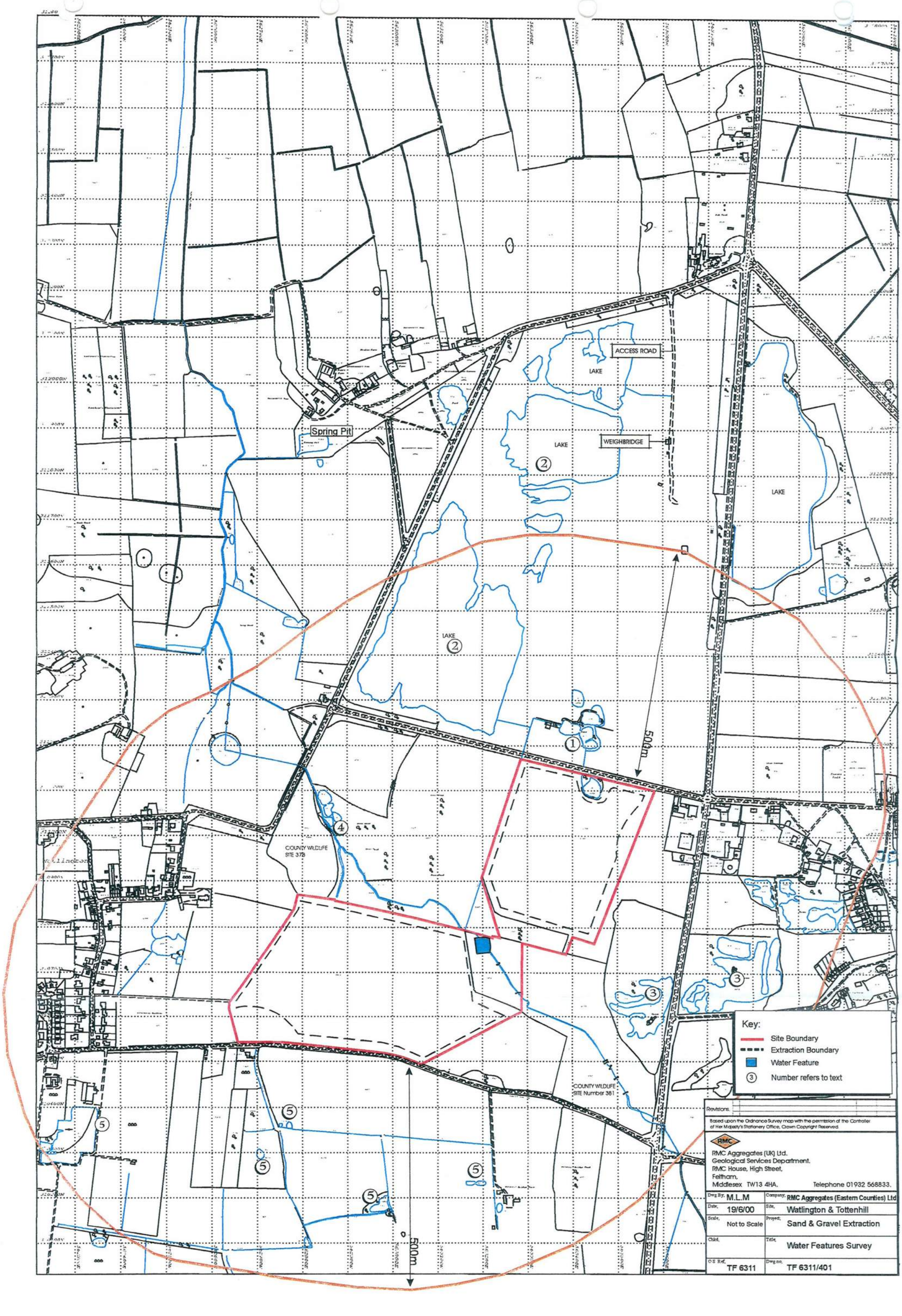

ACCESS ROAD
LAKE
Spring Pit
WEIGHBRIDGE
LAKE
2
LAKE
LAKE
2
1
500m
4
COUNTY WILDLIFE SITE 378
3
3
COUNTY WILDLIFE SITE Number 381
5
5
5
5
5
500m
Key:
Site Boundary
Extraction Boundary
Water Feature
3 Number refers to text
Revisions.
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RMC
RMC Aggregates (UK) Ltd.
Geological Services Department.
RMC House, High Street,
Feltham,
Middlesex TW13 4HA.
Telephone 01932 568833.
Dwg By. M.L.M
Company. RMC Aggregates (Eastern Counties) Ltd
Date. 19/6/00
Site. Watlington & Tottenhill
Scale. Not to Scale
Project. Sand & Gravel Extraction
Chkd.
Title. Water Features Survey
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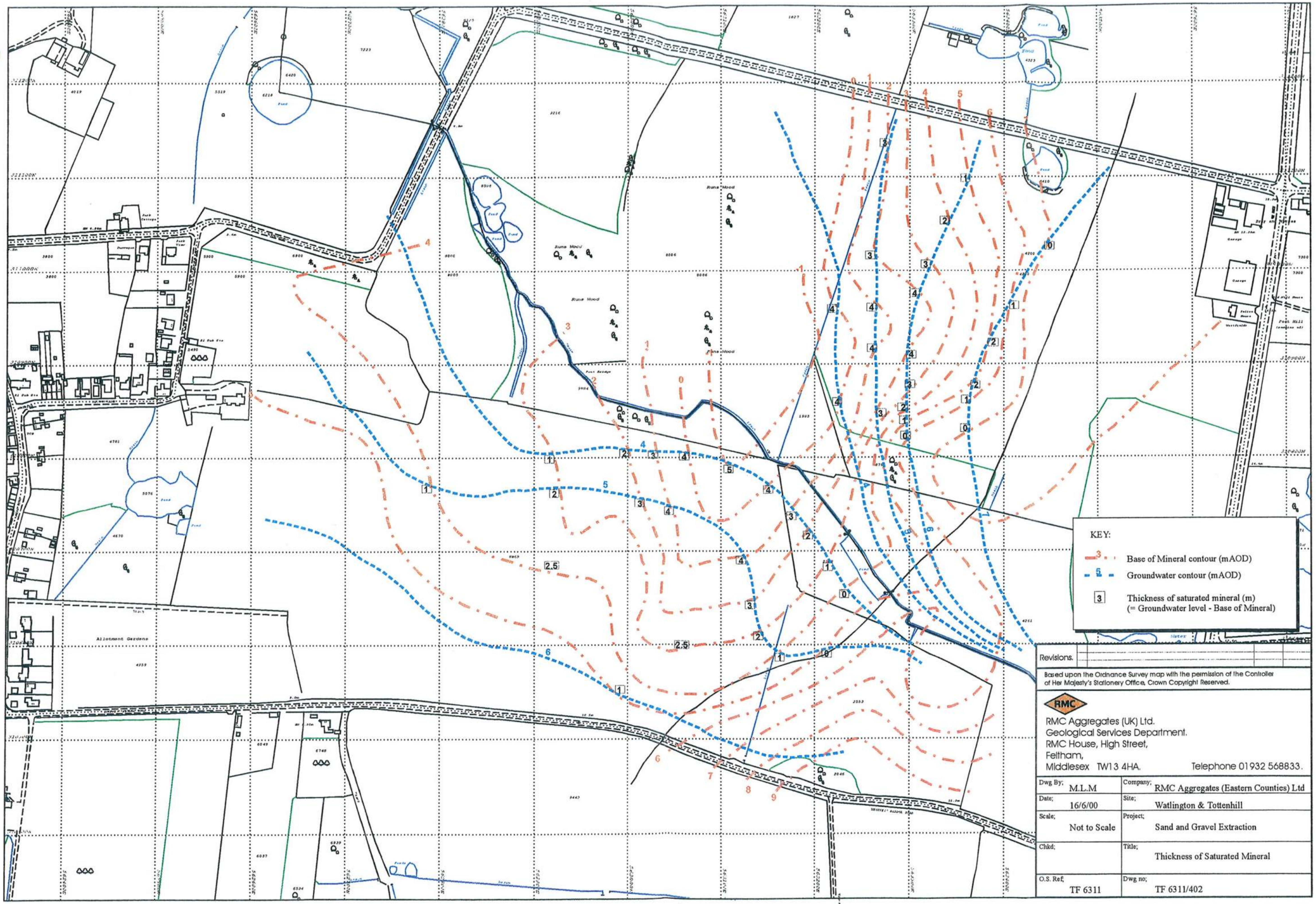

Revisions.

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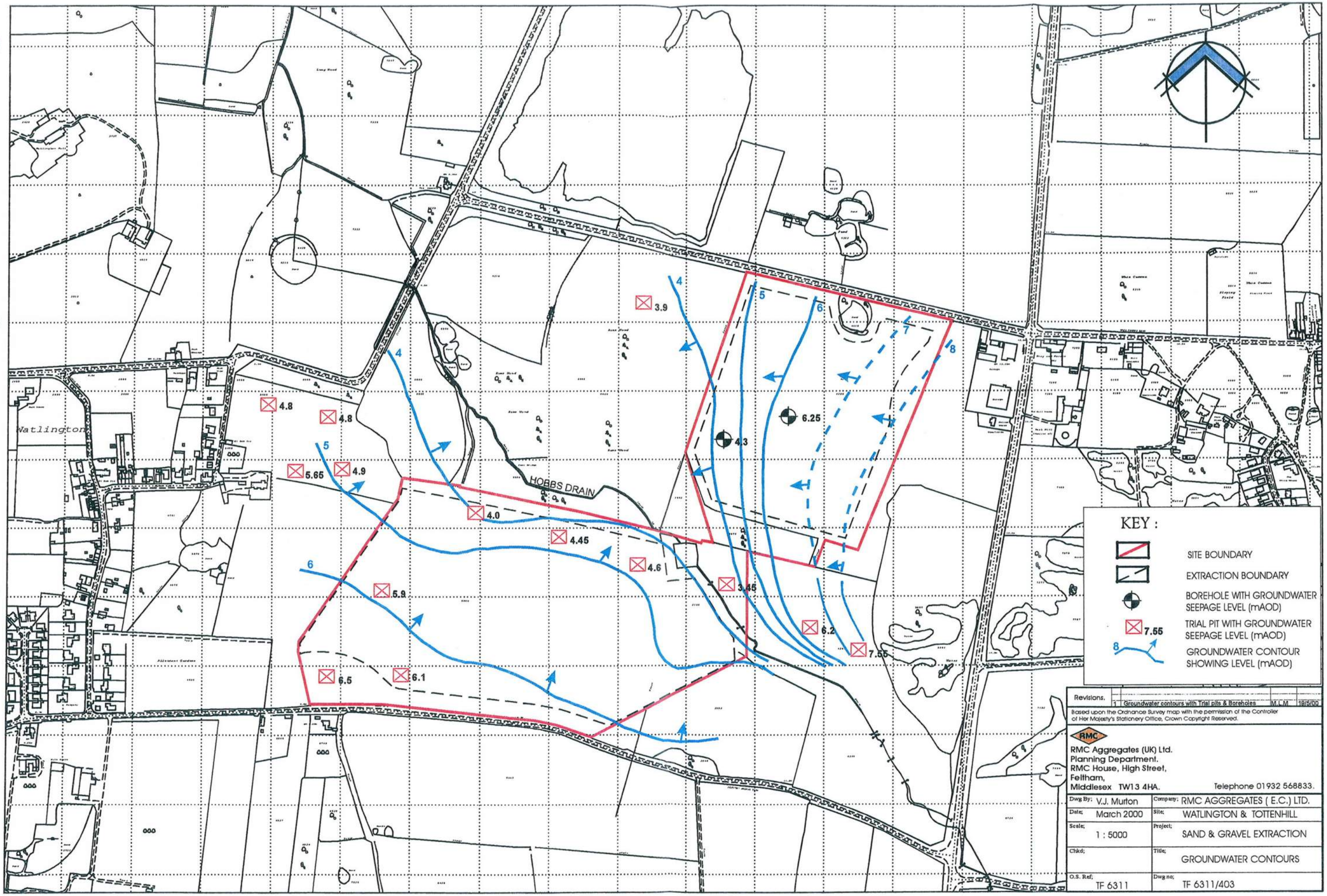
Geological Services Department.
RMC House, High Street,
Feltham,
Middlesex TW13 4HA. Telephone 01932 568833.

Dwg By; M.L.M	Company; RMC Aggregates (Eastern Counties) Ltd
Date; 16/6/00	Site; Watlington & Tottenhill
Scale; Not to Scale	Project; Sand and Gravel Extraction
Chkd;	Title; Thickness of Saturated Mineral
O.S. Ref; TF 6311	Dwg no; TF 6311/402


Watlington
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8
KEY :
SITE BOUNDARY
EXTRACTION BOUNDARY
BOREHOLE WITH GROUNDWATER SEEPAGE LEVEL (mAOD)
TRIAL PIT WITH GROUNDWATER SEEPAGE LEVEL (mAOD)
GROUNDWATER CONTOUR SHOWING LEVEL (mAOD)
Revisions.
1 Groundwater contours with Trial pits & Boreholes M.L.M 19/5/00
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Telephone 01932 568833.
Dwg By; V.J. Murton
Company; RMC AGGREGATES (E.C.) LTD.
Date; March 2000
Site; WATLINGTON & TOTTENHILL
Scale; 1 : 5000
Project; SAND & GRAVEL EXTRACTION
Chkd;
Title; GROUNDWATER CONTOURS
O.S. Ref; TF 6311
Dwg no; TF 6311/403