Study of interaction between Broad Oak Reservoir and Richborough Connection project

South East Water

Geo-environmental Desk Study

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Executive Summary

South East Water (SEW) is proposing the development of a new dam and reservoir to be located north of the village of Broad Oak, Canterbury, Kent. In connection with this, National Grid plc is proposing a new over ground transmission route which, in part, will run adjacent to the southern boundary of the reservoir.

The proposed development site is located approximately 1km north of the village of Broad Oak and 5km north-east of Canterbury, Kent. The site at present is open farmland with a small river (Sarre Penn) running through the site. From historical records, the area has been open farmland since the mid-19th Century.

The geology of the area is detailed on the British Geological Survey (BGS) Sheet No 273 (1:50,000 scale) and indicates that part of the site is underlain by superficial head deposits, which are present along the route of the Sarre Penn river. For the remainder of the dam and reservoir site, these superficial deposits are absent. The underlying bedrock comprises the London Clay Formation, to a depth of approximately 23m.bgl. Below the London Clay, the strata sequence comprises the following; Harwich Formation, Lambeth Group, Thanet Sand Formation, then Upper Chalk Formation, with the top of the Upper Chalk at a depth of approximately 75m.bgl.

The London Clay and head deposits are both unproductive strata for groundwater abstraction and there are no landfills, industrial land uses or sensitive land uses within 1km of the site.

Geological and geotechnical data has been obtained from a ground investigation Factual Report which was undertaken in 2008 for the proposed dam and reservoir. Although this covers the same footprint of the proposed dam / reservoir, it did not include the diversion of the Sarre Penn River, or National Grid transmission route. The Interpretative Report associated with this ground investigation was not available. Outline geotechnical design parameters have therefore been suggested based on the factual information.

The main geotechnical and environmental risks are as follows;
- Unknown ground and groundwater conditions,
- Unknown geotechnical parameters
- Unexploded ordnance (UXO),
- Asbestos including sheets and loose fibres (demolition of buildings),
- Fertilizer, pesticides,
- Pathogens from septic tanks and slurry spreading,
- Diesel storage, spillage and fuelling of vehicles,
- Volatile Organic compounds.

Further detailed ground investigation will be required once the final layout / design of the dam, reservoir and re-routing of the Sarre Penn has been confirmed, however, a preliminary ground investigation is recommended to provide further site specific geotechnical and environmental information.

The National Grid are in the process of commissioning a ground investigation for the proposed transmission line to the south of the reservoir. Information from the preliminary ground investigation can be shared with the National Grid to avoid potential duplication of investigation work. It is envisaged that the National Grid will also provide relevant information from their ground investigation, to assist in the interpretation of ground conditions at the dam and reservoir site. A suggested scope of preliminary investigation is provided.
1. Introduction

1.1 General

South East Water (SEW) is proposing to construct a new dam and reservoir to the north of the village of Broad Oak, Canterbury, Kent. Raw water abstracted from the Great Stour at Plucks Gutter, approximately 12km downstream of Canterbury, will be pumped to the new reservoir for storage. Water from the reservoir will then be treated at a new water treatment works downstream of the new dam and pumped into supply. In addition, National Grid Transmissions plc (NG), is proposing a new over ground transmission line, which will run adjacent to the southern edge of the reservoir boundary. Figure 2 in Appendix A shows the proposed development.

This geotechnical desk study looks at the available ground information in the area of the proposed dam and reservoir, as well as the route of proposed re-alignment of the Sarre Penn stream. The information will also be used by NG to assist in the design of the transmission tower foundations. Recommendations are made for further ground investigation, considered necessary to fill any gaps in the available information.

1.2 Report Objectives

The objectives of this desk top study report are to identify and assess the existing information relating to ground conditions and the environmental setting at the site of the proposed development as noted above. The desk study includes:

- Review existing available geotechnical investigations and publically available data,
- Provide an initial appraisal of the existing ground conditions at the development site,
- Provide a description of the site history, environmental setting, anticipated ground conditions and potential for ground contamination sources and,
- Provide recommendations for an initial ground investigation, contamination testing and further assessment (if required).

1.3 Information Sources

The following information sources have been used to inform this desk study report:

- Landmark Information Group Envirocheck Report (1), including historical Ordnance Survey (OS) maps, data sheets and site sensitivity plans, dated April 2015 Ref No.66428786_1_1,
- British Geological Survey (BGS) 1:50,000 Sheet No 273 – Faversham, Solid and Drift (2),
- British Geological Survey (BGS) Onshore GeoIndex (3),
- Environment Agency's website “What's in your back yard?” (4),
- Factual Report Broad Oak Reservoir – Norwest Holst, October 2008(5),
- Preliminary site walkover in relation to the proposed ground investigation.

1.4 Limitations

This report was prepared for the exclusive use of South East Water and its designated representatives. Any use a third party makes of this report, any reliance on or decisions made based on it, are the responsibility of such third parties. Jacobs UK Ltd (Jacobs) accepts no responsibility for damages suffered by any third party as a result of decisions made or actions taken based on this report.

There is no warranty, expressed or implied that the work reported herein has uncovered all potential geotechnical and environmental liabilities associated with the site. The findings of this report were developed in a manner consistent with a level of care and skill normally exercised by members of the environmental science and engineering profession currently practising under similar conditions.

A number of the findings and conclusions presented in this report are based on information provided by third parties and / or historical records which South East Water have relied on in good faith. Jacobs
accepts no responsibility for any deficiency, misstatements, or inaccuracy contained in this report as a result of errors, omissions or misstatements of said third parties or from information obtained from them.

A potential remains for the presence of unknown, unidentified, or unforeseen surface and sub-surface contamination. Any additional evidence of such potential site contamination would require appropriate surface and subsurface exploration and testing.

If new information is obtained or developed during future work (which may include excavations, borings, or other studies), Jacobs should be requested to re-evaluate the conclusions of this report, and to provide amendments as required.
2. Site Setting and History

The following information has been obtained from the Landmark Envirocheck Report \(^{(1)}\), BGS 1:50,000 Sheet No 273\(^{(2)}\) and other sources of information referred to in Section 1.3.

2.1 Location and Description

The proposed dam and reservoir are located approximately 1km north of the village of Broad Oak and 5km north-east of Canterbury, Kent. The site at present is open farmland with a small stream (Sarre Penn) running through the site. It is understood that this will be diverted to the south of its present course as part of the development. In addition, National Grid Transmissions Plc (NG) is constructing a new overhead line transmission route, which will run along the southern side of the proposed reservoir. See Figure 2 in Appendix A for the proposed location of the new dam, reservoir and transmission line.

2.2 Site History

Historical OS maps dating from 1872 to 2015 and contained within the Envirocheck Report \(^{(1)}\) have been used to review the development of the site. Table 2.1 below summarises the history of the proposed development site;

<table>
<thead>
<tr>
<th>OS Map Date</th>
<th>Comment</th>
</tr>
</thead>
</table>
| 1872        | Proposed Development Site  
First available OS map (scale 1:2,500) indicates the buildings of Vale Farm and Vale Cottages in the approximate location of the proposed dam. The proposed development site and surrounding area comprises open fields and connecting farm tracks. The small water coarse (Sarre Penn) runs west to east through the site.  
Off-site  
The small settlement of Broad Oak is located approximately 1km to the south. A road (Herne Bay Road) lies on the future alignment of the A291, approximately 0.7km to the east of the site and runs from Broad Oak in the south, towards Calcott Common to the north. The buildings of Mayton Farm are situated on higher ground approximately 1km to the west of the proposed dam. | |
| 1951        | Site location in relation to the farm buildings and open fields remain unchanged. The fields to the south of the proposed reservoir, south of Heel Lane are now indicated as an orchard. | |
| 1961        | Site location in relation to the farm buildings and open fields remain unchanged. In the south west corner of the footprint of the proposed reservoir and west of Mayton Cottages, a small reservoir is first indicated, approximately 170m x 25m in size. The orchard to the south now extends north of Heel Lane and east of Mayton Lane. | |
| 2006        | No change in use of the proposed dam and reservoir location, the village of Broad Oak indicates an increase in housing within the village boundary. | |
| 2015        | No change | |

*Table 2.1: History of the proposed development site and surrounding area from historic OS maps.*
2.3 Geological Setting

The BGS 1:50,000 Sheet No 273\(^{(2)}\) describes the superficial deposits along the route of the Sarre Penn stream as head deposits. For the remainder of the proposed dam and reservoir, the superficial deposits are absent. The underlying bedrock comprises London Clay Formation. The BGS Lexicon of Named Rock Units\(^{(3)}\) describe the head deposits and London Clay as below.

2.3.1 Superficial (Head) Deposits

Comprising gravel sand and clay depending on upslope source and distance from source. Poorly sorted and poorly stratified deposits formed mostly by solifluction and/or hill-wash and soil creep. Essentially comprises sand and gravel, locally with lenses of silt, clay or peat and organic material.

2.3.2 London Clay Formation

Mainly comprises bioturbated or poorly laminated, blue-grey or grey-brown, slightly calcareous, silty to very silty clay, clayey silt and sometimes silt, with some layers of sandy clay. It commonly contains thin courses of carbonate concretions (‘cementstone nodules’) and disseminated pyrite. It also includes a few thin beds of shells and fine sand partings or pockets of sand, which commonly increase towards the base and towards the top of the formation. At the base, and at some other levels, thin beds of black rounded flint gravel may occur in places. Glauconite is present in some of the sands and in some clay beds white mica occurs at some levels.

2.4 Environmental Setting

2.4.1 Hydrogeology

The superficial deposits (head deposits) along the route of the Sarre Penn and the underlying London Clay bedrock are both designated by the Environment Agency (EA) as “Unproductive Strata” with low permeability and negligible significance for water supply or river base flow. The site is not indicated to be within a source protection or groundwater vulnerability zone. The nearest water abstraction point is at Goose Farm, Broad Oak, located 0.9km west of the proposed dam and reservoir location.

2.4.2 Hydrology

The main natural water course in the vicinity and flowing west to east through the centre of the proposed site is the Sarre Penn, designated a Primary river by the EA. Flowing into this are numerous small secondary streams/rivers and drains, mainly joining the Sarre Penn in the vicinity of Vale Farm. The Sarre Penn is a tributary of the River Wantsum, joining it 8km to the north-east. There are springs indicated on the OS maps; located on the higher ground approximately 1km to the north and south of the proposed development site.

There are a number of man-made lakes in the vicinity; located west of Matyon Cottages is a reservoir approximately 0.5ha in area, and located beyond the A291 approximately 0.8km to the east are a series of lakes totalling approximately 2.4ha in area. It is understood these are leisure / fishing facilities.

The EA Flood Risk Assessment which uses ground levels, predicted flood levels, information on flood defences and local knowledge, indicates the risk of flooding from the Sarre Penn and adjacent streams to be low in the vicinity of Vale Farm, increasing to medium to the east. The risk of flooding from surface water and drains along the route of the Sarre Penn is locally medium to high. However the development site is not in an area where the EA issue flood warnings.
2.4.3 Environmental Sensitivity
The environmental sensitivity of the potential receptors has been assessed as follows;

- Construction worker - Medium
- Maintenance/utility workers after development - Medium
- Shallow groundwater in the head deposits and London Clay - Medium
- The Sarre Penn River - Medium

2.4.4 Landfill
The nearest landfill is located approximately 1.0km to the south of the proposed reservoir’s southern extent, listed as Shelford Quarry and sandpit. This is on the location of an historic sand/gravel pit. The EA records indicate that the landfill first received waste in 1976, with the waste listed as including inert, industrial, commercial, household, special and liquid/sludge. The landfill is currently operated by Viridor Waste (Kent) Ltd. The waste licence is for household, commercial and industrial wastes. There are no other historic landfills in the immediate vicinity.

2.4.5 Industrial Land Uses
No industrial land uses are listed in the Envirocheck Report within 0.75km of the proposed development. The site of the proposed dam and reservoir has been farmed since the OS records are available. There are existing farm buildings including houses, barns and storage units that may contain, asbestos in their construction. It is recommended that this is investigated in future investigations if demolition is being considered.

2.4.6 Sensitive Land Uses

The nearest Site of Special Scientific Interest (SSSI) is the West Blean and Thornden Woods, located 1km to the north of the proposed dam and reservoir site.

2.4.7 Unexploded Ordnance (UXO)
It is understood that WS Atkins Ltd (Atkins) commissioned a UXO survey from Fellows International Ltd in 2008, which formed part of their Interpretative Report on the ground investigation carried out that year by Norwest Holst. However, at the time of writing the Atkins report was not available and the following is therefore taken from a brief summary of the unexploded ordnance threat supplied by Fellows, in an email sent prior to the issue of the report, dated August 2008 (supplied by SEW). It is understood that the survey covers the proposed dam location and the pipeline route to the dam. The email is reshowed below with the basic outline of the survey (as supplied) indicated on Figures 2.2 and 2.3;

“...the threat posed by unexploded munitions along the proposed pipeline route from Sarre to Tyler, Kent Our research so far indicates that there was a substantial amount of ordnance dropped on or launched at the South East during WW2, and this whole area was heavily bombed, given its location south of the Thames Estuary and proximity to the French coast. It was therefore a major target for air dropped bombs, incendiaries, parachute mines and V1 rockets.

During the Second World War, some 10,445 bombs were dropped on Canterbury and the surrounding areas during 135 separate air raids. 731 homes and 296 other buildings were destroyed and 115 people killed.

Because of the level of bombing and numbers of unexploded bombs still thought to be undiscovered, the chances of encountering unexploded bombs cannot be discounted. The area was also covered by numerous anti-aircraft batteries and civil airfield decoys were sited nearby.
Therefore as a result of this information, the risk associated with German WW2 land launched and air dropped weapons plus British anti-aircraft defensive weapons along the proposed pipeline route is assessed as medium, although this may be higher given the increased activity in the Southern part (of the site), especially around Sturry.

It is recommended that non-intrusive ground investigations be considered prior to the commencement of any intrusive ground investigation or earthworks along the route. The requirement for further intrusive work will be based upon the results of any non-intrusive investigations.

As a high percentage of ordnance was of non-ferrous construction it is recommended that any non-intrusive survey conducted in support of your ground investigations should be conducted using locators that detect all kinds of metals and alloys”.

Figure 2.2 and 2.3 below indicate wartime incidents recorded along the proposed pipeline route.

![Wartime Incidents](image)

*Figure 2.2: Wartime Incidents recorded along the proposed pipeline route.*
2.5 Mining

Based on the Envirocheck Report\(^1\) obtained for this desk study, there is no indication of coal mining activity within 1km of the proposed development site; it is understood that the Kent Coal measures are at significant depth (>300m bgl), ie below the chalk. No further investigation to the location of the coal measures was undertaken for this desk study. However, a review of mining activity (including both coal and chalk) is recommended as part of updating the risk assessment.

\(\text{Figure 2.3: Local AA batteries, decoys and airfields along the proposed pipeline route.}\)
3. **Ground Conditions**

3.1 **BGS Records**

The BGS Onshore GeoIndex\(^3\) includes records of historic boreholes. However in the vicinity of the proposed development there are only four records of which three are marked as “confidential”. The one available record is a 124m deep well located on Goose Farm, Broad Oak, drilled in 1999 (TR16SE12). The record only provides the following brief descriptions of the strata encountered;

- GL to 23m Green / blue clay – Assumed to be the London Clay Formation,
- 23m to 40m Yellow / buff sand – Assumed to be Lambeth Group,
- 40m to 75m Grey sandy clay – Assumed to be Thanet Sand Formation,
- 75m to >124m Chalk with flints – Assumed to be the top of the Upper Chalk.

Standing groundwater was recorded as 48.6m.bgl in the Thanet Sand Formation.

3.2 **2008 Norwest Holst Ground Investigation**

3.2.1 **Introduction and Scope**

A ground investigation was commissioned in 2008 by Atkins on behalf of SEW, with the ground investigation work being carried out by Norwest Holst. However, at the time of writing, only the Factual Report\(^5\) issued by Norwest Holst for the work undertaken was available from the archives of SEW. The plan of the 2008 investigation is included on Figure 3 in Appendix A. This covered the reservoir, dam site and connecting pipeline. The investigation included the following;

- 19 No. Cable percussive boreholes, drilled to depths between 10.0m.bgl to 25m.bgl, (BH08/01 to BH08/19).
- 6 No hand excavated inspection pits to between 0.5m.bgl to 1.0m.bgl, (IP08/01 to IP08/06).
- 17 No. machine excavated trial pits to between 3.5m.bgl to 4.5m.bgl (TP08/51 to TP08/67).
- 25 No. Window sample boreholes drilled to depths between 4.4m.bgl to 6.0m.bgl (WS08/23 to WS08/47), with dynamic probing undertaken in four locations (WS08/23, 25, 30 & 47).
- Hand vane tests in trial pits and window sample boreholes between 0.5m.bgl to 6.0m.bgl.
- 13 No. In situ variable head permeability tests in four boreholes (BH08/01, 03 04 & 16) at depths of between 5m.bgl to 21.3m.bgl.
- Installation of 16 standpipes in 15 boreholes and window sample boreholes, with groundwater and gas monitored for four weeks at the end of the investigations.
- Geotechnical laboratory tests on samples from boreholes, trial pits and window sample boreholes including classification, strength, oedometer consolidation and soil re-use tests.
- Chemical testing for concrete classification.
- 10 No. contamination suit of tests for metals, PAH, TPH-CWG & VOC.

3.2.2 **Ground Conditions Encountered**

The exploratory hole logs generally concur with the general stratigraphical sequence from the BGS records, outlined in Sections 2.3 and 3.1. Geological cross section locations are shown on Drawing 1400058/BROADOAK/1003 – Location Plan with the cross sections shown on drawings 1400058/BROADOAK/1003 Geological Section 1-1, 2-2, 3-3, 4-4, 5-5 and 6-6, in Appendix A. The following is a summary of the ground conditions encountered across the site.
3.2.2.1 Along the route of the Sarre Penn

Along the route of the existing Sarre Penn there are superficial deposits in the form of cohesive and granular head deposits overlying a relatively thin layer of London Clay Deposit. This overlies a succession of mainly granular deposits, comprising of the Harwich formation, Lambeth Group and Thanet Sand formation.

The thicknesses of the strata recorded in the boreholes along the proposed new route of the Sarre Penn, is variable. Below is a summary of the succession of strata encountered. It should be noted that London Clay was not recorded in borehole BH08/03 and granular head deposits were not encountered within borehole BH08/04:

- 0.90m to 3.70m of sandy Clay (Cohesive Head Deposits);
- 0.50m to 1.90m of sandy Gravel (Granular Head Deposits);
- 1.50m to 3.30m of stiff silty Clay (London Clay Formation);
- 2.70m to 5.70m of dense clayey fine Sand (Harwich Formation – Oldhaven Member);
- 0.40 to 1.20m of very dense Gravel (Harwich formation – Blackheath Beds);
- 5.20m to 10.40m of very dense yellow/brown Sand (Lambeth Group – Upnor Formation);
- >6.60m of very dense green fine Sand (Thanet Sand Formation).

Groundwater was encountered in the head deposits during drilling in three of the boreholes, at depths of between 2.50m and 3.50m.bgl. No groundwater was recorded during drilling in BH08/03.

3.2.2.2 North of the Proposed Reservoir and North Abutment

On the higher ground to the north of the dam and Sarre Penn, the head deposits are less in evidence and there is a greater thickness of London Clay. Thicknesses of strata recorded in the boreholes to the north of the proposed reservoir (BH08/05 and BH08/06) are summarised below:

- 1.10m to 1.50m of sandy gravelly Clay (Cohesive Head Deposits)
- 10.60m to 12.10m of stiff silty Clay (London Clay Formation)
- 6.0m of very dense silty Sand (Harwich Formation – Oldhaven Member)
- >0.8m of dense clayey Gravel (Harwich formation – Blackheath Beds).

Groundwater was encountered during drilling at the top of the Lambeth Group formation at 13.60m.bgl.

3.2.2.3 East of Proposed Dam / Reservoir

To the east of the proposed dam the superficial deposits comprised mainly cohesive head deposits, with little evidence of, or an absence of the London Clay Formation. Thicknesses of the strata recorded in the boreholes to the east of the proposed new dam (BH08/07 and BH08/08) are summarised below:

- 2.30m to 4.20m of slightly sandy Clay (Cohesive Head Deposits)
- 0.90m of slightly clayey fine sand (Granular Head Deposits)
- 1.10m to 3.50m of dense clayey fine Sand (Harwich Formation – Oldhaven Member)
- 1.40m to 2.00m of very dense clayey Gravel (Harwich formation – Blackheath Beds)
- >9.00m of very dense yellow/brown Sand (Lambeth Group – Upnor Formation).

Groundwater was recorded during drilling in BH08/07 at 6.0m.bgl, at the top of the Lambeth Group.
3.2.2.4 West of the Proposed Reservoir

To the west of the proposed reservoir the superficial head deposits were only encountered in one borehole (BH08/16), overlying the London Clay Formation. Thicknesses of the strata recorded in the boreholes to the west of the proposed reservoir site (BH08/15 to BH08/17) are summarised below:

- 2.70m of sandy Clay (Cohesive Head Deposits) over,
- 3.60m to 19.60m of firm to stiff silty Clay (London Clay Formation) over,
- 3.10m to 5.50m of dense clayey fine Sand (Harwich Formation – Oldhaven Member) over,
- 0.30m of sandy rounded Gravel (Harwich formation – Blackheath Beds) over,
- >6.70m of very dense yellow/brown Sand ((Lambeth Group – Upnor Formation).

No groundwater was recorded during drilling in the boreholes located west of the proposed dam / reservoir.

3.3 Geotechnical Parameters

The historical ground investigation data from the 2008 Factual Report by Norwest Holst has been reviewed and the following typical geotechnical parameters have been assessed from exploratory holes in the vicinity of the proposed dam and reservoir. However, the values are preliminary and are for guidance only;

<table>
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<th>Strata</th>
<th>Bulk Density (kN/m³)</th>
<th>Undrained Shear Strength c_u (kPa)</th>
<th>Young’s Modulus E’ (MPa)</th>
<th>Friction Angle Φ’ (°)</th>
<th>Drained Cohesion c’ (kPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head Deposits *</td>
<td>21</td>
<td>40</td>
<td>60</td>
<td>28</td>
<td>0</td>
</tr>
<tr>
<td>London Clay</td>
<td>19</td>
<td>50 – 150 **</td>
<td>7 – 30 **</td>
<td>24</td>
<td>0</td>
</tr>
<tr>
<td>Harwich Formation</td>
<td>NA</td>
<td>NA</td>
<td>70</td>
<td>38</td>
<td>NA</td>
</tr>
<tr>
<td>Lambeth Group</td>
<td>NA</td>
<td>NA</td>
<td>&gt;45</td>
<td>32 to 38 **</td>
<td>NA</td>
</tr>
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</table>

* Superficial deposits are polymict deposits containing more than one constituent material. The soliflucted head deposits typically have variable sand and clay content. It is therefore not possible to reliably predict the geotechnical parameters of the head deposits likely to occur at the proposed development site.

** Increasing with depth

Table 3.1 - Geotechnical parameters assessed from 2008 Ground Investigation data.
3.4 Permeability

Eleven variable head permeability tests were undertaken in four boreholes during the 2008 ground investigation by Norwest Holst; these are summarised below:

<table>
<thead>
<tr>
<th>Borehole Number</th>
<th>Depth of Test (mbgl)</th>
<th>Description</th>
<th>Reported Permeability (m/sec)</th>
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<tbody>
<tr>
<td>BH08/03</td>
<td>5.0 to 6.0</td>
<td>Very dense sand (Harwich Formation)</td>
<td>6.6x10^-6</td>
</tr>
<tr>
<td>BH08/03</td>
<td>6.40</td>
<td>Very dense sand (Harwich Formation)</td>
<td>9.4x10^-6</td>
</tr>
<tr>
<td>BH08/03</td>
<td>7.50</td>
<td>Dense gravel (Harwich Formation)</td>
<td>3.6x10^-5</td>
</tr>
<tr>
<td>BH08/16</td>
<td>13.40</td>
<td>Dense gravel (Harwich Formation)</td>
<td>3.2x10^-6</td>
</tr>
<tr>
<td>BH08/03</td>
<td>10.00</td>
<td>Very dense greyish brown fine sand (Harwich Fm)</td>
<td>4.0x10^-6</td>
</tr>
<tr>
<td>BH08/04</td>
<td>12.90</td>
<td>Brown fine silty sand (Harwich Formation)</td>
<td>3.2x10^-6</td>
</tr>
<tr>
<td>BH08/03</td>
<td>11.50 to 12.50</td>
<td>Brown fine sand (Harwich Formation)</td>
<td>1.8x10^-8</td>
</tr>
<tr>
<td>BH08/03</td>
<td>10.70</td>
<td>Very dense sand (Lambeth Group)</td>
<td>1.5x10^-5</td>
</tr>
<tr>
<td>BH08/16</td>
<td>12.50 to 13.40</td>
<td>Very dense dark grey sand (Lambeth Group)</td>
<td>4.3x10^-6</td>
</tr>
<tr>
<td>BH08/03</td>
<td>14.00</td>
<td>Greenish grey fine sand (Thanet Sand Fm)</td>
<td>3.2x10^-6</td>
</tr>
<tr>
<td>BH08/03</td>
<td>20.40</td>
<td>Dark greenish grey fine sand (Thanet Sand Fm)</td>
<td>1.4x10^-5</td>
</tr>
</tbody>
</table>

No permeability testing was undertaken in the superficial deposits or London Clay formation.
4. Conceptual Site Model (CSM)

The UK framework for the assessment of contaminated land endorses the principle of risk assessment and a “suitable for use” approach to contaminated land. Remedial action is only required if there are unacceptable risks to human health or the environment, taking into account the use of the land and its environmental setting. The assessment of the impacts arising from potentially contaminated land is based upon considerations of pollution linkages between contamination sources and sensitive receptors. The methodology of risk assessment is normally set out in terms of significant pollutant linkages within a source-pathway-receptor model of the site. All three of these elements must be present for a site, or an area of a site, to be determined as contaminated.

The development of the Conceptual Site Model (CSM) follows current industry practice in risk management as a means of identifying potential sources, pathways and receptors and providing a focus for future more detailed investigations. At each stage of the investigation of a site the CSM should be critically examined to determine whether or not the assumptions made in its creation are still valid or require modification to reflect the greater degree of understanding of the ground conditions.

4.1 Potential Sources of Contamination

From the records obtained from SEW, there is no environmental data available for input into an environmental conceptual ground model. Therefore the potential sources of contamination identified are based on a review of historical maps and information presented in the Envirocheck Report (1). The potentially contaminative sources identified within 1km of the proposed site are those associated with farming, have been initially assessed as to potentially include:

- Storage of diesel fuel,
- Storage of and use of fertilizers and pesticides,
- Pathogens from septic tanks and slurry spreading,
- Demolition of old farm buildings potentially containing asbestos,
- Volatile organic compounds.

4.2 Potential Receptors

The following potential receptors have been identified during and after development:

- Construction workers during construction,
- Maintenance/utility workers after development,
- Shallow groundwater in the head deposits and London Clay,
- The Sarre Penn River.

4.3 Potential Pathways

Potential pathways considered with the assessment of pollutant linkages include the following:

- Ingestion of soils or dust,
- Inhalation of dust and airborne particulates,
- Dermal contact with soils or dust,
- Leaching of contaminants directly to groundwater;
- Migration in groundwater
- Migration in surface water and run-off
- Direct contact of building materials with soil and groundwater.

A Preliminary Risk Assessment is included in Appendix B.
5. Conclusions and Recommendations

5.1 Geotechnical Conclusions

Following review of the available data for the proposed dam and reservoir site, the key potential geotechnical constraints to development at the site are identified below;

- Unknown ground and groundwater conditions,
- Unknown geotechnical parameters
- Unexploded ordnance (UXO),

The full preliminary geo-environmental risk register included in Appendix B.

It is understood that the geotechnical and environmental interpretative report obtained from a previous ground investigation undertaken by Atkins in 2008 for the proposed dam and reservoir is no longer available, with only the Factual Report being supplied. It is likely that further detailed ground investigation will be required once the final layout / design of the dam, reservoir and re-routing of the Sarre Penn has been confirmed, however, a preliminary ground investigation is recommended to provide further site specific geotechnical and environmental information, to aid planning consent and provide the authorities (EA, Local Councils etc.) with confirmation that the proposed development is a viable and cost effective option. The results of the preliminary ground investigation would be combined with that from the 2008 investigation for this purpose.

5.2 Land Contamination Conclusions

A desk based review and assessment of the risks from potential contamination issues has been undertaken for the proposed development site, based on the available information. A review of the available sources identified that the site has been open farmland since the late nineteenth century. Potentially contaminative activities associated with historic land use include the following:

- Asbestos including sheets and loose fibres (demolition of buildings),
- Fertilizer, pesticides,
- Pathogens from septic tanks and slurry spreading,
- Diesel storage, spillage and fuelling of vehicles,
- Volatile Organic compounds.

These contaminants pose the greatest risk to the Sarre Penn River which flows through the centre of the development.

5.3 Recommendations

5.3.1 Preliminary Ground Investigation

The proposed preliminary ground investigation is aimed at providing site specific geotechnical and environmental information on the following;

- Proposed route of the watercourse diversion, including the proposed transmission line route
- Soil classification, strength, characterisation and permeability,
- Groundwater levels,
- Dam foundations,
- Outline permeability of the strata.

5.3.2 Geotechnical Scope

The scope for the preliminary ground investigation may include the following;
• Nine mechanically excavated trial pits to 3m.bgl,
• 22 window sample boreholes to 5m.bgl,
• Five cable percussive boreholes to depths between 10m and 20m.bgl, to include four piezometer installations,
• Contamination sampling from trial pits and boreholes from a range of locations and depths,
• Geotechnical laboratory testing to include classification, particle grading and strength tests.

5.3.3 Environmental Investigation

The Chemical analysis of environmental samples for a range of contaminants to include;

• Metal (soil suite) Arsenic, Cadmium, Chromium, Copper, Lead, Mercury, Nickel, Selenium and Zinc
• Polyaromatic Hydrocarbons (US EPA 16 plus coronene (PAH),
• Total Petroleum Hydrocarbon (TPH) (Criteria Working Group),
• Semivolatile Organic compounds (SVOC),
• Volatile Organic compound (VOC),
• OCP and OPP Pesticides
• Asbestos screen,
• Waste classification,
• Waste Acceptance Criteria (inert)* (WAC).
• Waste Acceptance Criteria (inert) (Leachate).

*WAC (total suite) testing to be undertaken if material is going to be disposed of via non-hazardous landfill. It is not known at the time of writing if this is the case.

The location of the proposed exploratory holes is shown on Figure 4 in Appendix A.
References

1. Landmark Information Group (Ltd), Envirocheck Report Ref No 66428786_1_1 Dated April 2015.
2. British Geological Survey (BGS) 1:50,000 Sheet No 273 – Faversham, Solid and Drift.
5. Factual Report on a Ground Investigation for Broad Oak Reservoir – Norwest Holst, dated October 2008,
Appendix A. Figures and Drawings

Figure 1 – Proposed Development Location
Figure 2 – Proposed Development Layout
Figure 3 – 2008 Site Investigation Locations
Figure 4 – Proposed Site Investigation Locations (2015)

Drawings
B14000AG/BORStudy/710-716 - Geological Cross Sections; Plan and sections 1-1, 2-2, 3-3, 4-4, 5-5 and 6-6
Drawings

B14000AG/BORStudy/710-716 - Geological Cross Sections; Plan and sections 1-1, 2-2, 3-3, 4-4, 5-5 and 6-6
### Appendix B. Preliminary Risk Assessments

#### Geotechnical

<table>
<thead>
<tr>
<th>Hazard/Risk</th>
<th>Cause</th>
<th>Consequence</th>
<th>Mitigation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unknown ground conditions.</td>
<td>Lack of ground investigation data and interpretation of limited data.</td>
<td>Cost and programme implications if unexpected ground conditions encountered during construction.</td>
<td>Specify a suitable and adequate ground investigation, followed by interpretation of data to determine the ground conditions, permeability, design of dam and associated structures.</td>
</tr>
<tr>
<td>Uncertain groundwater regime leading to inaccurate assumptions to be used as basis of preliminary design.</td>
<td>Lack of ground investigation data and interpretation of limited data, lack of groundwater monitoring records.</td>
<td>Inadequate design of the dam, spillway, associated structures and diversion route of the Sarre Penn. Permeability issues under dam / reservoir.</td>
<td>Specify a suitable and adequate groundwater investigation and monitoring, followed by interpretation of data to determine the construction and diversion route of the Sarre Penn.</td>
</tr>
<tr>
<td>Damage and impacts to existing services and structures adjacent to and above the tunnel.</td>
<td>Inadequate services data obtained from utility providers, prior to construction.</td>
<td>Damage to utility services causing disruption.</td>
<td>Obtain up to date and accurate data from utility providers. Include GPR surveys to locate services.</td>
</tr>
<tr>
<td>Aggressive ground and groundwater</td>
<td>Lack of ground investigation data and interpretation of limited data, to determine the ground and groundwater conditions at the site.</td>
<td>Inadequate design of the concrete protection used to construct spillway and other structures.</td>
<td>Specify suitable and adequate groundwater investigation, followed by interpretation of data to determine the concrete protection during construction.</td>
</tr>
<tr>
<td>Unexploded ordnance (UXO)</td>
<td>Lack of UXO surveys / data during desk study.</td>
<td>Encountering UXO during construction with associated risks to safety and delay to construction.</td>
<td>Obtain UXO survey to provide adequate data on potential risk during construction.</td>
</tr>
<tr>
<td>Unknown geotechnical parameters</td>
<td>Lack of ground investigation data leading to incorrect interpretation of limited data.</td>
<td>Inadequate, incorrect design of the dam, spillway and associated structures.</td>
<td>Specify a suitable and adequate ground investigation, followed by interpretation of data to determine the ground conditions, and design of dam and associated structures.</td>
</tr>
<tr>
<td>Hazard/Risk</td>
<td>Cause</td>
<td>Consequence</td>
<td>Mitigation</td>
</tr>
<tr>
<td>------------------</td>
<td>------------------------------------------------------------------------</td>
<td>-------------------------------------------------------------------------------------------------</td>
<td>--------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Mining activities</td>
<td>Historical coal mining activates in the vicinity of the proposed dam and reservoir</td>
<td>Cost and programme implications if unexpected ground conditions encountered during construction. Inadequate and incorrect design of the dam, spillway and associated structures. Permeability issues under dam / reservoir.</td>
<td>Obtain a full review of coal mining activities to provide adequate data on potential risk during construction.</td>
</tr>
</tbody>
</table>
## Environmental

<table>
<thead>
<tr>
<th>Source</th>
<th>Pathway</th>
<th>Receptor</th>
<th>Possible Pollutant Linkage</th>
<th>Risk Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Farms, agricultural land – vehicle fuel, pesticides, herbicides and fertilisers</td>
<td>Construction and/or maintenance workers</td>
<td>Dermal contact Inhalation, Ingestion</td>
<td>There is considered to be a <strong>low likelihood</strong> that existing contamination (if present) may impact on construction workers given that they are likely to be in contact with the ground during excavation works. The consequences of exposure may be <strong>low</strong>.</td>
<td>Moderate/Low Risk</td>
</tr>
<tr>
<td></td>
<td>Future site users of the reservoir (without mitigation)</td>
<td>Inhalation, Ingestion Surface water run off infiltration</td>
<td>It is <strong>unlikely</strong> that existing contamination (if present) may impact on future site users as the area will be covered by either under the dam structure and water (reservoir). The consequences of exposure may be <strong>low</strong>.</td>
<td>Low Risk</td>
</tr>
<tr>
<td></td>
<td>Ground and surface waters (including Sarre Pen Stream and drainage)</td>
<td></td>
<td>The majority of the site is underlain by unproductive strata (London Clay) with only the area in the vicinity of the Sarre Penn river, underlain by superficial head deposits. In addition there are a number of small drains that span the proposed scheme area. Overall there is considered to be a <strong>low likelihood</strong> that existing contamination (if present) may impact on ground and surface water during construction of the proposed scheme. The consequences may be <strong>medium</strong>.</td>
<td>Moderate/Low Risk</td>
</tr>
<tr>
<td></td>
<td>Offsite users</td>
<td></td>
<td>It is <strong>unlikely</strong> that offsite users would be impacted by existing contamination. The consequences of exposure may be <strong>low</strong>.</td>
<td>Low Risk</td>
</tr>
<tr>
<td></td>
<td>Soil quality (in terms of material re-use)</td>
<td></td>
<td>It is <strong>unlikely</strong> that the quality of soils has been impacted significantly enough by potential source’s to render the material unsuitable for re-use during the scheme (with necessary environmental permitting or similar regulations adopted). The consequences would be <strong>mild</strong> given the likely localised impact of soils.</td>
<td>Very Low Risk</td>
</tr>
</tbody>
</table>