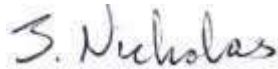## Appendix K

Hydrogeological Detailed Quantitative Risk Assessment

CAPITA

Hydrogeological Detailed Quantitative Risk Assessment for A29 Realignment

March 2021

Quality Management

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1. Introduction

Subsequent to initial ground investigations for the A29 realignment road scheme, additional investigation in the area of the future Fontwell Avenue roundabout has encountered contaminated soils. This area was previously inaccessible to the initial site investigation and this initial work did not originally find any land quality issues, though desk studies had highlighted the presence of an infilled gravel pit in the area this report is concerned with.

This document outlines the hydrogeological conceptual model and modelling methodology and results of the modelling to derive soil site specific target levels (SSTLs) for the specific area in question and which will allow validation of the remediation in this sector. Specifically, the SSTLs will be used to validate remediation in the area of the Fontwell Avenue roundabout where there is a former gravel pit containing elevated concentrations of polyaromatic hydrocarbons (PAHs) and total petroleum hydrocarbons (TPH). The methodology uses the Environment Agency remedial targets worksheet (P20) to derive SSTLs. Consideration has been given as to how soakage infiltration tanks, to be located in the centre and to the south of the roundabout, will impact the concentration of potential contaminants arriving in groundwater and hence inform SSTLs. Background information on the geological and hydrogeological setting of the site and results of the recent ground investigation can be found in the Capita Ground Investigation Report (GIR, Oct 2020).

The initial ground ingestion was undertaken by WSP (WSP, 2018) and the most recent ground investigation, which has involved boreholes drilled at the Fontwell Avenue roundabout, was undertaken by Nicholls Colton in 2020 (NC, 2020).

2. Hydrogeological Conceptual Site Model

A key element of undertaking an environmental risk assessment is the development of a conceptual model of the site that describes the environmental features of the site together with the expected interaction of potential contamination sources with the environment. This is done by undertaking a Source – Pathway – Receptor analysis of the site:

- Sources (S) are potential or known contaminant sources e.g. a former fuel storage area;

- Pathways (P) are environmental systems thorough which a contaminant could migrate e.g. air, groundwater; and

- Receptors (R) are sensitive environmental receptors that could be adversely affected by a contaminant e.g. site occupiers, groundwater resources.

Where a source, relevant pathway, and receptor (S-P-R) are present, a pollutant linkage is considered to exist whereby there is a circumstance through which environmental harm could occur and a potential environmental liability is considered to exist. Information presented in the Capita GIR (2020) has been used to compile a conceptual site model (CSM) identifying potential contaminant sources and receptors together with plausible pathways that may link them. The assessment considers risk to controlled waters only from the soil and groundwater sources identified on-site from the 2018 WSP and Nicholls Colton site investigations. Off-site sources have not been considered in this conceptual model.

2.1 Contaminant Source

A summary of the findings of the different phases of investigation at the site are given below in order to determine which of the potential contaminants of concern (CoC) should be taken forward to the modelling phase. The summary also provides evidence for the size of the source areas associated with the different potential CoC in soil. To identify the contaminants of concern, groundwater and leachate concentrations from samples obtained from all the investigations have been compared with both environmental quality standards (EQS) to be protective of surface water receptors (drains leading to the Lidsey Rife), and also drinking water standards (DWS) to be protective of groundwater receptors (the Secondary A aquifer of the Head Deposits).

2.1.1 Soil

Two sets of soils data have been taken at the highway scheme relating to the following dates and investigation locations:

- WSP (October/November 2018 BH04 – BH09, TP's 2, 7, 12, 16 and 18); and

- Nicholls Colton (July/August 2020 TP101 through to TP105, DCS101 through to DCS128, BH101).

A composite exploratory hole plan is provided as Drawing A29-CAP-HGT00-DR-GR-0040 P04. Table 1 below presents the leachate data that exceed the relevant water quality standards when compared to the July and August 2020 data. It can be seen that there are some exceedances for the metals, specifically chromium and copper but the most significant exceedances were for

polyaromatic hydrocarbons (PAH) in DCS111 at 0.9 m below ground level (bgl), DCS124 at 0.1 m bgl and DCS125 at 0.5 m bgl. DCS125 is located approximately 15 m east of the proposed Fontwell Avenue roundabout. Material to a depth of 1.2 m will be removed at this location, and hence this particular area is not considered to act as a source zone. Leachate testing in BH101, despite total elevation in the soils (140 mg/kg total PAH at 0.3 m) did not record any exceedances of the adopted criteria (although detection limits were not low enough for certain PAH species to provide total confidence in absence of source). The exceedances in DCS124 are recorded in very shallow soils (0.1 m bgl) and they will be removed as part of topsoil strip. DCS111 is located at the site of the proposed eastern roundabout, due south of the proposed balancing pond in what is thought to be 'virgin' ground, with no obvious cause for the slightly elevated readings. Concentrations of PAHs up to a total of 0.2 to 2 mg/kg are considered to be typical of rural soils in England (Environment Agency, 2007) and hence represent background concentrations. The locations discussed above in this paragraph are above these background concentrations.

Table 1: Leachate data from 2020 site investigation compared to WQS

Contaminant of Concern	EQS µg/l	DWS µg/l	Maximum concentration µg/l	Exceedances/Notes
Chromium (Cr III assumed)	4.7	50	590 in BH101 at 2 m depth	420 DCS128 at 1 m depth also.
Copper	1	2000	20 in DCS128	BH101, DCS101, DCS111, DCS124 also.
Phenanthrene	0.003	-	0.08 in DCS111	Only 1 exceedance

The EQS for phenanthrene is not a formal EQS but rather a predicted no effect concentration (PNEC) (WRc plc (2002), R&D Technical Report P45) and therefore will not be taken forward for modelling.

As noted in the Capita GIR, the Limit of Detection (LoD) for cadmium (Cd), mercury (Hg), benzo(a)anthracene, benzo(b)fluoranthene, benzo(ghi)perylene, benzo(k)fluoranthene, chrysene, fluoranthene, indeno(1,2,3-cd)pyrene, and phenanthrene are all greater than their EQS screening values. As such, there is a 'grey area' between the EQS and LoD in which a CoC may be in exceedance of the EQS but not detected due to instrument analysis limitations.

Whilst copper concentrations are above EQS, the margin of exceedance is not great. The soil concentrations that give rise to these leachate concentrations are below average natural background copper concentrations (62 mg/kg, Defra, 2012) with the exception of one out of 43 samples in BH101 at 3 m depth. The average copper soil concentration across the site is 20.7 mg/kg. However, given that BH101 appears to be in region of the main source zone of the former gravel pit this potential contaminant has been taken forward into the modelling.

Given that the leaching data, which employs routinely available detection limits for PAHs, cannot give complete assurance on absence of source, it is recognised that maximum soil concentrations can give an indication of where on-site soil sources may lie. This has been discussed in more detail in the Capita Ground Investigation Report. Specifically, elevated PAH concentrations were recorded in:

- five samples within BH101 between 0.10 and 2.00 m bgl;

- two samples within DCS125 at 0.20 m bgl and 0.50 m bgl;

- one sample in TP4 at 0.50 m bgl;

- one sample in TP5 at 0.50 m bgl;

- one sample in DCS128 at 1.00 m bgl; and

- three samples in DCS101 0.10, 0.70 and 1.50 m bgl.

BH101 and DCS128 are located in a region of the site that has been identified as a former gravel pit and the backfill here contains pieces of tarmac. The outline of the gravel pit is marked by 'teeth' markings on drawing A29-CAP-HGT00-DR-GR-0040 P04. DSC125 is located due east of the current A29 roadway, adjacent to the east of the proposed location for the western roundabout. TP4 and TP5 are located towards the southeast of the proposed realignment and represent bund material. The contamination in the bund is recognised in the earthworks specifications and impacted material will not be reused in the scheme so following completion of earthworks this material will no longer present a source to controlled waters.

The remediation strategy is to remove and appropriately dispose of a large portion of materials as part of achieving the line and level of the road scheme. Post road construction this would leave a soil source zone that has a maximum thickness of 1.2 m in the vicinity of the Fontwell Avenue roundabout within the filled gravel pit area (with the exception of the area immediately surrounding BH101 which will have 3 m of material removed) plus a small area in the vicinity of DCS101 at 0.8 m soil depth.

Based on Table 1 of leachate concentrations and the prevalence of PAHs in soil, combined with the fact that some PAHs may exceed EQS, the following CoC have been taken forward into the controlled waters risk assessment modelling for potential to impact the surface water receptors from the soil source in the vicinity of the Fontwell Avenue roundabout:

- Chromium;

- Copper;

- Benzo(a)pyrene;

- Benzo(b) fluoranthene;

- Benzo(k) fluoranthene; and

- Benzo (ghi)perylene.

The five PAHs in the list above have been added to represent the elevated soil PAH concentrations. Based on Table 1 of leachate concentrations and the prevalence of PAHs in soils (TPH was not analysed in leachate), the following CoC have been taken forward into the controlled waters risk assessment modelling for potential to impact the groundwater resource from the soil source:

- Chromium;

- Benzo(a)pyrene to represent PAHs;

- Aromatic TPH C16-C21 to represent heavier PAH compounds such as indeno(1,2,3-cd)pyrene; and

- Aromatic TPH C21-C35 to represent heavier PAH compounds such as indeno(1,2,3-cd)pyrene.

2.1.2   Groundwater

The 2020 Nicholls-Colston factual report gives details of the groundwater sample analyses from seven monitoring wells from the sampling rounds undertaken on the 12th and 28th of October and 2nd November 2020. A summary of concentrations that exceed the EQS and/or DWS are presented in Table 2 below and showed little in the way of significant water quality standard (WQS) exceedances.

Table 2: Groundwater concentration data from October and November 2020 sampling rounds compared to WQS

Contaminant of Concern	EQS µg/l	DWS µg/l	Maximum concentration µg/l	Exceedances/Notes
Copper	1	2000	6 in DCS120 on 28/10/2020	All wells
Benzo (a)pyrene	0.00017	0.01	0.07 BH101 28/10	DCS120 on 12/10 and DCS113 on 2/11. Rest < LoD
Benzo(b) fluoranthene	0.017		0.11 BH101 28/10	DCS117 on 12/10, DCS 120 on 12/10 and DCS113 on 2/11. Rest < LoD.
Benzo(k) fluoranthene	0.017		0.05 BH101 28/10	DCS 120 on 12/10. Rest < LoD.
Benzo (ghi)perylene	0.0082		0.06 BH101 28/10	DCS 120 on 12/10. BH101 on 2/11, DCS113 on 2/11. Rest < LoD.
Fluoranthene	0.0063	-	0.08 BH101 28/10	DCS113, 117 on 12/10, all bhs except DCS112 on 2/11
PAHs (sum of 4: B(b)F, B(k)F, Indeno and Benzo(ghi))	-	0.1	0.27 BH101 28/10	Only 1 exceedance location and event
TPH	-	10[(1)]	100 in BH101 12/10 – Ali and Aro C21-C35 dominant	DCS112, DCS117 and DCS120 on 12/10, BH101 only on 28/10 and BH101, DCS120, DCS122 and DCS124 on 2/11. Dominant fractions are Ali and Aro C21-C35

(1)   Environment Agency (2009), 'Petroleum hydrocarbons in groundwater: supplementary guidance for hydrogeological risk assessment'.

Two other TPH fractions were also detected above 10 µg/l; aromatic C16-C21 and aliphatic C5-C6. The maximum concentration of these fractions is 12.2, with 13.6 µg/l for TPH C5-C6 in DCS112 and DCS122 and 13.9 µg/l of TPH C16-C21 in BH101.

Based on Table 2 of groundwater concentrations the following CoC have been taken forward into the controlled waters risk assessment modelling for potential to impact the groundwater receptors:

- Benzo(a)pyrene; and

- Aromatic TPH C21 - C35.

Despite exceedances of the relevant DWS or EQS the aliphatic hydrocarbons that have not been taken forward into the modelling. Aliphatic hydrocarbons are far less mobile and persistent in the aquatic environment than aromatic hydrocarbons and hence taking forward the aromatic bandings will provide sufficient protection to the groundwater resource.

Based on Table 2 of groundwater concentrations the following CoC have been taken forward into the controlled waters risk assessment modelling for potential to impact the surface water resource:

- Copper;

- Fluoranthene;

- Benzo (ghi) perylene;

- Benzo(a)pyrene;

- Benzo(b)fluoranthene; and

- Benzo(k)fluoranthene.

In summary, generally low concentrations of CoC are detected in groundwater, with the source being in the soil (probably tarmacadam) so it is not considered necessary to simulate a groundwater source at the site. Soil concentrations appear to be causing elevated groundwater concentrations, rather than a separate groundwater source being present.

2.2   Sensitive Receptors

Potential receptors include:

- Controlled waters - groundwater within the Head Deposits Secondary A aquifer;

- Controlled waters – groundwater within the Chalk Principal Aquifer; and

- Controlled waters – unnamed surface water drains feeding the Lidsey Rife potentially fed by groundwater 820 m down hydraulic gradient of the site and another unnamed drain askew to the gradient line, 500m away.

The site is located within the groundwater source protection zone of two public supply wells in the Chalk. However, these abstraction wells are beneath at least 70 m of combined London Clay and cohesive Lambeth Group beds according to the cross section on the 1996 BGS geological map of Chichester and Bognor Regis and up hydraulic gradient (in Head Deposits) of the site and a local BGS borehole log. The groundwater within the Chalk is therefore not considered to be a receptor of concern from on-site concentrations and has not been taken forward into the modelling.

No groundwater abstraction well could be drilled within 50 m of the A29 realignment scheme and therefore an appropriate compliance point within groundwater would be 50 m down hydraulic gradient of the soil source.

The nearest surface water body/drain to the soil source at the Fontwell Avenue roundabout is 820 m down hydraulic gradient (there is another drain a little closer but this lies across the flow gradient, 500 m due south of Fontwell Avenue roundabout). A photograph of the feature 500m away is provided below. Therefore, in order to provide a more conservative assessment, a distance of 500 m has been selected for the modelling.

Photo 1 showing unnamed drain located 500m to south of infilled gravel pit

2.3   Pathways

The following pathways relating to controlled waters have been identified:

- Leaching from the unsaturated zone followed by vertical and/or horizontal migration of leachable contaminants via the unsaturated zone and then into groundwater within Head Deposits; and

- Migration of contaminated groundwater within the Head Deposits and subsequent interaction with the drains feeding to the Lidsey Rife which may be groundwater fed. Groundwater flow direction is towards the south east as shown in the figure below. This pathway could be enhanced during rainfall events by the action of added discharge from planned soakaways to be built at/near the roundabout.
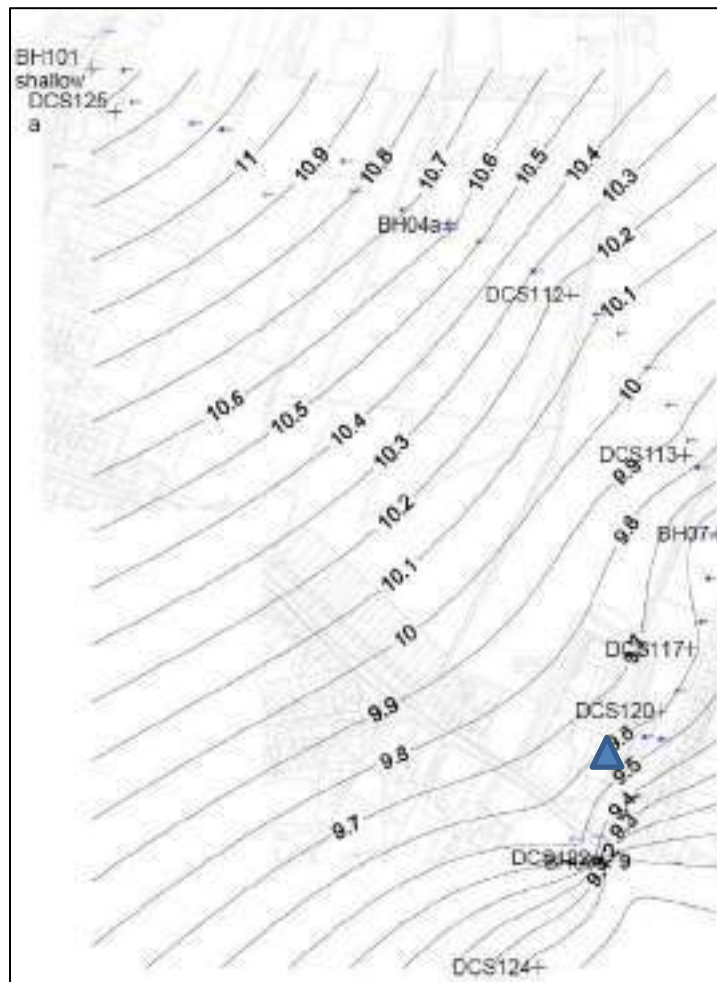

Figure 1: Groundwater flow contours for 28th October 2020 (blue triangles mark drains)

Refer Appendix B for selected borehole logs also showing well installations (BH101 and DCS125).

3.   DQRA Methodology

The controlled waters risk assessment has been conducted in accordance with the risk assessment methodology presented in Environment Agency document "Remedial Targets Methodology; Hydrogeological Risk Assessment for Land Contamination", 2006 (RTM). The accompanying spreadsheet tool calculates risk based remedial targets for soils and groundwater. At the end of each "tier" of assessment a Site-Specific Target Level (SSTL) is derived. Each additional tier of assessment includes more site-specific data as the model is refined. At the end of each tier of assessment, a decision can be made whether to undertake remedial action at the site in order to achieve the remedial target concentration (SSTL), or to refine the model by conducting further tiers of analysis using more site-specific data.

The Environment Agency Remedial Targets Worksheet v3.1 has been used to simulate SSTLs for soil at the site. A comparison can then be made with post remediation soil concentrations to assess whether on-site concentrations pose a risk to the identified receptors. The model allows vertical migration of contaminants from the soil source to the underlying aquifer and subsequent lateral migration of contaminants to the nearest relevant receptors down hydraulic gradient, in this case:

- a 50 m compliance point in the groundwater of the Head Deposits to be protective of the Secondary A Aquifer; and

- a hypothetical drain compliance point 500 m from the Fontwell Avenue roundabout source to be protective of surface waters.

The worksheet model utilises a series of levels, the functions of which are outlined below:

- **Level 1:** Assesses concentrations of contaminants of concern in soil pore water (leachate). If no leachate data are available, simulated pore water concentrations are calculated utilising soil properties and chemical properties. No dilution or attenuation is assumed in Tier 1.

- **Level 2:** Considers dilution of leachate in a receiving controlled water body; the groundwater beneath the site. The dilution factor is calculated by considering infiltration and aquifer flow beneath the site. No attenuation is assumed.

- **Level 3:** Models the attenuation of contaminants in the aquifer as they migrate from the source area to the receptor and predicts a concentration at the receptor. Attenuation processes of sorption, dispersion and degradation are also modelled and have been assumed in this assessment.

3.1   Input Parameters

The parameters required for the assessment can be split into two types; non-contaminant specific and contaminant specific. Non-contaminant specific parameters include hydraulic gradient, hydraulic conductivity, effective porosity, infiltration, bulk density of the soil and aquifer materials, air and water filled porosity for the soil source zone, fraction of organic carbon in the soil and aquifer materials and saturated aquifer thickness. These parameters and their justifications for

the soil source are given in Table 3 for each of the two receptors. Contaminant specific parameters include source dimensions, Henry's Law constant, biodegradation half-life and soil/water partition coefficient. These parameter values and justifications are given in Table 4. Where possible site-specific data have been applied, but in cases where site data are not available appropriate literature values have been used with justification.

A number of the parameters, such as partition coefficients, hydraulic conductivity and half-life have a significant impact on concentrations and time of breakthrough at the receptors as well as SSTLs. Since there are few site-specific data for these particular parameters and only literature data can be used, it is important that a sensitivity analysis is conducted. This will establish whether the analysis and conclusions drawn in the model simulations are robust.

Since there are several priority and priority hazardous substances identified within the list in the previous section, there is a requirement to derive SSTLs at the base of the unsaturated zone prior to entry into groundwater for these substances. Therefore, model simulations using an EQS target concentration to be protective of surface waters will only be conducted to Tier 1 for:

- Benzo(a)pyrene;
- Benzo(b)fluoranthene;
- Benzo(k)fluoranthene;
- Benzo(ghi)perylene; and
- Fluoranthene.

To be protective of the groundwater resource the following CoC will be modelled to the 50 m compliance point receptor as they have exceeded their respective DWS values:

- Chromium;
- Benzo(a)pyrene;
- Aromatic TPH C16 -C21; and
- Aromatic TPH C21-C35.

To be protective of the Lidsey Rife and associated drains at a hypothetical 500 m down hydraulic gradient the following CoC have been modelled using EQS values as the basis for the SSTL derivation:

- Chromium; and
- Copper.

Further details on the input parameters are provided below.

3.1.1 Level 1 Soil Source

The source material has conservatively been assumed to be a gravelly sand given the descriptions from the borehole logs. This gravelly sand Made Ground contains brick, glass, concrete, macadam, plastic, and metal with some rubber sheeting. The Made Ground extends from the ground surface to the upper surface of the Head Deposits in all investigation locations

for which logs were available. Using the site-specific moisture contents and an assumed bulk density of the gravelly sand it has been possible to obtain values for air and water filled porosities. Total organic carbon values were also taken on site from which it was possible to obtain an estimate of the site-specific fraction of organic carbon value. The data must be taken from the least contaminated samples. The Made Ground has been considered to be of uniform composition in this risk assessment.

3.1.2   Level 2 and 3 Aquifer

The aquifer in the Level 2 and 3 assessments has been based on the lithological description obtained for natural strata during excavation of the boreholes, which comprise gravelly sand. The depth to the base of the Head Deposits was 10.0 m bgl for BH101 at the site but becomes shallower to the east. A saturated zone thickness in the Head Deposits was approximately 4.5 m since the average depth to groundwater from the surface of the site was around 2.44 m and there was an average depth to the London Clay top surface of 7.2 m.

Data on infiltration is required in Level 2. 922 mm/year of rainfall occurs in the catchment according to the rainfall station at Chichester (National River Flow Archive, 2021) but the Meteorological Office averages for Bognor Regis are 725 mm/year on average (Met Office, 2021). Since the site is likely to be more aligned with Chichester as it is inland a value of 922 mm/year is considered more appropriate. Effective rainfall for the area is quoted as 476 mm/year in Table 1 of the BGS report on the Chalk aquifer of the South Downs (1999). Taking into account the site post development will be 50% hardstanding this effective rainfall equates to 6.52×10^{-4} m/day of infiltration across the site.

The soil source for TPH/PAH is located principally around BH101, DCS125, DCS128 and DCS101. There does not appear to be a significant different between the source sizes for the PAH and TPH fractions. The areas where the highest concentrations have been found in soil and groundwater will be under the hardstanding of the road which provides a mitigating factor for risk to controlled waters due to reduced infiltration. The metal source sizes are however different with chromium only covering the area around BH101 and DCS128 and copper covering the area around BH101, DCS101 and DCS128.

3.1.3   Level 3 Compliance Points

The nearest down hydraulic gradient surface watercourse is the drain leading ultimately to the Lidsey Rife which is approximately 820 m southeast of the principal source zone. A hypothetical compliance point of 500 m has been selected to be protective of surface waters. A 50 m compliance point has been selected to assess the risk to the Secondary A Head Deposits aquifer. Only non-priority and priority hazardous CoC were simulated to these distances.

Table 3 presents the proposed physical input parameters for the modelling exercise to derive SSTLs for soils.

Table 3: Physical Input Data for Remedial Target Model for Soils

Parameter	Value	Units	Justification
Level 1 Soil			
Water Filled Soil Porosity	0.129	Fraction	P20 porosity calculator used assuming 1.37 - 1.81 g/cm^3 (average bulk density 1.59 g/cm^3) and a moisture content of 8.83% on average from on-site sand/gravel materials. Total porosity 47.4 %
Air Filled Soil Porosity	0.345	Fraction	P20 porosity calculator used assuming 1.59 g/cm^3 bulk density and a moisture content of 8.83% on average from on-site materials.
Bulk Density	1.59	g/cm^3	1.37 to 1.81 g/cm^3: Gravelly sand - ConSim. BH101, DCS126, DCS127, DCS128 have log descriptions of gravelly sand through to medium sand.
FOC	0.0064	Fraction	Data from 1 unsaturated sample from sand/gravel in TP02 in the Made Ground. Other samples are from a clay matrix and therefore not appropriate.
Level 2 Soil (Dilution in the RTD)			
Infiltration	6.52E-04	m/d	922 mm/year of rainfall occurs in the catchment according to the rainfall station at Chichester (https://nrfa.ceh.ac.uk/data/station/spatial/41023). MetOffice averages for Bognor Regis give 725 mm/year average (https://www.metoffice.gov.uk/research/climate/ maps-and-data/uk-climate-averages/gcp8bswvw). Site likely to be more aligned with Chichester as it is inland. Effective rainfall is quoted as 476 mm/year in Table 1 of http://nora.nerc.ac.uk/id/ eprint/12713/1/SD99001.pdf. Taking into account the site post development will be 50% hardstanding this equates 6.52 x 10^{-4} m/day
Length of Contaminant Source	10-20	m	Length of source is contaminant specific. Groundwater flow assumed to be to the east south east. See Table 5.
Saturated Aquifer Thickness	4.48	m	Depth to London Clay recorded in WSP BH01, BH04A, BH06 - BH09, DCS124 at an average depth of 7.17 m bgl. Groundwater strike levels after 20 mins in these boreholes an average of 2.44 m bgl giving an average saturated thickness of 4.48 m
Hydraulic Conductivity	0.5	m/d	Site data average – Nicholls Colton Hvorslev analysis of falling head tests on BH101 and DCS125 give 6.08 x 10^{-6} m/s (BH101 deep) to 2.4 x 10^{-7} m/s (DCS125) which converts to 0.52 m/day and 0.02 m/day. Check via Bouwer and Rice analysis

Parameter	Value	Units	Justification
			reveals similar values giving confidence. Log descriptions in BH101 indicate a coarse sandy gravel in the saturated zone, so as layers of silt are present within the aquifer 0.5 m/day is considered appropriate.
Hydraulic Gradient	0.002	Fraction	Average hydraulic gradient on-site from 28th October 2020 monitoring round data. Data from 2nd and 9th November 2020 supports this value and direction of SE.
Width of Contaminant Source	20-30	m	Contaminant specific - see Table 5. Dimension perpendicular to groundwater flow.
Level 3 Soil			
Bulk Density	2.09	g/cm^3	Average values taken from samples from Head Deposits in WSP BH07, BH08, TP15 and Nicholls Colton BH101
Effective Porosity	0.15	Fraction	From De Marsily (1986) for a gravelly sand (specific yield)
Distance to Compliance Point	500 and 50	m	Distance from the edge of the soil source zone around BH101 to the drain at the Halo complex - 820 m. Hypothetical compliance point selected at 500 m. 50 m compliance point in Head Deposits Secondary A aquifer.
FOC	0.0028	Fraction	Site specific data for BH09 taken at depths of 2 and 4 m in sand/gravel at 0.26 and 0.30%

3.1.4   Contaminant Specific Parameters

The partition coefficient (K_d) of organic contaminants has been calculated from the partition coefficient for organic carbon (K_{OC}) and fraction of organic carbon (F_{OC}). Literature values for K_{OC} were initially used combined with site-specific values for F_{oc}.

Aerobic degradation has been assumed for organic compounds since the aquifer and Made Ground is relatively permeable and close to the surface so dissolved oxygen concentrations are likely to be relatively high. Literature values for contaminant half-lives are used. In Level 3 the model allows the option of modelling biodegradation in either the dissolved phase only, or in the dissolved and sorbed phases. Due to the use of literature values of half-lives, the dissolved phase only method of modelling biodegradation has been selected. For contaminants not subject to decay, such as copper, a very large half-life (9×10^{99} years) has been used. Since the Made Ground and aquifer materials are similar in nature, it is considered appropriate to use the same K_d values in the Level 1 and Level 3 assessment. The chemical input parameters are presented in Table 4.

To derive site-specific target concentrations UK DWS and EQS freshwater guidelines to be protective of either groundwater or surface water receptors have been used.

Soil source dimensions for each of the contaminants of concern (CoC) have been derived from the on-site concentrations and are presented in Table 5.

Table 4: Chemical Input Data for P20 Model

Parameter	Value	Units	Justification
Benzo(a)pyrene			
Henrys Law Constant	1.76E-06	-	SC050021/SR7
KOC	128825	ml/g	log Koc = 5.11 from Science Report - SC50021/SR7
Half Life	1060	Days	Half-life in groundwater Howard et al. 1991
Benzo(b) fluoranthene			
Henrys Law Constant	0.00000205	-	SC050021/SR7
KOC	104713	ml/g	log Koc = 5.02 from Science Report - SC50021/SR7
Half Life	1220	Days	Half-life in groundwater Howard et al. (1991) Environmental degradation rates
Benzo(k) fluoranthene			
Henrys Law Constant	0.00000174	-	SC050021/SR7
KOC	147911	ml/g	log Koc = 5.17 from Science Report - SC50021/SR7
Half Life	4280	Days	Half-life in groundwater Howard et al. (1991) Environmental degradation rates
Fluoranthene			
Henrys Law Constant	0.0000629	-	Science Report – SC050021/SR7
Koc	18197	ml/g	log Koc = 4.26 from Science Report - SC50021/SR7
Half Life	1990	Days	https://pubchem.ncbi.nlm.nih.gov/compound/9154#section=Environmental-Biodegradation Average of the 3.1 to 7.8 years quoted.
Benzo (ghi) perylene			
Henrys Law Constant	2.36E-06	-	Science Report – SC050021/SR7

Parameter	Value	Units	Justification
Koc	416869	ml/g	log Koc = 5.62 from Science Report - SC50021/SR7
Half Life	1299	Days	Groundwater Chemicals Desk Reference Montgomery 4th ed. 3.23 to 3.56 years given – 3.56 years used as a conservative value.
Indeno(1,2,3-cd) perylene			
Henrys Law Constant	0.00000205	ml/g	Science Report – SC050021/SR7
Koc	87096	ml/g	log Koc = 4.94 from Science Report - SC50021/SR7
Half Life	1.46E+03	days	Howard et al. (1991) Environmental degradation rates
Chromium			
Kd	31622	ml/g	https://archive.epa.gov/epawaste/hazard/web/pdf/s0524.pdf. Converted from log Kd of 4.5
Half Life	9.00E+99	days	No biodegradation assumed.
Copper			
Kd	15849	ml/g	https://archive.epa.gov/epawaste/hazard/web/pdf/s0524.pdf. Converted from log Kd of 4.2
Half Life	9.00E+99	days	No biodegradation assumed.
TPH C16-C21 Aromatic			
Henrys Law Constant	0.013	-	TPH CWG Vol 5 p8.
KOC	15849	ml/g	TPH CWG log Koc = 4.2
Half Life	3650	Days	New Zealand Guidelines: 1999: Modules. Guidelines for Assessing and Managing Petroleum Hydrocarbon Contaminated Sites in New Zealand. Ministry for the Environment.
TPH C21-C35 Aromatic			
Henrys Law Constant	6.7×10^{-4}	-	TPH CWG Vol 5 p8.
KOC	125892	ml/g	TPH CWG Volume 5 p8. Log Koc = 5.1

Parameter	Value	Units	Justification
Half Life	3650	Days	New Zealand Guidelines: 1999: Modules. Guidelines for Assessing and Managing Petroleum Hydrocarbon Contaminated Sites in New Zealand. Ministry for the Environment.

Table 5: Soil source sizes

Contaminant	Width (m)	Length (m)	Justification
Cr	10	10	Elevated leachate in BH101 and DCS128 only
Cu	30	20	Elevated leachate in BH101 particularly so area of gravel pit taken for conservatism
TPH aromatic C16-C21	30	20	Elevated soil and groundwater concentrations in the vicinity of BH101, DCS128, DCS125 and DCS101
TPH aromatic C21-C35	30	20	Elevated soil and groundwater concentrations in the vicinity of BH101, DCS128, DCS125 and DCS101
Fluoranthene	30	20	Elevated soil and groundwater concentrations in the vicinity of BH101, DCS128, DCS125 and DCS101
Benzo(b) fluoranthene	30	20	Elevated soil and groundwater concentrations in the vicinity of BH101, DCS128, DCS125 and DCS101
Benzo(k) fluoranthene	30	20	Elevated soil and groundwater concentrations in the vicinity of BH101, DCS128, DCS125 and DCS101
Benzo(ghi)perylene	30	20	Elevated soil and groundwater concentrations in the vicinity of BH101, DCS128, DCS125 and DCS101
Indeno(123-cd) pyrene	30	20	Elevated soil and groundwater concentrations in the vicinity of BH101, DCS128, DCS125 and DCS101
Benzo(a)pyrene	30	20	Elevated soil and groundwater concentrations in the vicinity of BH101, DCS128, DCS125 and DCS101

4.   Results

4.1   Results for 500 m Compliance Point to be Protective of the Drainage Channel to Lidsey Rife

The results of the remedial targets methodology spreadsheet modelling for the theoretical compliance point 500 m down hydraulic gradient of the source to be protective of the drainage channels ultimately leading to Lidsey Rife are shown in Table 6 below. Appendix A presents the remedial target spreadsheets. Table 6 gives the soil and leachate SSTLs derived using EQS values. The priority and priority hazardous substances are shown in italicised bold font. The tables also indicate if the CoC takes longer than 1000 years to reach the receptor; if it does take longer then it is considered an insignificant risk to the receptor (Environment Agency, 2006). If on-site concentrations were found to be above the SSTL and take less than 1000 years to reach the receptor, the maximum soil value and the boreholes that exceeded that value have been given a bold font and highlighted yellow.

Where exceedances of the soil SSTL has occurred then the SSTLs have only been compared to unsaturated zone samples, i.e. those at depths of < 2.44 m bgl. Soil SSTLs have only been compared to the most recent 2020 data.

Table 6: Soil Source Impact on 500 m theoretical drainage channel to be protective of surface waters based on EQS

Contaminant	Water Quality Standard (µg/l)	Reference	Level 1 Soil RT to be protective of drainage channel (mg/kg)	Level 3 Soil RT to be protective of drainage channel (mg/kg)	Maximum soil concentration on site below agreed removal depths (mg/kg)	Level 3 leachate RT to be protective of drainage channel (mg/l)	Time of contaminant breakthrough >1000 years?
Chromium III	4.7	EQS	N/A	2.03E+04	All below SSTL	0.641	Yes, >10,000 years
Copper	1	bioavailable EQS		7.98E+02	All below SSTL	0.0504	Yes, >10,000 years
Benzo(a)pyrene	0.00017	*EQS*	1.40E-04			N/A	N/A
Benzo(b) fluoranthene	0.017	*EQS*	1.14E-02		BH101 2m, DSC101 1.5 m, DCS104, DCS125 0.5, DCS128 2m	N/A	N/A
Benzo(k) fluoranthene	0.017	*EQS*	1.61E-02	N/A		N/A	N/A
Benzo(ghi) perylene	0.0082		2.19E-02			N/A	N/A
Fluoranthene	0.0063	*EQS*	7.34E-04			N/A	N/A

All leachate concentrations were found to be below their relevant SSTLs. Soil SSTLs to be protective of the surface water receptor were exceeded by on-site concentrations of PAHs. This is because the PAHs are priority/priority hazardous substances and as such cannot be allowed to enter controlled waters. They have therefore only been modelled to the base of the unsaturated zone. They have, however, already been detected in groundwater.

Due to the high partition coefficient for the PAHs it takes much longer than 1000 years to reach the theoretical surface water receptor, taking over 10,000 years. Benzo(a)pyrene takes >10,000 years and fluoranthene takes 1650 years to reach the receptor, which is a significant length of time and hence it is highly unlikely that there will be any significant impact to the receptor. So, whilst the DQRA cannot simulate these PAH concentrations in soils to the receptor, it is known that they are unlikely to significantly impact the Lidsey Rife and associated drainage channels.

Benzo(a)pyrene is a priority hazardous substance and hence only a Tier 1 SSTL should be derived. The SSTL to be protective of the surface waters down gradient of the site is extremely low at 1.4×10^{-4} mg/kg and is far below natural background concentrations in an urban environment of 3.6 mg/kg (Defra, 2012). Maximum soil concentrations are below this normal background concentration where remediation is not planned. It would be impractical to have a SSTL of 1.87×10^{-4} mg/kg for the site and it is suggested that the background concentration should be used.

Due to the low EQS values for fluoranthene the Tier 1 SSTL is also very low. It is recognised that the Tier 1 SSTL for fluoranthene at 7.3×10^{-4} mg/kg would be an impractical target concentration since it is below achievable laboratory method detection limits. Normal background concentrations of other PAHs in soils were not defined by Defra during the 2012 series of reports. The Environment Agency (2007) completed a large study of PAH concentrations in rural, urban, and industrial soils which found that fluoranthene concentrations rural soils were on average 0.216 mg/kg and in urban areas were 5.28 mg/kg.

Similarly, concentrations of benzo(b)fluoranthene in rural and urban settings are 0.188 mg/kg and 1.66 mg/kg respectively. Concentrations of benzo(k)fluoranthene in rural and urban settings are 0.0852 mg/kg and 1.26 mg/kg respectively. Concentrations of benzo(ghi)perylene rural and urban settings are 0.854 mg/kg and 0.109 mg/kg respectively. Therefore, consideration should be given as to adopting these urban values up to 50 m from the A29 rather than the SSTL value which are impractical target concentrations as they are below or almost at the limit of detection.

4.2   Head Deposits 50 m Compliance Point Results

The results of the remedial targets methodology spreadsheet modelling for the Head Deposits Secondary A aquifer receptor are shown in Table 7 below. Table 7 gives the soil and leachate SSTLs derived using DWS values. The hazardous substances are shown in italicised bold font. The tables also indicate if the CoC takes longer than 1000 years to reach the receptor; if it does take longer, then it is considered to pose an insignificant risk to the receptor. If on-site concentrations were found to be above the SSTL and take less than 1000 years to reach the receptor (Environment Agency, 2006), the maximum recorded value and the boreholes that exceeded that value have been given a bold font.

Table 7: Soil Source Impact 50 m compliance point based on DWS

Contaminant	Water Quality Standard (µg/l)	Reference	Level 1 or 3 Soil RT to be protective of Head Deposits aquifer (mg/kg)	Maximum soil concentration on site below agreed removal depths (mg/kg)	Level 3 Leachate RT to be protective of Head Deposits aquifer (mg/l)	Time of contaminant breakthrough >1000 years?
Chromium	50	DWS	5.37E+03 (Level 3)	All below SSTL	0.170	Yes, >10,000 years
Benzo(a)pyrene	0.01	DWS	8.25E-03 (Level 1)	DSC101 1.5 m, DCS104, DCS125 0.5, DCS128 2m	N/A	N/A
Aromatic C16-C21	10	withdrawn private DWS	2.10E+00 (Level 3)	DCS125 0.5, DCS128 2m above LoD (10 mg/kg)	0.0207	No, 770 years
Aromatic C21-C35	10	withdrawn private DWS	3.18E+02 (Level 3)	All below SSTL	0.0207	No, 770 years

From Table 7 only benzo(a)pyrene and TPH Aromatic C16-C21 were found to pose a risk to the groundwater receptor from soil concentrations. As discussed in the previous section benzo(a)pyrene is a hazardous substance and as such cannot be allowed to enter controlled waters. It has therefore only been modelled to the base of the unsaturated zone. Benzo(a)pyrene has, however, already been detected in groundwater. Once within groundwater, due to the high partition coefficient it takes much longer than 1000 years to reach the compliance point, taking over 10,000 years. Therefore, there is considered to be an insignificant risk from this CoC to the Head Deposits compliance point receptor.

Benzo(a)pyrene is a hazardous substance with respect to groundwater and hence only a Tier 1 SSTL should be derived. The SSTL to be protective of the surface waters down gradient of the site is low at 8.3×10^{-3} mg/kg and is far below natural background concentrations in an urban environment of 3.6 mg/kg (Defra, 2012). Maximum soil concentrations are below this normal background concentration where remediation is not planned. It would be impractical to have a SSTL of 8.3×10^{-3} mg/kg for the site and it is suggested that the background concentration should be used instead.

Although there are exceedances of the TPH Aromatic C16-C21 soil SSTL at the site, the time that this CoC takes to reach a 50 m compliance point is 770 years and therefore a significant length of time, indicating that there is little risk to the overall groundwater resource from the concentrations that are to remain at the site.

Chromium has not been treated as a hazardous substance as no chromium VI was detected in the soils on site and has therefore been modelled to Tier 3. From Table 7 only one leachate sample for chromium exceeded the leachate SSTL in DCS128 at 1 m depth and no soil samples exceeded the soil SSTL.

4.3   Sensitivity Analysis

A sensitivity analysis has been conducted for two CoC to assess whether the derived SSTLS are robust. The two selected COC have their maximum on-site soil concentrations above the derived SSTL. Site-specific data are available for some parameters, and some data have been derived from literature; both data types having uncertainty associated with them due to variability of ground conditions across the site as well the array of literature values.   A number of the parameters such as half-life, hydraulic conductivity and partition coefficients have a significant impact on remedial target values and the time taken to the receptors. The two CoC that have been selected to assess the impact of the parameter variation on the risk to the receptors are:

- Benzo(a)pyrene for soil remedial targets to be protective of the surface water receptors at a 500 m compliance point; and

- TPH Aromatic C16 – C21 for soil remedial targets to be protective of the Head Deposits aquifer at a 50 m compliance point.

The range in partition coefficients for benzo(a)pyrene was obtained from the ATSDR toxicological profile (date unknown) (log Koc = 6.74) as well as MacKay et al. (2006) (range of log Koc from 4.49 to 6.49 for most closely matching sediment types) and Montgomery (2007) (log Koc from 5.53 to 8.25). The final range selected has therefore been from log Koc of 4.49 to 6.74.

Henry's Law constants for benzo(a)pyrene come from Montgomery (2007) as 2.71×10^{-7} atm-m^3/mol which converts to 9.34×10^{-6} dimensionless using the USEPA converter (USEPA, 2016). 0.0079 Pa-m^3/mol (7.8×10^{-8} atm-m3/mol) was obtained from MacKay et al. (2006) at 10 degrees which converts to a dimensionless value of 3.35×10^{-6}.

Bulk densities and water filled porosities do not have any significant impact over the plausible range and so these parameters have not been included in the sensitivity analysis.

The results of the sensitivity analysis are shown in Table 8 for benzo(a)pyrene.

Table 8: Sensitivity Analysis Results for benzo(a)pyrene for Level 1 Soil Remedial Target for surface water receptor.

Parameter	Value	Level 1 soil remedial target for RTD DWS (mg/kg)	Maximum on site concentrations after removal of material from areas A, B and C (mg/kg)
Partition Coefficient (ml/g)	Log Koc = 6.74	3.98E-03	8 mg/kg in DCS128 at 2m depth
	Log Koc = 5.11	1.40E-04	
	Log Koc = 4.49	3.36E-05	
Henry's Law coefficient	9.34×10^{-6}	1.40E-04	
	3.35×10^{-6}	1.40E-04	
	1.76×10^{-6}	1.40E-04	

Table 8 shows that there is no impact on the Level 1 SSTL for variations in Henry's Law coefficient. When examining the upper end of plausible partition coefficients the SSTL does increase, as expected, although does not rise about the limit of detection in the laboratory and

hence the overall conclusion for benzo(a)pyrene and hence the PAHs as a whole at Tier 1 does not change and the analysis remains robust. As discussed in the previous section it would be more appropriate for the benzo(a)pyrene SSTL to be set at background levels for an urban environment in the vicinity of the roundabout (within 50 m of the A29), so 3.6 mg/kg. This would result in just one sample from the site exceeding this value outside of the intended remediation area at 2 m depth in the area of DCS128.

Results of the sensitivity analysis for TPH Aromatic C16-C21 are presented in Table 9. The variation in hydraulic conductivity is based on the range of possible values from MacDonald et al. (2012) for a sandy gravel aquifer with silts to support the borehole log descriptions, as well as the range of site-specific data from the falling head tests. However as noted in MacDonald et al. (2012) the bulk descriptors "sand", "silt" and "gravel" have little predictive power in helping to quantify the permeability of unconsolidated heterogeneous sediments. A range from 5 m/day to 0.05 m/day has therefore been selected.

The range in partition coefficients for TPH Aromatic C16-C21 have come from the surrogates of fluoranthene (C16) to benzo(k)fluoranthene (C20) which were initially from a log Koc of 4.26 to 5.17 respectively (Environment Agency, 2008). Further data have been obtained from MacKay et al. (2006) which gives a range of log Koc from 5.91 to 7 for benzo(k)fluoranthene and a range of log Koc of 4.6 to 6.7 for fluoranthene. The final range selected has therefore been from 4.2 to 6.7.

The value for the Henry's Law constant for TPH Aromatic C16-C21 of 0.013 came from TPH CWG (1999). Further data have been obtained from Montgomery (2007) as 2.71×10^{-7} atm-m^3/mol which converts to 9.34×10^{-6} dimensionless using the USEPA converter (USEPA, 2016) for benzo(k) fluoranthene and a range of 2.57 to 5.53×10^{-6} atm-m^3/mol at 10°C for fluoranthene which convert to a range of 1.11×10^{-4} to 2.38×10^{-4}. The final range selected has therefore been from dimensionless values of 0.013 to 9.34×10^{-6} with a midpoint as 1.11×10^{-4}.

Half-lives for TPH Aromatic C16-C21 come from Howard et al. (1991) as a maximum value of 3.34 years in groundwater for fluoranthene and 11.7 years for benzo(b)fluoranthene. These two values have been used in the sensitivity analysis.

The range of hydraulic gradients comes from an analysis of the infiltration areas and predicted maximum flows. There are two areas of infiltration; one within the roundabout (infiltration area 1A-just south of yellow shaded area on Dwg A29-CAP-HGT00-DR-GR-0227 P01 and one just south of the roundabout (infiltration area -close to green shaded area on above mentioned drawing). Infiltration volumes have been based on a 1 in 100 year storm event lasting 4 hours with an addition of 40% to take into account climate change variation. The data for the infiltration areas are as follows:

	Area of base of tank (m^2)	Vol. (m^3)	Rainfall event duration
Infiltration tank 1A	12 x 12 = 144	74.9	240 mins
Infiltration tank 1B	47 x 5.5 = 259	172.6	240 mins

The equivalent daily discharge rate would therefore be 449 m^3/day for tank 1A and 1036 m^3/day for tank 1B, or an infiltration of 0.52 m for tank 1A and 0.67 m for tank 1B over a duration of 4 hours.

Making some very broad assumptions that the aquifer is unconfined, homogeneous, groundwater level is at the base of the tanks and steady state flow occurs, the Dupuit formula for unconfined flow can be used to estimate the size of the cone of influence that would occur from these infiltration values.

$$Q = \pi K \frac{h_2^2 - h_1^2}{ln\left(\frac{r_2}{r_1}\right)}$$

Q in is the injection rate in m^3/day, K is the hydraulic conductivity in m/day and h and r are the heads and radii from the "well" at two distances with the second being further away than the first. If we assume that the saturated aquifer thickness is 4.48 m and that it is increased to 4.48+0.52m for tank 1A at its outer edge (6 m from the centre) and 4.48+0.67 m for tank 1B and that an insignificant impact is considered to be +/- 0.02 m change in groundwater level, with a K value of 0.5 m/day and a discharge rate of 449 x 6 m^3/day (to obtain 24 hour equivalent) or 1036 x 6 m^3/day then the sphere of influence is in fact very small and less than 1 m from the infiltration tank where hydraulic gradients will be altered. This gives reassurance that hydraulic gradients along the modelled path of 50 m will not be significantly affected during a storm event due to the tanks alone. Therefore, a range of hydraulic gradients have been used from 0.002 (calculated across the site from October 2020 data) increased to a maximum of 0.005.

However, infiltration may well increase because of climate change and hence a range of infiltration rates have been applied using the UKCP18 scenarios. Winter precipitation may increase by up to 40% in south-east England and summer precipitation may increase by approximately 14%. Annually this may be reflected as a 27% increase. The infiltration has therefore been increased by factors of 1.14 and 1.27 in the sensitivity analysis.

Table 9 indicates that for plausible ranges of half-lives, Henry's Law constants, infiltration amended to reflect injection rates, hydraulic gradients, and site-specific hydraulic conductivity values there is no significant change to the value of the SSTL.

On examination of the partition coefficient it would appear that this parameter does have a significant effect on the SSTL value. It has not been possible to obtain site-specific data for partition coefficients for TPH as it was not considered appropriate to analyse for leachate for these compounds. However, leachate analyses were conducted for PAHs for a number of samples, with DCS125 having detections in both soil and leachate samples. Partition coefficients were calculated for those determinands with detections in DCS125 resulting in values between 1166 ml/g for acenaphthene to 17,692 ml/g for phenanthrene. It was not considered appropriate to calculate partition coefficients for those samples which had leachate concentrations below the limit of detection since it is not known how far below the limit of detection the true value would be, potentially giving a falsely high value and so the more conservative option has been selected. As literature partition coefficients for acenaphthene and phenanthrene vary from log Koc of 1.25 to 5.87 and log Koc 3.6 to 6.9 (Montgomery, 2007) respectively it would appear the site-specific values are in the mid-range of literature quoted.

This indicates that a mid-range partition coefficient for TPH Aromatic C16-C21 is more appropriate giving an SSTL of 41.9 mg/kg. The areas that have been highlighted for removal of material have concentrations above this SSTL, whereas all other remaining locations have

sample concentrations that would fall below this SSTL value. This gives confidence in the proposed strategy for removal of materials at the site.

Referring back to Table 8 and the analysis of the partition coefficients in the above paragraph that a mid-range value is appropriate, the SSTL of 1.4 x 10^{-4} mg/kg for benzo(a)pyrene is also robust. However, as previously mentioned the SSTL for the site cannot be lower than the laboratory limit of detection and hence a background value of 3.6 mg/kg is more appropriate for the site.

Table 9: Sensitivity Analysis Results for TPH Aromatic C16-C21 for Level 3 Soil Remedial Target for Head Deposits.

Parameter	Value	Level 3 groundwater remedial target for RTD DWS (mg/kg)	Maximum on site concentration after removal of areas A, B and C (mg/kg)
Partition Coefficient (ml/g)	Log Koc = 4.2	2.10	32 in DCS128 at 2 m depth
	Log Koc = 5.5	41.9	
	Log Koc = 6.70	664	
K (m/day)	5	4.75	
	0.5	2.10	
	0.05	1.79	
Henry's Law constant (dimension-less)	0.013	2.10	
	0.00011	2.10	
	9.34 x 10^{-6}	2.10	
Infiltration (m/day)	6.52 x 10^{-4}	2.10	
	7.43 x 10^{-4}	1.97	
	8.28 x 10^{-4}	1.88	
Hydraulic gradients	0.005	2.64	
	0.002	2.10	
	0.001	1.93	
Half-life (days)	4273	2.00	
	3650	2.10	
	1220	3.98	

It can be seen that the modelling is robust for TPH Aromatic C16-C21 chemicals and certain soil samples have been correctly identified as exceeding their relevant SSTL values.

At this point it was seen that taking the mid-range partition coefficients for PAHs was a sensible approach to make sure that the SSTLs will be protective of surface water. Table 10 gives the outcome of this re-analysis.

Table 10: Revised PAH SSTLs for surface water compliance point based on mid-range Koc values.

CoC	EQS	Koc Used (ml/g)	Original SSTL	Log Koc Range (Midpoint of range) ml/g	Revised SSTL (mg/kg)
Benzo(a)pyrene	0.00017	Log Koc = 5.11	1.40E-04	4.49 – 6.74 (5.61)	4.43E-04
Benzo(b) fluoranthene	0.017	Log Koc = 5.02	1.14E-02	4.26 to 5.17 (4.72)	5.71E-03
Benzo(k) fluoranthene	0.017	Log Koc = 5.07	1.61E-02	5.97 – 6.94 (6.45)	0.307
Benzo(ghi) perylene	0.0082	Log Koc = 5.62	2.19E-02	5.43 – 8.91 (7.17)	1.61
Fluoranthene	0.0063	Log Koc = 4.26	7.34E-04	4.6 – 6.7 (5.6)	0.0161

Significance of comparing Table 9 and Table 10 SSTL's with GI findings

Soil concentrations at five locations exceed the SSTLs for PAHs. On site concentrations of TPH Aromatic C16-C21 were also found to exceed the SSTL in two locations.

Many of the detected benzo(a)pyrene concentrations are in line with concentrations expected within an urban environment as background concentrations (3.6 mg/kg, Defra (2012)). Analysis of background concentrations of fluoranthene and the other PAHs in soils in the UK has not been completed in the same way completed by Defra for benzo(a)pyrene, but a similar study was conducted by the Environment Agency (2007). The Environment Agency study (2007) indicates that from all sources of PAHs fluoranthene (average concentration in England of 0.216 mg/kg in rural and 5.28 mg/kg in urban settings) and pyrene were the dominant PAH species within soils, being approximately three times as abundant as benzo(a)pyrene.

The Environment Agency (2007) data indicates background concentrations of benzo(b)fluoranthene in urban settings are 1.66 mg/kg, benzo(k)fluoranthene is 1.26 mg/kg, benzo(ghi)perylene 0.854 mg/kg respectively. Therefore, consideration should be given as to adopting the urban values within 50 m of the A29 rather than the SSTL value which are impractical target concentrations as they are below or almost at the limit of detection. This is summarised in Table 11.

The sensitivity analysis has shown that the PAH SSTLs to be very sensitive to the variation in possible partition coefficients. Initial partition coefficients were selected from the Environment Agency SR7 dataset to be consistent, but further review of the site data allowed a few site-specific partition coefficients to be calculated for PAHs. This revealed that values were likely to be more

in the mid-range of literature values and hence the PAH SSTLs were re-derived. Table 11 presents the SSTLs derived for those CoC which had exceedances on site and suggests possible overall soil and leachate remedial targets for the site and this table brings in earlier SSTL's for copper and chromium. The lower of the EQS or DWS derived SSTL has been selected if practical. However, in some cases the SSTL is much lower than laboratory detection limits and where natural background concentrations of PAHs are higher in soils than the derived SSTLs these have been replaced with natural background levels. The SSTLs in Table 11 should only be applied to areas within 50 m of the A29 and in the vicinity of the Fontwell Avenue roundabout. Should SSTLs be required for other parts of the realignment then values will need to be calculated separately to those in this report.

Table 11: Combined SSTL table with suggested remedial targets for the site.

CoC	Soil SSTL for Surface Water Compliance Point mg/kg	Soil SSTL for Head Deposits Compliance Point mg/kg	Suggested Combined Soil SSTL mg/kg	Leachate SSTL for Surface Water Compliance Point mg/l	Leachate SSTL for Head Deposits Compliance Point mg/l	Suggested Combined Leachate SSTL mg/l
Chromium - total	20300	5370	5370	0.641	0.170	0.170
Copper	798	ND	798	0.0504	ND	0.0504
Benzo(a)pyrene	4.43×10^{-4}	0.0261	3.60 (NBC)	ND	ND	ND
Benzo(b)fluoranthene	5.71×10^{-3}	ND	1.66 (NBC)	ND	ND	ND
Benzo(k)fluoranthene	0.307	ND	1.26 (NBC)	ND	ND	ND
Benzo(ghi) perylene	1.61	ND	1.61	ND	ND	ND
Fluoranthene	0.0161	ND	5.28 (NBC)	ND	ND	ND
TPH C16-C121 Aromatic	ND	41.9	41.9	ND	0.0207	0.0207
TPH C21-C35 Aromatic	ND	318	318	ND	0.0207	0.0207

ND – SSTL not derived as no relevant water quality standard or that CoC not an issue for that particular source or standard or for leachate the SSTL is the same as the EQS.

NBC – natural background concentration (Defra, 2012) and standardly found concentrations in rural soils (Environment Agency, 2007)

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5. Summary and Conclusions

This DQRA has been conducted in order to quantify the risk posed to controlled waters receptors from the soil concentrations identified at the Fontwell Avenue roundabout site post remediation, and to derive site specific target levels to inform any further assessment. The most significant areas of contamination in soils were linked to the site as a former gravel pit which had been filled. This report has quantified the extent of the potential risk to controlled waters receptors, both groundwater and surface water, from the soil concentrations identified on site after the 2020 site investigation by deriving site-specific target levels.

The hydrogeological conceptual model of the site identified two key receptors; the drains leading to the Lidsey Rife 820 m to the south and east of the site and the Head Deposits Secondary A aquifer. Compliance points were selected for the surface water receptor and also for the Head Deposits aquifer at 500 m and 50 m respectively. The metal and organic contamination identified in soil would leach into the unsaturated zone, pass vertically downwards to the groundwater approximately 2.4 m below ground level and then migrate down hydraulic gradient to the southeast towards the drains.

The remedial target methodology spreadsheet model was used to quantify the risk to the Secondary A Head Deposits aquifer and the drains leading to the Lidsey Rife. The metal CoCs and TPH Aromatic C21-C35 identified in elevated concentrations in the soil have proved to pose an insignificant risk to these two receptors. Five priority hazardous CoCs (benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(ghi)perylene and fluoranthene) in soils were found to exceed their SSTLs at the base of the unsaturated zone below the proposed remediation levels when considering risk to controlled waters.

The sensitivity analysis showed that the PAH SSTLs were very sensitive to the variation in possible partition coefficients. Analysis of site-specific data for partition coefficients revealed that values were likely to be more in the mid-range of literature values and hence the PAH SSTLs were re-derived.

Table 12 presents the SSTLs derived for those CoC which had exceedances on site and suggests possible overall soil and leachate remedial targets for the site. The lower of the EQS or DWS derived SSTL has been selected if practical. However, in some cases the SSTL is much lower than laboratory detection limits and where natural background concentrations of PAHs are higher in soils than the derived SSTLs these have been replaced with natural background levels. The SSTLs in Table 11 should only be applied to areas within 50 m of the A29 and in the vicinity of the Fontwell Avenue roundabout.

Table 12: Summary combined SSTL table with suggested remedial targets for the site.

CoC	Suggested Combined Soil SSTL mg/kg	Suggested Combined Leachate SSTL mg/l
Chromium - total	5370	0.170
Copper	798	0.0504
Benzo(a)pyrene	3.60 (NBC)	ND
Benzo(b)fluoranthene	1.66 (NBC)	ND
Benzo(k)fluoranthene	1.26 (NBC)	ND
Benzo(ghi) perylene	1.61	ND
Fluoranthene	5.28 (NBC)	ND
TPH C16-C121 Aromatic	41.9	0.0207
TPH C21-C35 Aromatic	318	0.0207

ND – SSTL not derived for leachate the SSTL is the same as the EQS.

NBC – natural background concentration (Defra, 2012) and standardly found concentrations in rural soils (Environment Agency, 2007)

Should SSTLs be required for other parts of the realignment then values will need to be calculated separately to those in this report. On removal of material at the former gravel pit area, should validation samples show elevated concentrations at depth above the SSTLs and evidence of a mobile source of contamination then a replacement monitoring well for BH101 will be provided. In that scenario, groundwater samples will be taken monthly for a duration of four months to demonstrate that minimal impact to the aquifer has occurred.
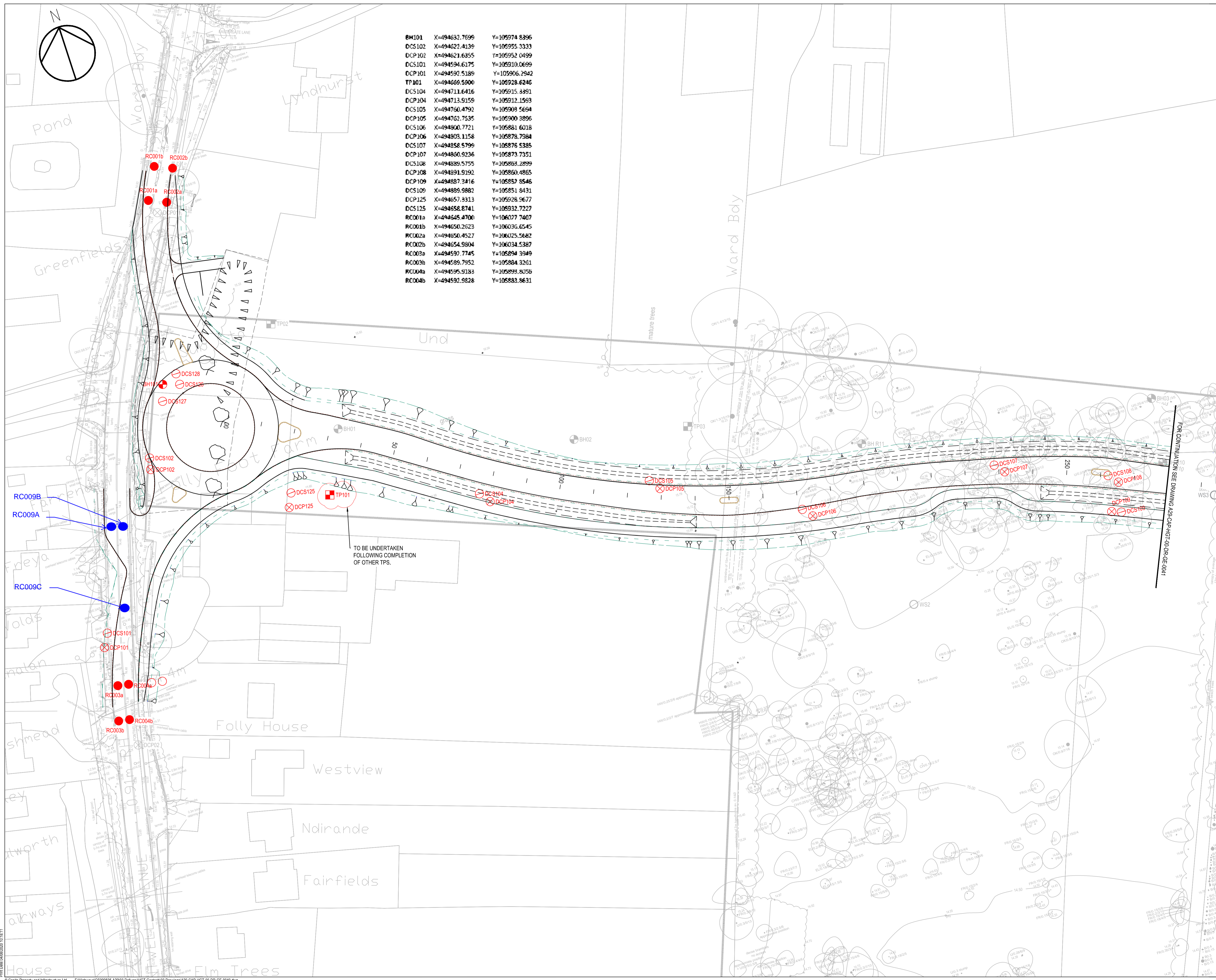
As over 600 m^3 of material will be removed from the site, leaving a greatly depleted soil source at the site, as the higher concentrations were found in the shallow samples, the risk to controlled waters receptors following the highway development is considered to be relatively minimal and this includes any slightly enhanced hydraulic gradients caused by new soakage pits.

CAPITA

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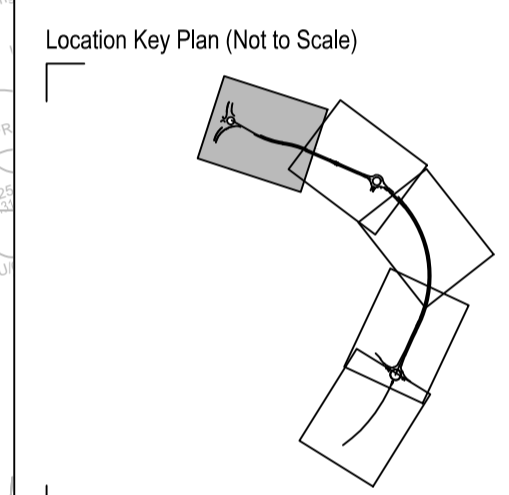
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Drawings

NOTES:

1. ALL DIMENSIONS ARE IN MILLIMETRES UNLESS SHOWN OTHERWISE.
2. EXISTING SP - EXISTING STANDPIPE TO BE CHECKED FOR FUNCTIONALITY AND MONITORED AS PART OF THIS INVESTIGATION.

KEY: EXISTING / HISTORIC LOCATIONS

- BOREHOLE WSP2018
- DYNAMIC CONE PENETROMETER WSP2018
- TRIAL PIT WSP2018
- WINDOW SAMPLE WSP2018
- EXISTING BOREHOLE WILSON BAILEY 2018

KEY: PROPOSED EXPLORATORY LOCATIONS

- CABLE PERCUSSIVE BOREHOLE
- DYNAMIC SAMPLER HOLE
- DYNAMIC PROBE LOCATION
- TRIAL PIT
- PAVEMENT CORE
- WATER SAMPLE
- GRAVEL PIT

Coordinate list:

Point	X	Y
BH101	X=494632.7699	Y=105974.8396
DCS102	X=494623.4139	Y=105955.3333
DCP102	X=494621.6355	Y=105952.0499
DCS101	X=494594.6175	Y=105910.0699
DCP101	X=494592.5189	Y=105906.2942
TP101	X=494669.5900	Y=105928.6246
DCS104	X=494711.6416	Y=105915.3891
DCP104	X=494713.9159	Y=105912.1593
DCS105	X=494760.4792	Y=105903.5694
DCP105	X=494762.7535	Y=105900.3896
DCS106	X=494800.7721	Y=105881.6018
DCP106	X=494803.1158	Y=105878.7984
DCS107	X=494858.5799	Y=105876.5385
DCP107	X=494860.9236	Y=105873.7351
DCS108	X=494889.5755	Y=105863.2899
DCP108	X=494891.9192	Y=105860.4865
DCP109	X=494887.3416	Y=105857.8546
DCS109	X=494889.9882	Y=105851.8431
DCP125	X=494657.9313	Y=105928.9677
DCS125	X=494658.8741	Y=105932.7227
RC001a	X=494645.4700	Y=106027.7407
RC001b	X=494650.2623	Y=106036.6545
RC002a	X=494650.4527	Y=106025.5682
RC002b	X=494654.9804	Y=106034.5387
RC003a	X=494597.7745	Y=105894.3949
RC003b	X=494589.7952	Y=105884.3261
RC004a	X=494595.9183	Y=105899.8056
RC004b	X=494592.9828	Y=105883.8631

TO BE UNDERTAKEN FOLLOWING COMPLETION OF OTHER TPS.

FOR CONTINUATION SEE DRAWING A29-CAP-HGT-00-DR-GE-0041

Location Key Plan (Not to Scale)

N

KEY:

■ (green) REMEDIATION AREA WHERE ACTIONS OVER AND ABOVE PLANNED CUT ARE NEEDED

■ (yellow) REMEDIATION AREA WHERE CUT SHOULD DELIVER REMEDIATION
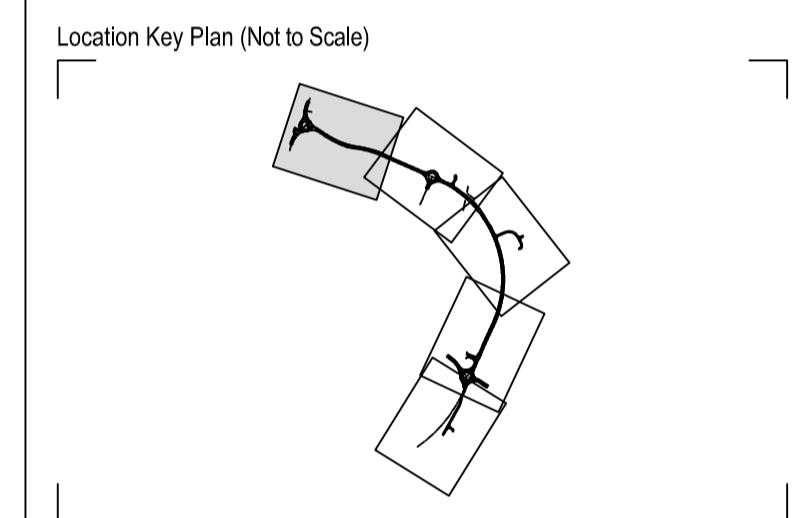
■ (red) VALIDATION SAMPLING PIT
TP302

SAFETY, HEALTH AND ENVIRONMENTAL INFORMATION

IN ADDITION TO THE HAZARDS/RISKS NORMALLY ASSOCIATED WITH THE TYPES OF WORK DETAILED ON THIS DRAWING, NOTE THE FOLLOWING

CONSTRUCTION

C1 - PAH AND ASBESTOS PRESENCE IN SOILS PRESENT IN REMEDIATION AREAS

MAINTENANCE / CLEANING

NONE IDENTIFIED.

DECOMMISSIONING / DEMOLITION

NONE IDENTIFIED.

IT IS ASSUMED THAT ALL WORKS WILL BE CARRIED OUT BY A COMPETENT CONTRACTOR WORKING, WHERE APPROPRIATE, TO AN APPROVED METHOD STATEMENT

TP307

TP306

WATCHING BRIEF MUST INCLUDE INSPECTION OF FORMATION ONCE SUBSTATION SLAB REMOVED

FORMER GRAVEL PIT (APPROX. EXTENT)

A29 FONTWELL AVENUE ROUNDABOUT 40m ICD

REMEDIATION AREA C DEPTH OF IMPACT IS 0.6m TO 1.2m

TRAFFIC CALMING ISLAND

5m VERGE WITH 4m SWALE

TRAFFIC CALMING ISLAND

PLANTER

TP301   TP305

7.3m CARRIAGEWAY

A29 REALIGNMENT

TP304

TP302   TP303

REMEDIATION AREA A DEPTH OF IMPACT IS 0.3m

1m VERGE

SECTION OF COMBINED DRAINAGE KERB

REMEDIATION AREA B (THIS AREA COVERS 3NO. SEPARATE SUB AREA) DEPTH OF IMPACT IS 1.0m

3m SHARED FOOTWAY / CYCLEWAY

LOCALISED REDUCTION OF SWALE TO ACCOMMODATE THE SIGN POST

A29 FONTWELL AVENUE

Location Key Plan (Not to Scale)

P02	KS	NG	NG	TP NUMBERS AMENDED, WELL REMOVED, NOTE 4 ADDED.	23.02.21
P01	JB	KS	KS	FIRST ISSUE	15.01.21
Rev	Drwn	Chk'd	Appd	Description	Date

Purpose of Issue
For Review and Comment   S3

Classification
Commercial in Confidence

Client
west sussex county council   Jackson

Project
A29 Realignment Scheme

Drawing
Remediation Actions
Sheet 1 of 1

| Scale @ A1 | Drawn | Checked | Approved |
| 1:500 | JB | NG | KS |

| Project No. | Date |
| CS099505 | 13.01.21 |

Drawing Identifier
Project - Originator - Zone - Level - File Type - Role - Number   BS1192 Compliant
A29-CAP-HGT-00-DR-GE-0227   revision P02

10m 0 10m 20m 30m 40m
1:500

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Appendix A RTM Spreadsheets

Soil Source leaching vertically through Made Ground/Head Gravels and then laterally migrating through the gravels to drainage ditch and ultimately the Lidsey Rife

Parameter	Value	Units	Justification
Level 1 Soil			
Water Filled Soil Porosity	0.129	Fraction	P20 porosity calculator used assuming 1.37 - 1.81 g/cm^3 (average bulk density 1.59 g/cm^3) and a moisture content of 8.83% on average from on-site sand/gravel materials. Total porosity 47.4 %
Air Filled Soil Porosity	0.345	Fraction	P20 porosity calculator used assuming 1.59 g/cm^3 bulk density and a moisture content of 8.83% on average from on-site materials.
Bulk Density	1.59	g/cm^3	1.37 to 1.81 g/cm^3: Gravelly sand - ConSim. BH101, DCS126, DCS127, DCS128 have log descriptions of gravelly sand through to medium sand - conservative value
FOC	0.0064	Fraction	Data from 1 unsaturated sample from sand/gravel in TP02 in the Made Ground. Other samples are from a clay matrix and therefore not conservative.
Level 2 Soil (Dilution in the RTD)			
Infiltration	6.52E-04	m/d	922 mm /year of rainfall occurs in the catchment according to the rainfall station at Chichester (https://nrfa.ceh.ac.uk/data/ station/spatial/41023). MetOffice averages for Bognor Regis give 725 mm/year average (https://www.metoffice.gov.uk/research/climate/ maps-and-data/uk-climate-averages/gcp8bswvw). Site likely to be more aligned with Chichester as it is inland. Effective rainfall is quoted as 476 mm/year in Table 1 of http://nora.nerc.ac.uk/id/ eprint/12713/1/SD99001.pdf. Taking into account the site post development will be 50% hardstanding this equates 6.52 x 10^{-4} m/day
Length of Contaminant Source	5 - 15	m	Length of source is contaminant specific. Groundwater flow assumed to be to the east south east. See Table 12.
Saturated Aquifer Thickness	4.48	m	Depth to London Clay recorded in WSP BH01, BH04A, BH06 - BH09, DCS124 at an average depth of 7.17 m bgl. Groundwater strike levels after 20 mins in these boreholes an average of 2.44 mbgl giving an average saturated thickness of 4.48 m
Hydraulic Conductivity	0.5	m/d	Site data average – falling head tests on BH101 and DCS125 give 6.08 x 10^{-6} m/s (BH101 deep) to 2.4 x 10^{-7} m/s (DCS125) which converts to 0.52 m/day and 0.02 m/day. Check via Bouwer and Rice analysis reveals similar values giving confidence. Log descriptions in BH101 indicate a coarse sandy gravel in the saturated zone with silt, so whilst layers of silt are present within the aquifer 0.5 m/day considered appropriate. Higher values of 5 m/day to be used in sensitivity analysis.
Hydraulic Gradient	0.002	Fraction	Average hydraulic gradient on-site from 28th October 2020 monitoring round data. Data from 2nd and 9th November 2020 supports this value and direction of SE
Width of Contaminant Source	10-25	m	Contaminant specific - see table. Dimension perpendicular to groundwater flow.
Level 3 Soil			
Bulk Density	2.09	g/cm^3	Values taken for Head Deposits in WSP BH07, BH08, TP15 and Nicholls Colton BH101
Effective Porosity	0.15	Fraction	From De Marsily (1986) for a gravelly sand (specific yield)
Distance to Compliance Point	500	m	Distance from the edge of the soil source zone around BH101 to the drain at the Halo complex and drain around residential housing around Downview Road - 820 m. Hypothetical compliance point selected at 500 m as a cross gradient stream is closer.
FOC	0.0028	Fraction	Site specific data for BH09 taken at depths of 2 and 4 m in sand/gravel at 0.26 and 0.30%

Soil Source leaching vertically through Made Ground/Head Deposits and then laterally migrating through the RTD to 50 m compliance point in Head Deposits

Parameter	Value	Units	Justification
Level 1 Soil			
Water Filled Soil Porosity	0.129	Fraction	P20 porosity calculator used assuming 1.37 - 1.81 g/cm3 (average bulk density 1.59 g/cm3) and a moisture content of 8.83% on average from on-site sand/gravel materials. Total porosity 47.4 %
Air Filled Soil Porosity	0.345	Fraction	P20 porosity calculator used assuming 1.59 g/cm3 bulk density and a moisture content of 8.83% on average from on-site materials.
Bulk Density	1.59	g/cm3	1.37 to 1.81 g/cm3: Gravelly sand - ConSim. BH101, DCS126, DCS127, DCS128 have log descriptions of gravelly sand through to medium sand - conservative value
FOC	0.0064	Fraction	Data from 1 unsaturated sample from sand/gravel in TP02 in the Made Ground. Other samples are from a clay matrix and therefore not conservative.
Level 2 Soil (Dilution in the RTD)			
Infiltration	6.52E-04	m/d	922 mm of rainfall occurs in the catchment according to the rainfall station at Chichester (https://nrfa.ceh.ac.uk/data/ station/spatial/41023). MetOffice averages for Bognor Regis give 725 mm/year average (https://www.metoffice.gov.uk/research/climate/ maps-and-data/uk-climate-averages/gcp8bswvw). Site likely to be more aligned with Chichester as it is inland. Effective rainfall is quoted as 476 mm/year in Table 1 of http://nora.nerc.ac.uk/id/ eprint/12713/1/SD99001.pdf. Taking into account the site post development will be 50% hardstanding this equates 6.52 x 10-4
Length of Contaminant Source	5 - 15	m	Length of source is contaminant specific. Groundwater flow assumed to be to the east south east. See Table 12.
Saturated Aquifer Thickness	4.5	m	Depth to London Clay recorded in WSP BH01, BH04A, BH06 - BH09, DCS124 at an average depth of 7.17 m bgl. Groundwater strike levels after 20 mins in these boreholes an average of 2.44 mbgl giving an average saturated thickness of 4.48 m
Hydraulic Conductivity	0.5	m/d	Site data average – falling head tests on BH101 and DCS125 give 6.08 x 10-6 m/s (BH101 deep) to 2.4 x 10-7 m/s (DCS125) which converts to 0.52 m/day and 0.02 m/day. Check via Bouwer and Rice analysis reveals similar values giving confidence. Log descriptions in BH101 indicate a coarse sandy gravel in the saturated zone with silt, so whilst layers of silt are present within the aquifer 0.5 m/day considered appropriate. HIgher values of 5 m/day to be used in sensitivity analysis.
Hydraulic Gradient	0.002	Fraction	Average hydraulic gradient on-site from 28th October 2020 monitoring round data. Data from 2nd and 9th November 2020 supports this value and direction of SE
Width of Contaminant Source	10-25	m	Contaminant specific - see table. Dimension perpendicular to groundwater flow.
Level 3 Soil			
Width of Plume	10-25	m	Contaminant specific - see table. Dimension perpendicular to groundwater flow.
Bulk Density	2.09	g/cm3	Values taken for Head Deposits in WSP BH07, BH08, TP15 and Nicholls Colton BH101
Effective Porosity	0.15	Fraction	From De Marsily (1986) for a gravelly sand (specific yield)
Distance to Compliance Point	50	m	Distance from the edge of the soil source zone to 50 m compliance point in aquifer
FOC	0.0028	Fraction	Site specific data for BH09 taken at depths of 2 and 4 m in sand/gravel at 0.26 and 0.30%

Contaminant Specific Parameters

Parameter	Value	Units	Justification
Benzo(a)pyrene			
Henrys Law Constant	1.76E-06	-	SC050021/SR7
KOC	128825	ml/g	log Koc = 5.11 from Science Report - SC50021/SR7
Half Life	1060	Days	Half life in groundwater Howard et al. 1991
Benzo(b) fluoranthene			
Henrys Law Constant	0.00000205	-	SC050021/SR7
KOC	104713	ml/g	log Koc = 5.02 from Science Report - SC50021/SR7
Half Life	1220	Days	Half life in groundwater / Howard et al. (1991) Environmental degradation rates
Benzo(k) fluoranthene			
Henrys Law Constant	0.0000017	-	SC050021/SR7
KOC	147911	ml/g	log Koc = 5.17 from Science Report - SC50021/SR7
Half Life	4280	Days	Half life in groundwater / Howard et al. (1991) Environmental degradation rates
Fluoranthene			
Henrys Law Constant	0.0000629	-	Science Report – SC050021/SR7
Koc	18197	ml/g	log Koc = 4.26 from Science Report - SC50021/SR7
Half Life	1990	Days	https://pubchem.ncbi.nlm.nih.gov/compound/9154#section=Environmental-Biodegradation Average of the 3.1 to 7.8 years quoted.
Benzo (g,h,i) perylene			
Henrys Law Constant	2.36E-06	-	Science Report – SC050021/SR7
Koc	416869	ml/g	log Koc = 5.62 from Science Report - SC50021/SR7
Half Life	1299	Days	Groundwater Chemicals Desk Reference Montgomery 4th ed. 3.23 to 3.56 years given – 3.56 years used as a conservative value.
Indeno(1,2,3-cd) perylene			
Henrys Law Constant	0.00000205	ml/g	Science Report – SC050021/SR7
Koc	87096	ml/g	log Koc = 4.94 from Science Report - SC50021/SR7
Half Life	1.46E+03	days	Howard et al. (1991) Environmental degradation rates
Chromium			
Kd	31622	ml/g	https://archive.epa.gov/epawaste/hazard/web/pdf/s0524.pdf. Converted from log Kd of 4.5
Half Life	9.00E+99	days	No biodegradation assumed.
Copper			
Kd	15849	ml/g	https://archive.epa.gov/epawaste/hazard/web/pdf/s0524.pdf. Converted from log Kd of 4.2
Half Life	9.00E+99	days	No biodegradation assumed.
TPH C16-C21 Aromatic			
Henrys Law Constant	0.013	-	TPH CWG Vol 5 p8.
KOC	15849	ml/g	TPH CWG log Koc = 4.2
Half Life	3650	Days	New Zealand Guidelines : 1999 : Modules. Guidelines for Assessing and Managing Petroleum Hydrocarbon Contaminated Sites in New Zealand. Ministry for the Environment.
TPH C21-C35 Aromatic			
Henrys Law Constant	6.70E+04	-	TPH CWG Vol 5 p8.
KOC	125892	ml/g	TPH CWG Volume 5 p8. Log Koc = 5.1
Half Life	3650	Days	New Zealand Guidelines : 1999 : Modules. Guidelines for Assessing and Managing Petroleum Hydrocarbon Contaminated Sites in New Zealand. Ministry for the Environment.

Soil source sizes

Contaminant	Width (m)	Length (m)	Justification
Cr	10	10	Elevated leachate in BH101 and DCS128 only
Cu	30	20	Elevated leachate in BH101 particularly so area of gravel pit taken for conservatism
TPH aromatic C16-C21	30	20	Elevated soil and groundwater concentrations in the vicinity of BH101, DCS128, DCS125 and DCS101
TPH aromatic C21-C35	30	20	Elevated soil and groundwater concentrations in the vicinity of BH101, DCS128, DCS125 and DCS101
Fluoranthene	30	20	Elevated soil and groundwater concentrations in the vicinity of BH101, DCS128, DCS125 and DCS101
Benzo(b) fluoranthene	30	20	Elevated soil and groundwater concentrations in the vicinity of BH101, DCS128, DCS125 and DCS101
Benzo(k) fluoranthene	30	20	Elevated soil and groundwater concentrations in the vicinity of BH101, DCS128, DCS125 and DCS101
Benzo(ghi)perylene	30	20	Elevated soil and groundwater concentrations in the vicinity of BH101, DCS128, DCS125 and DCS101
Indeno(123-cd) pyrene	30	20	Elevated soil and groundwater concentrations in the vicinity of BH101, DCS128, DCS125 and DCS101
Benzo(a)pyrene	30	20	Elevated soil and groundwater concentrations in the vicinity of BH101, DCS128, DCS125 and DCS101

Appendix B Selected borehole logs

CAPITA

BOREHOLE RECORD - BH101

Cable Percussion

NICHOLLS COLTON
GROUP

Site:						
A29 Eastergate						

Client:			Boring Diameter:	Casing Diameter:	Project No.:
Jackson Civil Engineering			150mm to 20.00m	200mm to 9.00m	G20107

Logged by:	UW	Ground Level:	14.99m AOD	Date:	30/07/30	Location: –	494838, 108999N	Scale:	1:50

Samples and in situ Tests			Water	Level (mAOD)	Depth (m)	Strata Description	Legend	Backfill
Ref:	Depth (m)	SPT N						
018	10.00					Stiff grey silty CLAY		
						...occasional stiff red silty clay bands between 10.50m and 13.0m		
821	11.00 - 11.50							
020	11.00							
U22	11.00 - 11.45	(100)						
023	11.50							
825	12.00 - 12.50							
024	12.00							
3	12.50	N=50						
827	13.00 - 13.50							
028	13.00							
831	14.00 - 14.50							
028	14.00							
U29	14.00 - 14.45	(100)						
030	14.50							
833	15.00 - 15.50							
032	15.00							
3	15.50	for 275mm						
835	16.00 - 16.50							
034	16.00							
839	17.00 - 17.50							
036	17.00							
U37	17.00 - 17.35	(100)						
038	17.40							
841	18.00 - 18.50							
040	18.00							
3	18.50	50 for 200mm						
843	19.00 - 19.50							
042	19.00							
3	20.00	50 for 200mm		-5.01	20.00			

Remarks and Water Observations

Sheet 2 of 3

1. Hand dug starter pit to 1.20m.
2. Unable to carry out SPT at 1.20m due to refusal on concrete (made ground).
3. Groundwater encountered at 5.90m, rising to 4.90m after 10 minutes and 4.10m after 20 minutes.
4. Borehole installed with 50mm standpipe (4.00m-6.00m response zone) and 19mm piezo standpipe (17.00m-20.00m response zone).

AGS

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BOREHOLE RECORD - DCS125A
Window Sampler

Site:
A29 Eastergate

NICHOLLS COLTON GROUP

Client: Jackson Civil Engineering			Boring Diameter: 100mm to 5.00m			Casing Diameter:		Project No.: G20107	
Logged by: UW	Ground Level: 15.741m AOD			Date: 17/07/20		Location: - 494698E, 109929N		Scale: 1:50	

Samples and in situ Tests			Water	Level (mAOD)	Depth (m)	Strata Description	Legend	Backfill
Ref.	Depth (m)	SPT N						
				15.54	0.20	MADE GROUND - Topsoil		
						Firm brown slightly gravelly very sandy clayey SILT. Gravel is angular to sub-angular fine to medium flint.		
				14.54	1.20	Medium dense angular to sub-angular flint GRAVEL in a brown silty slightly sandy clay matrix		
				13.74	2.00	Medium dense angular to sub-angular flint GRAVEL in a brownish cream silty sandy clay matrix		
D1	3.00 - 4.00							
C	4.00	N=52		11.74	4.00	Medium dense brownish cream gravelly sandy silty CLAY. Gravel is angular to sub-angular fine to coarse flint and chalk		
D2	4.50 - 5.00							
C	5.00	N=15		10.74	5.00			

Remarks and Water Observations

Sheet 1 of 1

1. Hand dug starter pit to 1.00m.
2. No groundwater seepages encountered during boring operations.
3. Borehole installed with 50mm HDPE standpipe (GL-0.50m plain, 0.50-4.50m slotted).

CAPITA

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