Groundwater Validation Addendum Report

Former Bayer CropScience Site Hauxton

December 2012

On behalf of:

Harrow Estates Plc

Vertase F.L.I. Limited
19 Napier Court
Barlborough Links
Barlborough
Sheffield S43 4PZ

Tel +44 (0) 1246 813289
Fax +44 (0) 1246 812963

Email info@vertasefli.co.uk
www.vertasefli.co.uk

REPORT TITLE:	**Groundwater Validation Addendum Report, Former Bayer CropScience Site, Hauxton, Cambridgeshire**
REPORT NUMBER:	907BRI/RevB
CLIENT NAME:	**Harrow Estates Plc**

Author	Signed	Date
Matt Lennard		11/12/12

Project Manager	Signed	Date
Michael Allsobrook		11/12/12

QA Approved	Signed	Date
Steve Edgar		11/12/12

Issue:1	Final	28/09/12
Issue: 2	Final Revision B	11/12/12

Table of Contents

Figures

Appendices

1.0 Introduction

VertaseFLI were appointed by Harrow Estates Plc to undertake remedial works at the former Bayer Crop Science agrochemicals works in Hauxton, Cambridgeshire (the site). The site has been determined as a Special Site under Part IIa of the Environmental Protection Act (EPA) 1990 due to identified significant pollutant linkages being present with respect to groundwater and surface water resulting from the former use in the production and storage of agrochemicals.

Remedial works at the site have comprised the excavation of contaminated soil material, the formation of biopiles (including the addition of organic matter) and turning of the contaminated soil material. The remedial works also included the removal of a bentonite cement cut-off wall located along a portion of the North Eastern site. Following remediation, the excavated soils were reinstated at the site. At the time of writing, these remedial works were complete and the remediated soils have been reinstated.

During the bentonite wall removal in August 2011, ingress of contaminated groundwater occurred from soils immediately behind the bentonite wall (to the east), and contaminated soil was noted immediately beyond the bentonite wall and remediation site boundary. To further assess and characterise the contamination outside the remediation site boundary, additional site investigation works and monitoring have been undertaken.

This report presents the findings of the additional investigations and monitoring, and discussion of:

- the extent and nature of any contamination outside if the main remediation site; and
- the presence of potential contaminant sources and pathways outside of the main remediation site with respect to previously identified receptors (i.e. the Riddy Brook).

2.0 Environmental Setting

2.1 Site Description

The site is situated approximately 200 m northwest of the village of Hauxton (National Grid Ref TL 432 524), and covers an area of approximately 9 hectares. It was previously occupied by Bayer CropScience and used for the production and storage of agrochemicals including pesticides, insecticides and herbicides. Following the main remedial works, the site is generally level and currently comprises reinstated remediated soils to ground level. A site location plan is presented in Drawing D907_01, Appendix A.

The site is bounded to the west by the A10 trunk road beyond which is agricultural land and the Waste Water Treatment Plant (WWTP) for the Site. The northern and eastern site boundaries are formed by the Riddy Brook, with Church Road forming the southern site boundary and the southeast of the site bounded by agricultural land.

The site is generally level with a ground elevation of between 12 and 13 mAOD.

The locations of the investigations outside the remediation boundary are shown on Drawings D907_191 and D907_196, Appendix A. Boreholes were drilled on the east and west banks of the Riddy Brook to assess the extent and distribution of any contamination. Boreholes drilled primarily for geotechnical assessment were drilled in open farmland to the east of the River Cam with geo-environmental information being collected also to aid in the assessment.

2.1.1 Ground Conditions

Based on the information provided from the available British Geological Survey (BGS) map for Saffron Walden – Sheet 205 Solid and Drift edition), and the findings of the initial site investigations (Atkins 2006 (Reference 2) and Enviros 2005 (Reference 3)) and remedial works undertaken by VertaseFLI between 2010 and 2011 (Reference 4), the likely ground conditions in theboreholes outside the remediation site are presented in Table 1.

Table 1: Ground Conditions

Description	Thickness
Superficial Deposits – Alluvium and River Terrace Gravels.	Where encountered the superficial deposits were generally < 3 m thick with deposits of sand increasing in the south of the main site.
West Melbury Marly Chalk Formation (WMMCF) – Marly chalk with thin limestone bands, typically described in available logs as a stiff light grey clay –	Typically less than 3m thick with a maximum thickness of 7m in some areas.

appeared to be reworked in a number of areas of the site.	
Cambridge Greensand Member – Described by the BGS as a pale greenish grey marl rich in phosphatic nodules present at the base of the WMMCF.	Not encountered during remediation works. BGS indicates it is 'typically between 0.1 to 1.0 m with locally thicker developments infilling hollows on the top of the Gault.
Gault Clay – typically described as stiff grey clay.	Typically present at a depth of 3 to 8 mbgl underlying Made Ground/Superficial deposits and/or WMMCF across the majority of the site. The depth increases to greater than 10 mbgl in the south of the site. A detailed plot the depth to the Gault is presented in Appendix N. The thickness is understood to be up to 50 m (based on historic borehole data presented in Atkins (2006).
Woburn Sands Formation (part of the Lower Greensand Formation).	Understood to be present underlying the Gault Clay (based on BGS map).

The Cambridge Greensand Member was not observed during the remediation works or previous investigations. This may have been due to the presence of significant amounts of WMMCF over the site and similarities in appearance between the WMMCF and Cambridge Greensand making it difficult to distinguish with the two units. However, the Cambridge Greensand was excavated across much of Cambridgeshire, including the Hauxton Area, during the 1800s to access the phosphatic nodules (coprolites) (O'Connor (2011) – Reference 7), and the potential for the Greensand to have been removed across the site cannot be discounted.

2.1.2 Hydrogeology

2.1.2.1 Geological Units

Drift Deposits

The natural drift deposits to the east of the site comprise River Terrace Gravels and Alluvium and are classified by the Environment Agency as a Secondary A Aquifer which are described as:

> *'Permeable layers capable of supporting water supplies at a local rather than strategic scale, and in some cases forming an important source of base flow to rivers. These are generally aquifers formerly classified as minor aquifers.'*

West Melbury Marly Chalk Formation

The Lower Chalk (which includes the WMMCF) is classified by the Environment Agency as a Principal Aquifer. A Principal Aquifer is described as:

> *'These are layers of rock or drift deposits that have high intergranular and/or fracture permeability - meaning they usually provide a high level of water storage. They may support water supply and/or river base flow on a strategic scale. In most cases, principal aquifers are aquifers previously designated as major aquifer.'*

Based on observations during the main remedial works on site, the WMMCF in the vicinity of the site predominantly comprises stiff clay with thin isolated discontinuous lenses of sand and gravel. The full thickness of WMMCF was been exposed in the sides of the remediation excavations and based on these exposed sections, groundwater flow within the natural WMMCF surrounding the site is very low with any flow generally occurring as small seepages through the discontinuous sand and gravel lenses.

Gault Clay

The underlying Gault Clay is considered to act as an aquiclude, preventing continuity between any shallow groundwater present in on the site and the Lower Greensand which underlies the Gault (at depths greater than 50 m below ground level (bgl)). However, during the remediation works, the top of the Gault Clay was observed to be fractured in places with some localised groundwater present within the fractures.

2.1.2.2 Groundwater Levels and Flow Direction

Prior to remediation, groundwater was typically present across the site at depths between 0.69 and 2.42 mbgl) on site with an average depth on the site of 1.3 mbgl.

Prior to remediation of the site and the removal bentonite wall, it was assumed that groundwater flow was likely to be towards the Riddy Brook and River Cam. However, following completion of the remediation works, the direction of groundwater flow across the site appears to be more variable and influenced by geology (discussed in Section 6.0).

2.1.3 Hydrology

The Riddy Brook, Hauxton Mill Race and River Cam are the closest water bodies to the site. The Riddy Brook and Mill Race form much of the northern and eastern site boundary of the site and the River Cam is present immediately to the east of the Riddy Brook. Shallow groundwater (where present) both on and off site is likely to be in direct continuity with the Riddy Brook and/or the River Cam.

2.2 Summary of Site History and Remediation Works

The development of the site and remediation works is briefly summarised below. More details are available in VertaseFLI (2011) (Reference 6), Atkins (2006) (Reference 2) and Enviros (2005) (Reference 3).

The site was operated for the manufacture of pesticides between 1943 and 2004.

- During the 1970s, following evidence of contaminants entering the Riddy Brook, a bentonite clay and cement cut-off wall was constructed along the northwest site boundary. Groundwater flow on site was also controlled by an abstraction system in the south of the site and groundwater sumps were also installed to prevent migration of groundwater to the north of the site.
- Remediation was undertaken on the site from March 2010 to November 2011. Remedial works at the site comprised the excavation of contaminated soil material, the formation of biopiles (including the addition of organic matter) and treatment of the contaminated soil. Following remediation, the excavated soils were reinstated and compacted at the site.
- As part of the remediation works on the site, the bentonite wall along the northeast site boundary (adjacent to the Riddy Brook) was removed during July and August 2011. During the removal, strong pesticide and chlorinated solvent odours were noted in soil material and groundwater from one short section of the eastern) side of the wall (outside of the remediation boundary). As much material as practicable was excavated from this area whilst maintain the integrity of the brook.
- Control of groundwater levels at the site using the abstraction system and sumps was stopped in October 2011.

2.3 Historical Investigations

2.3.1 Investigations Adjacent to Riddy Brook

Investigations on the site undertaken by Enviros (2005) (Reference 3) included four boreholes (S3/3, S3/3a, S3/4 and S3/5) drilled between the bentonite wall and the Riddy Brook. A groundwater monitoring standpipe was installed in S3/4 and three piezometers (P25, P30 and P38) were also installed between the Riddy Brook and bentonite wall. A borehole location plan is presented in Drawing D907_205, Appendix A, available Enviros borehole logs are presented in Appendix B. No information was available regarding the installation of the piezometers.

Encountered ground conditions in S3/4 comprised a thin layer of Made Ground (concrete gravel in a sand matrix) to 0.2 mbgl, overlying drift deposits (sandy gravelly clay with bands of gravel) to 2.5 mbgl overlying Gault Clay. S3/5 was drilled to 1.6 mbgl and comprised; a thin veneer of topsoil and granular Made Ground was present to 0.15 mbgl over ' very' firm brown and grey sandy clay. No logs were available for S3/3 or S3/3a.

During drilling, groundwater was encountered at approximately 1.5 mbgl (9.4 mAOD) in S3/4 and 1.6 mbgl in S3/5. Monitored groundwater levels were 9.68 mAOD in S3/4, 9.76 mAOD in P25 and 10.66 mAOD in P38, no groundwater level data was available for P30.

Recorded soil and groundwater concentrations of VOCs and pesticides are summarised in Tables 2 and 3 respectively. The laboratory detection limits for pesticides in soils at that time were typically 100 µg/kg but 500 µg/kg for Hempa and Schradan and therefore potentially significant pesticide concentrations may not have been detected. With the exception of one sample from S3/4 at 2.2 mbgl, all soil samples analysed were from the top 1m of ground.

Table 2 – Enviros (2005) Soil Analysis between Former Bentonite Wall and Riddy Brook

Sample	Concentration in Soil (µg/kg)
S3/03 – 0 mbgl	VOCs not detected Pesticides not detected
S3/03 – 0.5 mbgl	VOCs not analysed Pesticides not detected
S3/03a – 0.5 mbgl	VOCs not detected Total Pesticides – 900 µg/kg including - Ethofumesate 400 µg/kg
S3/04 – 0.4 mbgl	VOCs not detected Total Pesticides – 300 µg/kg including - Ethofumesate 300 µg/kg
S3/04 – 2.2 mbgl	VOCs not detected Total Pesticides – 26,100 µg/kg including - Ethofumesate -12,700 µg/kg - 2,3,6-TBA - 7,910 µg/kg - MCPA – 1,640 µg/kg
S3/05 – 0.4 mbgl	TCE - 116 µg/kg PCE – 214 µg/kg Pesticides not detected

Table 3 – Enviros (2005) Groundwater Analysis between Bentonite Wall and Riddy Brook

Borehole	Concentration in Soil (µg/l)
S3/04	PCE – 832 µg/l TCE – 213 µg/l cDCE – 11.7 µg/l VC – 8.2 µg/l Total Pesticides – 6,901 µg/l including - Schradan – 4,600 µg/l - Hempa – 2,100 µg/l
P25	PCE – 14,400 µg/l TCE – 32,900 µg/l cDCE – 11,900 µg/l VC – 2,110 µg/l Toluene – 3,840 µg/l Total Pesticides – 1,537 µg/l including - Mecoprop 680 µg/l - MCPA – 460 µg/l - 236 TBA – 310 µg/l
P30	PCE – 10.4 µg/l TCE – 1.6 µg/l Total Pesticides – 8.25 µg/l
P38	PCE – 1.1 µg/l TCE – 6.2 µg/l cDCE – 124 µg/l VC – 35.6 µg/l Toluene – 1230 µg/l Total Pesticides – 34.86 µg/l

2.3.2 Monitoring Of Riddy Brook

Enviros also undertook two rounds of surface water sampling at five locations along the Riddy Brook (Enviros 2005). Analysis of the water samples showed a slight increase in trace levels of pesticide contaminants along the course of the Riddy Brook. It should be noted that only two monitoring rounds were undertaken both of which were during summer months.

3.0 VertaseFLI Investigations Outside the Remediation Boundary

As a consequence of observations during the remediation of the main site, supplemental site investigations have been undertaken on the site and outside of the remediation boundary and are described below.

3.1 Intrusive Investigations

Prior to excavation, each exploratory location was scanned with a cable avoidance tool and service plans consulted to confirm the absence of buried services.

Borehole location plans are presented in Appendix A. The investigations outside the main remediation site comprised the following:

3.1.1 Investigation of potential contamination adjacent to the Riddy Brook (12 – 13 October 2011)

The eleven boreholes drilled in the investigation area were OS1, OS2, OS6, OS7, HA3, HA4, HA5, HA6, HA7, HA8 and HA/OS5.

- All boreholes were drilled to the east of the former bentonite cement cut-off wall in soils undisturbed by the remediation works;
- Drilling of four boreholes (OS1, OS2, OS6 and OS7) to a maximum depth of 6 mbgl (in soils undisturbed by the remediation works) on the east and western sides of the Riddy Brook using solid stem auger;
- Drilling of seven boreholes (HA3, HA4, HA5, HA6, HA7, HA8 and HA/OS5) to a maximum depth of 4 mbgl (in soils undisturbed by the remediation works) on the east and west sides of the Riddy Brook using hand held window sampler;
- Installation of ten shallow groundwater monitoring boreholes; and
- Soil Sampling. A total of 43 soil samples were collected with 32 submitted for chemical analysis.

3.1.2 Investigation of land to the east of the River Cam (24 – 28 November 2011)

- Drilling of five boreholes (WM1, WM2, WM3, WM4 and WM5 (Island) to a maximum depth of 6 mbgl using a Commachio Geo 205 drill rig including geotechnical testing within natural soils;
- Installation of groundwater monitoring boreholes in all boreholes;

- Soil Sampling. Soil samples were colle cted on average every 1m durin g investigations. 17 samples were submitted for chemical analysis.

3.1.3 Validation Boreholes

During the installation of groundwater validation boreholes (VertaseFLI 2012d – Reference 9), four ad ditional boreholes were installed in the un disturbed soils out side of the remediation boundary.

- Three boreholes (F10, G8 and G9) were drilled to the west of teh Riddy Brook. One borehole (F9) was drilled to the east of the Riddy between boreholes OS1 and OS2.
- The boreholes were drilled to a maxi mum depth of 3m bgl and installed with groundwater monitoring installations to a maximum depth of 2.8 m bgl with reponse zones from 1m to the base of the borehole.
- The boreholes were drilled to provide info rmation on groundwater condit ions within shallower deposits relative to the boreholes described in section 3.1.1.

Additionally, borehole H7, installed t hrough reinstated soil material into natural soils on the remediation site boundary (adjacent to the Riddy Brook) has also be en considered in the assessment, due to its proximity to the Riddy Brook.

3.1.4 Borehole Response Zones

With the exception of HA4 and F 9, all boreholes described above were installed with response zones in the WMMCF through to the top of the Gault Clay. Boreholes HA4 and was installed within drif t deposits and the sha llow WMMCF, F9 was installed in shallow deposits of WMMCF. Further details of gr ound encountered ground conditions are presented in Section 5.

3.1.5 Groundwater Sampling

Monthly groundwater sampling of the boreholes outside of the main remediation site has been undertaken since December 2011 using peristaltic pumps and low flow sampling methods. In all boreholes the groundwater samples were taken from the lower 0.5 m of th e boreholes.

3.1.6 Chemical Analysis

Based on t he findings of the remedial works at the site, soil samples and grou ndwater samples were analysed for the following determinands:

- Organophosphates and Organonitrates: Dimefox, Ethofumesate, Hempa, Schradan and Simazine;

- Phenoxy Acid Herbicides: Dicamba, Dichlorprop, MCPA and Mecoprop;
- Semi Volatile Organic Compounds (SVOCs): 2,4,6-Trichlorophenol, 2-Methyl-4,6-dintrophenol, 4-Chloro-2-methylphenol, Bis (2-chloroethyl) ether and Phenol; and
- Volatile Organic Compounds (VOCs): 1,2-dichlorobenzene, 1,2-dichloroethane, cis-1,2-dichloroethene (cDCE), Cyclohexanone, Tetrachlorethene (PCE), Toluene, Trichlorethene (TCE), Vinyl chloride (VC) and Xylene.

Additionally, water samples were also screened for contaminants that were not previously identified (CNPIs).

3.2 Surface Water Sampling

Monthly monitoring and sampling of both the Riddy Brook and the River Cam, upstream and downstream of the site has been undertaken since 2009 and is still continuing at the time of writing (September 2012). Additionally, from January 2012 samples were taken at 40 m intervals along the Riddy Brook and these results are discussed in Section 7.4.

3.3 Works to Remove Manhole and Associated Pipe-Work Adjacent to the Riddy Brook

Historically, a number of seepages have been present along the length of the Riddy Brook. As part of the works detailed in this report (Section 7.5) sampling of the seepages taken in January 2012 identified the presence of a number of contaminants including Trichloroethene which indicated the potential presence of an unknown contaminant source outside of the remediation boundary. Subsequent intrusive investigations were undertaken in March 2012 in the un-remediated soils adjacent to the Riddy Brook which identified the presence of a concrete chamber and associated pipework. The chamber and pipework were decommissioned in July 2012. The location of the chamber is shown on drawing D907_230.

Full details of the investigation and decommissioning are given in the VertaseFLI report ‘Addendum to Contract Completion Report’ August 2012 (Reference 5). It is important to note that the decommissioning works were completed after the results and findings discussed were completed.

4.0 Results

4.1 Ground Conditions

Borehole logs are presented in Appendix C and the borehole locations are shown in Drawings D907_191 and D907_196. The findings of the investigations are summarised below.

4.1.1 Adjacent to Riddy Brook

Encountered ground conditions generally confirmed the findings of previous investigations and are summarised as follows:

- Made Ground – Made Ground was absent from the majority of borehole locations. Where encountered, it typically comprised re-worked natural soil material. In HA7 this comprised a lense of and and gravel to a depth of 1.4 mbgl, Made Ground was also present in HA5 where it comprised a lens ofsand and gravel to 1.4 mbgl over sandy clay to 2.8 mbgl. In both HA5 and HA7 the Made Ground was considered to be possible reworked natural materials;
- Drift Deposits – Drift deposits were present to depths between 0.8 and 2.2mbgl with a typical depth of 1.4 mbgl. The drift deposits generally comprised firm to stiff sandy brown clay and lenses of sand and gravel. In HA4, drift deposits comprised sand and gravel between 0.3 and 2.2 mbgl, and were stained black below 1.4m;
- West Melbury Marly Chalk Formation (WMMCF) – The WMMCF was present in all locations underlying the drift deposits and typically consisted of firm to stiff grey gravelly clay with some sandy clay lenses. In boreholes OS1, OS2, OS6, OS7 and HA5, the WMMCF became soft to very soft towards the base of the unit, typically in the lower 0.5 m; and
- Gault Clay – The Gault clay was present underlying the WMMCF and consisted of stiff dark grey clay.

4.1.2 East of River Cam

Ground conditions to the east of the River Cam are summarised as follows:

- Topsoil – Typically comprising clayey organic soils (drillers' description) top soil was present in 4 boreholes (WM1, WM2, WM3 and WM5 (Island)) to 0.1 mbgl.
- Drift Deposits – Drift deposits were present in all boreholes and typically comprised soft to very soft brown clay overlying sand and gravel in WM1, WM2 and WM3, a

band of peat was present between the clay and sand and gravel between 4 and 4.5 mbgl in WM1. Drift deposits in WM4 comprised sand and gravel to 1. 8 mbgl overlying 3.2 m of soft silty peat which in turn was overlying gravelly sand. The base of the drift deposits was not proved in either WM1 or WM4 and was 2.6, 2.8 and 3.0 mbgl in boreholes WM5 (Island, WM3 and WM2 respectively.

- Gault Clay – Where the base of the drift deposits were proved, they were underlain by firm to stiff grey Gault Clay. The WMMCF was not encountered in any of the boreholes to the east of the River Cam.

4.2 Odours and VOCs

4.2.1 Odour Observations During 12-13 October Investigations

No odours were observed in the boreholes to the east of the River Cam.

In the boreholes drilled adjacent to the Riddy Brook, the following odour observations were made:

- OS1: Solvent odour present below 3.7 mbgl (WMMCF);
- OS2: Solvent odour below 4.0 mbgl (base of WMMCF);
- OS6: Solvent odour below 3 mbgl (WMMCF);
- OS7: Solvent odour at 2 mbgl in WMMCF;
- HA4: Slight sulphurous odour between 1.4 and 2.2 mbgl associated with black stained sand and gravel and presence of groundwater;
- HA5: Solvent odour present between 1.4 and 2.0 mbgl in WMMCF;
- HA6: Solvent odour present below 3.4 mbgl becoming stronger within the Gault clay; and
- HA7: Solvent odour was noted below 3mbgl (WMMCF).

In general, the solvent odours were associated with the soft to very soft deposits at the base of the WMMCF and the upper deposits of Gault Clay.

4.2.2 VOC Monitoring

Soil material from boreholes drilled adjacent to the Riddy Brook were monitored for VOCs using a photo-ionisation detector. The results are included on the borehole logs presented in Appendix C.

4.3 Monitoring of Riddy Brook and River Cam

4.3.1 Water Levels

Water Levels in the Riddy Brook were monitored at the upstream and downstream monitoring points (Drawing D907_203, Appendix A) and the water levels for 2011 (January to October) are presented in Appendix D. The levels within the Riddy Brook remained constant with very little variation.

Water levels in both the River Cam and Riddy Brook were measured to Ordnance Datum in October 2011. The water level in the Riddy Brook was 9.76 mAOD, with the brook bed at 9.53 mAOD. Given the small variations in water level within the Riddy Brook, this level is considered representative of typical levels within the Brook. The River Cam (measured at the top of the weir to the Hauxton Mill Race) was at 10.73 mAOD with the river bed at 10.14 mAOD. The water level at the base of the weir was 9.01 mAOD. Given the wier control of the River Cam, this is also considered representative of typical levels.

4.3.2 Monitoring of the Riddy Brook and River Cam

4.3.2.1 *VertaseFLI Monitoring*

Monthly monitoring of the Riddy Brook and River Cam, both upstream and downstream of the site, has been undertaken since May 2008. The results of the monitoring from November 2010 (one year before the investigations outside of the remediation boundary and prior to the reinstatement of the majority of soil material at the site) are summarised in Appendix F and further details are available in the VertaseFLI completion report (Reference 4).

Chemical profiling of the Riddy Brook has been undertaken monthly from January 2012. The sampling locations for the profiling are shown in Drawing D907_203, Appendix A, the results are summarised in Appendix F.

4.3.2.2 *Environment Agency Monitoring of the River Cam*

Regular monitoring of the River Cam for Tetrachloroethene (PCE) and trichloroethene (TCE) has been undertaken at upstream (approximately 1.2 km east of the site) and downstream of the site. The downstream sampling location is situated immediately downstream of the site. The results of the monitoring are presented in Appendix H and show regular elevated concentrations of PCE in both upstream (up to 8.5 ug/l) and downstream (up to 6 ug/l) samples. The observed concentrations generally decrease between the upstream and downstream monitoring points.

4.3.3 *In-Situ* Monitoring

Monitoring of *in-situ* temperature, dissolved oxygen, pH, conductivity and Oxygen Redox Potential were recorded. The results between December 2011 and May 2012 are presented in Appendix E.

4.3.4 Observations in the Riddy Brook

During monitoring of the Riddy Brook, the following features were noted:

- A vertical metal pipe was present in the bed of the Riddy Brook to the northwest of the site (see Drawing D907_203, Appendix A). The pipe was approximately 25 cm in diameter and greater than 1.5 m deep; the top of the pipe was just above the water level of the Riddy Brook. Water from within the pipe was sampled on 14 October 2011 following which the pipe was backfilled with a 0.5 m bentonite plug.
- A horizontal pipe was observed in the bed of the Riddy Brook running under the bank towards site. The pipe was 15cm in diameter and ran largely below the bed of the Riddy Brook. No evidence of any site infrastructure leading to the pipe was observed during the remedial works. The pipe was sealed and left *in-situ;* and

During monitoring on 17th January 2012, following a period of heavy rainfall two small seepages (previously noted prior to and during the remedial works) were identified running into the Riddy from the western bank. Samples of the seepages were taken and the results are presented in Appendix K.

4.4 Groundwater Levels

4.4.1 Observations during site investigation

Adjacent to the Riddy Brook, groundwater strikes were recorded in the following boreholes:

- OS1: Approximately 4.5 to 5.0 mbgl;
- OS2: Approximately 4 mbgl (rising to 3 mbgl after 20 minutes);
- HA4: Groundwater was present in deposits of sand and gravel between 1.4 and 2.2 mbgl; and
- HA7: Groundwater was encountered between 3 and 4 mbgl.

With the exception of HA4, the presence of groundwater surrounding the Riddy Brook appeared to be associated with the soft deposits of WMMCF overlying the Gault clay.

To the east of the River Cam groundwater strikes were encountered in all bore holes between 1.8 and 4.5 mbgl, the presence of groundwater in all five boreholes was associated with the presence of sand and gravel deposits.

4.4.2 Groundwater monitoring and sampling

At the time of writing, up to 14 No. rounds of groundwater monitoring and sampling had been undertaken in the installed boreholes outside of the remediation boundary and the results are summarised in Appendix J. Groundwater levels in boreholes adjacent to the Riddy Brook were between 9.09 and 10.84 mAOD and are discussed further in Section 6.

BH11 (shown on drawing D907_196), is located adjacent to the Riddy Brook in unremediated soils (outside of the remediation boundary) and has been since 2008. The recorded groundwater levels relative to the level of the Riddy Brook (see Section 4.3.1) are presented in Appendix L.

Groundwater levels to the east of the River Cam were between 8.83 and 10.33 mAOD.

Drawings D907_223A, D907_225 and D907_228, Appendix A shows the groundwater regime for the entire site as monitored between December 2011 and July 2012 following completion of the main remediation works.

4.5 Chemical Analysis

Results of the chemical analysis for soil, groundwater and surface water are presented in Appendixes I, J and F respectively. Analysis certificates are presented in Appendix O.

4.5.1 Adjacent to Riddy Brook

Given the location of the sample locations, adjacent to the Riddy Brook and River Cam, as an initial screening tool the results of the chemical analysis have been compared to the Zone 1 Maximum Threshold Values (MTV) derived in the VertaseFLI report 'Further Quantitative Risk Assessment for Controlled Water and Preliminary Post Remediation Validation Model', Dated July 2011 (Reference 5).

4.5.2 Ground to East of River Cam

Contaminant concentrations in both soil and groundwater were generally below detection limits with the following exceptions:

- Xylene and Toluene present at trace levels in all soil samples with maximum concentrations of 46 µg/kg and 28 µg/kg respectively;
- Dicamba (40 µg/kg), Dichlorprop (30 µg/kg) and MCPA (50 µg/kg) present in soil from WM2 between ground level and 0.5 mbgl;

- PAHs, Fluoranthene (3,400 µg/kg), Pyrene (3,000 µg/kg) and Benzo (b/k) fluoranthene present in soil from WM4 between 0.5 and 1.0 mbgl;
- Hempa concentrations were detected in groundwater from boreholes WM1 to WM4 with a maximum concentration of 3 µg/l in WM4, significantly below the screening value of 350 µg/l. Typically, hempa concentrations were below laboratory detection limits;
- Schradan was detected in water from WM1 and WM3 on with a maximum concentration of 4.6 µg/l in WM3 on 12 December 2011. All other concentrations of Schradan were at or below detection limits;
- MCPA was identified in groundwater samples from all boreholes with a maximum concentration of 45 µg/l (WM2, June 2012) All other monitoring data was 0.6 µg/l or below and typically below detection limits;
- A dicamba concentration of 0.2 µg/l was recorded in groundwater from WM1 on 21 December 2012. Maximum recorded concentrations of Ethofumesate were 0.4 µg/l and trace concentrations of PCE were detected up to 6 µg/l in WM1 and WM2. All concentrations were below the selected screening criteria.

4.5.3 Surface Water analysis

The results of the surface water analysis are summarised in Appendix F. Full details of the up-stream and downstream analysis are presented in the VertaseFLI completion report for the remediation works (Reference 4).

4.5.4 Historic Drainage Feature

In January 2012, a historic drainage feature was identified in un-remediated soils in the north of the site (outside the remediation boundary). The drainage feature appeared to create a direct pathway between surface water in the un-remediated part of the site and the Riddy Brook. Following identification, the drainage feature was decommissioned.

The historic drainage feature was considered to be a contributing source of the elevated contaminant levels in the Riddy Brook downstream samples that were recorded from December 2011 to January 2012 during a period of high rainfall. Following the decommissioning of the drainage feature, contaminant concentrations in the downstream samples have returned to the typical low/negligible (below detection limits) concentrations observed for the duration of the monitoring.

5.0 Distribution of Soil/Geology Types Adjacent to Riddy Brook

To aid interpretation of the encountered geology adjacent to the Riddy Brook, cross sections are presented in Drawing D907_191. In addition, cross sections including the entire remediated site and the land to the east of the Riddy Brook are presented in D907_236.

5.1 Base of Drift Deposits/Top of WMMCF

In the boreholes (outside of the remediation boundary) adjacent the Riddy Brook, the depth to the base of the drift deposits was between 8.83 and 10.69 mAOD.

With the exception of HA4 and HA5 (both located to the west of the Riddy Brook) and HA7, the drift deposits comprised firm to stiff clay. In HA5, the drift deposits (possible Made Ground) comprised clay to 2.8 mbgl with a band of sand and gravel between 1.1 and 1.4 mbgl, in HA4 the clay was absent and sand and gravel were present from 0.3 m to 2.2 mbgl. Drift deposits (possible Made Ground) in HA7 consisted of sand and gravel to a depth of 1.4 mbgl (9.03 mAOD).

The presence of increased thickness of drift deposits and sand and gravel in HA4 and HA5 coincides with the greatest depth to the WMMCF and suggests the presence of a possible channel running from the site to the Riddy Brook (see Figure 1 below). It should also be noted that the sand and gravel identified in HA4 and HA5 is adjacent to a lens of sand and gravel observed during the remedial works (now removed) which contained between 20 and 30 corroded steel drums (as described in Section 4.4.2 of VertaseFLI (2011) – Reference 6). It is considered likely that the observed gravel lens and that present in HA4 and HA5 are part of the same gravel body and before the construction of the bentonite wall would have acted as a direct contaminant pathway for any contaminants within the drums or other historic shallow contaminant sources.

To the east of the River Cam, the WMMCF was not present in any of the five boreholes with the base of the drift deposits overlying the top of the Gault Clay.

5.2 Base of the WMMCF/Top of the Gault Clay

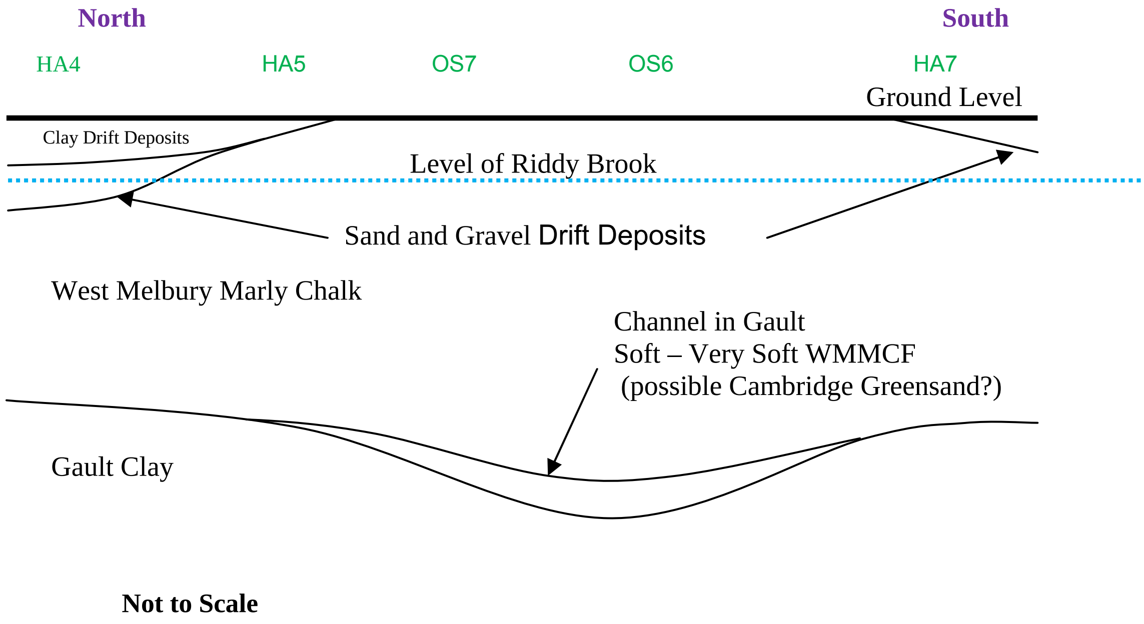
From the encountered ground conditions, the boundary between the WMMCF and the Gault Clay outside of the remediation boundary was between 6.84 and 9.43 mAOD (1.7 to 4.3 mbgl) adjacent to the Riddy Brook. The shallowest depth to the Gault Clay was observed in OS/HA5. The Gault clay was not proved in boreholes HA4, HA5 or F9. With respect to Ordnance Datum, the depth of the WMMCF/Gault clay interface decreased to the south with the lowest depths recorded in OS6 (6.8 4 mAOD), and OS2 (7 .00 mAOD). When considered with the depth to the Gault clay encountered across the site during the remediation works, there appears to be a channel in the surface of th e Gault clay running through the centre of the site and under the Riddy Brook (see Appendix N).

It is important to note, that the depth to Gault Clay over the main remedi ation sitediscussed above reflects the site conditions be fore remediation was undertaken. The remedi al works included the excavation of the areas of the uppe r Gault Clay and subse quent remediation and reinstatement have altered the distribution and nature of the WMMCF/Gault interface to some extent

In a number of boreholes, the WMMCF became soft to very soft at the interface with the Gault clay (See Figure 1). Soft to very soft WMMCF was encountered in OS1, OS2, OS6, OS7 and HA5 corresponding closely with the greatest depth of the WMMCF/Gault interface. These soft to very soft deposits were generally associat ed with an increased amount of sand and gravel and it is considered possible that the deposits may be representative of the Cambridge Greensand described by the BGS.

In boreholes to the ea st of the River Cam, the Gault clay was proven in three of the five boreholes drilled, in these boreholes the depth of the top of the Gault clay was b etween 7.33 to 9.028 mAOD (2. 6 to 3 mbgl), broadly similar to the depths enco untered adjacent to the Riddy Brook. Ho wever, the Gault clay was not encountered in WM1 and WM4 indicating the Gault clay was present below 5.81 mAOD (5.5 mbgl) in WM1 and 4.33 mAOD (6.0 mbgl) in WM5 su ggesting the top of th e Gault clay decreases to the north and southeast of the site.

Figure 1: Indicative Cross Section Showing Encountered Ground Conditions West of Riddy Brook



6.0 Groundwater Regime

6.1 Relationship between Ground Conditions and Groundwater

Groundwater observations during the drilling of the site investigation included water strikes at the base of the WMMCF/top of the Gault Clay in three boreholes (OS1, OS2 and HA7) and perched water within deposits of sand and gravel overlying the WMMCF in HA4.

Response zones in seven of the ten boreholes adjacent to the Riddy Brook were installed within the WMMCF and Gault clay. In boreholes HA4, HA5 and HA/ OS5, the top of the response zone was installed in drift deposits which included deposits of sand and gravel in HA4 and HA5. Ground water levels in the bore holes adjacent to the Riddy Brook recorded between October 2011 and January 2012 were between 9.24 and 10.37 mAOD.

Cross sections showing ground conditions across the entire site are presented in D907_236, Appendix A.

6.1.1 Groundwater in Drift Deposits

As discussed in Section 5.1, the presence of sand and gravel in HA4 and HA5 (both located to the west of the Riddy Brook) was associated with an increase in depth to the WMMCF. The monitored water level in the Riddy Brook was 9.76 mAOD which corresponds closely to the groundwater level encountered during drilling in the sand and gravel in HA4 of 9.63 mAOD (1.4 mbgl). It should also be noted that the groundwater encountered in HA4 during drilling was associated with black stained sand and gravel deposits which had a slight sulphurous odour giving a potential indication of historical contaminant degradation within the shallow groundwater.

The potential for perched groundwater to be present in other 'un-remediated' deposits of sand and gravel overlying the WMMCF along the bank of the Riddy Brook cannot be discounted. It should be noted however, that the two boreholes installed through the sand and gravel returned limited groundwater samples due to poor groundwater recovery. Given the presence of sand and gravel, the poor recovery is unlikely to be due to low permeability material and considered likely to be due to the low volumes of ground water present in the sand and gravel deposits

6.1.2 Groundwater within the WMMCF and Gault Clay

The encountered WMMCF typically comprised firm to stiff grey gravelly clay with some sand lenses. In boreholes OS1, OS2, OS6, OS7 and HA5 the WMMCF became soft to very soft in the lower 0.5m above the Gault Clay, these softer deposits were overlain by between 1 to 3 m of firm to stiff WMMCF. Groundwater strikes in OS1, OS2 and HA7 were associated with the base of the WMMCF/top of the Gault Clay. The soft to very soft WMMCF deposits appear to be associated with the base of a channel in the top of the Gault Clay (discussed in Section 5) and are considered likely to be indicative of a groundwater/Gault Clay boundary within the channel. No evidence of groundwater was encountered in the firm to stiff WMMCF and it should be noted that during the remediation works on site negligible groundwater was encountered during excavation of the WMMCF with the exception of minor seepages in isolated lenses of sand and gravel (Reference 6). The potential presence of fractures within the upper deposits of Gault Clay (observed during the remediation works) may also influence the groundwater regime.

The base of the WMMCF in the boreholes (outside the remediation boundary) is typically between 5.30 and 8.13 mAOD compared with the monitored groundwater levels of 9.24 to 10.37 mAOD. Given the presence of 1 to 3 m of firm to stiff clay (WMMCF) overlying the soft WMMCF deposits it is considered that the shallow firm to stiff WMMCF is likely to be acting as a confining layer to some extent for the deeper groundwater body within the base of the WMMCF/top of the Gault Clay.

6.2 Groundwater Levels

Plots of recorded groundwater levels to m AOD are presented in Appendix L. The plots have been split into boreholes to the east and west of the Riddy Brook and BH11. Cross sections presented in D907_236, show the general relationship between ground conditions across the remediated site and groundwater. It should be noted that all boreholes showed a significant increase in levels in May 2012 as can be seen in Appendix L which was coincident with a period of very high rainfall and flooding during monitoring.

East of Riddy Brook

With the exception of the May monitoring results, groundwater levels to the east of the Riddy Brook (between the River Cam and the Riddy Brook) were generally consistent over the monitoring period (October 2011 to August 2012) with groundwater levels typically varying by less than 0.25 m during the monitoring period. The only exception to this was borehole OS/HA5 where one possibly anomalous reading of 9.56 m AOD was recorded in November 2011. Groundwater levels in these boreholes were typically greater than surface water levels in the Riddy Brook.

West of Riddy Brook

BH11 is located in un-remediated soils adjacent to the Riddy Brook and has been monitored since April 2008. During the remedial works, water levels were monitored daily with data loggers, outside of this period monthly monitoring was undertaken. Groundwater levels in BH11 were between 8.83 and 11.03 m AOD, but typically fluctuated around the level of the level of the Riddy Brook (9.76 mAOD). During the remedial works, the groundwater on the main remediation site was actively managed and with the exception of a brief groundwater peak above 11.03 m AOD in April 2010 at the start of the works (the peak observed in February 2011 appears to be an anomalous reading), groundwater levels remained relatively steady until the bentonite wall was removed in July to August 2011 and groundwater control was stopped in October 2011. Groundwater levels both before and after the remedial works (with no groundwater management) appears to show a larger variation than during the remedial works. Following the end of the remedial works in November 2011, groundwater levels had risen to 10.59 m AOD in August 2012.

In the boreholes to the west of the Riddy Brook (outside the remediation boundary between the remediated soils and the Riddy Brook), initial water levels in all boreholes were below the level of the Riddy Brook. With the exception of HA5, groundwater levels increased between borehole installation (October 2011) and December 2011 showing a very similar response to BH11. Subsequently, with the exception of May 2012, groundwater levels to the west of the Riddy Brook have remained consistent, although at a slightly lower elevation compared to the water levels to the east of the Riddy Brook. Groundwater levels in HA4, HA5 and OS7 have remained very close (marginally above or below) to the recorded water levels in the Riddy Brook while levels in HA7 have consistently been above the Riddy Brook levels.

Remediated Site

Plots of groundwater levels from January to July on the remediated site are presented in Appendix A. The plots generally show an increase in groundwater levels between January and July as levels recover following the completion of the remedial works. However, a large groundwater low is present in the north of the site and groundwater levels have remained largely unchanged in this area. This low may represent a region of groundwater flow towards the centre of the low (and away from the Riddy Brook) or an area of effective negligable flow such that groundwater outside this area on site will be influenced by it.

6.3 Groundwater Flow Direction

East of Riddy Brook

The water level in the River Cam (10.73 mAOD) is significantly higher than both the levels in the Riddy Brook (9.76 mAOD) and all recorded groundwater levels suggesting that groundwater in the surrounding area is away from the River Cam. To the east of the Riddy

Brook, all groundwater levels are lower than the River Cam but generally higher than the Riddy Brook. Based on this, groundwater flow appears to be driven by the River Cam towards the Riddy Brook.

Groundwater Flow from Remediated Site

It is important to note that since the 1970s following the installation of the bentonite cement cut-off wall, negligible groundwater flow is likely to have occurred from the site to the Riddy Brook along the length of the bentonite wall via the shallow sand and gravel or WMMCF. However, following the removal of the wall in July and August 2011 (VertaseFLI (2012) – Reference 4) reinstated clay soils (largely comprising WMMCF) at the site were heavily compacted and the permeabilities achieved in this reinstated material were between 2×10^{-10} to 7.1×10^{-6} ms^{-1} with a median permeability of 2.2×10^{-7} ms^{-1}. Therefore, rates of groundwater flow through the reinstated material are likely to be very low.

The presence of the groundwater low in the north of the site (discussed in Section 6.2) generally confirms the likely negligible flow from the remediated site to the Riddy Brook. The groundwater contours suggest generally negligable flow from the majority of the north and centre of and therefore negligable flow from the remediated soils to the Riddy Brook.

West of Riddy Brook

As discussed in 6.2, to the west of the Riddy Brook groundwater levels in the 2011 outside the remediation boundary, boreholes were initially below the level in the Riddy Brook but groundwater levels increased between borehole installation and December 2011. From December 2011 onwards, groundwater levels in HA4, HA5 and OS7 have fluctuated around the level of the Riddy Brook, and HA7 has been above the Riddy Brook.

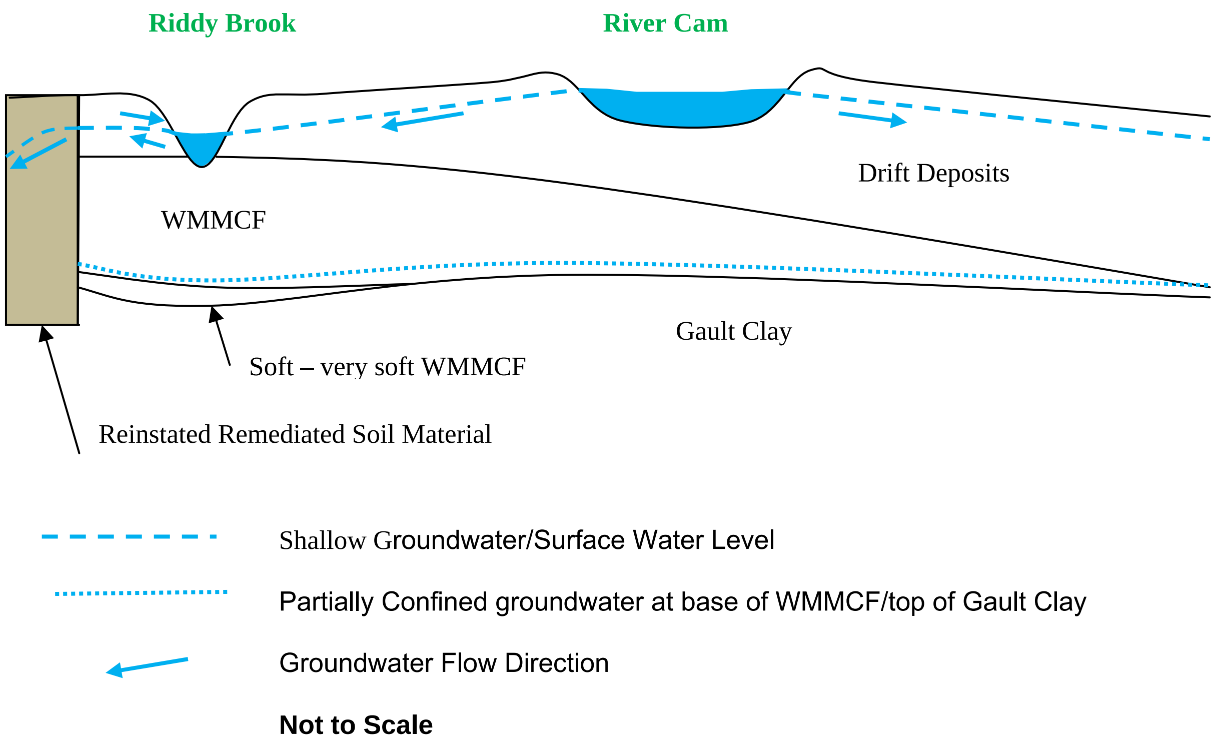
Similarly, groundwater levels from BH11 from 2008 show groundwater levels to have fluctuated close to the level of the Riddy Brook. Groundwater levels decreased below the Riddy Brook level following the removal of the bentonite wall in August 2011 but have risen above the Riddy Brook following the completion of remedial works (in line with the increases observed in HA4, HA5, OS7 and HA7) and the ending of groundwater management/control at the site.

Therefore, to the west of the site as the groundwater levels fluctuate above/below the level of the Riddy Brook groundwater flow direction will also fluctuate to/from the Riddy Brook. Following the removal of the bentonite wall and until the on-site groundwater controls were removed groundwater flow was away from the Riddy Brook, following the recovery of groundwater levels after completion of the remedial works groundwater from the area of

HA7 and BH11 appears to be towards the Riddy Brook and flow around HA4, HA5 and OS7 appears to fluctuate to and from the Riddy.

Given the observed ground and groundwater conditions on the remediated site, as discussed above it is considered that there is negligible contribution of groundwater flow to the Riddy Brook from the majority of the site. The observed groundwater flow is therefore largely limited to bank storage in the un-remediated soils adjacent to the Riddy Brook. The flux between groundwater and surface water is possibly driven by seasonal variations and localised ground conditions so that groundwater from the west will only intermittently feed the Riddy Brook.

Figure 2: Summary of Groundwater Regime



7.0 Contaminant Distribution

7.1 Distribution in Soil

The contaminant distribution in soils outside the main remediation site boundary and adjacent to the Riddy Brook is summarised in Figure 3.

7.1.1 Organo-phosphate and Organo-nitrates

Hempa, Schradan and Ethofumesate all recorded exceedances of the Zone 1 MTVs within soil material adjacent to the Riddy Brook. Concentrations of Dimefox or Simazine did not exceed the limits of detection in any sample.

Hempa and Schradan showed almost identical distributions and were generally not detected in samples at depths less than 2.0 mbgl. The only exception to this were samples from HA4 (1.7– 2.0 mbgl) and HA5 (1.4 – 1.8 mbgl), both located to the west of the Riddy Brook and associated with shallow deposits of sand and gravel overlying the WMMCF which were not encountered in other investigation positions along the Riddy Brook.

Concentrations of Hempa and Schradan increased with depth with the greatest concentrations occurring in the base of the WMMCF and top of the Gault Clay. The maximum concentration of Hempa was 1,800 µg/kg recorded in the Gault Clay in OS7 at 4.0 mbgl, the maximum concentration of Schradan was 510 µg/kg recorded at 3.0 mbgl in OS6 (WMMCF). All boreholes to the west of the Riddy Brook recorded elevated concentrations of both Hempa and Schradan, to the east of the Riddy Brook, Hempa and Schradan were only detected in deposits of Gault Clay in OS1 (5.0 mbgl) and OS2 (4.8 mbgl)

Elevated concentrations of Ethofumesate were identified in 8 of the 32 samples analysed, all of which were from sample locations to the west of the Riddy Brook. Two samples exceeded the MTV, HA4 (1.7 – 2.0 mbgl) located in shallow sand and gravels and OS6 (2.0 mbgl) in the WMMCF. With the exception of HA4 (1.7 – 2.0 mbgl), Ethofumesate was detected in samples from the WMMCF only.

7.1.2 Phenoxy Acid Herbicides

Analysis for Dicamba, Dichlorprop, MCPA and Mecoprop identified one exceedance of the Zone 1 MTVs, a concentration of 270 µg/kg of MCPA in OS1 at 0.4 mbgl.

7.1.3 Semi Volatile Organic Compounds (SVOCs)

Four samples recorded phenol concentrations above detection limits. All four samples were above the MTV, with the greatest concentration 10,000 µg/kg present in OS1 in shallow

Made Ground at 0.4 mbgl. The other exceedances were in from OS1 5.0 mbgl (710 µg/kg), OS2 4.8 mbgl (110 µg/kg) both within the Gault Clay and OS6 3.0 mbgl (150 µg/kg) within the WMMCF.

Bis(2-chloroethyl)ether exceeded detection limit and MTV in 18 of the 32 samples analysed, the distribution adjacent to the Riddy Brook was very similar to that of Hemp a and Schradan. With the exception of o ne sample associated with shallow Made Ground (OS1 0.4 mbgl) and one sample associated with a s hallow sand and gravel above the WMMCF (HA5 1.4 – 1.8 mbgl) all exceedances of t he MTV were present in the WMMCF and Gault Clay. Bis(2-chloroethyl)ether concentrations typically increased with depth with the greatest concentrations recorded in the Gaul t Clay in OS1 5.0 mbgl (95,000 µg/kg), OS2 4.8 mbgl (76,000 µg/kg) and HA5 3.5 to 3.8 mbgl (12,000 µg/kg).

Two exceedances of the MTV for 4-chloro-2- methylphenol were identified, OS1 5.0 mbgl (9,600 µg/kg) and OS2 4.8 mbgl (8,700 µg/kg). 2,4,6 Trichlorophenol (246TCP) was present slightly above detection limits in three samples but not exceeding the MTV and 2 - methyl-4,6-dinitrophenol was not detected.

7.1.4 Volatile Organic Compounds (VOCs)

All VOCs exceeding the appropriate MTVs were limited to soil material below 2.0 mbgl in four boreholes, OS1, OS2, OS6 and HA6.

Tetrachloroethene (PCE) was pre sent above detection limits in 31 of the 32 samples analysed. Generally the majority of recorde d concentrations were below 10 0 µg/kg, however 7 exceedances of the MTV for PCE were recorded. Three exceedances were located in t he WMMCF (OS1 – 4.2 mbgl, OS6 – 2.0 mbgl and OS6 3.0 mbgl) with concentrations between 930 and 11,000 µg/kg with the concentration s increasing with depth (see Figure 3). The other four exceedances were located in th e Gault Clay in HA6 3.6 – 4.0 mbgl (34,000 µg/kg), OS1 5.0 mbgl (340,000 µg/kg), OS2 4.8 mbgl (49,000 µg/kg) and OS6 4.5 mbgl (5,400 µg/kg).

Trichloroethene (TCE) was identified in 26 of the 32 samples analysed and exc eeded the MTV in four samples. All exceedances of the MTV were limited to the Gault Clay in OS1 (31,000 µg/kg), OS2 (8,500 µg/kg), OS6 (1,100 µg/kg) and HA6 (2,000 µg/kg).

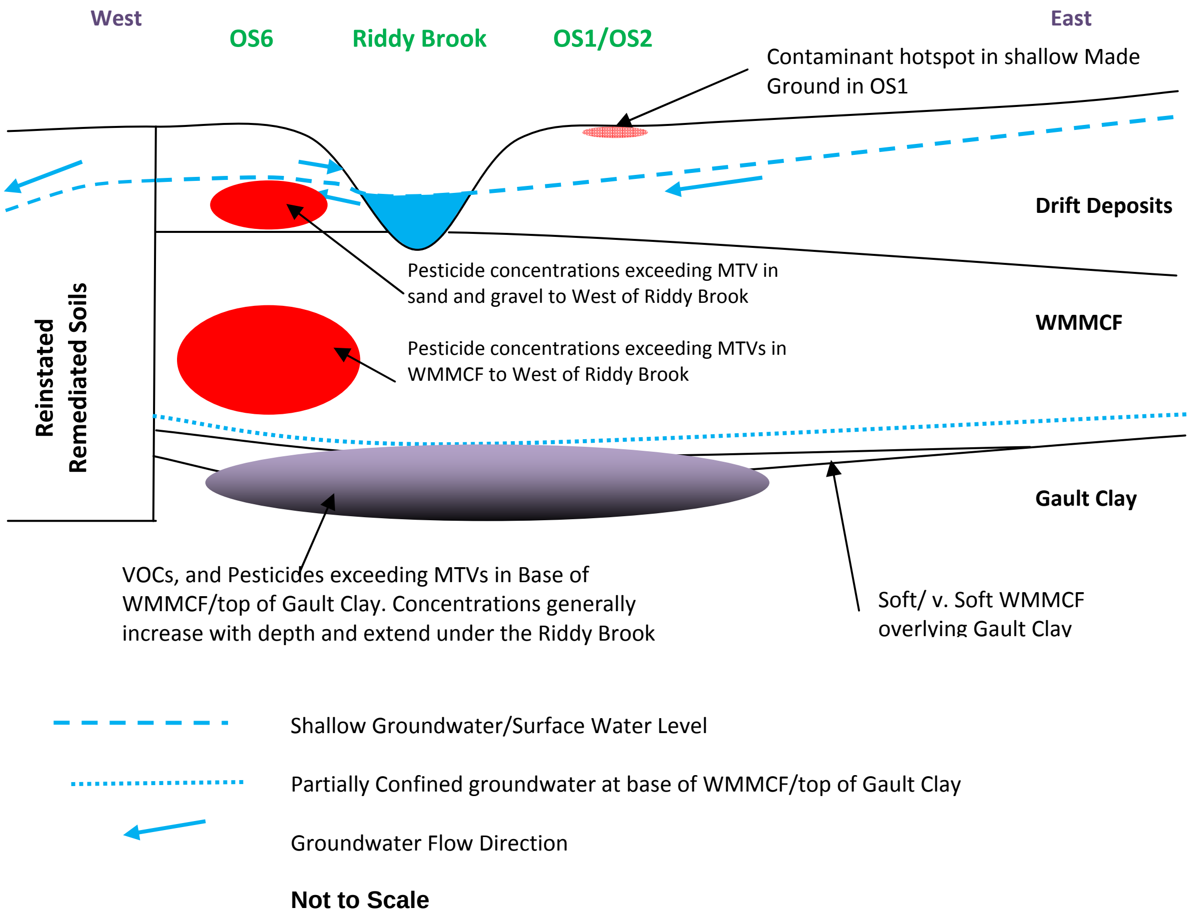
Cis 1,2-Dichloroethene (cDCE) wa s identified in 6 of the 32 samples analysed a nd was present in samples of WMMCF in OS6 and OS7 and Ga ult Clay in OS1, OS2 and OS6. Only one sample from) S6 3.0 mbgl (81 µg/kg) in the WMMCF exceede d the MTV. Vinyl chloride was not detected in any samples.

In general, chlorinated solvents (PCE, TCE, cDCE) exceeding MTVs were present only in the deepest deposits of Gault Clay and WMMCF encountered during the site investigation in the area of the identified channel in the top of the Gault (see Section 5.0)

1,2-dichlorobenzene exceeded the MTV in one location from OS1 5.0 mbgl (8,000 µg/kg). 15 samples exceeded the laboratory detection limit with the majority of elevated concentrations present within the base of the WMMCF and Gault Clay.

Toluene and Xylene was present above detection limits in 17 and 15 samples respectively, no samples exceeded the respective MTVs. Cyclohexanone was not detected in any sample.

Figure 3: Summary of Distribution of Contaminants in Soil



7.2 Contaminant Distribution in Groundwater

At the time of writing, 14 No. groundwater sampling rounds had been undertaken. The distribution of contaminants is summarised in the following sections.

7.2.1 Contaminant Variations with Depth

Borehole F9 was installed directly between OS1 and OS2. The response zone of F9 was within shallow firm to stiff WMMCF to a depth of 2.8 m compared with the response zones installed through the soft deposits in the base of the WMMCF and into the upper surface of the Gault Clay in OS1 and OS2 with the response zones below 3 m bgl.

Despite the relative proximity of t he three bo reholes, contaminants concentrations in F9 were signicantly less than those in OS1 and OS2 e.g:

- Maximum PCE Concentrations:OS1 – 30,000 ug/l, OS2 – 140,000 ug/l, F9 – 48 ug/l
- Maximum TCE concentration: OS1 – 11,000 ug/l, OS2 75,000 ug/l, F9 – 110 ug/l; and
- Maximum bis(2-chloroethyl)ether concentrations: OS1 - 38,000 ug/l, OS2 – 20,000 ug/l, F9 – 1,300 ug/l

Based on this observed vertical variation of gro undwater contaminant concentrations with depth it is considered t hat migration of contaminants is pre dominantly through the base of the WMMCF and the u pper surface of the Ga ult Clay. The significant difference between the three boreholes would also suggest that significant upward migration through the firm to stiff WMMCF is unlikely to occur.

7.2.2 Organo-phospahte and Organo-nitrates

Groundwater samples exceeding the Groundwater MTV f or Hempa and Schradan were identified in the all of boreholes adja cent to the Riddy Brook . The greatest concentr ations were recorded in G9 with concentrations of hempa between 610 to 20,000 µg/l and schradan between 400 to 29,000 µg/l. Concen trations of both hempa and schradan were typically much greater (by 1 to 3 orders of mag nitude) in boreholes to the west of Riddy Brook compared with those to the e ast. To the east of the Riddy Brook (boreholes OS1, OS2, OS/HA5, HA6 a nd HA8), the maxi mum recorded concentrations of hempa and schradan were 50 and 14 µg/l respectively, both in OS1.

Ethofumesate concentrations exceeded the groundwater MTV in boreholes OS6, OS7, HA4 HA6, G8 a nd G9 with the maxi mum recorded concentra tion of 360 µg/l (G9, December 2011). No exceedances of the MTV were recorded to the east of the Riddy Brook.

Simazine did not exceed the groundwater MTV in any sample, Dimefox was not detected in any sample of groundwater.

7.2.3 Phenoxy Acid Herbicides

Samples from G9 and one sample from OS6 taken exceeded the MT V of 1,000 ug/l for MCPA. The maximum recorded concentration was 4,100 ug/l. recorded a concentration of 3,500 ug/l for MCPA which exceeded the groundwater MTV. One exceedance of t he MTV for Dicamba was recorded in borehole G9. No other exceedances of Dicamba, dichlorprop, MCPA or Mecoprop were recorded.

7.2.4 SVOCs

Of the four compounds analysed, 2-methyl-4, 6-dinitropheno l was not detected and 2,4,6-TCP did not exceed the groundwater MTV. It should also be noted that 2,4,6-TCP was not identified in boreholes to the east of the Riddy Brook.

Bis(2-chloroethyl)ether concentrations exceeding the groundwater MTV were present in the majority of boreholes throughout the monitoring with the the MTV exceeded in eight locations. Maxi mum concentration recorded in OS6 (33, 000 to 40,000 µg/l) and OS1 (38,000 µg/l). Typical concentration s in boreholes G8 and G9 were 1,200 to 20,000 ug/l and in OS1 , OS2, OS6, OS7, HA4, and HA5 were between 740 to 5,400 µg/l. These concentrations were significantly higher than those identified in OS/HA5, HA6 and HA8 (all located to the east of the Riddy Brook) where the maximum concentration was 150 µg/l and typically less than 50 µg/l.

Elevated concentrations of 4-ch loro-2-methylphenol were identified in most bor eholes. However exceedances of the MTV were limite d to G8 (4,400 µg/l), G9 (2,500 µg /l), HA5 (2,500 µg/l), OS6 (1,200 µg/l) and OS7 (2,600 µg/l) all of w hich are located to the east of the Riddy Brook.

Phenol concentrations were below MTV on all monitoring rounds with the exception of May 2012 when the following exceedances were recorded; G8 (1,600 µg/l), G9 (3,600 µg/l) OS6 (6,600 µg/l), OS1 (1,500 µg/l), OS7 (1,000 µg/l) and HA7 (1,000 µg/l). It should be noted that the elevated phenol concentrations corresponds with the period of elevated rainfall and groundwater levels.

7.2.5 VOCs

Chlorinated Solvents

Exceedances of the groundwater MTV for PCE were regularly recorded in OS1, OS2, OS6, HA6, HA7 F10, G8, G9 and H7 and in HA4 on 10 November 2011. The greatest concentrations were recorded in OS2 (140,000 µg/l) and OS6 (120,000 µg/l) on 21 October and 10 November 2011.

Distribution of TCE was very similar to PCE with all exceedances of the MTV recorded in OS1, OS2, OS6 and HA7, F10, G8 and G9, one exceedance of the MTV was also recorded in HA4 on one occasion and in OS7 on four occasions. The maximum concentrations were recorded in OS2 (75,000 µg/l) and OS6 (77,000 µg/l) on 21 October and 10 November 2011 respectively.

Concentrations of cDCE exceeding the groundwater MTV were present in OS1, OS6, OS7 and HA7, F10, G8 and G9 with maximum concentrations in G9 66,000µg/l) and G8 (23,00 µg/l). Vinyl chloride exceeding the MTV was present in OS1, OS2, OS6, OS7, HA5 and HA7. With the greatest concentration in OS6 (1,500 µg/l) and OS7 (950 µg/l).

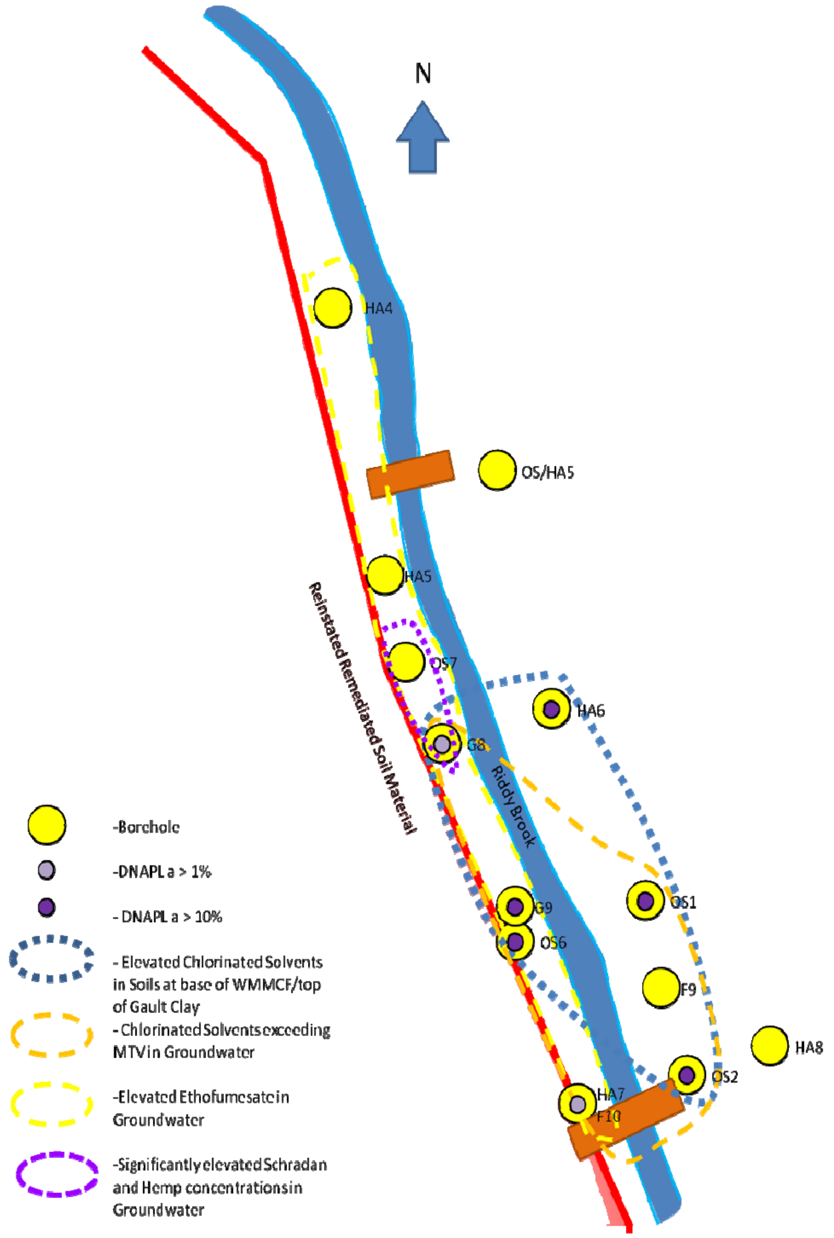
Generally, the boreholes with the greatest concentrations of chlorinated solvents corresponded closely with the greatest concentrations in soil (OS1, OS2 and OS6) and the deposits of soft to very soft WMMCF.

To the east of the Riddy Brook, Borehole F9, installed to a depth of 2.8 m bgl directly between OS1 and OS2 and in the firm to stiff WMMCF above the soft to very soft WMMCF has recorded relatively low concentrations of contaminants with maximum chlorinated solvent values of PCE (48 ug/l), TCE (110 ug/l), cDCE (1,100 ug/l) and VC (130 ug/l)

Other Solvents

Elevated toluene concentrations exceeding the MTV were present in OS6, OS7,HA5, G8 and G9 with a maximum concentration of 9,100 µg/l in HA5. 1,2-dichloroethane exceeded the MTV in one sample from 21 October 2011 in OS6 (1,600 µg/l) and samples from G9 (1,900 µg/l) . No exceedances of the MTV for Xylene or 1,2-dichlorbenzene were recorded and cyclohexanone was not detected.

Figure 4: Approximate Distribution of Contaminants in Groundwater



7.2.6 Evidence of Chlorinated Solvent Degradation

A number of groundwater samples show evidence that degradation of chlorinated solvents (PCE and TCE) is occurring. Degradation of chlorinated solvents is via successive dechlorinations so that PCE degrades to TCE which degrades to cDCE which degrades to VC which degrades to ethene. Therefore, the presence of increased proportions of cDCE and VC would be expected to increase as degradation occurs.

From the monitoring data, there is evidence of degradation occurring in a number of boreholes including the following:

- OS7: Typical percentages were PCE (0.4 – 32%), TCE (2.1 – 27%), cDCE (49 – 79%) and VC (5.5 to 20.0%);
- HA5: Typical percentages were PCE (49 – 64 %), TCE (1.18 – 11%), cDCE (27 – 28%) and VC (7 – 13 %);
- HA6: Typical percentages were PCE (32 – 42%), TCE (41 – 45%), cDCE (16 – 23%) and VC (0%); and
- HA7: Typical percentages were PCE (8.3 – 32%), TCE (50 – 57%), cDCE (17%) and VC (1 – 1.5%);
- F9: Typical percentages were PCE (3 – 38 %), TCE (8 - 43%), cDCE (47 – 81%) and VC (5.5 – 9.5%);
- F10: Typical percentages were PCE (7 - 14%), TCE (44 – 58%), cDCE (26 – 40%) and VC (3 to 6%);
- G8: Typical percentages were PCE (1 – 7.5%), TCE (5 - 37 %), cDCE (52 - 73%) and VC (4 – 24.5%);
- G9: Typical percentages were PCE (36.7 to 75.9%), TCE (17.5 – 41.6%), cDCE (5 – 23.5%) and VC (0.5 to 2.5%);
- H7: Typical percentages were PCE (80 to 90%), TCE (5 - 12 %), cDCE (3 – 7%) and VC (0.5 %);

Groundwater samples from HA4, recorded negligible cDCE and VC concentrations. Groundwater from OS2 and OS6 recorded very similar chlorinated solvent percentages with high PCE (40 – 65%) and TCE (35 – 57 %) with low levels of cDCE (0.2 – 9%) and VC (<0.5%).

In summary, strong evidence of chlorinated solvent degradation was present in boreholes OS7, F9 and G8 where percentages of cDCE and VC combined exceeded typically exceeded PCE and TCE combined.

7.2.7 Assessment of Presence of Dense Non-Aqueous Phase Liquids (DNAPL)

No DNAPL was observed during the site investigations. In the case of H7, no evidence of DNAPL was observed at the base of the grid square during remediation, however, this was the area was an area of the site where impacted water was observed in the undisturbed soils in the banks of the Riddy Brook during the removal of the bentonite wall and these impacted waters are considered a potential source of the contatmination in this area.

Given the concentrations of chlorinated hydrocarbons observed, further assessment on the presence of DNAPL has been undertaken. Groundwater samples from all boreholes have been assessed for the presence of DNAPL in accordance with the methodology set out in the Environment Agency report 'An illustrated handbook of DNAPL transport and fate in the subsurface' (Reference 10). Data was selected from each borehole based on the maximum recorded value of total chlorinated solvents (PCE, TCE, cDCE and VC). Maximum solubility limits have been taken from Reference 10 and data obtained in VertaseFLI 2012c (Reference 8).

The results of the assessment are presented in Appendix M. Based on the Environment Agency recommended approach, where the value of *a* (the ratio of observed contaminant concentration to effecitive contaminant solubility) is greater than 0.01 (1%) DNAPL is likely to be present up hydraulic gradient of the borehole. Based on this rule of thumb, DNAPL is likely to be present adjacent to boreholes OS1, OS2, OS6, HA6, HA7, G8, G9 and F10. The ratio *a* exceeded 10% in boreholes OS1, OS2, OS6, HA6 and G9 suggesting a greatly increased likelihood that DNAPL is present in these locations. It should be noted that these five boreholes are located within the observed low in the surface of the Gault Clay (discussed in Section 5.2) which suggests and that flow of DNAPL appears to follow the surface of the Gault Clay and that the extent of DNAPL concentration is limited to the base of the WMMCF/upper surface of the Gault Clay.

Potential DNAPL was also identified in bore hole H7, located to the north of the low in the Gault Clay. The borehole was installed in natural soil strata outside the remediated soils and immediately to the east of the former bentonite wall. It is considered that the DNAPL was held in this area by the bentonite wall and as in other boreholes outside the main remediation site, the DNAPL is present at the base of the WMMCF/top of the Gault Clay.

7.3 Monthly Monitoring of the Riddy Brook

Monitoring of the Riddy Brook and River Cam (upstream and downstream of the site) has been undertaken since 2008. The results from November 2010 onwards are summarised in Appendix F.

As discussed in 4.5.4, elevated contaminant concentrations recorded in the Riddy Brook between December 2011 and February 2012 was attributed to be the presence of a historic drainage feature entering the Riddy Brook. The drainage feature was identified in January 2012 and decommissioned.

7.3.1 Organo-phosphate and Organo-nitrate Pesticides

Negligible concentrations of pesticides were generally detected upstream of the site in the monthly monitoring. Over 47 monitoring rounds (to August 2012), dimefox was not detected, schradan was recorded on one occasion (1.7 µg/l in February 2012) and trace concentrations of ethofumesate (up to 1.5 µg/l), hempa (6.1 µg/l in February 2012, all other concentrations were equal or below 0.2 µg/l) and simazine (2 µg/l) were recorded on seven, three and three occasions respectively.

Outside of the period between December 2011 and February 2012, down-stream of the site, trace concentrations of hempa (up to 1.2 µg/l) were detected on four occasions, simazine (up to 2 µg/l) on three occasions, schradan (up to 4.8 µg/l) on six occasions and ethofumesate (up to 1.4 µg/l) on 28 occasions.

The following elevated concentrations of pesticides were recorded between December 2011 and February 2012 that exceeded typical concentrations recorded in other periods. It should be noted that none of the pesticides were detected in March 2012.

- Ethofumesate – 6.7 µg/l recorded in December 2011 decreasing to 1.2 and 1.4 µg/l in January and February 2012 respectively;
- Hempa – Concentrations increased from 10 µg/l in December 2011 to 26 µg/l in February 2012;
- Schradan – Concentrations in December 2011, January 2012 and February 2012 were 14, 8 and 9.4 µg/l respectively;
- Simazine – 4.4 µg/l was recorded in December decreasing to 0.7 µg/l in Janaury and February 2012.
- Dimefox was not detected.

7.3.2 Phenoxy Acid Herbicides

- Dicamba – Three up-stream concentrations above detection limits were recorded with a maximum of 1 µg/l in February 2012. Downstream, prior to December 2011, dicamba was recorded in two samples with a maximum concentration of 0.2 µg/.In December 2011 a concentration of 2.8 µg/l was recorded and between January and May 2012 concentrations were between 0.2 and 1.0 µg/l. Downstream monitoring from June to August 2012 did not record any dicamba concentrations.

- Up stream concentrations of Dichlorprop (one occasion), MCPA (three occasions) and Mecoprop (four occasions) exceeded detection limits with maximum concentrations of 1.5, 7.4 and 7.6 µg/l respectively recorded in June 2011
- Down-stream, concentrations above detection limits were recorded on 4, 3 and 16 occasions prior to December 2011 for Dichlorprop (maximum 0.6 µg/l), MCPA (2.9 µg/l) and Mecoprop (3.6 µg/l) respectively. The maximum concentrations were all recorded in June 2011.
- Down-stream concentrations of 0.9, 6.9 and 9.7 µg/l were recorded in December 20112 for Dichlorprop, MCPA and Mecoprop respectively. Concentrations above detection limits of MCPA were recorded until May 2012 (between 0.2 and 1.3 µg/l), concentrations of Mecoprop above detection limits were recorded until June 2012 (0.2 to 0.7 µg/l). No Dichlorprop was detected after December 2011.

7.3.3 SVOCs

With the exception of Bis(2-chloroethyl)ether no SVOCs were detected in the Riddy Brook. A Bis(2-chloroethyl)ether concentration of 17 µg/l was detected in an up-stream sample from July 2010, no other up-stream concentrations were detected. Down-stream sampling identified five elevated concentrations, in January and March 2009, July and December 2011 and January 2012 with a maximum concentration of 45 µg/l.

7.3.4 VOCs

Monthly monitoring up-stream and down-stream on the Riddy Brook recorded the following contaminant levels:

- PCE was detected up-stream of the site on 32 out of 47 monitoring rounds. Concentrations were typically between 1 and 3 µg/l with a maximum concentration of 6 µg/l. Down-stream, PCE was present in 44 of the 47 monitoring rounds, with concentrations typically between1 and 5 µg/l with a maximum concentration of 14 µg/l;
- TCE was only identified in one up-stream sample from January 2011 with a concentration of 1 µg/l. Down-stream; TCE was present in 33 of the 47 monitoring rounds. Prior to December 2011 concentrations were typically between 1 and 9 µg/l although between November 2008 and April 2009 concentrations between 14 and 25 µg/l were recorded. From December 2011 to February 2012, concentrations of 53, 19 and 13 µg/l were recorded with subsequent sampling to August 2012 showing concentrations decreasing to below detection limits.

- cDCE was not detected in any up-stream samples. Down-stream, cDCE was detected on 36 of the 47 monitoring rounds with concentrations typically between 1 to 9 µg/l with the exception of November 2008 and April 2009 down-stream concentrations were between 7 and 13 µg/l; and December 2012 where a concentration of 18 µg/l was recorded.
- Negligible concentrations of other VOCs were detected at the down-stream monitoring point with no other VOCs recorded up-stream.

7.3.5 Comparison of Surface Water Monitoring and Water Quality Screening Criteria

Table 4 presents the selected screening criteria for the contaminants discussed above.

Table 4 – CoC/CNPI Selected Water Quality Screening Criteria

Contaminant	Screening Criteria (ug/l)	Source	Justification
Dicamba	10	Canadian EQS for Fresh Water	Water quality guideline for the protection of aquatic life more appropriate with respect to Riddy Brook than UK Pesticide DWS
Schradan	0.35	VertaseFLI derived PNEC	See VertaseFLI 2012c (Reference 8)
Bis(2-chloroethyl)ether	1	Limit of Detection	No other screening value available
Ethofumesate	30	Swedish Freshwater EQS	Derived using EU recommended methodology (as used for UK EQS) (Reference 16). Considered more appropriate with respect to Riddy Brook than UK Pesticide DWS
Trichloroethene	10	UK DWS/EQS	
Tetrachloroethene	10	UK DWS/EQS	
Cis 1,2, Dichloroethene	6.7	Dutch Freshwater Maximum Permissible Concentration	European Freshwater quality guideline (Reference 26) considered appropriate with respect to Riddy Brook – no other guidance values available
Vinyl Chloride	0.5	UK DWS	
Hempa	350	VertaseFLI derived PNEC	See VertaseFLI 2012c (Reference 8)
Dichlorprop	0.1	UK DWS	UK DWS for pesticdes
MCPA	12	Freshwater EQS	UK Non-statutory EQS listed by Environment Agency as used by UK regulatory authorities (Reference 25)
Mecoprop	18	Annual mean Freshwater EQS	Environment Agency – River Basin District Typography, Standards and Groundwater Threshold Values (Reference 15)

Contaminant	Screening Criteria (ug/l)	Source	Justification
Simazine	1	Freshwater EQS	Environment Agency – River Basin District Typography, Standards and Groundwater Threshold Values (Reference 15)

For the majority of monitoring, the contaminant concentrations recorded in the Riddy Brook have been below the screening criteria listed in the Table 4. However, the following contaminants have exceeded the screening criteria:

- Schradan exceeded the PNEC of 0.35 µg/l on 3 occasions prior to December 2011. 0.35 µg/l was exceeded between December 2011 and February 2012, and in July 2012;
- Simazine EQS (Annual Average) of 1 µg/l was exceeded on one occasion in December 2011 (4.4 µg/l). The simazine concentration slightly exceeded the maximum allowable EQ (4 µg/l) but the annual average calculated for the period August 2011 to August 2012 (including the value of 4.4 µg/l) was 0.5 µg/l below the EQS;
- Tetrachloroethene exceeded the EQS of 10 µg/l on one occasion (December 2011);
- Trichloroethene exceeded the EQS during November 2008 to April 2009 (prior to the start of the remediation) and between December 2011 and February 2012; and
- Cis 1,2-dichloroethene marginally exceeded the EQS periodically during the monitoring with greater exceedances recorded between November 2008 to April 2009 and December 2011.

7.4 Chemical Profiling of the Riddy Brook

In January 2012, water samples were taken at 40 m intervals along the Riddy Brook as shown in Drawing D907_203, Appendix A. Subsequently, monthly samples were taken at the 40m, 80 m and 160 m sample points together with the up and down stream samples. The profiling was undertaken to provide an increased resolution between the up-stream and down-stream sample points. The principal findings are summarised in Appendix G and discussed below.

7.4.1 Organo-phospahte and Organo-nitrate Pesticides

In January, Hempa and Schradan concentrations increased along the Riddy Brook from 0.2 µg/l up-stream of the site to maximum concentrations of 11 and 12 µg/l respectively 240 m along the site boundary. Immediately down-stream of the site (280 m along the Riddy

Brook) concentrations of both Hempa and Schradan decreased to 9.7 and 7.2 µg/l respectively. Monitoring in February showed very similar Schradan distribution to January but increased Hempa concentrations (up to 26 µg/l). Subsequent monitoring between March and July 2012 recorded concentrations at all monitoring points below detection limits. It should be noted that hempa did not exceed the screening criteria presented in Section 7.3.5

Ethofumesate showed marginal increases from 0.2 µg/l up-stream of the site to 0.5 µg/l (below the screening critieria) from 200 to 280 m downstream in January and concentrations slightly increased in the February monitoring, subsequent monitoring was below detection limits. The maximum simazine concentration detected was 0.1 µg/l; and Dimefox was not detected.

7.4.2 Phenoxy Acid Herbicides and SVOCs

No elevated concentrations of dichlorprop, MCPA, Mecoprop or SVOCs were detected in any part of the Riddy Brook. Slightly elevated dicamba concentrations of 0.3 and 0.8 µg/l were detected 10 m and 20 m from the up-stream monitoring point.

7.4.3 VOCs

In January 2012, concentrations of chlorinated solvents showed significant variations along the Riddy Brook.

- TCE concentrations increased from the detection limit at the up-stream monitoring point to 56 µg/l 40 m down-stream (compared with the EQS of 10 µg/l). TCE concentrations then decreased steadily to 120 m down-stream (39 µg/kg) before increasing to 88 µg/kg at the 160 m monitoring point. From 160 m to the down-stream monitoring point concentrations of TCE decreased to 37 µg/l;
- PCE concentrations were between 1 and 3 µg/l (similar to the concentrations recorded in the monthly up-stream monitoring) between the up-stream monitoring point and 120 m down-stream. Concentrations increased at 160 m to 16 µg/l before decreasing steadily to 9 µg/l at the down-stream monitoring point.
- cDCE showed very similar distribution to PCE although at slightly greater concentrations. Between the up-stream monitoring point and 120 m cDCE was not detected, concentrations increased to 19 µg/l and decreased steadily to 11 µg/l at the down-stream sampling point.
- Vinyl Chloride (VC) was detected at 160 m and 200 m from the up-stream monitoring point with concentrations of 2 and 1 µg/l.

Subsequent monitoring in February showed a similar pattern to the January monitoring but at lower concentrations. However concentrations between March and July were at low levels with no contribution from the identified seepages (before the 40 m monitoring point) and concentrations slightly increasing between 80 and 160 m to maximum PCE/TCE concentrations of 6 µg/l.

In general, the proportions of PCE, TCE, cDCE and VC identified in the monitoring were similar to those observed during the historical monthly down-stream monitoring with TCE showing the greatest concentrations followed by cDCE, PCE and VC.

Based on the results of the VOC analysis in January 2012 a source of TCE contamination appeared to impact the Riddy Brook between the up-stream and 40 m monitoring points. However, subsequent removal of previously unidentified TCE impacted tank/pipes outside of the remediation boundary has removed the likely contaminant source (VertaseFLI 2012b, Reference 5).

The increase in contaminant concentrations between 120 and 160 m from the up-stream sampling location appears to be coincident with the identified area of contamination outside the remediation boundary described in Sections 7.1 and 7.2 indicating that the observed contamination is likely to be contributing to the increased concentrations in the Riddy Brook. However, although increased concentrations were identified in January and February 2012, subsequent monitoring along the length of the Riddy Brook has been below the relevant EQS/screening criteria. Based on the observed vertical variations in contaminant concentrations (both in soil and groundwater) and the presence of low permeability WMMCF (1 to 3 m of firm to stiff clay) over the zone of deeper contamination (below 3 m bgl) it is considered that the observed impact have resulted from the contaminants present within the shallow drift deposits/WMMC and not the contaminatns at the base of the WMMCF/top of the Gault Clay.

7.5 Water Sampling of Seepages and Vertical Pipe

7.5.1 Seepages

Two seepages on the western bank of the Riddy Brook had previously been noted prior to and during the remediation works and were also observed in January 2012 The seepages were located at approximately 5 and 15 m down-stream of the up-stream monitoring point (see drawing D907_203, Appendix A). Both seepages were sampled in January 2012 and analysed for the same suite of contaminants as the Riddy Brook and groundwater samples. The results are presented in Appendix K and are summarised below:

- VOCs – Only PCE, TCE, cDCE and Toluene were detected in the seepages. TCE was present in the first Seepage (Sample Riddy US+5) at a concentration of 2,100 µg/l and in the second seepage (Riddy US+15) at 83 µg/l. PCE concentrations were 29 and 30 µg/l and cDCE concentrations were 20 and 6 µg/l, Toluene was at 4 µg/l;
- OP and ON Pesticides – Contaminants identified in the seepages included dimefox (0.7 and 0.5 µg/l), Ethofumesate (3.8 and 1.5 µg/l), Hempa (27 and 30 µg/l), Schradan (3.0 and 5.0 µg/l) and Simazine (0.91 and 1.7 µg/l);
- Phenoxy Acid Herbicides – Only dicamba (17 and 20 µg/l) was detected; and
- No SVOCs were detected.

Given the elevated TCE concentrations observed in the first seepage it is considered likely that this is a significant contribution to the elevated TCE concentrations observed between the up-stream monitoring point and 40 m monitoring point in the Riddy Brook. The concrete chamber and associated pipework discussed in Section 3.3 is considered to be a potential source of the contamination present in the seepage. The chamber was located outside of the main remediation area adjacent to the seepages (see drawing D907_230) and was decommissioned/remediated in July 2012 (see Reference 5).

7.5.2 Vertical Pipe

Prior to decommissioning with bentonite, water within the vertical pipe in the Riddy was sampled and the results are summarised as follows:

- VOCs – PCE, TCE, cDCE and VC concentrations were 9, 18, 27 and 82 µg/l respectively. Xylene (140 µg/l) and Toluene (250 µg/l) were also detected;
- OP and ON pesticides – Ethofumesate, Hempa and Schradan were detected at concentrations of 78, 130 and 660 µg/l respectively;
- Phenoxy Acid Herbicides – Dicamba, Dichlorprop, MCPA and Mecoprop were identified at 0.9, 4.1, 0.8 and 11 µg/l respectively; and
- SVOCs – 4-chloro-2-methylphenol (1,000 µg/l) and Bis(2-chloroethyl)ether (120 µg/l) were present above detection limits.

7.6 Monthly Monitoring in River Cam

Monthly monitoring of the River Cam, up-stream and down-stream of the site, has been undertaken since May 2008. In general, negligible contaminant concentrations have been detected with the following exceptions:

- VOCs – Maximum concentrations of 3 µg/l of PCE were recorded both up-stream and down-stream of the site. Typically, the concentrations at both monitoring points were between 1 and 3 µg/l. The concentrations were typically below typical concentrations identified by the Environment Agency at a sample point approximately 1.2 km east of the site (see appendix H)
- OP and ON Pesticides – Up-stream, elevated schradan (0.3 µg/l) and ethofumesate (0.3 µg/l) were each recorded on one occasion. Down-stream of the site, elevated ethofumesate concentrations (up to 0.8 µg/l) were recorded on five occasions, and schradan (3.4 µg/l in June 2011) and Hempa (0.1 µg/l in July 2011) were recorded on one occasion each;
- Phenoxy Acid Herbicides – Slightly elevated concentrations of MCPA (1.4 µg/l) and Mecoprop (up to 2.9 µg/l) were recorded up-stream of the site on one and three locations respectively. Down-stream of the site MCPA (up to 0.1 µg/l), Mecoprop (up to 3.4 µg/l) and Dichlorprop (0.1 µg/l) were recorded on three, four and one occasions respectively;
- Phenol – An elevated phenol concentration of 36 µg/l was recorded in the downstream sample in March 2012. No other concentrations of phenol have been recorded in the upstream or downstream samples for the duration of the remediation works; and
- Bis(2-chloroethyl)ether - A bis(2-chloroethyl)ether concentration of 18 µg/l was recorded in the upstream sample from May 2012. No other concentrations were recorded above detection limits in the River Cam.

The PCE and TCE concentrations recorded by the Environment Agency since 1996, upstream (approximately 1.2 km) and immediately downstream, did not exceed the EQS for either compound.

7.7 Summary

The principal contaminant distributions outside of the main remediation site are:

- Concentrations of contaminants including PCE, TCE, hempa, schradan, ethofumesate and bis(2-chloroethyl)ether exceeding the MTV were detected in soils in the majority of boreholes;
- Contaminant concentrations in soils generally increase with depth, with the greatest concentrations recorded in the base of the WMMCF/top of the Gault Clay in

boreholes OS6 and OS2. Generally, significant contaminant concentrations were only encountered below 2.0 mbgl (below the base of the Riddy Brook) with the exception of elevated pesticide concentrations (hempa, schradan and ethofumesate) encountered in deposits of sand and gravel (drift deposits) in HA4 and HA5 below 1.4 mbgl.

- With the exception of the base of the WMMCF/top of the Gault and shallow Made Ground in OS1, pesticides and herbicides and SVOCs were generally only identified in soils to the west of the Riddy Brook;
- Contaminant concentrations exceeding the appropriate MTVs in ground water were identified in the majority of boreholes. With the exception of VOCs in OS1 and OS2, contaminant concentrations were significantly higher to the west of the Riddy Brook compared with boreholes on the eastern side;
- Identified contaminants in groundwater included , ethofumesate, hempa, schradan, bis(2-chloroethyl)ether, PCE, TCE, cDCE, VC and toluene. The greatest concentrations of VOCs were recorded in OS1, OS2, OS6,HA7, G8 and G9;
- The greatest concentrations of chlorinated solvents appear to be associated with a channel within the top of the Gault clay;
- Good evidence of degradation of VOCs was present in groundwater in several boreholes (including OS7) given the proportion of cDCE and VC present compared to PCE and TCE concentrations. However, the VOC concentrations in the two most impacted boreholes indicated low degradation levels;
- PCE and some TCE concentrations recorded in the boreholes adjacent to the Riddy Brook suggest the presence of DNAPL. The presence of DNAPL is generally limited to the observed low in the surface of the Gault Clay (see Section 5.2). The only exception to this is borehole H7 where presence of DNAPL in soils outside of the remediation boundary is likely to have resulted from the presence of the former bentonite wall limiting migration;
- Contaminant concentrations in the Riddy Brook down-stream of the site were generally higher than concentrations up-stream. The site appears to have very little impact on the River Cam;
- Sampling in January 2012 along the Riddy Brook identified elevated concentrations of TCE, cDCE and PCE along the Riddy Brook. Subsequent monitoring from the same locations from March 2012 onwards has shown much reduced concentrations

in the Riddy Brook, with many contaminants below detection limits and all contaminants at concentrations less that screening criteria.

- Samples of observed seepages in the western bank of the Riddy Brook identified elevated concentrations of TCE, ethofumesate, dimefox, hempa and schradan, however negligible concentrations of phenoxy acid herbicides and SVOCs were detected. Elevated contaminant concentrations were also identified in a vertical pipe present in the Riddy Brook. Both the source of the seepages and the pipe have subsequently been remediated; and
- Recorded PCE concentrations have been slightly elevated in up-stream and down-stream samples from both the Riddy Brook and the River Cam throughout the surface water monitoring. Given the presence of PCE at locations significantly up-stream of the site (based on monitoring data provided by the Environment Agency), it is considered that the PCE results from the presence of separate contaminant source some distance up-stream of the site and is not related to the contaminants present at the site.

In general, the presence of significant contaminant concentrations has been identified in soil and groundwater adjacent to the Riddy Brook. However following the completion of remediation and an initial rise in contaminant concentrations in the Brook between December 2011 and February 2012, concentrations in the Riddy Brook have declined despite groundwater concentrations remaining relatively constant throughout the monitoring period.

8.0 Discussion

8.1 Observed Impacts on Surface Water

Evidence from the monthly surface water monitoring indicates there have been four periods between May 2008 and August 2012 when elevated contaminant concentrations were detected at the Riddy Brook downstream monitoring point. The most significant impacts (exceeding EQS or equivalent values) were typically from chlorinated solvents (TCE and cDCE), bis (2-chloroethyl)ether and schradan.

The most recent impact during December 2011 and February 2012 followed the completion of the remediation work at the site which included the removal of the bentonite wall (July to August 2011) and the ending of groundwater control (October 2011). From February 2012 onwards no exceedances of the EQS and selected screening criteria have been observed in the Riddy Brook and negligable pesticide concentrations have been detected.

No impact from the site was recorded in the River Cam.

Chemical profiling along the Riddy Brook (discussed in Section 7.4) identified the following which were generally attributed to shallow soil contamination (typically less than 2 m bgl) adjacent to the Riddy Brook:

- In January and February 2012, a source of TCE appeared to be entering the Riddy Brook close to the up-stream sampling point and the former concrete chamber shown on drawing D907_230. PCE and cDCE concentrations remained at background concentrations at this point. Monitoring between March and July 2012 did not show any impact in the Riddy Brook from the TCE source;
- A second source of chlorinated solvents entering the Riddy Brook was present between 120 and 160 m from the up-stream monitoring point. It was considered likely that this was associated with the identified area of contamination outside of the main remediation site within the shallow soils (less than 2 m bgl) on the western bank of the RIddy Brook. From 160 m the chlorinated solvent concentrations steadily decreased. Impact from the contaminants outs source was greatest in January and February 2012; and
- Concentrations of hempa and schradan showed a generally steady increase along the length of the site boundary in January and February 2012. No concentrations of hempa and schradan were recorded in the Riddy Brook between March and June 2012.

Pre-remediation, an increase in pesticide concentrations along the Riddy Brook was also identified by Enviros (2005) (Reference 3).

8.2 Potential Sources of Contamination

Remediation at the site comprised the excavation, ex-situ bioremediation and reinstatement of soil material. Due to regular turning as part of the bioremediation soil material became homogenised and reinstatement included the compaction resulting in a very low permeability material (Reference 4). Following remedial works, the groundwater monitoring across the site (Appendix A) indicates the presence of a groundwater 'low' in the north of the site suggesting either flow of groundwater in the remediated soils is away from the Riddy Brook towards the 'low' or an effective no-flow zone in the remediated soils. Therefore, the remediated soils are not considered to be a source of the observed contamination impacts on the Riddy Brook.

Investigations to the east of the River Cam did not identify any significantly elevated contaminant concentrations and this area has also been discounted as a potential source.

Therefore, based on the observations during remediation works, the investigations outside the main remediation site, sampling and the previous investigations, the following potential contaminant sources were identified outside of the site boundary:

- Historically VOC and pesticide impacted soils and groundwater in un-remediated shallow soils comprising drift deposits (including sand and gravel), and shallow WMMCF between the site boundary and the Riddy Brook;
- Historically VOC and pesticide impacted soils and groundwater at the base of the WMMCF/top of the Gault Clay underlying the Riddy Brook. The site investigation data would suggest that chlorinated solvent migration (including DNAPL) has followed the contours of the Gault Clay surface and in particular a channel low that runs under the Riddy Brook in the vicinity of boreholes OS2 and OS6. It is important to note that there is typically between 1 to 3 m of firm to stiff clay overlying the identified contaminant source.;
- Former concrete chamber and associated pipe work located adjacent to the Riddy Brook (see drawing D907_230). The chamber is located outside of the remediation boundary adjacent to the TCE impacted seepages entering the Riddy Brook (now removed);
- Vertical pipe present within the Riddy Brook; and

- Any remaining unidentified contaminant sources in the bank between the remediated site and the Riddy Brook.

Additionally, monthly monitoring of both the Riddy Brook and the River Cam has identified slightly elevated PCE concentrations up-stream of the site suggesting the presence of an up-stream source of PCE contamination. Monitoring undertaken by the Environment Agency (Appendix H) confirmed the presence of elevated PCE concentrations 1.2 km to the east of the site (up gradient) at greater concentrations than those observed adjacent to the site. This would therefore indicate that the source of the PCE concentrations is located some distance up-stream of the site and is therefore not connected with the contaminants identified . Further consideration of the up-stream source is outside the scope of this report.

8.3 Potential Pathways

The potential pathway for contaminants to migrate from the identified contaminant sources to the Riddy Brook are considered to be the following:

- via groundwater through isolated shallow sand and gravel deposits and sand and gravel lenses within the WMMCF;
- via groundwater at the base of the WMMCF and top of the Gault Clay; and
- via the vertical pipe within the base of the Riddy Brook.

Additionally, at the time of the Riddy Brook profiling in January 2012, the concrete chamber and associated pipework adjacent to the Riddy Brook may have acted as a pathway for TCE impacted groundwater into the Riddy Brook (as seen in the seepages on the bank of the Riddy Brook). However, it is important to note that these features were decommissioned in July 2012 (VertaseFLI 2012b – Reference 5) and are no longer considered to represent a potential pathway.

8.4 Assessment of Groundwater/Surface Water Levels and Potential Shallow Contaminant Impacts on the Riddy Brook

Appendix L presents graphs showing recorded ground water levels in BH11 compared with the approximate water level in the Riddy Brook (based on the levels recorded in October 2011) for the duration of monitoring and in relation to the recorded contaminant concentrations in the Riddy Brook. BH11 was selected as it is located in un-remediated soils adjacent to the Riddy Brook and offers a continuous record before, during and after the remedial works. However, it should be noted that BH11 is a historic borehole that pre-dates the remediation and no construction details are available for the borehole.

The graphs confirm that groundwater levels adjacent to the Riddy Brook fluctuate above and below the level in the Riddy Brook. As shown in Appendix D water levels in the Riddy Brook are typically between 0.2 to 0.3 m deep and show very little variation. Groundwater levels appear to decrease following the removal of the bentonite wall as would be expected given the observed seepages/flow of groundwater onto the main remediation site as the wall was removed. Groundwater levels decreased until October 2011 when the groundwater control at the site was stopped and groundwater levels subsequently increased to levels above the Riddy Brook. The increase in groundwater levels can also be seen in the boreholes to the west of the Riddy Brook presented in Appendix L.

The graphs show that during the remedial works (with active groundwater control including the bentonite wall) the groundwater levels outside the remediation boundary were very similar to the Riddy Brook with occasional periods when groundwater levels increased and flow would be anticipated to be towards the Riddy Brook. These occasional increased levels were also seen pre-remediation but the levels were generally lower than the Brook. Following completion of remedial works and the removal of groundwater controls, groundwater levels adjacent to the Riddy Brook recovered to natural levels between October and December 2011. From December 2011 onwards groundwater levels in the undisturbed soils outside of the remediation boundary have remained above the Riddy Brook suggesting groundwater flow within the banks of the Brook is towards the Brook.

Throughout the monitoring of the Riddy Brook, there appears to be a good correlation between the periods when groundwater levels exceeded surface water levels and the presence of elevated contaminant levels within the Riddy Brook. Similarly, when groundwater levels dropped below the level in the Riddy Brook (such as the period following the removal of the bentonite wall), there is a good correlation to recording of very low contaminant levels. This would indicate that contaminated groundwater in drift deposits and shallow WMMCF was the principal source of elevated contaminants observed within the Riddy Brook.

Following the end of groundwater control groundwater levels rebounded to higher levels than before and during the remedial works and this initial rebound period corresponds well with the elevated contaminant concentrations observed along the Riddy Brook between December 2011 and February 2012. Therefore it seems very likely that groundwater within the un-remediated shallow soils close to or above the water level in the Riddy Brook was either acting as a source and a pathway for contaminants.

It should be noted that from February 2012 contaminant levels in the Riddy Brook decreased progressively although groundwater levels remained above the surface water levels (and the typical groundwater levels during remediation). Assuming there was a significant contaminant source remaining in the drift deposits and shallow WMMCF adjacent to the Riddy Brook, it would have been anticipated that elevated contaminant concentrations would continue to be identified in the Riddy Brook due to the flow from groundwater in these shallow deposits to the Brook. This has not been the case with contaminant levels generally decreasing to below detectable levels. Therefore, it is considered that initially elevated contaminants in shallow groundwater (within bank storage) have been flushed through along the length of the Riddy Brook following the rebound in natural groundwater levels. Elevated contaminant concentrations were only detected in the Riddy Brook following the groundwater levels rising above the surface water levels and the subsequent decrease in contaminant levels strongly suggests that the source of the contaminants was relatively limited in size and durationand subsequently less impacted water has continued to feed into the Riddy Brook.

8.5 Comparison of Contaminant Distributions in Surface Water and Boreholes Outside the Main Remediation Site

8.5.1 Chlorinated Solvents

In all down-stream sampling in the Riddy Brook (see Appendixes F and G), when detected the chlorinated solvent ratios were generally consistent such that TCE concentrations were greater than cDCE concentrations which were greater than PCE concentrations.

- PCE – 11 to 21%;
- TCE – 50 to 64%; and
- cDCE – 22 to 35%.
- VC was generally not detected.

TCE and cDCE concentrations along the Riddy Brook showed very similar distribution patterns suggesting they originate from the same source. However PCE concentrations were much lower than the TCE concentrations, generally only showing a marginal increase along the length of the site. Even allowing for the additional TCE source observed in January and February 2012 (maximum of 2,100 µg/l identified at Seepage 1), TCE concentrations exceed the PCE concentrations.

Significant chlorinated concentrations were generally found in soils and groundwater to the west of the Riddy Brook and boreholes OS1, OS2 and HA6 to the east in the Gault Clay with contaminant migration seeming to be associated with the a channel/low in the surface of the Gault Clay. Soil contamination concentrations increased with depth with the generally low concentrations of chlorinated solvents above 3m bgl and the greatest concentrations present in samples of Gault Clay. Chlorinated solvent ratios in the soil and groundwater analysis from the investigations were typically very different to those in surface water. The ranges of ratios are summarised in Table 3 below.

Table 3 – Typical Chlorinated Solvent Ratios in Soil, Groundwater and Surface Water

Contaminant	Soil (%)	Groundwater (%)	Surface Water (%)
PCE	68 – 100 (85.6 average)	40 – 91 (OS1, OS2, OS6, HA4, HA5, OS/HA5 & HA8) 8.3 – 42 (HA6 & HA7) 0.4 – 32 (OS7)	11 – 21
TCE	0 – 32 (average 13.9)	1 – 38 (OS1, OS2, OS6, HA4, HA5, OS/HA5 & HA8) 41 – 57 (HA6 & HA7) 2 – 27 (OS7)	50 -64
cDCE	0 – 5%	0 – 32 (OS1, OS2, OS6, HA4, HA5, HA6,HA7, HA8 & OS/HA5) 49 – 79 (OS7)	22 – 35
VC	0	0 – 13 (OS1, OS2, OS6, HA4, HA5, HA6,HA7, HA8 & OS/HA5) 5 – 20 (OS7)	0

PCE was present in greater concentrations relative to TCE and cDCE in all soil samples and the majority of groundwater samples. The only exceptions were in groundwater samples from OS7, HA6 and HA7. Groundwater from OS7 recorded significantly elevated cDCE (up to 79%) and VC (up to 20%) showing evidence of chlorinated solvent degradation; HA6 recorded similar PCE and TCE concentrations; and HA7 was the only borehole to record TCE, PCE and cDCE concentrations similar to those observed in the Riddy Brook. The response zone of most boreholes was installed at least 0.5 m into the Gault Clay, the only exception was HA7 which was only installed 0.1 m into the Gault suggesting the groundwater in HA7 is likely to be largely from the WMMCF.

PCE contamination was also encountered in greater concentrations than other chlorinated solvents during the remedial works (Reference 4). Given the observations during remediation and considering both the observed chlorinated solvent concentrations (maximum PCE concentration of 140,000 µg/l and TCE concentration of 75,000 µg/l in

OS2) in boreholes located within 1 m of the Riddy Brook, and the chlorinated solvent ratios in the groundwater over the majority of the site it would be anticipated that greater PCE and TCE concentrations would have been recorded in the surface water if the groundwater from the boreholes screened within the base of the WMMCF/top of the Gault Clay was in direct continuity with the surface water and PCE would be the more dominant contaminant.

8.5.2 Bis(2-chloroethyl)ether

Together with PCE, Bis(2-chloroethyl)ether was one of the most widely encountered contaminants during the remediation work. It was also encountered in the majority of boreholes (outside of the main remediation site) adjacent to the Riddy Brook. The maximum concentration in groundwater recorded in this area was 40,000 µg/l in OS6, the maximum soil concentration was 95,000 µg/kg in OS1 at 5.0 mbgl.

Elevated Bis (2-chloroethyl)ether in the Riddy Brook was recorded on 5 of the 49 monthly monitoring rounds in the Riddy Brook since May 2008 with a maximum concentration of 41 µg/l . It was not detected during the chemical profiling undertaken in January 2012.

As with PCE, the concentrations of bis(2-chloroethyl)ether) increased with depth and were greatest in boreholes installed within the base of the WMMCF/top of teh Gault Clay. Given the bis(2-chloroethyl)ether levels observed in soil and groundwater in the boreholes, it would be anticipated that concentrations would be observed far more regularly if the Riddy Brook was in direct continuity with the deeper groundwater present in the base of the WMMCF/upper surface of the Gault Clay.

8.5.3 Ethofumesate

Ethofumesate was detected in surface water from the Riddy Brook down-stream of the site in the majority of monitoring rounds. Typically, ethofumesate was present at concentrations less than 1 µg/l but has recorded a maximum concentration of 6.7 µg/l. In the boreholes outside of the remediation boundary, ethofumesate was only identified in boreholes to the west of the Riddy Brook and with the exception of one sample sand and gravel from HA4 (1.7 – 2.0 mbgl) was only detected in the WMMCF. Ground water concentrations to the east of the Riddy Brook did not exceed 1.1 µg/l, to the west of the Riddy Brook concentrations were between 10 to 150 µg/l with the greatest concentrations recorded in HA7.

Based on the presence of ethofumesate in the WMMCF to the west of the Riddy Brook, it seems likely that elevations concentrations in the Riddy Brook result from contaminant migration from the WMMCF.

8.5.4 Hempa and Schradan

With the exception of December 2011 to February 2012, Hempa was only detected in the Riddy Brook down-stream of site on four occasions prior to July 2012 with a maximum concentration of 1.2 µg/l. Over the same period, Schradan was recorded on 6 occasions with a maximum concentration of 4.8 µg/l. Between December 2011 and February 2012 concentrations of Hempa were up to 53 µg/l and Schradan up to 14 µg/l, pProfiling along the length Riddy Brook in January and February identified elevated concentrations of both Hempa and Schradan. However, subsequent monitoring between March and July 2012 did not record any concentrations above detection limits.

With the exception of samples in the Gault clay at 4.8 and 5.0 mbgl, hempa and schradan were only found in soil samples from the west of the Riddy Brook. Concentrations increased through the WMMCF and Gault clay with depth, the greatest concentrations were recorded in the Gault Clay in OS7 at 4.0 m (Hempa 1,800 µg/kg and Schradan 260 µg/kg).

Concentrations in groundwater were higher in boreholes to west of the Riddy Brook by typically 2 to 3 orders of magnitude compared with boreholes to the east. The greatest groundwater concentrations were recorded in OS7 with monitoring in December 2011 recording hempa and schradan concentrations of 14,000 and 18,000 µg/l respectively, at least one order of magnitude greater than all other recorded concentrations.

8.5.5 Vertical Variation of Contaminant Distribution

Observed contaminant profiles in soil material adjacent to the Riddy Brook identified some shallow contaminants in the upper 2 m of soils to the west of the Riddy. However, contaminant concentrations generally increased with depth, with the greatest concentrations typically associated with the base of the WMMCF/upper surface of the Gault Clay.

As discussed in Section 7.2.1, borehole F9 was installed directly between OS1 and OS2 with a response zone at 2.8 mbgl in the relatively shallow firm to stiff WMMCF. Despite being immediately adjacent to OS1 and OS2 (both of which had response zones below 3 m through the WMMCF and upper Gault), chlorinated solvent levels in F9 (maximu total chlorinated solvent concetrationof 1388 ug/l) were typically 3 to 4 orders of magnitude below those encountered in OS1 and OS2 (36,979 and 215,415 ug/l respectively).

Given the large variation with depth observed in both soil and groundwater and the presence of relatively low contaminant concentrations within the firm to stiff clay and shallow groundwater overlying the identified contaminants in the base of the WMMCF/top of the Gault clay, potential vertical upward migration of contaminants through the WMMCF is not considered to be a viable pathway.

8.6 Potential Pollutant Linkages

Based on the identified contaminant sources and pathways, a number of potential pollutant linkages may exist in the area outside of the main remediation site and these are discussed below.

8.6.1 Contamination in the Base of the WMMCF and Top of Gault Clay

Significant soil contamination was observed in the Gault Clay in boreholes OS1, OS2, OS6 and HA6 extending under the Riddy Brook. The contamination appears to be related to a channel in the surface of the Gault Clay with contaminants following the surface contours. Much lower contaminant concentrations were identified in the overlying drift deposits and WMMCF. The Gault Clay in this area was between 6.84 and 7.30 mAOD significantly below the base of the Riddy Brook (approximately 9.5 mAOD). Groundwater encountered at the base of the WMMCF/top of the Gault Clay appears to be confined by the overlying relatively low permeability firm to stiff WMMCF. Therefore, as discussed in section 8.5.5 given the potential pathway length and relatively low permeability of the WMMCF, together with the observed increases in contaminant concentrions with depth (in soil and groundwater) it is considered unlikely that a viable pathway for upward migration exists between the contaminant source identified in the base of the WMMCF/Gault Clay and the Riddy Brook.

It is also important to note that as discussed in Section 8.5.1, the ratios of chlorinated solvents found in the Gault clay and the majority of groundwater samples are different to the ratios that have been periodically observed in the Riddy Brook. If upward vertical migration had been or was occuring, it would be anticipated that the ratios of chlorinated solvents between groundwater within the WMMCF/Gaul and the Riddy Brook would be far more similar. Therefore, it is considered unlikely that the contaminants in the Gault clay are not the source of the contamination in the Riddy Brook. Equally, no contaminants have been identified in the River Cam that would indicate that the River is being impacted by the contaminants present within the base of the WMMCF/top of the Gault Clay.

Additionally, boreholes WM2 and WM3 are both installed within the WMMCF/Gaut clay to the east of the Riddy Brook and the River Cam. Both boreholes are down gradient of the identified contaminant source within the WMMCF/Gault Clay, with WM2 located directly down gradient within 50 m of the source. No evidence of contamination has been identified in soil analysis and/or groundwater analysis in these boreholes confirming that the contaminant source does not extend beyond the identified source area and the River Cam.

8.6.2 Contaminants Within Drift Deposits and Shallow WMMCF and Shallow Groundwater

Shallow deposits of sand and gravel were present in HA4 overlying the WMMCF, encountered water levels during drilling suggested there was very close relationship between perched groundwater levels in shallow sand and gravels and the Riddy Brook.

A further line of evidence is, as discussed in Section 8.4, there appears to be a good correlation between periods when groundwater levels are higher than the water level in the Riddy Brook and the presence of contaminants in the Riddy Brook. Given the encountered ground, groundwater and contamination profiles, the source of this contamination is likely to be shallow groundwater perched above or within the shallow deposits of the WMMCF. The potential for upward vertical migration from deeper contaminantion in the base of the WMMCF/upper surface of the Gault Clay has been discounted based on the nature of the the shallow WMMCF (typically firm to stiff and 1 to 3 m thick above the soft WMMCF deposits) and the observed vertical variations in both soil and groundwater contaminant concentrations.

The distribution of ethofumesate also suggests there is a pathway from the drift deposits and/or shallow WMMCF into the Riddy Brook. As discussed in 8.5.3 trace concentrations of ethofumesate were regularly identified in the Riddy Brook and was only present in groundwater in boreholes west of the Riddy Brook. Therefore it seems likely that a pollutant linkage is present with respect to soil material to the west of the Riddy Brook but outside the remediated site boundary.

The ratios of chlorinated solvents in groundwater from HA7 matched closely with the observed ratios in the Riddy Brook. HA7 was the only borehole where this was the case and the potential for chlorinated solvent migration from the west of the Riddy Brook cannot be discounted.

However, the presence of significantly elevated bis(2-chloroethyl)ether, hempa and schradan concentrations did not correlate well with the observed sporadic concentrations in the Riddy Brook. Given the consistently elevated concentrations of bis(2-chororethyl)ether in groundwater in the majority of boreholes, higher concentrations would be anticipated far more regularly in the Riddy Brook than have been recorded.

Overall, it seems highly likely that pollutant linkages have previously existed between the 'un-remediated' soils adjacent to the Riddy Brook and the Riddy Brook via migration of shallow groundwater. Since March 2012, following the recovery of natural groundwater levels and the intial flush through of a relatively limited source of contaminated groundwater between December 2011 and February 2012, contaminant levels in the Riddy Brook have decreased to below the relevant EQS/screening criteria for all contaminants and the majority of contaminants have decreased to below detection limits. Based on the this, it is considered that the a significant pollutant linkage between shallow soils/groundwater and the Riddy Brook is no longer present as there is no significant source remaining

8.6.3 Vertical Pipe In Riddy Brook

Prior to backfilling with bentonite, a water sample from the pipe within the Riddy identified elevated contaminant levels including chlorinated solvents (with high levels of cDCE and VC suggesting degradation of solvents has occurred) and pesticides (see Section 7.5.2). The integrity of the pipe below the stream bed is unknown with the pipe extending at least 1 mbgl and despite the backfilling with bentonite, a pollutant linkage via shallow groundwater and/or surface water cannot be discounted although it is considered unlikely and based on the observed contaminant concentrations in the Riddy Brook the linkage is not considered significant.

8.6.4 Up-stream Seepage

The observed seepage (see Section 7.5.1) which was significantly impacted with TCE is a confirmed pollutant linkage with respect to the Riddy Brook. A potential source or pathway for the seepage is the former concrete chamber and associated pipework identified adjacent to the seepage (VertaseFLI 2012 – Reference 5). The chamber and pipework were decommissioned however, the potential for an additional source of TCE within the un-remediated soils between the site boundary and the Riddy Brook cannot be entirely discounted. However, given the removal of the source and the observed decrease in contaminant concentrations (below screening criteria) this linkage is not considered to be significant.

9.0 Summary

Investigations including the drilling of boreholes, chemical analysis of soil, groundwater and surface water have been undertaken in an area of contamination outside of the remediation boundary which was identified during the removal of a former bentonite cement cut-off wall along the northeast boundary of the former Bayer Crop Science Site.

The investigations identified elevated concentrations of contaminants including pesticides, herbicides and VOCs on both sides of the Riddy Brook. Generally, contaminant concentrations (in soil and groundwater) increased with depth with the greatest concentrations recorded in the Gault Clay. Observations during drilling suggested the possible presence of two groundwater bodies, one in shallow drift deposits and potentially the upper West Melbury Marly Chalk Formation (WMMCF), the other at the base of the WMMCF and top of the Gault Clay associated with a channel/low in the surface of the Gault Clay. Groundwater monitoring indicates a flow direction towards the Riddy Brook from the River Cam (to the east) and variable flow directions to the west of the Riddy Brook.

Given the groundwater regime in the reinstated remediated soils and assessment of the remediated sites (VertaseFLI 2012c and 2012d), the remediated soils are not considered to be a contaminant source with respect to the Riddy Brook.

Potential pollutant linkages at the site comprised:

1. Migration via shallow groundwater from contaminants in drift deposits and shallow WMMCF immediately around the Riddy Brook.
2. Contaminated soils and groundwater present in the the base of the WMMCF/top of the Gault; and
3. Migration of contaminants to the Riddy Brook via historic site infrastructure such as pipes/drains/etc.

The pollutant linkages 2 and 3 have been discounted due to:

- Linkage 2 – There is no evidence for vertical migration through the WMMCF from the contaminants (including DNAPL) with in the base of the WMMCF/upper surface of Gault Clay. Deposits of WMMCF and groundwater above the identified contaminant source in the WMMCF/Gault clay (less than 3 mbgl) are not significantly impacted and the identified contaminant ratios in these shallow soils and the historic contamination events in the Riddy Brook do not resemble the contaminant ratios in the deeper WMMCF/Gault. There is also no evidence of contamination in either the River Cam or down gradient boreholes (WM2 and WM3) indicating that the identified contaminantion does not extend to the land east of the River Cam.

- Linkage 3 – All known site-infrastucture has been decommissioned. Although the potential for pollutant linkages to still exist cannot be entirely discounted, there has been no observed impact on the Riddy Brook since the remaining site infrastructure was decommissioned/removed and therefore the any remaining linkage is not considered significant.

Following completion of remediation and the removal of all groundwater controls at the site (including the removal of the bentonite wall), groundwater levels outside of the remediation boundary have returned to natural levels. Following, the rebound in groundwater levels elevated contaminant concentrations were observed in the Riddy Brook between December 2011 and February 2012. However, since March 2011, contaminant concentrations in the Riddy Brook have decreased to below EQS/screening criteria and in most cases have decreased to below detection limits. It is considered that the rebound in groundwater level resulted in shallow groundwater previously stored in the banks of the Riddy Brook being flushed out into the Riddy between December 2011 and February 2012. However, the source of impacted groundwater was limited so that despite groundwater levels remaining above the surface water levels any remaining contaminant source is not significant and therefore the remaining pollutant linkage (linkage 1) between shallow groundwater and the Riddy Brook is not considered significant.

Given the above it is concluded that no further action is required in relation to the contamination previously identified in this area of the site as there is no active remaining significant pollutant linkages identified either causing or likely to cause significant impact on the Riddy Brook.

10.0 References

1. British Geological Society, 'England & Wales Sheet 205: Saffron Walden – Solid and Drift Geology', 2002
2. Atkins Ltd (2006), 'Remediation of Former Bayer Site, Hauxton, Preliminary Conceptual Model Report', August 2006 – Revision 4a.
3. Enviros Consulting Ltd (2005), 'Part IIA Site Investigation Report, Report for Bayer CropScience', January 2005, Ref. SH0250008A.
4. VertaseFLI (2012a), 'Completion Report, Former Bayer CropScience Site, Hauxton, Cambridgeshire', December 2012 Revision B
5. VertaseFLI (2012b), 'Addendum to Completion Report, Former Bayer CropScience Site, Hauxton, Cambridgeshire', December 2012 Revision B
6. VertaseFLI (2011), 'Further Quantitative Risk Assessment for Risks to Groundwater and Surface Waters, Former Bayer CropScience Site, Hauxton, Cambridgeshire', July 2011 Revision B
7. Bernard O'Connor (2011), 'The Hauxton Fossil Diggings', 2011
8. VertaseFLI (2012c), 'Post Remediation Quantitative Risk Assessment for Controlled Waters' December 2012 Revision B
9. VertaseFLI (2012d), 'Groundwater Validation Report', December 2012 Revision B.
10. Environment Agency (2003), 'An illustrated handbook of DNAPL transport and fate in the subsurface', June 2003,