NETHERSET HEY

Hydrogeological Desk Top Study Assessment Report
HYDROGEOLOGICAL ASSESSMENT

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TABLES

Tables should be used whenever possible and included within the text to which they relate, as they can summarise large volumes of information/data into a manageable format. The numbering and content of the tables presented within this report will alter according to site-specific circumstances. However, typical examples of tables that could be included are presented below.

Table HRA1. Permeability values of the glacial sand and gravel
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Drawings

The numbering and content of the drawings presented within this report will vary according to site-specific circumstances. Typical examples of drawings that could be included summarise the following:

NHSMP1: Borehole locations
NHSMP2: Rockhead contours of Salop Formation
NHSMP3: Groundwater Contour Plan
NHSMP4: River Route Alteration Plan

APPENDICES

The numbering and content of the appendices presented within this report will vary according to site-specific circumstances. However, typical examples of appendices that could be included are presented below.

Appendix HRA1  Borehole Logs RMC 1994
Appendix HRA2  Borehole Logs Tarmac 1994
Appendix HRA3  Sand Gradients
Appendix HRA4  Dip readings for new piezometers
1.0 INTRODUCTION

1.1 Report Context

Enviroarm Limited were instructed by Madeley Aggregates Ltd, the owners of the land and proposers of the Netherset Hey site to undertake a Hydrogeological Desk Top Study for the proposed extraction area. The hydrogeological assessment covers groundwater levels assessment, flow, potential draw down implications, site stability and long term benefits.

The landfill site is located off Netherset Hey Lane, near Madeley in North Staffordshire. The site is located at National Grid Reference SJ 778 438, see Figure 1.

Figure 1: Site Location

The site is currently agricultural land with proven glacial sand and gravel deposits up to some 10 metres in depth to the west side and northern phase with Etruria Marl deposits to the east nearest the M6, which are at least 50 metres in depth.

The current reserves of sand and gravel are approximately 17.5 million tonnes of sand and gravel.

The purpose of the recent hydrogeological desk top study is to assess the impacts of the works and to propose mitigation measures for the development.
2.0 SITE SETTING

2.1 Climate

Meteorological office readings are available for a 40km grid square centred on NGR SK000000 from 1961 to 1985. The typical monthly average rainfall range is between 45 and 65mm.

The number of hours of sunshine range from 44.3 in December to 181 hours in June with a temperature range of 3.5°C to 15.6°C. There are very large ranges observed from one year to the next.

Wind roses from the Meteorological Office at Birmingham Airport indicate winds predominately from the south-west, which are particularly strong in winter. The long term average potential evapotranspiration, obtained from the Ministry of Agriculture, Fisheries and Foode, is approximately 500mm/ year, for the period 1941-1970. The sides of the quarry will shade areas from the sun, rain or wind. Because of this, the evaporation rate will vary from place to place within the site itself.

2.2 Geology

2.2.1 REGIONAL GEOLOGY

General

The greater part of the district surrounding the site is underlain by Upper Coal Measures of the Carboniferous belonging to the Etruria Formation and the Alveley Member, (Keble Beds and Keele Formation), overlain by glacial deposits.

Most of the strata are red as a result of the diagentic alternation to iron oxide (haematite) of detrital ferromagnesian silicates and iron bearing clay minerals. The Regional Geology taken from the British Geological Survey Sheet 123 (Stoke on Trent), Solid and Solid and Drift.

Etruria Formation

The solid geology comprises strata of the Upper Carboniferous, Barren Coal Measures (Westphalian 'B' Stage), known as the Etruria Formation. The Etruria Marl Formation is dominantly a mudstone sequence, with some silty mudstones and some sandstone bands.

The Etruria Formation comprises red, purple, brown and ochreous grey commonly mottled mudstone, with dominant kaolinite clay mineralogy, with common pedogenic horizons, but few coal seams, and subordinate lenticular green to red coarse grained to conglomeratic sandstones, known as 'aspleys', rich in lithic detritus.

Salop Formation

The Salop Formation comprises two distinct members. A lower Alveley Member (Keele Formation) comprises a red mudstone dominated succession with red, fine to medium grained sandstone and subordinate thin Spiroba Limestone beds and pedogenic calcite. The overlying Enville Member typically is a sandstone dominated with red-brown, fine to coarse grained, locally pebbly sandstone and lenticular beds of conglomerate with common calcareous Limestone clasts, interbedded with red mudstones.

Structure

The site sits between two structural areas; the Western Boundary Fault to the west and the ASpedale Fault to the east and has an anticlinal structure to the west and the main syncline to the east and is
Drift deposits are present around the site as indicated on the BGS Geological Drift Map 123 Stoke on Trent.
2.2.2 LOCAL GEOLOGY

SOLID GEOLOGY

The Eltoria Marl occurs in the north eastern section of the site, as shown on Figure 3, comprises mainly heavily over consolidated, red-brown, purple, grey and yellow mottled silty, fissured mudstone and clays with mudstone lithorelicits in massive units up to 6m thick in which some coarser beds occur. They are poorly sorted and consist mainly of clay sized materials. Some round quartz grains up to 0.5mm in diameter form approximately 5% of the rock. Stiff to very stiff clays are interbeded with more weathered clays of soft to firm consistency.

The mudstones are composed predominantly of kaolinite with micaeous minerals, quartz, iron oxides and a little carbonate. They are therefore not correctly described as Marl.

The main area of the site is underlain by the Keele Formation, and contains upward fining sandstone and mudstone sequences. The lower 100 metres or so contains two major sandstones, the Springpool and Butlerston sandstones. Above this, there are several further sandstones, many of which have limited lateral extent, again shown to be present on site, see Figure 3.

Figure 3. Solid Geological Map.
DRIFT GEOLOGY

The site is covered with a glacial deposit of sand gravel of the Devensian Period, and is the product of glacial meltwater drainage. It is present across the site up to 10 metres in depth above the floodplain level and implies that the sand and gravel infilling this area was well in excess of 10 metres thickness.

Detailed drilling has been carried out on site to determine the depth of glacial sands and gravels, and the drill logs are presented from the two site investigations as Appendix HRA 1 and HRA2. The positions of the boreholes are shown on Drawing No. NHSMP1. The depth of the rockhead of the Salop Formation is shown as Drawing No NHSP2 and is summarised as Figure 4.

Figure 4: Rockhead Contour to Salop Formation

The overall average is 10 metres depth of glacial deposits overlying the Salop Formation. The rockhead level drops towards the River Lea, suggesting largest depths of drift are to the west.
The drift deposits are shown on Figure 5.

**Figure 4: Drift Geology**
2.3 Hydrology

To include details relating to the following:

- The River Lea runs along the western boundary of the site and flows in a northwards direction towards the village of Madeley.
- The minor tributary running into the River Lea is not recorded in the floodplain. The floodplain covers a limited part of the western side of the site, though during the recent heavy precipitation period of 2007 no extensive flooding as shown on the map was observed.
- The surface water run off from the site follows the contours of the land and flows in a generally western direction.

Figure 6: Indicative Floodplain
2.4 Hydrogeology

2.4.1 Aquifer Characteristics

The water resources are administered by Severn Trent Water PLC. In the Carboniferous rocks of the Etruria Formation and the Galop Formation and all sub units form a minor aquifer, although it may contain aquicludes and large proportions are aquitards. The Etruria Formation and Galop Formation are classed by the Environment Agency as a minor aquifer.

The nearest supply boreholes are located almost 10 kilometres to the south of the proposed quarrying activities as shown at Figure 6.

Figure 6: Groundwater Protection Zones near Netherset Hey.

The Etruria Marl at the base of the Barren Measures is predominantly of impermeable argillaceous rocks and yields little or no water. Fractures in the 'espleys' however can yield moderate quantities of water. This is a similar position for the Galop Formation, though the larger sandstone units can yield higher flows of water related to fractures in the large sandstone.

There are no known values of porosity or permeability for the Lower Coal Measures Group core or outcrop samples. Values are available for the younger Coal Measures for two outcrops: that at Saltwells Pit (SG 9353 8704), with average porosity and permeability values of 13.5% and $4.2 \times 10^{-4}$ m/d, and a single sample from a borehole at a depth of 74.7m at Snarestone Lodge (SK 3433 1015) having 16.8% porosity and a hydraulic permeability of $4.2 \times 10^{-5}$ m/d, and are considered to be representative of the Etruria Marl.

Local permeability values of the Upper Coal Measures are available from Poplars landfill are $4.6 \times 10^{-11}$ m/s.
to 8.8 x 10^{-4} m/s. This is considered to be representative of permeability values in the clays and mudstones, in the upper Coal Measure deposits at the site to the north.

Local water will be confined within the ‘esphey’ conglomeratic bands

The final regional groundwater unit is that of the glacial drift deposits. Groundwater monitoring and site investigations have been conducted in and around the potential Netherset Hey site and water strike information and historic data relating the glacial sand and gravels in Staffordshire have been used to assess the potential for groundwater flow in the sand and gravel deposits.

Groundwater is found in the glacial sand and gravel though it is used typically for local supplied for agricultural use and not as a major resource.

Groundwater is encountered in the glacial beds and this can be summarised in borehole results and groundwater observations, as set out in Table HRA2 based on the original site investigations contained in the Tarmac drill Log presented at Appendix HRA2.

The groundwater in the glacial drift is unconfined but can be confined by clay layers.

Local Hydrogeology

Groundwater monitoring of levels has been undertaken based on the water strikes encountered during the site investigations reported by Tarmac in 1994. The drill logs are presented at Appendix HRA2.

Typical permeability tests have previously been undertaken on the glacial drift, within Staffordshire at a major landfill site and the results are summarised in Table HRA 1 below:

Table HRA1: Site investigation boreholes permeability values for glacial sand and gravel

<table>
<thead>
<tr>
<th>STRATA</th>
<th>BH1</th>
<th>BH2</th>
<th>BH3</th>
<th>BH4</th>
<th>BH5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Made Ground</td>
<td>Lab, in-situ</td>
<td>3.4 x 10^{-7}</td>
<td>3.53 x 10^{-7}</td>
<td>3.65 x 10^{-7}</td>
<td>5.08 x 10^{-7}</td>
</tr>
<tr>
<td>Clayey sand and Gravel</td>
<td>Lab, in-situ</td>
<td>3.5 x 10^{-9}</td>
<td>2.7 x 10^{-9}</td>
<td>4.5 x 10^{-9}</td>
<td>4.17 x 10^{-10}</td>
</tr>
<tr>
<td>Clay/Silt/Sand</td>
<td>Lab, in-situ</td>
<td>3.6 x 10^{-8}</td>
<td>3 x 10^{-8}</td>
<td>4.5 x 10^{-9}</td>
<td></td>
</tr>
<tr>
<td>Sand/Gravel</td>
<td>Lab, in-situ</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The minimum permeability value recorded was 4.17 x 10^{-10} m/s, the maximum value is 4.5 x 10^{-9} m/s and the mean value is 6.13 x 10^{-9} m/s. This was considered to be conservatively low based primarily of re-compacted laboratory samples and additional testing has since been carried out.

Additional permeability assessments have been carried out using the gradings obtained from the site investigation boreholes presented at Appendix HRA 3.

The permeability of the sand and gravel has also been determined by Hazen’s Formula.

Using Hazen’s method:

\[
K = \frac{(D_{10})^2}{100} \text{ m/sec}
\]

\[K = \text{Permeability}\]

\[D_{10} = \text{Figure for size of particle passing at 10% of grading curve}\]

Characteristics of material from Particle Size Sieve values would suggest 10% passes the 0.02mm value.
0.02mm sieve = > 10% passing average value

Hence:

\[ D_0 = 0.02 \]

\[ K = 0.01 \times (0.02)^2 \text{ m/sec} \]

\[ K = 4.00 \times 10^{-8} \text{ m/sec} \]

Standing water levels in the glacial sand and gravel beds was encountered between 106.06 and 110.54m AOD.

The Environment Agency has confirmed that the site is not within a Groundwater Protection Zone.

The site is not within a Nitrate Sensitive Zone as presented at Figure 6.

**Figure 6: Nitrate Sensitive Zone Map**

The site is therefore not within a major resource catchment and would have minimal impact on major and minor groundwater resource.

The nearest area of protection is the surface water of the River Lea. Measures are proposed in Section 4.1 to protect this by way of initial diversion and lining and for the area to become compensation ponds for flood defence in the long term.
2.4.2 Groundwater Flow

Groundwater dip levels for the site have remained consistent showing similar cyclic trends with the levels rising in the winter period and dropping in the summer months and recent groundwater levels have shown similar flow patterns to those previously reported.

Standing water levels in the glacial sand and gravel beds was encountered between 106.06 and 110.54m AOD. The summary results from the Tarmac boreholes is presented at Table HRA 2.

<table>
<thead>
<tr>
<th>Easting</th>
<th>Northing</th>
<th>Groundwater</th>
</tr>
</thead>
<tbody>
<tr>
<td>T09</td>
<td>378155.2</td>
<td>342969.3</td>
</tr>
<tr>
<td>T01</td>
<td>378311.9</td>
<td>343189.7</td>
</tr>
<tr>
<td>T10</td>
<td>378170.3</td>
<td>343331.2</td>
</tr>
<tr>
<td>T16</td>
<td>377939.7</td>
<td>343503.8</td>
</tr>
<tr>
<td>T17</td>
<td>378123.0</td>
<td>343511.4</td>
</tr>
<tr>
<td>T28</td>
<td>377854.7</td>
<td>344051.6</td>
</tr>
<tr>
<td>T29</td>
<td>377747.1</td>
<td>344055.4</td>
</tr>
<tr>
<td>T31</td>
<td>377543.5</td>
<td>343859.3</td>
</tr>
</tbody>
</table>

Groundwater flows have been modelled based on dip levels recorded on the logs and are presented as a variogram Surfer plot model as Figure 7 and have been transposed onto the site map and are presented as Drawing No. NHSMP3.

Figure 7: Groundwater Plot
Groundwater flow is typically in a westerly direction draining towards the River Lea. The groundwater flow follows the contours of the land and is also influenced by the rockhead profile of the Salop Formation.

The hydraulic gradient has been assessed and can be seen to fall in a westerly direction at over a distance of 600 metres, and the head loss is 4.0 metres giving a gradient value of 0.0066.

Groundwater recharge would expect to be rapid on completion of any workings due to the high water table values at all locations around the proposed mineral quarry footprint.

3.0 SITE INVESTIGATIONS

3.1 Previous Site Investigations

In assessing the potential mineral reserves, depth of minerals and groundwater levels a number of site investigations have been carried out.

RMC Site Investigation Boreholes 1994, Appendix HRA1

Tarmac Site Investigation Boreholes, Appendix HRA2

Sand and Gravel Gradings, Appendix HRA3. The soil samples collected from each trial pit were collected and bagged in accordance with BS 5930:1999 Site Investigations

All of the boreholes and trial pit locations are presented at Drawing NHSMP1.

3.2 New Site Investigations

Recently installed piezometers have been installed near to the River Lea and the railway line to assess the water table and to be used for all design works relating to the stability of the railway and realignment of the river.

The new groundwater readings are presented at Appendix HRA 4.

All of the boreholes and trial pit locations are presented at Drawing NHSMP1.
4.0 HYDROGEOLOGICAL IMPACTS

The hydrogeological risk assessment has been required to demonstrate that the quarry workings will have no impact on the surface water, affect nearby structures, local supply and slope stability.

4.1 Surface Water Control

The River Lea runs along the western boundary of the development and currently meanders. The floodplain follows this route. In order to collect maximum mineral reserves and to prevent river base flow entering the site it is proposed to re-align the River Lea as shown on Drawing No NSM4 for the boundary length. The new course would be lined using a bentonite enhanced clay to prevent base flow loss into the quarry and reducing river flows.

The performance of the GCL is wholly dependent on the quality of its installation. It is the installer's responsibility to adhere to these guidelines, and to the project specification and drawings, as closely as possible. It is the engineer's and owner's responsibility to provide construction quality assurance (CQA) for the installation in order to ensure that the installation has been executed properly. This document covers only installation procedures. Recommended GCL CQA procedures can be found in CETCO's TR-410.

The GCL comes in rolls weighing from 980-1,320 kg. It is necessary to support this weight using an appropriate core pipe as indicated in Table 1. For any installation, the core pipe must not deflect more than 75 mm as measured from end to midpoint when a full GCL roll is lifted.

<table>
<thead>
<tr>
<th>Product</th>
<th>Nominal GCL Panel Size, length x width, m</th>
<th>Typical GCL Roll Wt, lbs (kg)</th>
<th>Interior Core Size, in (mm)</th>
<th>Core Pipe, length x diameter, (m x mm)</th>
<th>Minimum Core Pipe Strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bentomat SS</td>
<td>4.5 x 40</td>
<td>1190 and 1320</td>
<td>95</td>
<td>5 x 75</td>
<td>XXH</td>
</tr>
<tr>
<td>Claymax 200R</td>
<td>4.2 x 45</td>
<td>1,140</td>
<td>100</td>
<td>4.9 x 75</td>
<td>XXH</td>
</tr>
<tr>
<td>Claymax 600 SP</td>
<td>4.2 x 45</td>
<td>1,140</td>
<td>100</td>
<td>4.9 x 75</td>
<td>XXH</td>
</tr>
</tbody>
</table>

Lifting chains or straps each rated for at least twice the load of the GCL should be used in combination with a spreader bar made from an I-beam as shown in the cover illustration. The spreader bar ensures the lifting chains or straps do not chafe against the ends of the GCL roll, which must be able to rotate freely during installation.

A front-end loader, backhoe, dozer, or other equipment can be furnished with the spreader bar and core bar. Alternatively, a forklift with a "stinger" attachment may be used for on-site handling and, in certain cases, installation. A forklift should not be used to lift or handle the GCL rolls. Stinger attachments specially fabricated to fit various forklift should be used.

When installing over certain geosynthetic materials, a 4-wheel all-terrain vehicle (ATV) can be used to deploy the GCL from behind. An ATV can be driven directly on the GCL provided that no sudden stops, starts, or turns are made. Additional equipment needed for installation of GCL includes:

- Utility knives and spare blades (for cutting GCL).
Granular bentonite or bentonite mastic (for overlapped seams of GCLs with needlepunched non-woven geotextiles and for sealing around structures and details). Both are available from CETCO.

- Waterproof tarps (for temporary cover on installed material as well as for stockpiled rolls).
- Option chalk line marker to simplify bentonite placement at seams (when installing a GCL with needlepunched non-woven geotextile components).
- Optional flat-bladed vise-grip tools (for positioning GCL panel by hand).

If the GCL is placed over an earthen subgrade, the surface must be compacted to at least 90 percent modified Proctor density or to the extent required by the project specifications. Engineer's approval of the subgrade must be obtained prior to installation. The finished surface must be firm and unyielding, without abrupt elevation changes, voids, cracks, ice, or standing water.

The subgrade surface must be free of vegetation, sharp-edged rocks, stones, sticks, construction debris, and other foreign material that could contact the GCL. The subgrade should be rolled with a smooth-drum compactor to remove any wheel ruts, footprints, or other abrupt grade changes. Furthermore, all protrusions extending more than 12 mm from the subgrade surface shall either be removed, crushed, or pushed into the surface with a smooth-drum compactor. The GCL may be installed on a frozen subgrade, but the subgrade soil in the unfrozen state should meet the above requirements.

In most cases, GCLs are delivered on flatbed trucks. To unload the rolls from the flatbed, insert the core pipe through the roll. This may require removal of the core plug, which should be replaced after the roll is unloaded. Secure the lifting straps or chains to each end of the core pipe and to the spreader bar mounted on the lifting equipment. Holst the roll straight up; make sure its weight is evenly distributed so that it does not tilt or sway when lifted.

GCLs are also occasionally delivered in closed shipping containers. To remove the roll from the container, it is best to utilize a forklift equipped with a "stinger" attachment. Guide the stinger as far as possible through the core and lift the roll up and out of the container.

GCL rolls should be taken to the working area of the site in their original packaging. Immediately prior to their deployment, the packaging should be carefully removed without damaging the GCL. The orientation of the GCL (i.e., which side faces up) may be important if the GCL has two different geotextiles. Unless otherwise specified, however, the GCL shall be installed such that the product name printed on one side of the GCL faces up.

Equipment which could damage the GCL shall not be allowed to travel directly on it. Acceptable installation, therefore, may be accomplished such that the GCL is unrolled in front of the backward-moving equipment (Figure 1). If the installation equipment causes rutting of the subgrade, the subgrade must be restored to its originally accepted condition before placement continues.

Care must be taken to minimize the extent to which the GCL is dragged across the subgrade in order to avoid damage to the bottom surface of the GCL. A temporary geosynthetic subgrade covering commonly known as a slip sheet or rub sheet may be used to reduce friction damage during placement.

The GCL should be placed so that seams are parallel to the direction of the slope. End-of-roll seams should also be located at least 1 meter from the toe and crest of slopes steeper than 4H:1V.

All GCL panels should lie flat on the underlying surface, with no wrinkles or folds, especially at the exposed edges of the panels.

For Cleymax, which is an unreinforced GCL, the mat should be covered on the same day as installation to prevent the risk of premature hydration and delamination.

For Bentomat, which is a reinforced GCL, the mat may remain uncovered for up to a week as the needle-punching effectively prevents any adverse effect of premature hydration. However, if the mat is wet, it should not be frequently walked on.
If required by the project drawings, one end of the GCL roll should be placed in an anchor trench at the top of the slope. The front edge of the trench shall be rounded so as to eliminate any sharp corners that could cause excessive stress on the GCL. Loose soil should be removed or compacted into the floor of the trench.

Sufficient anchorage may alternately be obtained by extending the end of the GCL roll back from the crest of the slope. The length of this "runout" anchor is project-specific.

If a trench is used for anchoring the end of the GCL, soil backfill should be placed in the trench to provide resistance against pullout. The size and shape of the trench, as well as the appropriate backfill procedures, should be in accordance with the project drawings and specifications. Typical dimensions are shown in Figure 9.

The GCL should be placed in the anchor trench such that it covers the entire trench floor but does not extend up the rear trench wall.
Figure 9: Anchor trench details

GCL seams are constructed by overlapping their adjacent edges. Care should be taken to ensure that the overlap zone is not contaminated with loose soil or other debris. Supplemental bentonite is required if the GCL has one or more non-woven needlepunched geotextiles.

Unless otherwise specified, the minimum dimension of the longitudinal overlap should be 150 mm. End-of-roll overlapped seams should be similarly constructed, but the minimum overlap should measure 300 mm.

Seams at the ends of the panels should be constructed such that they are shingled in the direction of the grade to prevent the potential for runoff flow to enter the overlap zone.

Bentonite-enhanced seams are constructed first by overlapping the adjacent panels as instructed previously, then exposing the underlying edge, and then applying a continuous bead or fillet of granular sodium bentonite (supplied with the GCL) along a zone defined by the edge of the underlying panel and the 150 mm line (Figure 10). The minimum application rate at which the bentonite is applied is 0.4 kg/m.

Figure 10: Overlap details for GCL
4.2 De-watering

The groundwater has been monitored around the Netherset Hey and it has been demonstrated groundwater is encountered within the glacial sand and gravel. The groundwater plot is shown as Drawing No NHSMP3.

The groundwater levels in the glacial sand and gravel are locally unconfined and the drawdown is derived from the Dupuit assumptions;

\[ Q = 2\pi KH \frac{dh}{dr} \]

which when integrated between the limits \( h = h_w \) at \( r = r_w \) and \( h = h_0 \) and \( r = r_0 \)

\[ Q = \frac{\pi K h_0^2 - h_w^2}{\ln(r_0/r_w)} \]

\( r = 2 (YW)^{0.5} \)

\( Y \) = length of excavation
\( W \) = width of excavation
\( R \) = radius of influence

The radius of influence is a function of the drawdown \( h \) and the permeability \( K \).

\( R = C h v K \)

\( C \) is equal to 1800 for in line flow against quarry wall

The drawdown calculations are set out below

\( h = 8.9 \text{ m} \)

\( K = 4.17 \times 10^{-10} \text{m/s} \)

\( K = 4.00 \times 10^{-6} \text{m/s} \)

\( R_1 = 0.31 \text{m Minimum Zone of Influence} \)

\( R_2 = 30.6 \text{Maximum Zone of Influence} \)

Groundwater drawdown would only occur during the operational phase of quarrying and groundwater would rebound on completion of quarrying. The way to reduce the total impact on the clay

4.3 Slope Stability

The railway line will be at a distance of 9 metres from the edge of the river and with a 30 metre standoff from the railway line would have no influence of the water beneath the line. In addition the clay obtained from the excavation in the western area could be used to form an engineered barrier along this line to prevent groundwater ingress into the quarry and would be stable.

Further slope stability work will be required, but the factors of safety of the slopes will be designed with a short term FoS of 1.3.
5.0 LONG TERM BENEFITS

To provide information on the future benefits at the site and to consider the implication of improved biological diversity from restoration.

5.1 Compensation ponds and flood control

The current site western boundary is within the indicative flood plain. The lower section of the site could be restored using ponds with natural groundwater recharge. The size of the lake would provide two to three times the floodplain currently indicated on Figure 5.

The River Lea has the option to remain as an engineered lined section through the former quarry or could be diverted to flow through the new formed lakes.

The removal of the GCL is a straightforward operation and the material could be used to line additional ponds elsewhere as part of the long term restoration.

5.2 Landscape Benefits

The current landscape is agricultural land used for grazing. The use of ponds would allow for greater biological diversity benefiting the aquatic and land ecosystems, and allow for more diverse planting schemes and offer greater afteruse.
6.0 CONCLUSIONS

The site can be worked so as to have minimal groundwater impact by way of draw down and it is anticipated that recharge would occur very quickly.

The quarry would have no impact on the main line.

The estimated volume of sand and gravel is 12,883,464 tonnes of sand and gravel and assuming a working depth in the clay site of some 25 metres an available figure of 10,379,256 tonnes of Etruria Marl

The quarry has potential for greater biological restoration diversity than currently exists.