national highways

Lower Thames Crossing

6.3 Environmental Statement Appendices
6.3 Appendix 14.5 – Hydrogeological Risk Assessment (Part 2 of 2)

APFP Regulation 5(2)(a)

Infrastructure Planning (Applications: Prescribed Forms and Procedure) Regulations 2009

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Lower Thames Crossing

6.3 Environmental Statement Appendices Appendix 14.5 – Hydrogeological Risk Assessment

(Part 2 of 2)

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1 Introduction

1.1 Background

1.1.1 The A122 Lower Thames Crossing (the Project) would provide a connection between the A2 and M2 in Kent, east of Gravesend, crossing under the River Thames through a tunnel, before joining the M25 south of junction 29.

1.1.2 The A122 road would be approximately 23km long, 4.25km of which would be in tunnel. On the south side of the River Thames, the Project route would link the tunnel to the A2 and M2. On the north side, it would link to the A13 and junction 29 of the M25. The tunnel entrances would be located to the east of the village of Chalk on the south of the River Thames and to the west of East Tilbury on the north side.

1.1.3 The North Portal includes a southward dipping ramp entrance and a deep shaft area. The lowest point of the shaft would be -24m above ordnance datum (AOD).

1.1.4 As the ramp and shaft are below the groundwater level, which is approximately 1m AOD (Highways England, 2017) (Cascade, 2019), groundwater drainage is proposed so construction can proceed safely. A diaphragm wall is proposed around the perimeter of the shaft and ramp area, as part of the structural design and to aid groundwater control.

1.1.5 Groundwater control measures could cause drawdown and changes to the direction of groundwater flow. The underlying Chalk Group is a Principal aquifer (Highways England, 2017) and, in the North Portal area, is a sensitive receptor vulnerable to pollution from saline intrusion or potential movement of contamination from adjacent landfills. The Thames Estuary and Marshes (north of the River Thames) Ramsar site and the Mucking Flats and Marshes Site of Special Scientific Interest, both to the east of the North Portal, are also sensitive receptors.

1.2 Report and modelling objectives

1.2.1 This report has a focus on the development of the North Portal groundwater numerical model and includes the following:

a. Construction of the conceptual model based on Phase 1 and Phase 2 ground investigation data

b. Calibration against site-specific data including a time-variant calibration of tidal response in the Chalk

c. Simulation of the groundwater inflow into the excavation

d. Simulation of drawdown prediction of the groundwater level

e. Simulation of saline/freshwater interface movement

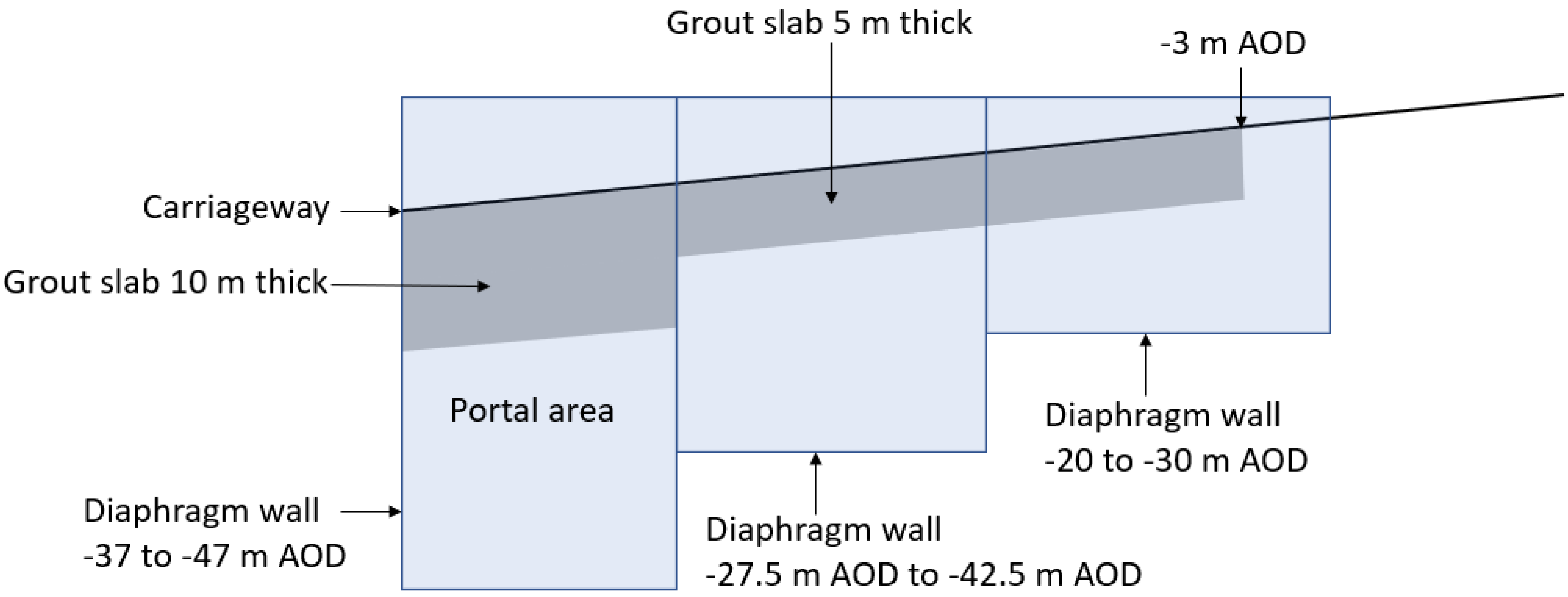
1.3 North Portal details

1.3.1 The groundwater model simulates the major components of the ‘main works’ relating to the North Portal, ramp and main tunnel. A detailed description of the overall Project is given in Chapter 2: Project Description (Application Document 6.1) and Appendix 2.1: Construction Supporting Information (Application Document 6.3).

1.3.2 The tunnel launch structure (referred to as the ‘box’, ‘shaft’ or ‘portal’) requires a large subterranean structure. The portal would be open during construction and incorporated into the cut and cover tunnel thereafter.

1.3.3 Plate 1.1 is a sketch of the suite of possible environmental mitigation measures for the North Portal excavation. The sketch includes maximum ranges for the thickness of the grout plug and depth of the diaphragm walls. The diaphragm wall would consist of individual overlapping panels filled with bentonite slurry during their excavation and displaced with concrete when completed (including reinforcement). Panels would be placed around the portal and ramp. This wall acts as ground support and is designed to be an effective groundwater flow cut-off barrier. A grouted block is proposed at the base of the excavation as further mitigation of groundwater ingress and for ground stability. Base grouting would be included along the length of the excavation where the ramp is below an elevation of -3m AOD.

Plate 1.1 Sketch of the potential environmental mitigations for the North Portal and shaft area



1.4 Assumptions and limitations

1.4.1 The following assumptions and limitations apply:

f. The infrastructure modelled and other simulations are in steady-state unless otherwise stated.

g. The models simulate saturated conditions only. This means it is not possible for perched water tables to be computed. This is a limitation for computing the water table within non-aquifers, such as in the Alluvium.

h. The conductivity of the diaphragm wall, concrete plug and potential slurry wall is based on advice from the Tunnel Portals Team.

i. Construction techniques and ground treatments would be used to avoid major dewatering during the excavation of the ramp and portal area. On this basis, it is assumed that rock/soil ground treatment would be achieved under ‘flooded’ conditions. This means that no advanced pressure relief dewatering has been included in the model.

j. Once constructed, the ramp and portal area would be made permanently watertight (to groundwater).

2 Methodology

2.1 Software

2.1.1 The model uses MODFLOW 2005, which is an industry standard software maintained by the United States Geological Survey (USGS) (Harbaugh, 2005). The model has been created using FloPy (Bakker *et al*., 2016). FloPy contains a set of Python scripts enabling one to build, run and postprocess MODFLOW, MT3D, SEAWAT and other MODFLOW-related groundwater programs. Visualisation and MODPATH simulations are also completed in Groundwater Vistas 7, produced by Environmental Simulations International (ESI) (Rumbaugh and Rumbaugh, 2017).

2.2 Model geometry

Model grid geometry

2.2.1 Table 2.1 shows the model grid geometry.

Table 2.1 Model grid extent

Top left easting (m)	559900
Top left northing (m)	182000
Bottom right easting (m)	562000
Bottom right northing (m)	173830
Delr (cell height)	35
Delc (cell width)	35
nCol (number of columns)	233
nRow (number of rows	228
Layers (no.)	46
Layer bottom (m below ground level (bgl))	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,22,24,26, 30,32,36,38,40,45,50,55,60,65,70,75,80,85,90,95,100, 105,110,115,120,130,150,170

2.2.2 The groundwater model uses a block model approach. In a block model the model layers are pre-defined and are independent of the geological layers. The geology is ascribed to the model by changing the material parameters of the individual cells to represent the geology. This approach differs from a standard approach whereby the top and bottom of model layers represents the top and bottom of geological surfaces. Advantages of this approach are as follows:

a. Rapid convergence often resulting in shorter run-times although more memory intensive. This allows for more vertical discretisation, especially in contaminant transport models.

b. Avoidance of pinched-out layers inside the model or at the top surface.

c. A more consistent representation of groundwater flow velocity within a layer. This can be beneficial if modelling a saline/freshwater interface or contaminant transport where solute dispersion is influenced by upstream and downstream velocities.

d. Better modelling of infrastructure features such as diaphragm wall, basal grout plugs and excavations (drains). These features are often independent of geological layers or do not fully penetrate geological layers. The elevation of these features may change as the design progresses. In a block model, these changes can be incorporated without changing the model layer structure, making the results comparable.

e. Relatively high vertical resolution around boundary conditions, thereby minimising model errors.

f. The numerical model is a block-centred finite difference model. All the model cells have a width and length of 35m. Within 20m of the ground surface, the thickness of the model layers is 1m. The top layer has the elevation of the topographic surface.

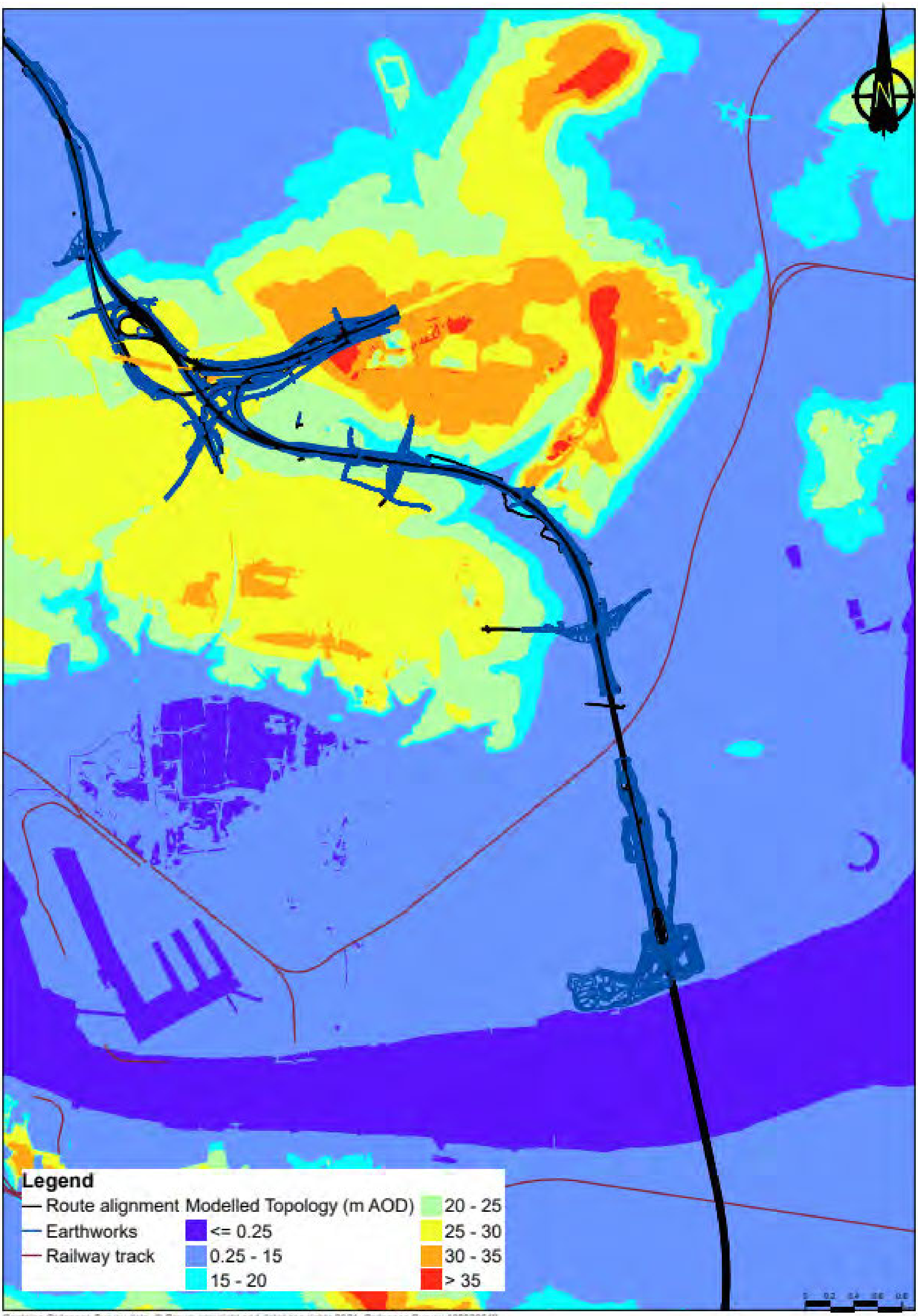
g. The bottom layer has a bottom elevation set to 170m below the topography. In total there are 46 layers in the model. Model layers are thinner in the top 30m to include for the increased geological data and project infrastructure in this zone. The top 20 layers have a thickness of 1m, between 20m and 30m bgl the layers are 2m thick, and between 30m bgl and 105m bgl the layers are 5m thick. This zone includes the groundwater level and unstructured Chalk in all parts of the domain. Below 105m bgl and to the maximum depth of the model of 170m bgl, the layer thickness is set to 10m.

MODFLOW layer setup

2.2.3 Layer 1 (the uppermost layer) is set unconfined (Type 1), so the transmissivity of the layer varies depending on the saturated thickness and the hydraulic conductivity. All remaining layers are Type 3 and can switch between unconfined and confined conditions. This is the default setting in MODFLOW. The transmissivity of these layers varies with the calculated saturated thickness and hydraulic conductivity. Specific yield or specific storage are used if the layer is unconfined or confined respectively. Rewetting is disabled for all layers.

2.2.4 Plate 2.1 shows the top elevation of the model and is the topography (Ordnance Survey, 2019).

Plate 2.1 Topography (m AOD)



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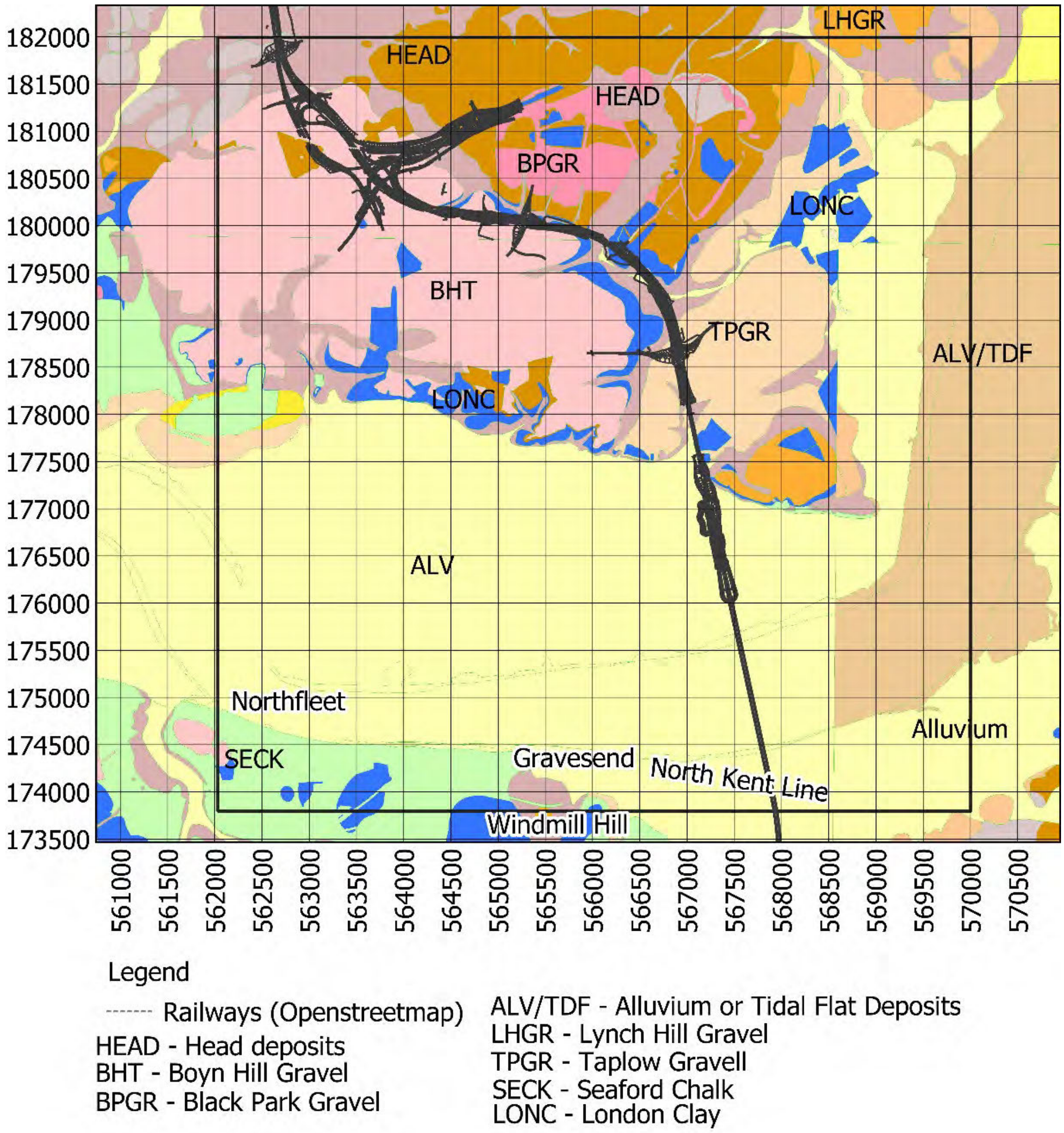
Geological model

2.2.5 A lithostratigraphic geological model purchased from the British Geological Survey (BGS) (2019) is used for the geological model. This geological model is a checked and peer-reviewed baseline. Results of the Project Phase 1 ground investigation (Perfect Circle, 2018) have been included in the model by the BGS.

2.2.6 The BGS model provides the skeleton of the model layers. The BGS model is assigned to model layers by comparing the model layer elevations with the geological surfaces.

2.2.7 Plate 2.2 shows the outcrop geology overlaid on the model grid in plan view for the model area.

Plate 2.2 Model domain (9x9km), cross-section location plan and outcrop geology



2.2.8 The geology is represented in the model using the hydrogeological parameters. The BGS model contains many layers, but there are four key surfaces/layers, which are described below:

a. Made Ground. The topography (Ordnance Survey, 2019) forms the top surface of the model. The base of the Made Ground surface is provided by the BGS. Made Ground in the model area includes areas alongside the River Thames, the Thames and Medway Canal and industrial land east of Gravesend.

b. Superficial deposits at outcrop including Alluvium, Head Deposits and River Terrace Deposits (RTD) underly the Alluvium. Assigned using elevation data from the BGS model for the bottom of the layer.

c. Eocene deposits, such as the London Clay, the Lambeth Group and the Thanet Formation. These cap the Chalk to the north of the North Portal.

d. Chalk. The top of the Chalk is defined from the BGS model.

2.2.9 The BGS geological model includes many ASCII format grids. The grids include a top elevation, bottom elevation and thickness for each different stratum identified by the BGS. FloPy imports all these as TIF files using the Geospatial Data Abstraction Library (GDAL) module. The raster band value of the TIF file is the elevation. The TIF files are re-gridded by GDAL[1] (Warmerdam, 2019) to match the model grid arrays. A comparison is done in Python whereby each BGS elevation grid is checked against the elevation of a model cell. The BGS layer with the least residual from this comparison is assigned to the cell and the suitable parameters are then applied to the cell. This process builds up a block model and overcomes many of the problems that can occur with complex geological models.

2.2.10 The groundwater model includes all 31 geological layers supplied in the BGS data.

Site-specific geological information

2.2.11 Site-specific geological data is gained from the site investigation and includes the following:

a. Material type at depth intervals as described in the Association of Geotechnical and Geo-environmental Specialists (AGS) dataset.

b. Construction Industry Research and Information Association (CIRIA) Chalk grade. This is split between types A, B and C (structured Chalk) and type D (structureless Chalk) within AGS datasets.

c. Rock Quality Designation (RQD). A low value of RQD of less than 0.1 can indicate very fractured Chalk rock materials. These areas of Chalk are often not able to be screened for hydraulic pressure testing.

d. Variable head pressure tests completed during fieldwork.

Assignment of AGS data to the model

2.2.12 Table 2.2 shows how the block model material parameters were altered to represent the AGS data. The geology listed in the AGS data is represented in the model by changing the hydraulic conductivity of the model cells to match parameters for the material found. At 180m distance from a borehole, the geology model value from the BGS model is used, whilst at 0m distance the AGS data is only used. In between, and/or where the radius of influence of multiple samples overlap, the average is given to the model cell.

[1] GDAL is a translator library for raster and vector geospatial data formats.

Table 2.2 Summary of AGS material included

Geological code recorded in AGS file	Conceptualisation	K_h, K_y (m/s)[1]	K_z (m/s)[2]	Sy[3]	Ss (1/m)[4]
Oth	Made Ground	As per bulk Made Ground value	As per bulk Made Ground value	As per bulk Made Ground value	As per bulk Made Ground value
CL	Clay superficial deposits	As per bulk Alluvium calibrated value	As per bulk Alluvium calibrated value	As per bulk Alluvium calibrated value	As per bulk Alluvium calibrated value
SA	Sand superficial deposits	$1x10^{-4}$	$0.3x10^{-4}$	0.1	$1x10^{-5}$
SI	Silt superficial deposits	As per bulk Alluvium calibrated value	As per bulk Alluvium calibrated value	As per bulk Alluvium calibrated value	As per bulk Alluvium calibrated value
GR	Gravel superficial deposits	As per bulk RTD calibrated value	As per bulk RTD calibrated value	As per bulk RTD calibrated value	As per bulk RTD calibrated value
AZCL/CKD/CK (in LECH/WHCK) RQD<0.1 (in LECH/WHCK)	Unstructured or karstic Chalk situated under the River Thames or under RTD. Corresponding with CIRIA grade Dc.	$5x10^{-2}$ Initial parameter to be calibrated.	$5x10^{-2}$ Initial parameter to be calibrated.	0.1 Initial parameter to be calibrated.	$1x10^{-5}$ Initial parameter to be calibrated.
CKABC RQD > 0.1	Structured Chalk	Calibrated parameter for the Chalk unit multiplier by 1/RQD		Calibrated parameter for the Chalk above the Belle Tout Formation	

[1] horizontal hydraulic conductivity in x and y directions
[2] vertical hydraulic conductivity
[3] specific yield
[4] specific, elastic storage coefficient

2.2.13 As there are over 50,000 lines of AGS data included in the model, this dataset is not presented in the report.

Packer and variable head tests

2.2.14 Packer and variable head tests are imported using the same approach as for AGS material type data. For packer and variable head tests, the radius of influence within the model is set to 120m and 60m respectively. This radius of influence is large enough that the data translates meaningfully into the conceptual model. It is noted that these types of tests generally have a smaller radius of influence than this. The hydraulic conductivity from the test result is applied to all cells within the screen interval and radius of influence. Annex A gives the data included in the model.

Cross-sections and conceptual model

2.2.15 Plate 2.3 shows a typical cross-section through the modelled geology along the Project route (colours presented are arbitrary). The section in Plate 2.3 is colour flooded by the hydraulic conductivity of the material. Annex B shows multiple cross-sections through the model along the line of the Project route.

2.2.16 Within the Chalk, the site-specific information has shown evidence for the following:

a. A fractured zone of Chalk gravels (CKD and AZCL) at the top of the Chalk sequence underlying the RTD (Point 2 on Plate 2.3).

b. A thicker zone of low RQD and CKD at depth beneath the River Thames with areas of missing core (AZCL) (Point 3 on Plate 2.3).

c. Along the central part of the River Thames, the Chalk rises up towards the channel bottom. There is no low permeability barrier between the River Thames and the top of the Chalk (Point 8 on Plate 2.3).

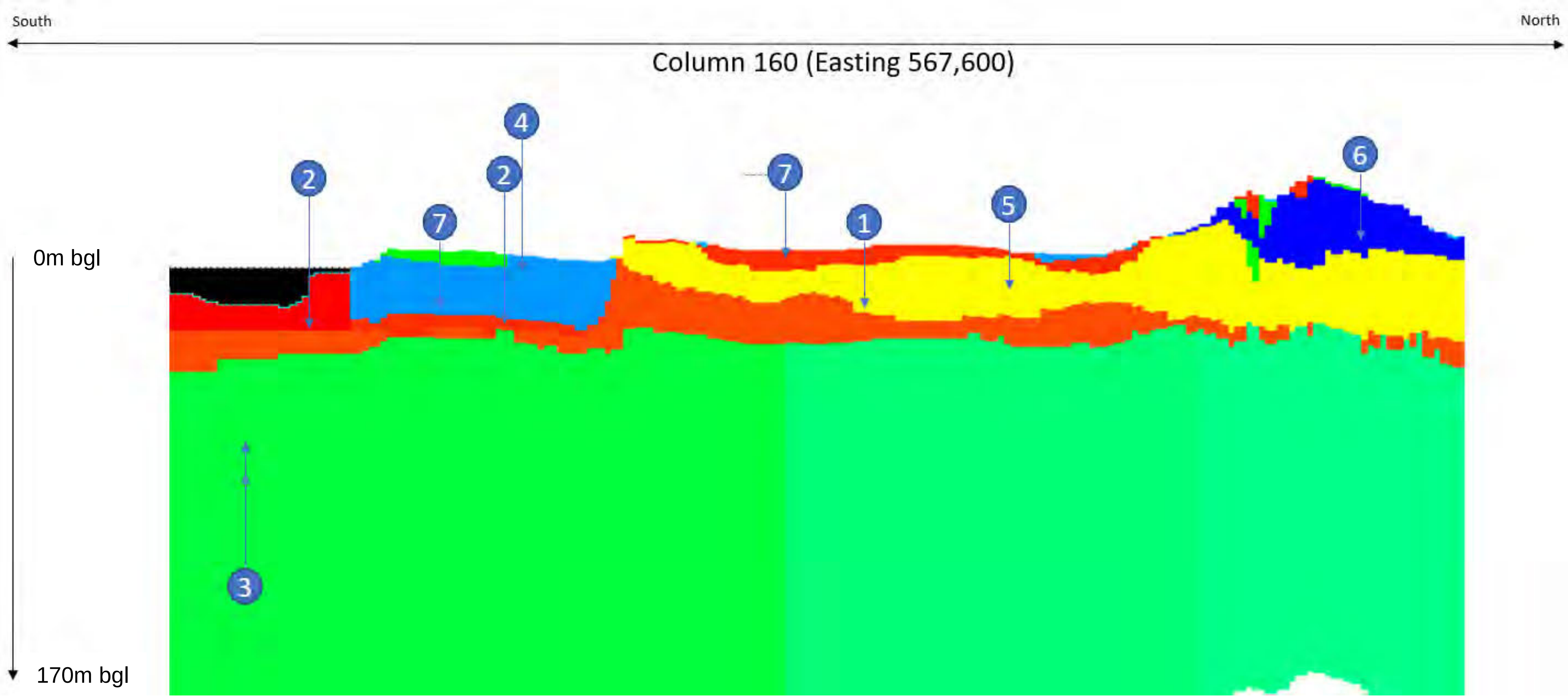
2.2.17 Within the Alluvium, the site-specific information has shown the following:

a. The Alluvium is predominantly clay material (Point 4 on Plate 2.3).

b. There are thin layers of gravel and sand on-lapping (draping) onto the Chalk within the Alluvium deposits, forming southward dipping sinuous discontinuous features (Point 4 on Plate 2.3).

2.2.18 The site-specific data corresponds well with the BGS model, particularly with regard to the elevations of the Alluvium, RTD and top of the Chalk.

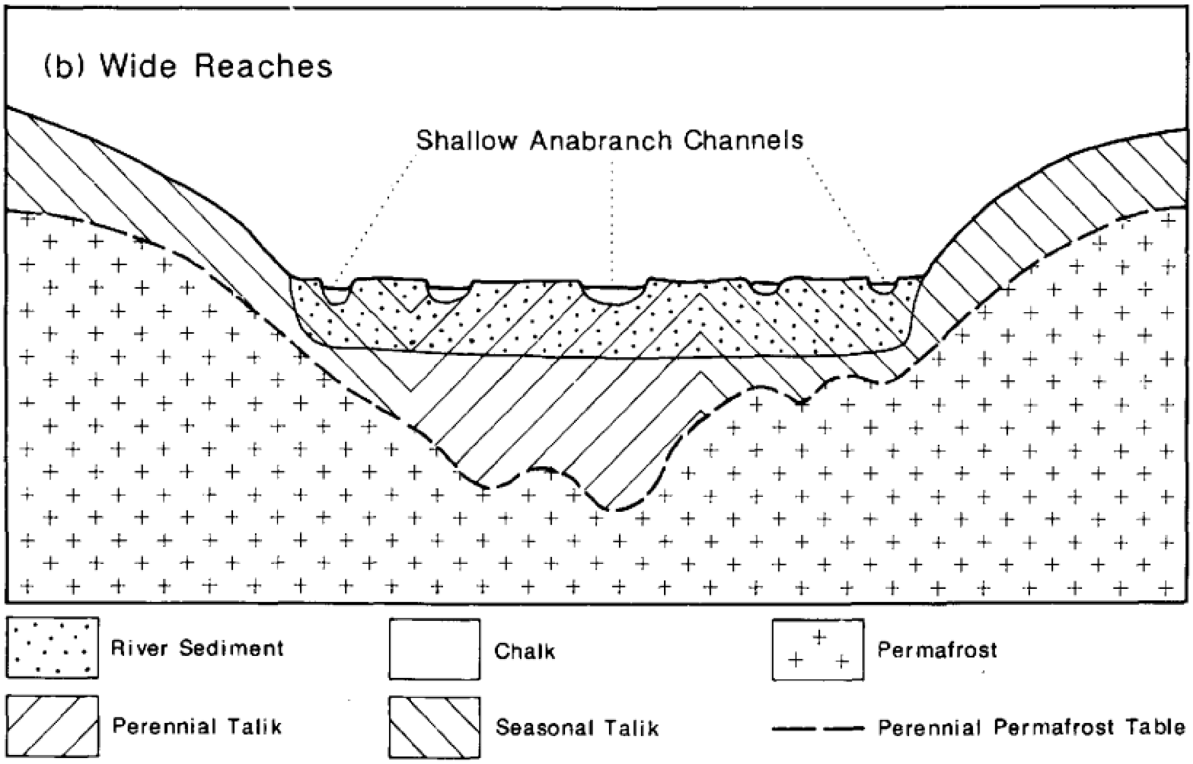
Plate 2.3 Geological structure including AGS information in the model along cross-section through Easting 567600



1. Belle Tout beds within the Seaford Formation
2. High K zones within the chalk, either CKD or RQD<0.1, recorded in borehole logs and generally at the top of the chalk
3. Zones of low quality (CKD or RQD<0.1) may be present at deeper locations indicative of fracturing
4. Interpolation within the alluvium and RTD giving layers of alluvium, silt and clay
5. Thanet Sands Formation
6. London Clay
7. RTD and outcrop gravel formations

2.2.19 The position of the high K Chalk around the River Thames is similar to that described in Younger (1989). Plate 2.4 shows the conceptual cross-section developed by Younger. It describes areas of higher permeability development within the Chalk around Shallow Anabranch Channels. For the Thames area, repetitive tidal action and a deeper scoured channel have caused increased dissolution of the Chalk in the zone of water table fluctuation and beneath the river sediments (RTD).

Plate 2.4 Cross-section proposed in Younger (1989)



2.3 Hydraulic conductivity

2.3.1 The model hydraulic conductivity (or permeability) ranges are collected from a range of sources including the following:

a. Previous site investigations for the Project (Perfect Circle, 2018)

b. Site investigations for the Project, reported in the Phase 2A Ground Investigation Factual Reports (Perfect Circle, 2020a, 2020b, 2020c)

c. The Thames Cable Tunnel Project (Haswell *et al*., 1970)

d. The Addendum Preliminary Sources Study Report (Highways England, 2017)

2.3.2 Table 2.3 provides parameter ranges for the model calibration created from a review of previously reported data ranges. Plate 2.2 shows the hydraulic conductivity mapped to the outcrop geology in Layer 1 of the model. Plate 2.3 shows the hydraulic conductivity in cross-section and Table 2.3 summarises the hydraulic conductivity ranges.

Table 2.3 Summary of hydraulic conductivity ranges

Geological unit	Hydraulic conductivity, minimum (m/s)	Hydraulic conductivity, maximum (m/s)	Hydrogeological behaviour and influences
Made Ground	-	Variable, approximately $1x10^{-5}$ to $1x10^{-4}$	Variable – depends on material content. Acknowledged to be cohesive in places but assuming higher values for worst-case.
Head Deposits	-	Variable, $1x10^{-8}$ to $1x10^{-6}$	Variable – depends on underlying geology
Alluvium	-	$k_h = 1x10^{-7}$ $k_v = 1x10^{-8}$ [1]	Aquitard or aquifer – depending on whether predominantly clay or granular material in the field but mapped as a single unit with an equivalent bulk permeability.
RTD	Lower values where clayey	$2x10^{-5}$ [1] to $1x10^{-3}$	Aquifer – depends on lateral extent and thickness
London Clay	Non aquifer	Non aquifer	This is a confining unit and has very limited potential to supply a water resource. On a broader scale may support underlying aquifers through slow leakage.
Harwich Formation	$1.09x10^{-5}$ [2]	$1.1x10^{-3}$ [2]	Aquifer
Lambeth Formation (Reading and Woolwich Formations)	$3.47x10^{-8}$ [2]	$2.29x10^{-3}$ [2]	Aquifer
Thanet Formation	$2x10^{-5}$ [2] $1.41x10^{-7}$ [3]	$4x10^{-5}$ [2] $3.34x10^{-6}$ [3]	Aquifer
Chalk	May vary with Chalk weathering grade and site-specific ground conditions. See Table 2.4 and Table 2.5.		Aquifer

References
[1] Bevan *et al*. (2010)
[2] The Physical Properties of Minor Aquifers in England and Wales (Jones *et al*., 2000)
[3] Annex N: Lower Thames Crossing Infiltration Drainage Hydrogeological Assessment North Portal to A13 Junction – Technical Note of Appendix 14.5 (Application Document 6.3). This report provides summary information from eight falling or rising head tests in Thanet Formation deposits.

Table 2.4 Chalk weathering grade and permeability range

CIRIA grade	Mundford grade	Chalk type*	Approximate permeability range (m/s)
A	I and II	Structured with bedding and/or jointing.	Highly variable because of presence of fissures
B and C	III and IV	Structured with bedding and/or jointing.	$1x10^{-5}$m/s to $1x10^{-3}$m/s
Dc	V and VI	Structureless, clast dominated.	$1x10^{-5}$m/s to $1x10^{-3}$m/s in relatively harder Chalk with chalk 'bearings' or frost shattered chalk evidenced
Dm	V and VI	Structureless, matrix dominated.	$1x10^{-7}$m/s to $1x10^{-9}$m/s

References for Table 2.4:
*After Spink (2002) and Preene and Roberts (2017).

Table 2.5 Project specific permeability results

Location	Chalk lithology	Reported Chalk permeability (m/s)
Thames Cable Tunnel (North Shaft), Tilbury, East London	Upper 9m of Chalk of high permeability. Permeability reduced significantly at depths greater than 15m below top of the Chalk. During the shaft sinking, the upper 6m of the Chalk indicated to be completely disintegrated. Similar to CKD (structureless Chalk) reported in the project AGS data. Also likely to have significant core loss (AZCL).	$1x10^{-3}$m/s to $4x10^{-6}$m/s in upper zones of Chalk from *in situ* permeability tests. $2x10^{-5}$m/s to $2x10^{-6}$m/s below 15m from top of Chalk, from Lugeon tests.
Medway Crossing, Chatham, Kent	Upper 2m to 5m of Chalk was noted to be structureless (Mundford grade VI to V) with grade III to IV structured Chalk below. Similar to CKD (structureless Chalk) reported in Project AGS data. Also likely to have significant core loss (AZCL).	$1x10^{-3}$m/s to $1x10^{-5}$m/s in structured Chalk (Mundford grade III to IV) estimated from *in situ* and laboratory tests $9x10^{-4}$m/s back-analysed from dewatering system flow rate. $1x10^{-7}$m/s to $1x10^{-9}$m/s in structureless Chalk (Mundford grade VI to V) estimated from *in situ* and laboratory tests.
HS1 Thames Tunnel, south side, Swanscombe, Kent (Bevan *et al*., 2010)	Upper Chalk. Implied that a high-permeability zone exists at the top of the Chalk beneath the RTD and at the edge of the Alluvium outcrop.	$2x10^{-6}$m/s to $1x10^{-4}$m/s from borehole packer tests. Numerical modelling to back analyse the dewatering system implied that a high-permeability zone of the order of $3x10^{-2}$m/s to $7x10^{-2}$m/s may have existed in Chalk in part of the excavation.

2.3.3 Plate 2.5 illustrates how the hydraulic conductivity of the Chalk reduces with its depth (Highways England, 2017). The ability to include this in the model is gained by subdividing the Chalk into CKD (unstructured Chalk), Belle Tout and Chalk.

Plate 2.5 Chalk horizontal hydraulic conductivity results from double packer testing carried out in boreholes located to the north and south of the River Thames in lowland areas

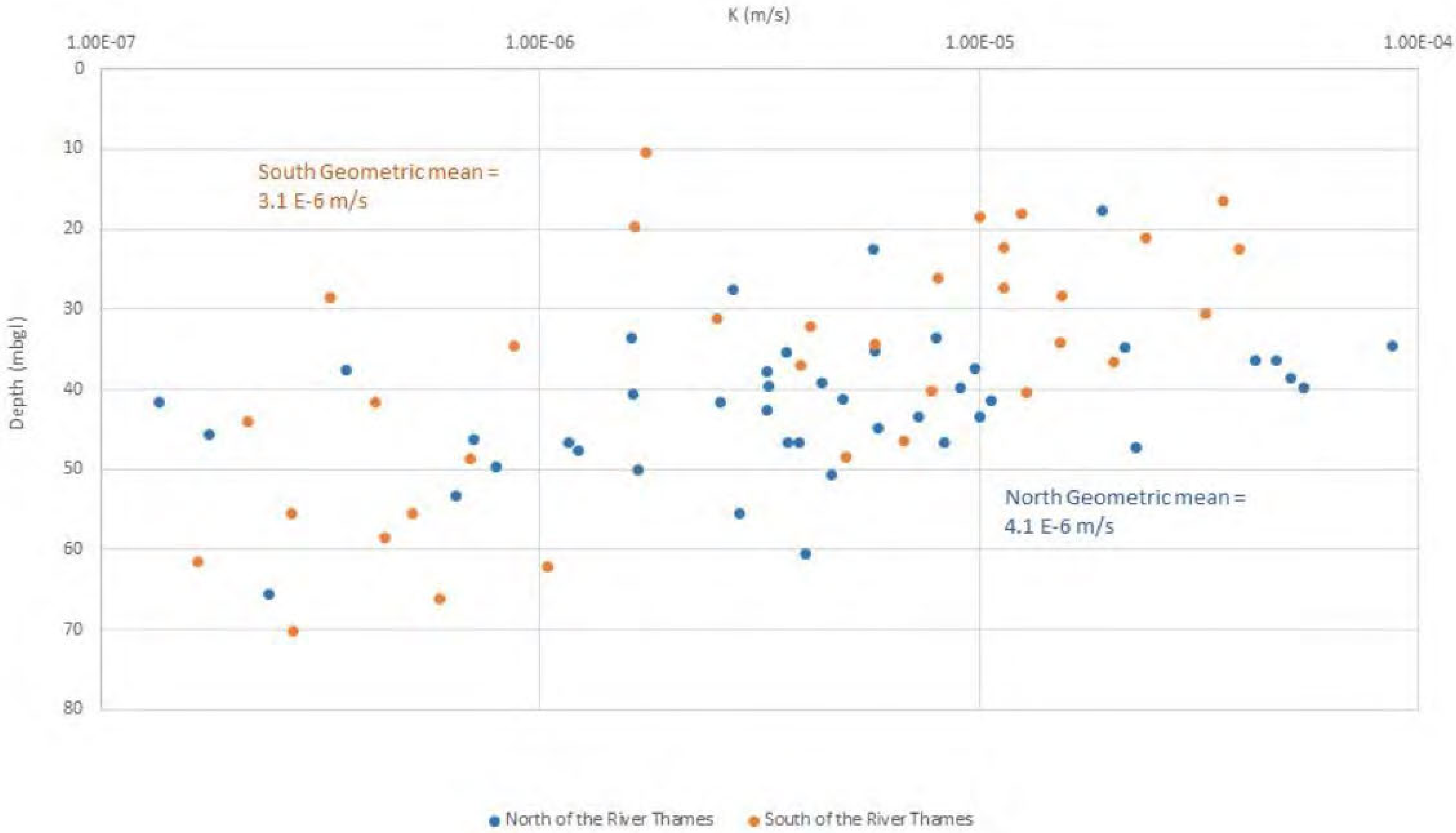
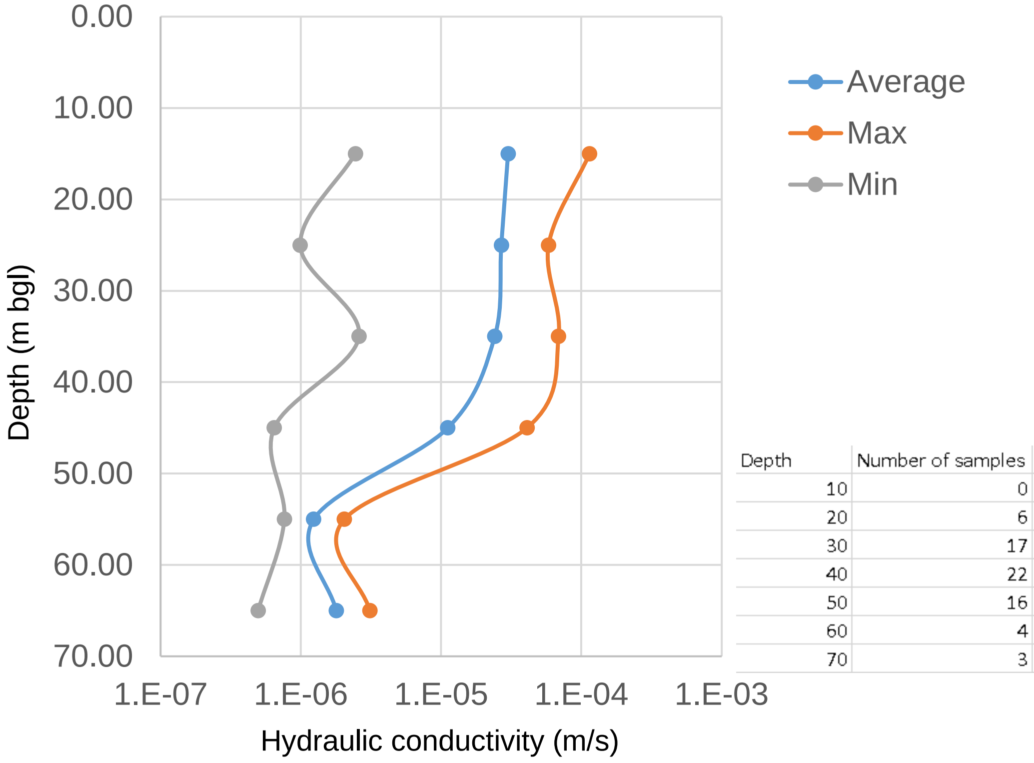


Plate 2.6 Packer test results against depth (2019–2020 AGS/SI packages)



Depth	Number of samples
10	0
20	6
30	17
40	22
50	16
60	4
70	3

2.3.4 Plate 2.6 shows the relationship of depth and hydraulic conductivity results from packer tests completed during Project Phase 2 ground investigation packages A-E. The reduction in hydraulic conductivity at between 50 to 60m AOD is approximately concurrent with the base of the Seaford Chalk Formation. A trend to lower hydraulic conductivity within the Chalk is present from around 35m bgl, possibly coinciding with the top of the Belle Tout Formation, present from approximately 15m above the base of the Seaford Formation. Packer tests assess a relatively small volume of aquifer. A rule of thumb is that the hydraulic conductivity calculated from a pumping test would be expected to be an order of magnitude larger than that for a packer test. This is because the amount of heterogeneity increases with the volume of rock tested.

2.3.5 There are various mechanisms by which this depth-trend may occur, such as the following:

a. Enhancement of discontinuity apertures by groundwater flows around the water table resulting in an increase in hydraulic conductivity. This enhancement may also occur at greater depths of burial where there has been an ancient water table.

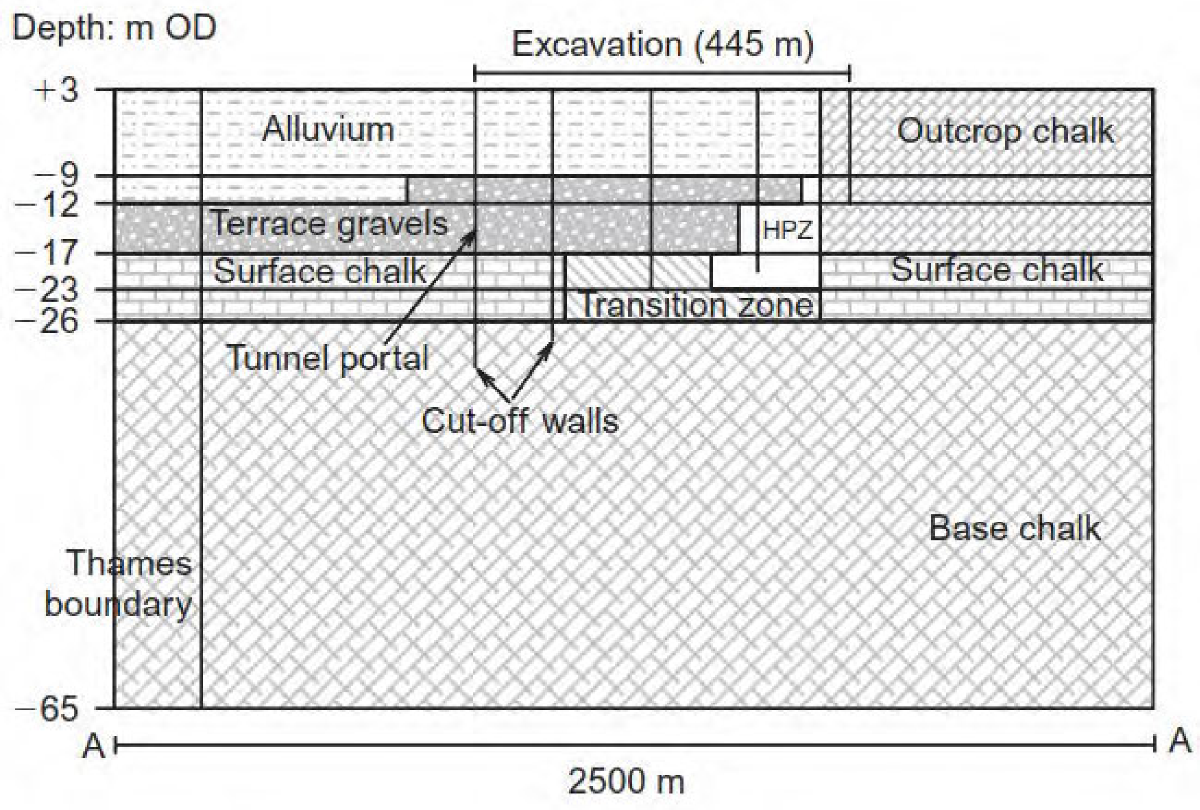
b. Historical frost-thaw weathering of the near-surface Chalk during pre-glacial conditions (Younger, 1989).

c. Closing of fractures due to burial resulting in a decrease in hydraulic conductivity with depth.

d. Presence of marl or shale beds at depth causing lower hydraulic conductivity horizons and likely reducing vertical hydraulic conductivity significantly.

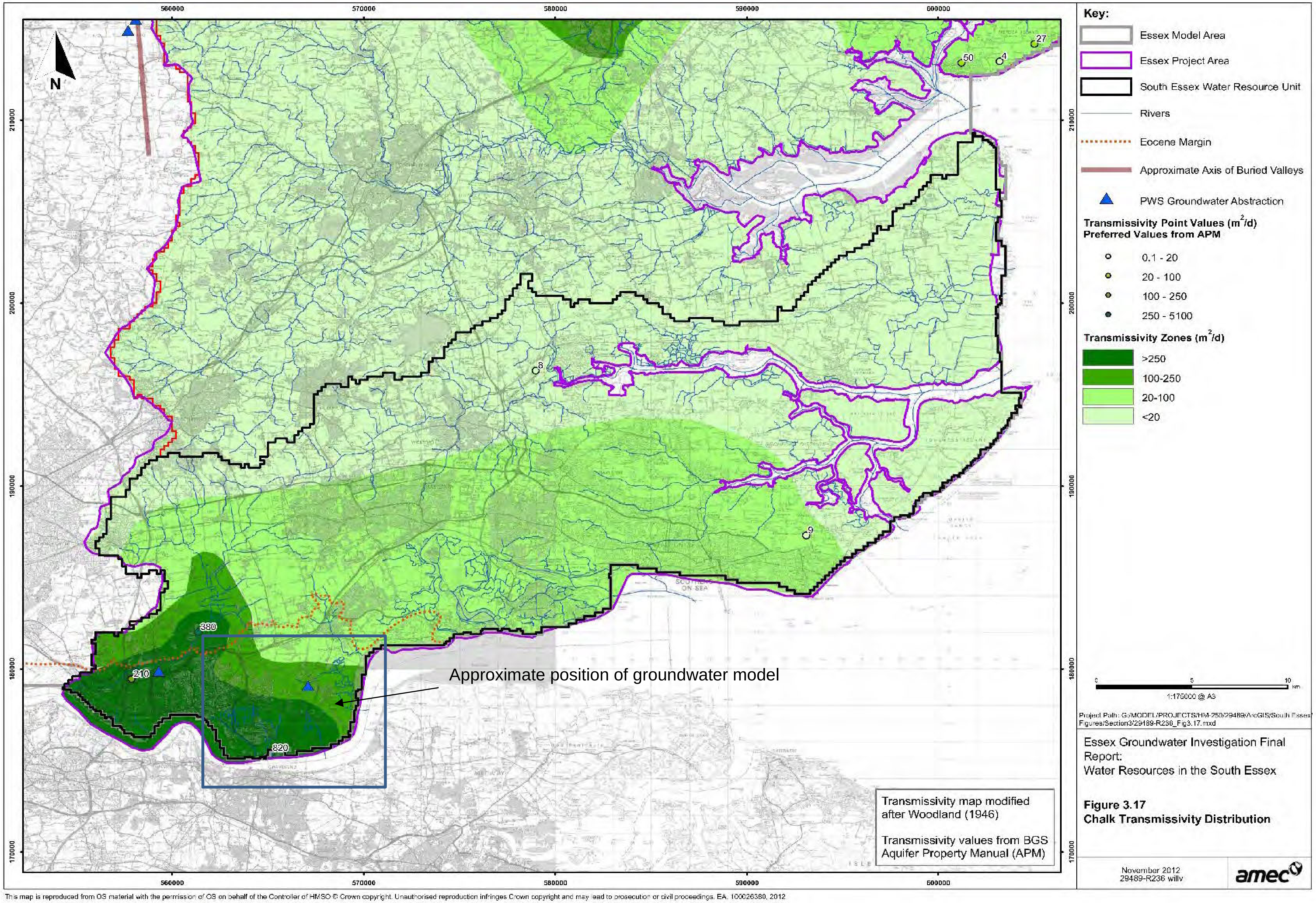
2.3.6 Table 2.4 includes an upper range for CKD (unstructured Chalk) that is similar to that encountered by High Speed 1 (HS1). Bevan *et al*. (2010) found that a zone of hydraulic conductivity in the range of $1x10^{-2}$m/s to $5x10^{-2}$m/s was present. The conceptual model was that this zone extended beneath the RTD and at the margins of the RTD deposits (Plate 2.7). Beneath the RTD, the zone was labelled the 'Transition Zone', while at the margin of the RTD it was labelled the 'Highly Productive Zone' (HPZ). The performance of the HS1 dewatering system could not be explained without these zones. This distribution has similarities with the distribution of high transmissivity zones shown in Plate 2.3, caused by the presence of CKD and Chalk RQD of less than 0.1. It does not appear that the Highly Productive Zone identified is present north of the River Thames or in the Project North Portal.

Plate 2.7 Extract from Bevan *et al*. (2010)



2.3.7 Plate 2.8 shows the Chalk transmissivity within the model area. The plate highlights that the Chalk transmissivity decreases northwards from the River Thames, across the model domain. The transmissivity at the site is expected to be over $250m^2/d$; the central part of the site has a range of $100m^{2/}d$ to $250m^2/d$ and the northern part is less, between $20m^2/d$ and $100m^2/d$. In the groundwater model, the transmissivity is mostly from shallow fractured and unstructured Chalk and the Seaford Formation.

Plate 2.8 Depiction of transmissivity in the Chalk (Environment Agency, 2016)

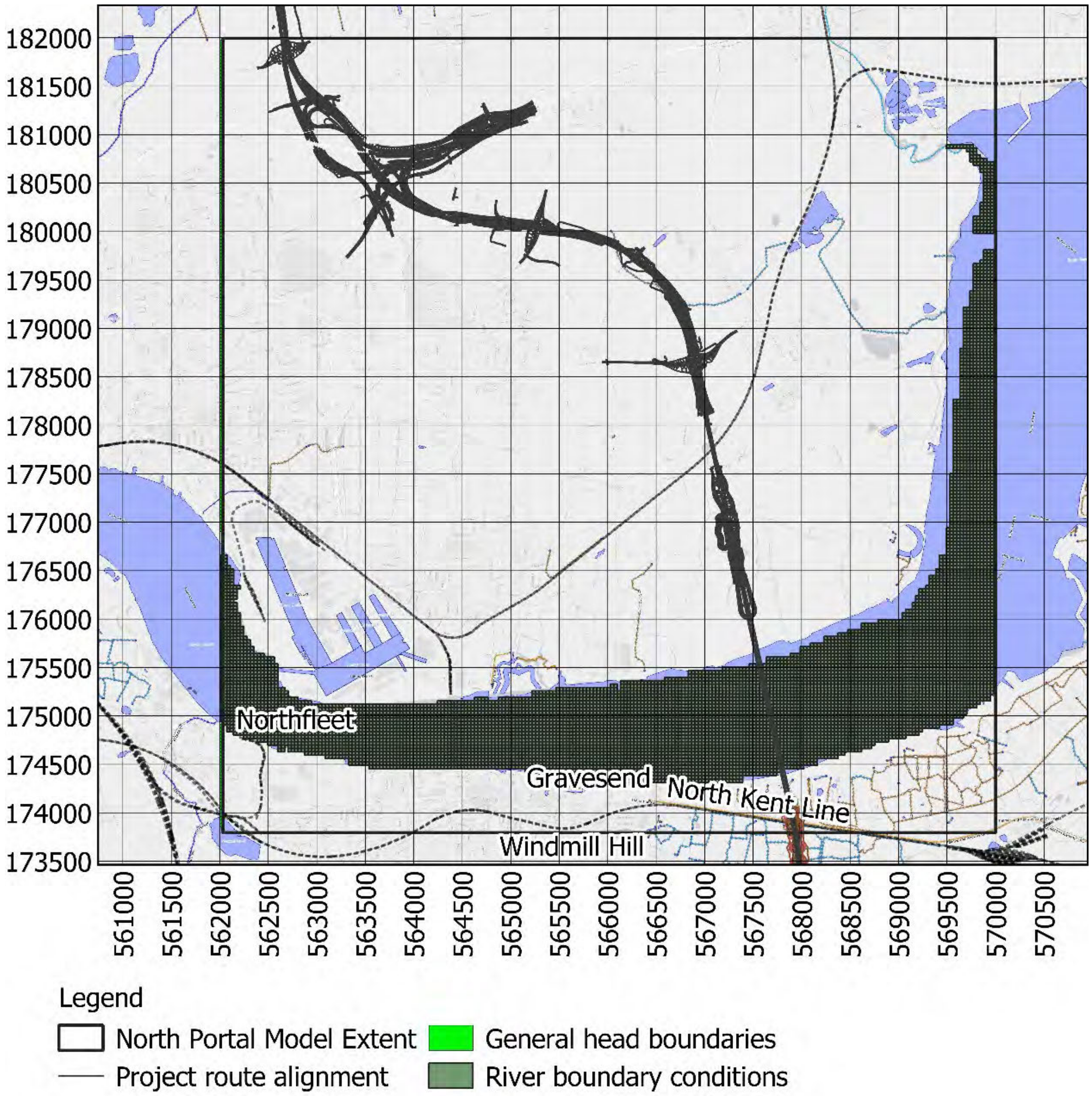


2.4 Boundary conditions

River Thames

2.4.1 Plate 2.9 shows the location of the river and general head boundary conditions. The Thames Estuary is along the southern model boundary. This is a river boundary condition has a river bottom elevation, stage and conductance. The river boundary conditions allow for water to move out or into the boundary from the aquifer.

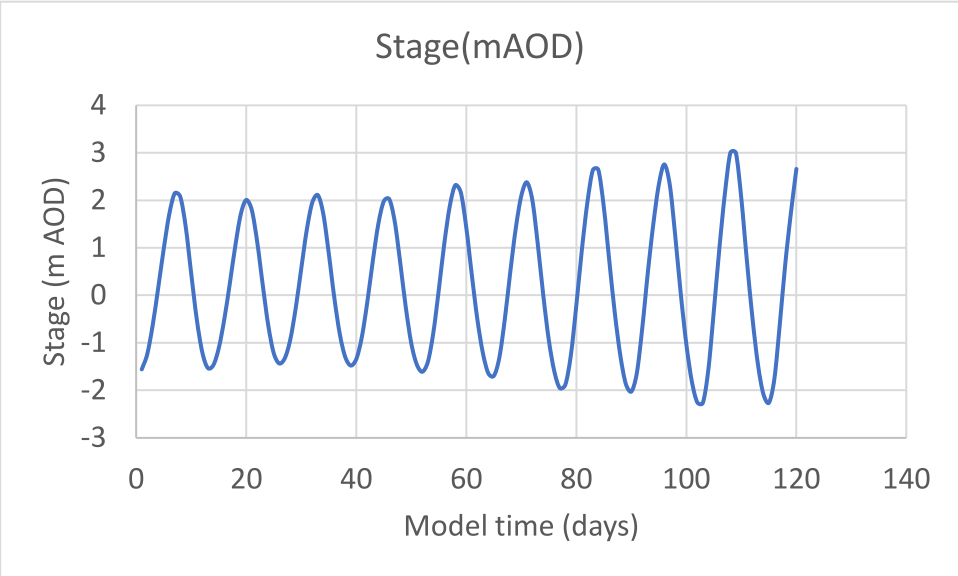
Plate 2.9 River and general head boundaries



2.4.2 The boundary is assigned into the single layer that encompasses the river bottom elevation. Layers above this are made inactive.

2.4.3 The stage is 0m AOD in steady state conditions. The time-variant simulation starts at 00:00 on 04 March 2020 and the stage follows the Thames tide at one-hour stress periods.

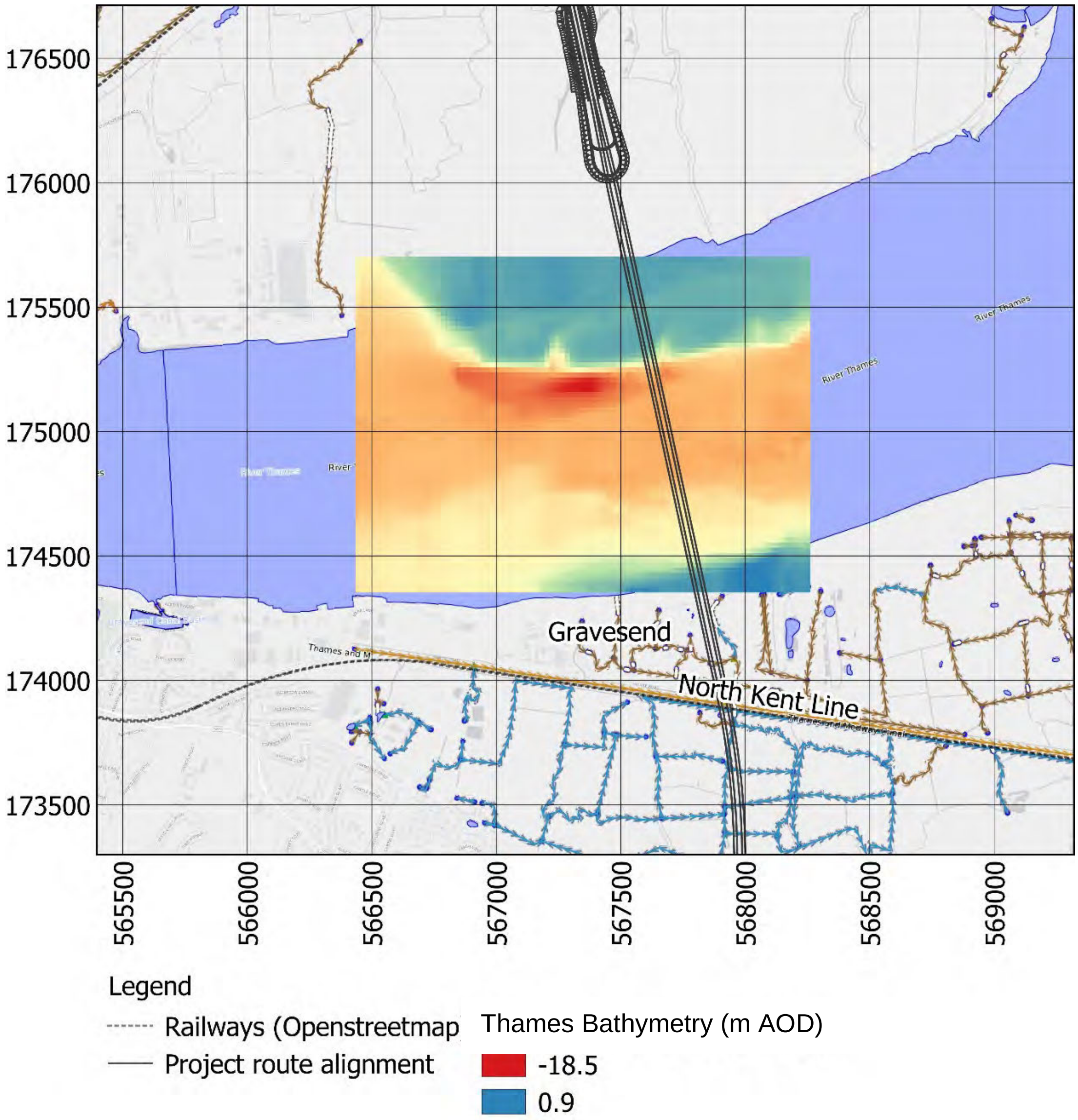
Plate 2.10 Stage for the Thames tide time-variant model



2.4.4 The rate of flow (per metre length of boundary) depends on the conductance of the boundary and a river 'stage'. The conductance is a function of the hydraulic conductivity, cell size and thickness of the riverbed in which the boundary resides. In practice, this is often a calibrated arbitrary value as riverbed information is not known. For this model, the riverbed conductance is the hydraulic conductivity of the river boundary model cell multiplied by the area of the cell.

2.4.5 Plate 2.11 shows the Thames bathymetry data collected for the Project. The riverbed elevation is matched to bathymetry information where it is available and is set to -13m AOD where it is not known. This is an approximation inferred from river geophysical survey results. The river bottom elevation is checked against the model layer elevations during assignment to avoid errors

Plate 2.11 Thames bathymetry data



2.4.6 During the model build process, the river bottom is checked against the minimum stage in the tidal range simulated. River cells are not applied where the minimum stage is less than the river bottom. This scenario may occur when modelling a tidal scenario at the river edges.

General head boundaries

2.4.7 The model simulates a part of the broader Chalk aquifer and so the aquifer continues out of the model to the north and east. A general head boundary (GHB) represents a constant head at a distance from the boundary cell. The amount of flow from or into the cell depends on:

a. the head difference between the model and the GHB

b. the GHB head value

c. the conductance of the cell

2.4.8 The GHB is useful where boundary effects are possible and for the case that the aquifer extends out of the model domain. The boundary assignment uses the MODFLOW-GHB module. A GHB is defined using a head and a conductance. The conductance is a combination of the hydraulic conductivity of the cell, boundary cell area and distance to the conceptual source of recharge.

2.4.9 Plate 2.9 shows the locations of the GHB in the groundwater model. A GHB is assigned to the western edge of the model domain. This is used to represent the continuation of the aquifer to the west. It is assigned with a hydraulic head that matches the February 2014 water level observed data.

2.4.10 The northern model boundary is no-flow. A groundwater divide caused by recharge to the outcrop RTD is present along the northern boundary edge. This no-flow boundary is conservative in terms of drawdown impact prediction.

Infrastructure – portals and tunnel outflows

2.4.11 The HFB (horizontal flow barrier), DRN (drain) and WEL (well abstraction) packages are used to create the infrastructure boundary conditions:

a. The drain boundaries simulate the North Portal and ramp excavation.

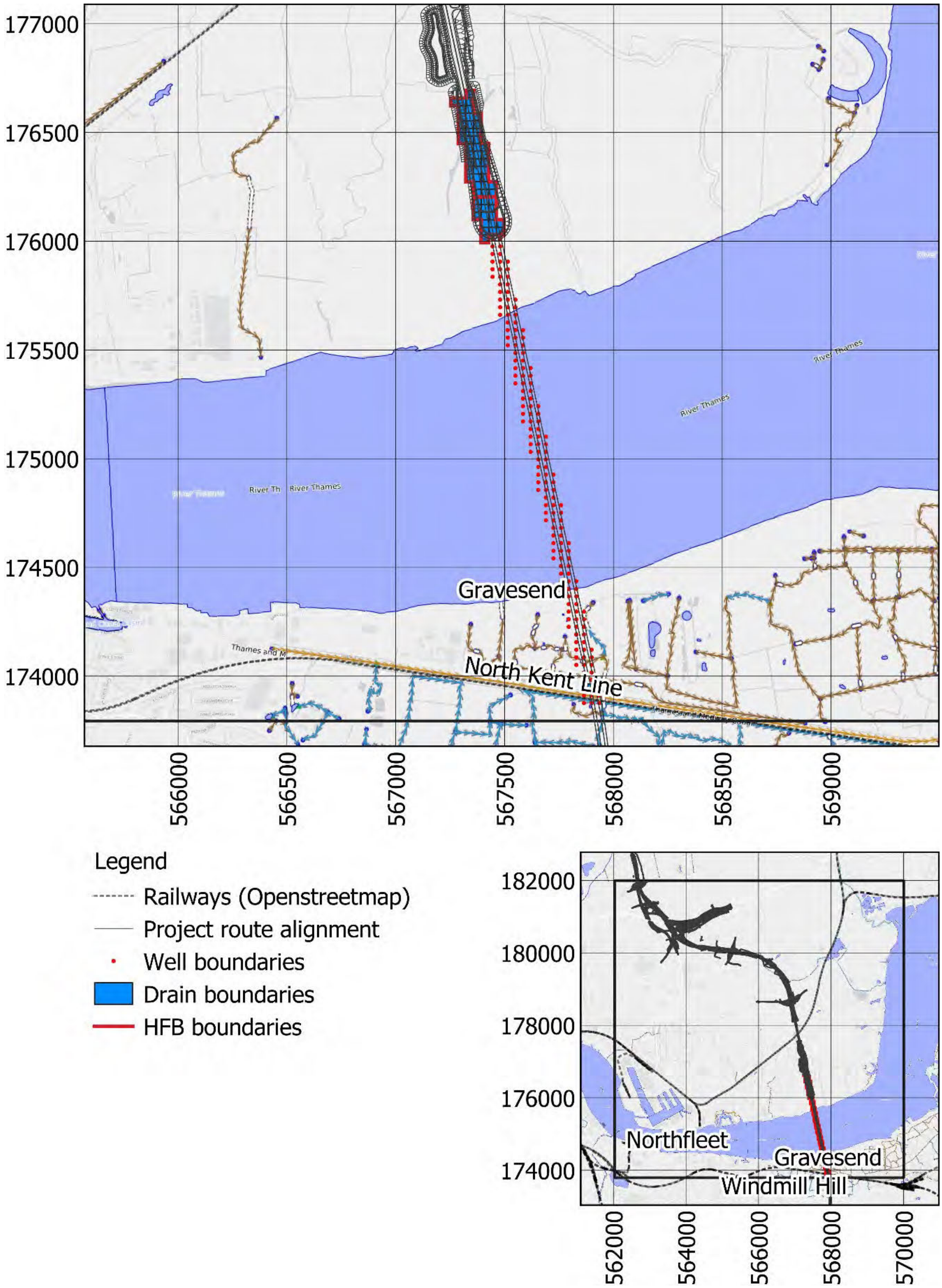
b. The WEL boundaries simulate the prescribed inflow rates into the main tunnel and cross-passages.

c. The HFB boundaries are used to represent diaphragm walls.

2.4.12 The hydraulic conductivity for infrastructure cells must be altered to include for the presence of the infrastructure.

2.4.13 Plate 2.12 shows a plan view of the infrastructure boundary conditions used to simulate components of the Project in the ground model.

Plate 2.12 Boundary conditions



2.4.14 Annex B provides cross-section views showing the Project infrastructure including drains, HFBs (representing the diaphragm walls) and wells (representing the main tunnels).

2.4.15 Table 2.6 provides details of the infrastructure boundaries in the model.

Table 2.6 Infrastructure boundary conditions

Feature simulated	Values	Boundary
Excavation	Elevation varies in different model cells, given the average elevation of the feature. Layer 1 elevation modified to match the excavation final surface.	DRN package. Drain cell applied to Layer 1 only. Conductance matching plug hydraulic conductivity multiplied by cell area and divided by the cell thickness.
Diaphragm walls	Varying in each cell in each layer where the top elevation is higher than the base of the wall. Three elevation zones (-20m AOD, -27.5m AOD and -37m AOD)	HFB package (horizontal flow boundary). Thickness: 1.2m. Hydraulic conductivity: $1x10^{-7}$m/s. This value is likely to be conservative (high) for a typical diaphragm wall installation.
Grout plug	Two zones. 10m thick in the portal area. 5m thick in the ramp area where the grout plug is below -3m AOD.	Change in horizontal and vertical hydraulic conductivity to $1x10^{-7}$m/s.
Slurry wall	In all layers where the top elevation of the layer is above the base of the diaphragm wall. Located outside of the East Tilbury Landfill but close to its western edge.	HFB package (horizontal flow boundary). Thickness: 1.2m. Hydraulic conductivity: $1x10^{-9}$m/s
Main tunnels (2 no.)	Variable elevation 16.8m diameter	The WEL package is used. A single well boundary per model cell with tunnel. The flow rate is calculated in advance, based on an inflow rate of 0.1L/d/m^2 (British Tunnelling Society and Institution of Civil Engineers, 2010). It is a factor of the prescribed inflow rate and the area of the circumference of the tunnel within the model cell, considering the cell thickness.

Feature simulated	Values	Boundary
		The total flow calculated for the main tunnels within the model area is 18.4m^3/d (0.2L/s). If a prescribed inflow of 0.5L/d/m^2 is used, the flow rate is proportionately larger. The tunnel would be surrounded by a concrete perimeter (tunnel lining), which is assumed to have a low hydraulic conductivity ($1x10^{-7}$m/s). The tunnels make up a large part of the volume of a model cell. It is necessary to reduce the hydraulic conductivity of the cell, to determine any mounding impact of the tunnel. This is calculated by comparing the volume of the tunnel in each cell with the remaining volume of the cell. Plate 2.12 shows a plan view of the boundary conditions relating to the main tunnel.

Linford abstraction well (Environment Agency abstraction licence 8/37/56/*G/0044)

2.4.16 Table 2.7 shows the details for the Linford abstraction well. The well is assigned over multiple layers using the standard well package. The flow rate for each layer is calculated using the transmissivity of the layer and the transmissivity of the aquifer across the total length of well screen.

Table 2.7 Linford abstraction well boundary conditions

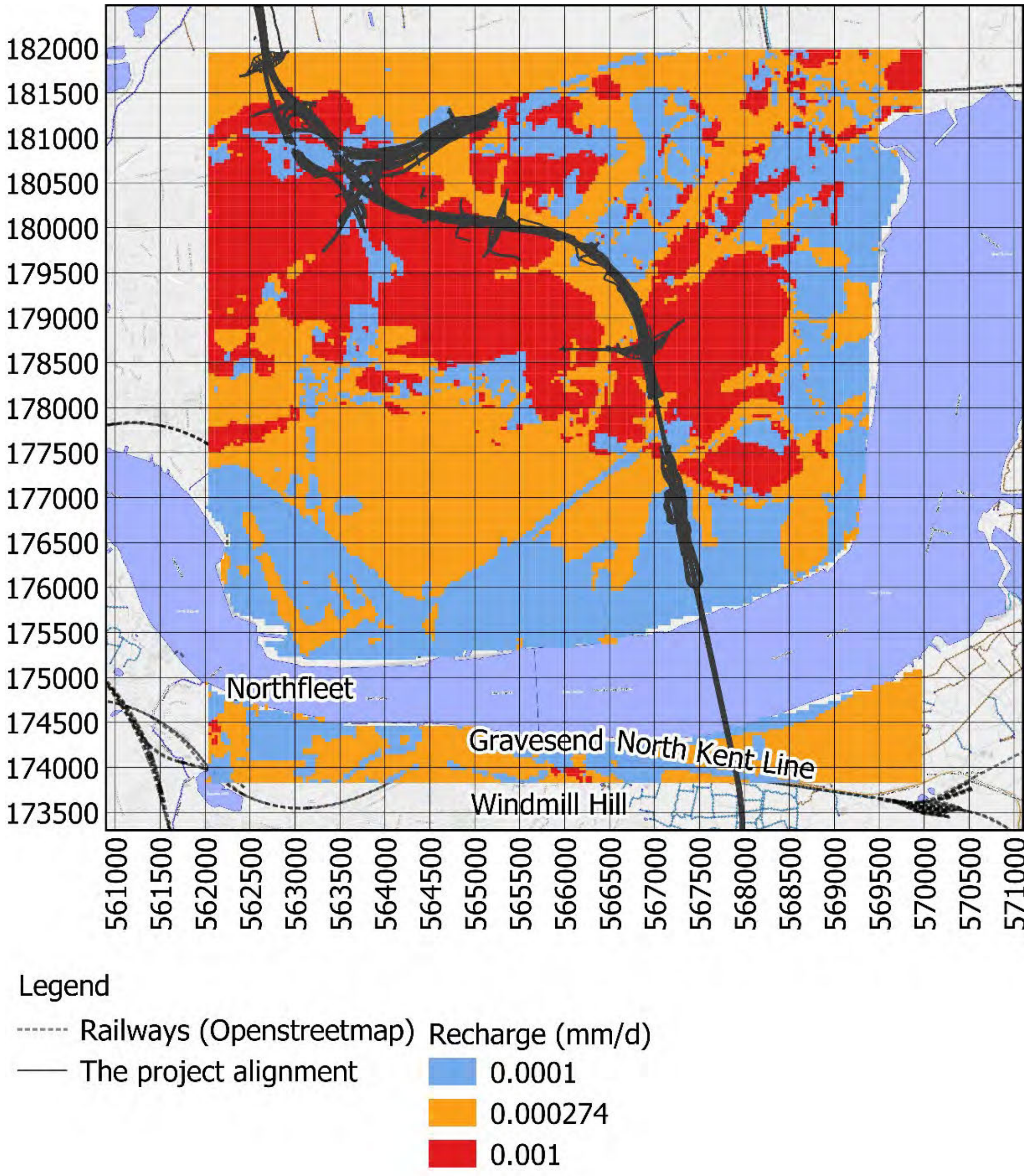
Linford abstraction well	
Easting	567168
Northing	179280
Screen top	18m bgl
Screen bottom	65m bgl
Abstraction rate	Variable: • Maximum licensed rate of 6.365ML/d • Average pumping rate of 1ML/d when pumping* • An instantaneous maximum rate of 25L/s

Recharge

2.4.17 Adams (2008) states that ‘*values* [of recharge] *of 100 mm/a were found for the north coast of Kent and values of over 280 mm/a to central and southern Kent*’. In the model, recharge is applied to the top-most active model cell, excluding cells with river or drain boundary conditions.

2.4.18 Plate 2.13 shows the recharge applied to the groundwater model.

Plate 2.13 Recharge applied to the model based on elevation and material type



2.4.19 Table 2.8 describes the expected distribution of recharge in the groundwater model, with topographical change. The recharge rates are defined based on the material type as well as the topographical elevation.

Table 2.8 Recharge in the groundwater model

Recharge rate[1] (metres/day)	Recharge rate (millimetres/year)	Distribution	Geological units	Conceptualisation
0.000767	280	Where the topography is above 100m AOD	Harwich Formation Lambeth Group Thanet Formation London Clay Chalk	Influenced by the amount of rainfall. Recharge to Chalk potentially influenced by slope, hence reducing with elevation. Recharge through lower-permeability deposits may be increased due to prolonged release from storage into unconfined Chalk.
0.000384	140	Where the topography is between 70m AOD and less than 100m AOD		
0.000274	100	Where the topography is less than 70m AOD		
0.000274	100	By outcrop type	Alluvium Tidal Flat Deposits Interglacial Deposits Head Deposits	Low elevation, with lower average rainfall and low hydraulic conductivity. Reasonable storage, but underlying Chalk is confined.
0.001	365	RTD at outcrop	RTD Gravels (Boyn Hill, Black Park, Taplow, Lynch Hill, Kempton Park, Glacio-fluvial Deposits, Stanmore, Hackney) Bagshot Formation	Highly permeable allowing for rapid infiltration of rainfall into the ground where these deposits are at ground surface.
0.0001		Made Ground	Made Ground	Likely highly layered material, often with perched water table.

[1] Vertical infiltration of percolation to the groundwater table

2.5 Calibration

Steady state calibration

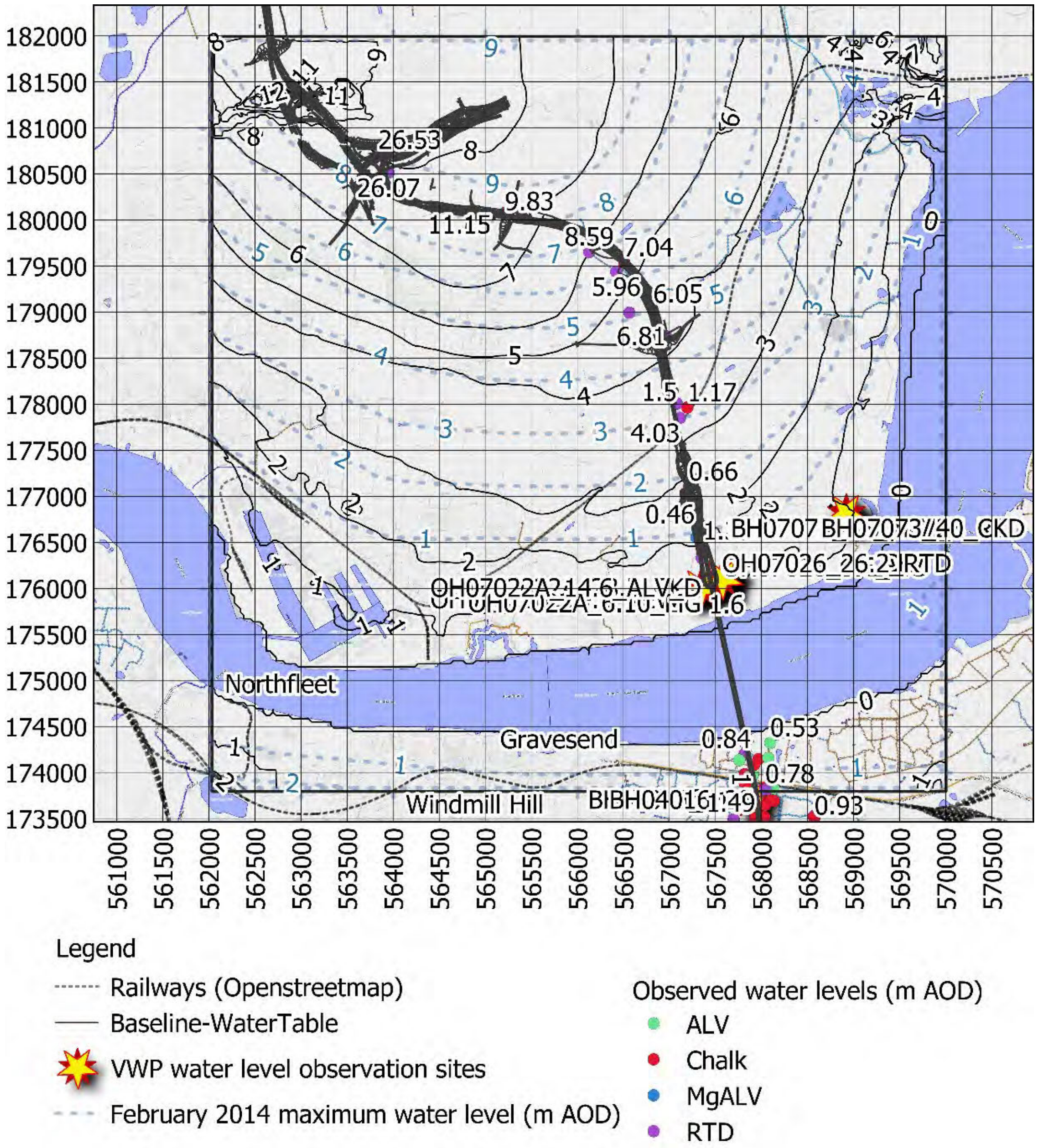
2.5.1 The steady state model was calibrated by comparing the model output with the following:

a. February 2014 groundwater contours (Plate 2.14, baseline model). These are interpolated from the Environment Agency regional monitoring network in the Chalk aquifer. They provide a grid across the whole model domain for calibration.

b. Plate 2.14 also shows the location of standpipe and vibrating wire piezometers (VWP) monitoring sites from which the maximum observed water levels from Project site investigation records have been used.

2.5.2 The borehole observation data shows similar trends as the February 2014 water level data from regional Environment Agency boreholes. The borehole data has a larger variability of water level on more local scales. Both data sets show that the groundwater level rises towards the north, where there is higher ground, outcrop gravels and likely higher recharge. The contour data is especially useful for calibrating the wider domain and model boundaries. The borehole data is most useful for the Project area. The calibration should aspire to achieve a good Standardized Root Mean Square Error (SRMSE) for both data sets, of less than 10%.

Plate 2.14 Water level data from observation sites used for calibration



2.5.3 The SRMSE is calculated for the February 2014 grid compared to the model domain as well as for observations within subzones for the Alluvium, RTD and Chalk. Table 2.9 presents the quality criteria according to which the model was calibrated, i.e. the relative importance (weighting) assigned to the different zones of the modelled domain for the calculation of the SRMSE.

Table 2.9 Weighting for steady state calibration

Subzone/zone	Data	Weighting	Justification
Whole domain Chalk water level	February 2014	45%	Reflects wider water balance and recharge/transmissivity ratio. Compensating for fact Project data is very linear in extent
Project – Chalk	Borehole water level monitoring data	45%	Important for controlling inflows into the Project.
Project – RTD	Borehole water level monitoring data	8%	Potentially important to Project inflows, but largely controlled by Chalk transmissivity.
Project – Alluvium	Borehole water level monitoring data	2%	Low conductivity and largely insensitive in steady state. High scatter due to very local inhomogeneities and perching, land drainage.

2.5.4 Plate 2.14 shows the scatter plots of calculated and observed water level data from observation sites. The SRMSE for each was calculated using the maximum and minimum observed water level of the whole data set and is as follows:

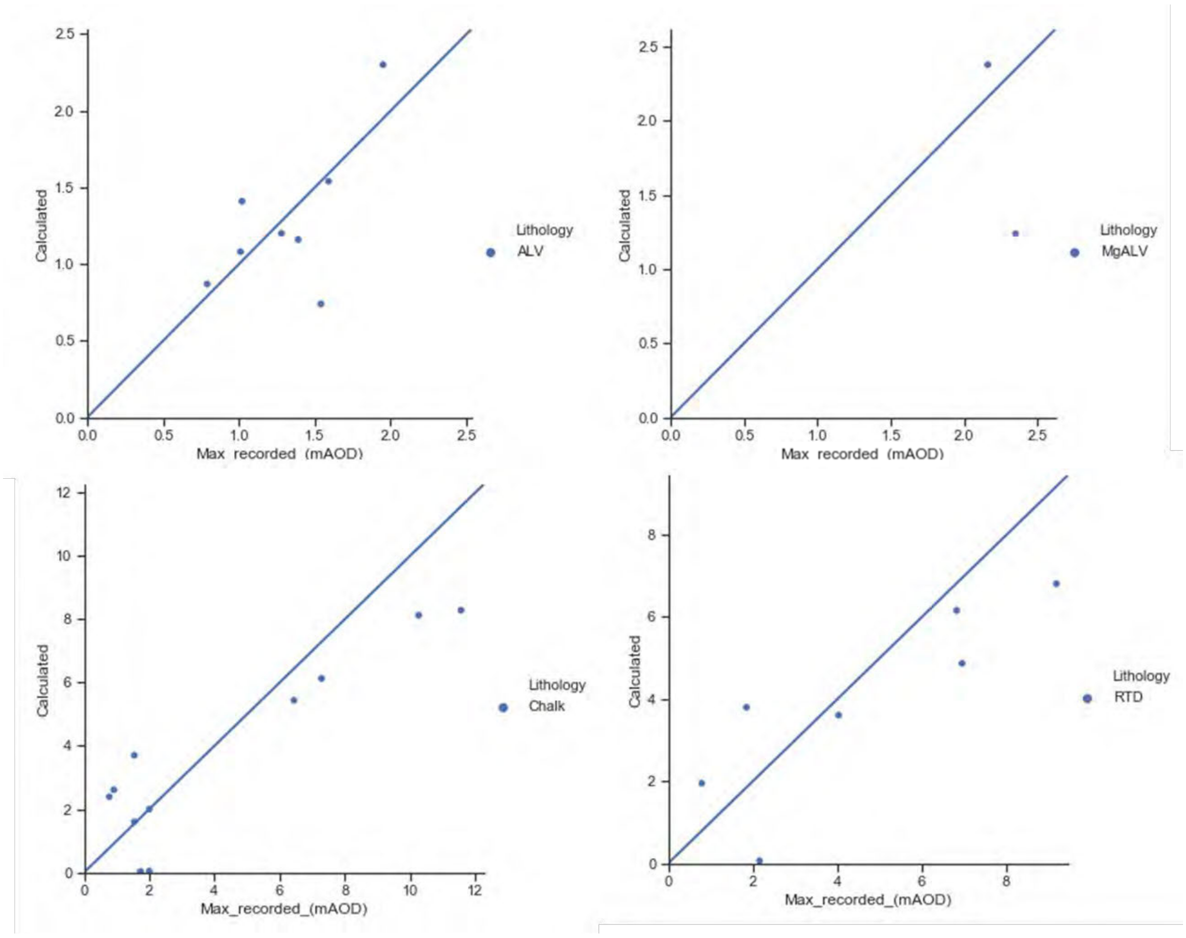
a. All observations: 4.8%

b. Alluvium: 2.2%

c. Chalk: 6.3%

d. RTD: 4.8%

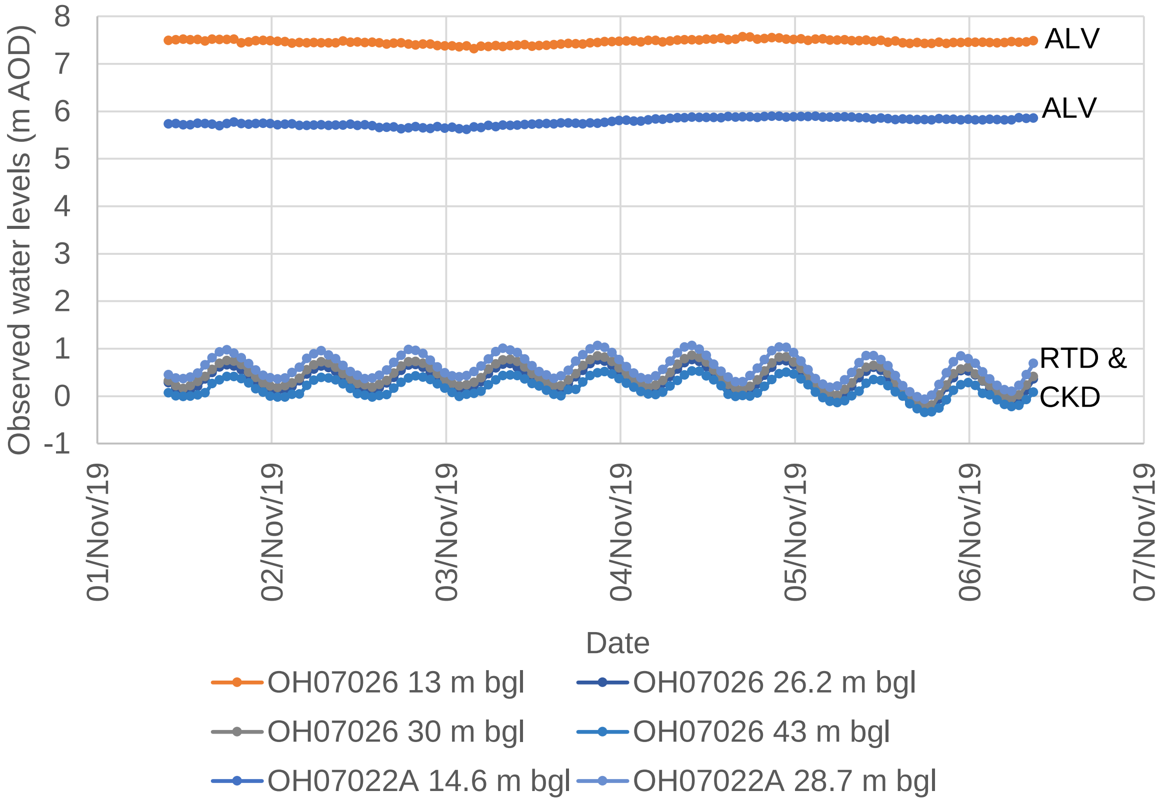
Plate 2.15 Scatter plots after manual calibration



Time-variant calibration

2.5.5 Plate 2.14 shows the locations of the VWP sites OH07022 and OH07026 which were used for time-variant calibration. Plate 2.16 shows the water levels at these sites at their different screen intervals.

Plate 2.16 VWP observations of tidal response in the Chalk (BH07026 and BH07022A)



2.5.6 The shallowest observations for each of these sites are at the base of the Alluvium at 13m bgl and 14.6m bgl. Both show no daily fluctuation. The deeper observations in the RTD and Chalk show significant daily oscillation. This shows that the Alluvium deposits are an aquitard as the water levels within it are very poorly connected to the RTD and Chalk aquifers beneath. The Alluvium deposits contain a perched water table.

2.5.7 The MODFLOW 'Hobs' package was used to extract water level data from the model at the right times, matching the observed data. A stress period of one hour was used to simulate the changing of the tide over a period of five days.

2.5.8 A manual iterative approach to calibration was used to adjust the material parameters to better fit the time-variant groundwater level data. The results presented under the 'steady state calibration' heading, above, also include these changes:

a. Beneath the central part of the Thames, the BGS model has a layer of Alluvium and RTD. In comparison, the ground investigation results show the Chalk rising to outcrop at the river base. A modification was required beneath the Thames to improve the connectivity with the Chalk.

b. The hydraulic conductivity of the deeper, 'bulk' Chalk is lower than that of the shallow or weathered chalk. Mapping by the Environment Agency (Environment Agency, 2016) suggests that the transmissivity of the Chalk north of the Project is likely between 20m^2/d and 100m^2/d. This area encompasses the Linford abstraction well. A transmissivity of 33m^2/d was used in the calibration.

c. The Alluvium was found not to be that sensitive, except that it has low hydraulic conductivity of 4x10^{-7}m/s. During time-variant simulations of the tide, a cycling upwards and downwards gradient develops between the Alluvium and Chalk. With such low hydraulic conductivity, recharge causes local mounding of the water table.

2.5.9 The observed tidal response is high. Such a tidal response can be achieved if there is a very high transmissivity, low storage and a strongly confined aquifer with the Chalk. Reviews of the nearby HS1 scheme showed that a thin but high transmissivity zone was present beneath RTD (Plate 2.7). After review of the AGS data for Chalk grade and core loss in the Chalk, this same zone of high transmissivity was included in the model. To obtain the high tidal response, the hydraulic conductivity of the unstructured, clast-dominated, Chalk in this area was found to be in the order of 1x10^{-2}m/s. Though the zone is only less than 5m thick in general, this high hydraulic conductivity determines the Chalk's large transmissivity. The high value has been previously reported during excavation in this locality (Bevan *et al*., 2010). It was also necessary that the RTD vertical hydraulic conductivity (k_z) was low so that the amplitude of the response was not dissipated.

2.5.10 Other changes included the following:

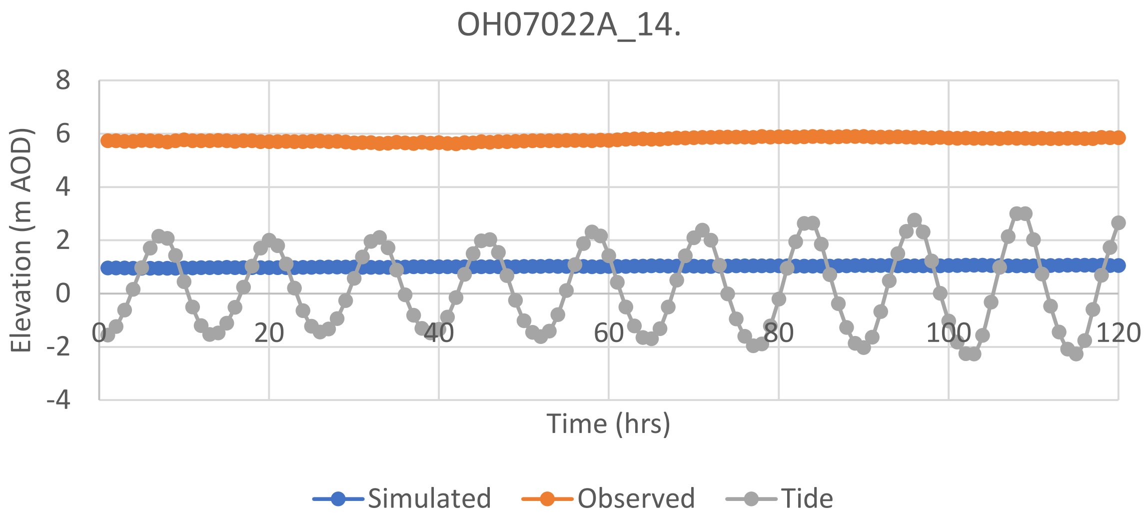
a. A zone with a hydraulic conductivity of 1x10^{-3}m/s (k_h=k_z) beneath the Thames to connect it with the Chalk

b. RTD gravel and chalk storage coefficient to 1x10^{-5}

c. A storage coefficient of 1x10^{-6} in the deep Chalk

2.5.11 Plate 2.17, Plate 2.18 and Plate 2.19 provide the calibration results showing both observed and calculated data. The calibration has focused on getting the correct amount of response by changing the model hydraulic conductivity parameters, structure and finally storage values. The VWP data has some uncertainty with absolute values as the field data matches poorly with manually dipped data in nearby boreholes. The raw VWP data has so been corrected to match the manual dips. VWP BH07073 has been excluded as all VWPs recorded the same erroneous water pressure.

Plate 2.17 Predicted and observed tidal variation for BH07022 at 14m bgl (top, Alluvium) and 28m bgl (bottom, CKD)



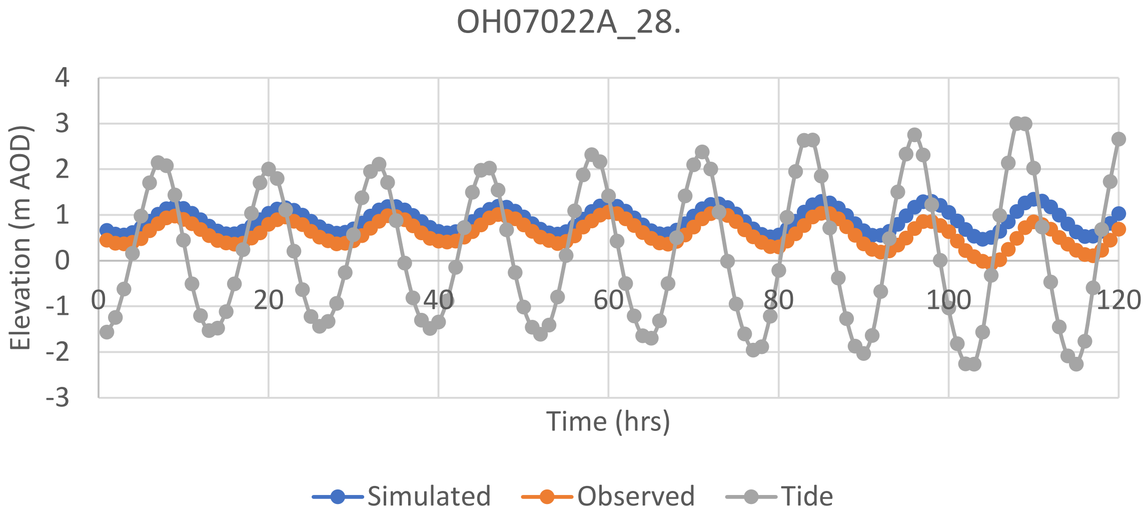
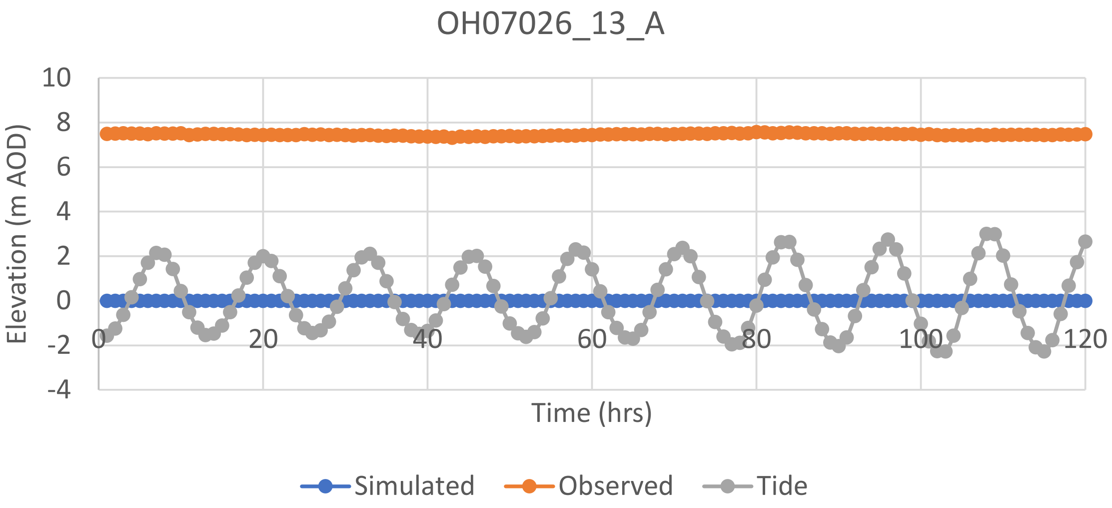


Plate 2.18 Predicted and observed groundwater levels for OH07026 at 13m bgl (top, Alluvium) and 26.2m bgl (bottom, RTD)



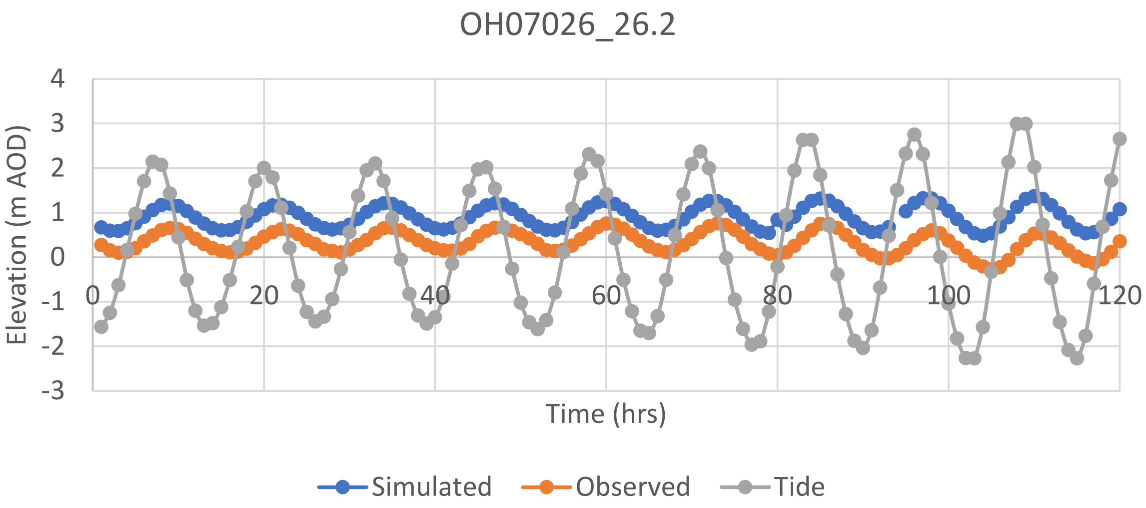
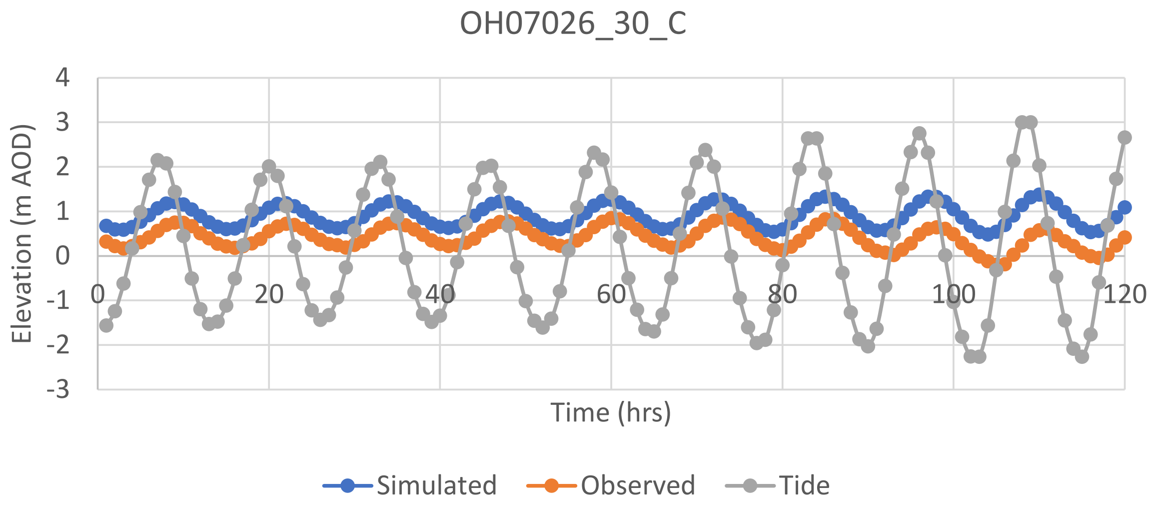
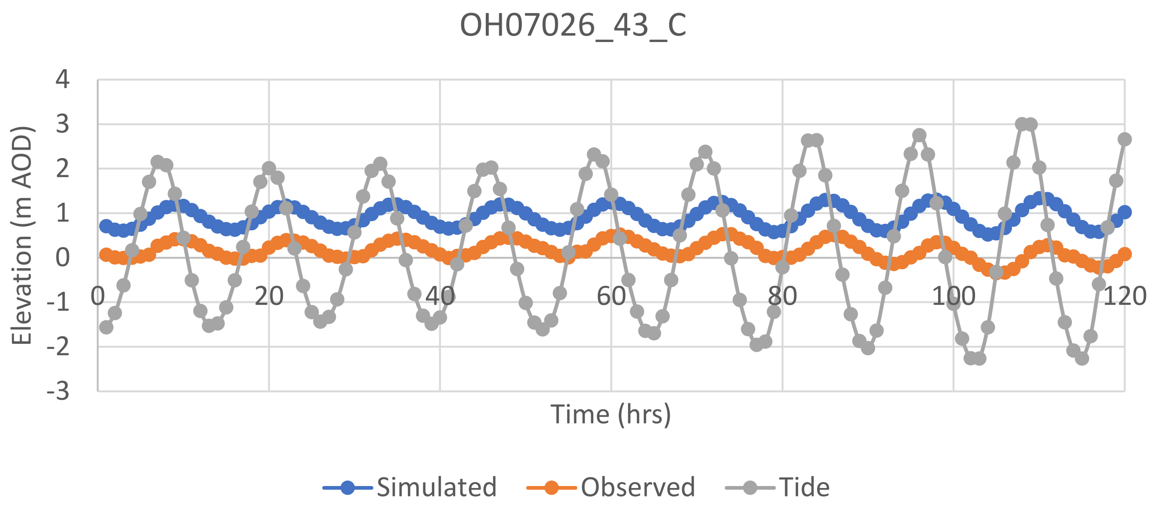


Plate 2.19 Predicted and observed groundwater levels for OH07026 at 30m bgl (top, CKD) and 43m bgl (bottom, CKABC)





2.5.12 This calibration was used to provide the starting point for a stochastic Monte Carlo assessment.

Summary of parameters

2.5.13 Table 2.10 gives a summary of the manually calibrated parameters.

Table 2.10 Calibrated parameters

Material	Hydraulic conductivity 50th percentile (m/s)	Specific yield (%) – Sy	Storage coefficient – S
Made Ground	$1.00x10^{-5}$	30	$5x10^{-3}$
Head Deposits	$5.00x10^{-7}$	10	$5x10^{-3}$
Alluvium	$7.90x10^{-7}$	2	$1x10^{-4}$
RTD	$6.55x10^{-4}$	0.15 (outcrop gravels) 0.05 (buried)	$1x10^{-5}$
London Clay	$1.00x10^{-7}$	2	$1x10^{-5}$
Lambeth Group	$1.00x10^{-7}$	1	$1x10^{-5}$
Harwich Formation	$1.00x10^{-5}$	8	$1x10^{-5}$
Thanet Formation	$1.00x10^{-4}$	10	$1x10^{-5}$
CKD (unstructured chalk)	$1.00x10^{-2}$	0.5	$1x10^{-5}$
Belle Tout Chalk layer	$5.00x10^{-4}$	0.5	$1x10^{-5}$
Bulk Chalk transmissivity (m^2/d) (excluding transmissivity in the Belle Tout and unstructured Chalk zones)	Three zones 50m^2/d [1] 33m^2/d [2] 25m^2/d [3]	0.5	$1x10^{-6}$

[1] Environment Agency zone mapped with a transmissivity of over 250m^2/d
[2] Environment Agency zone mapped with a transmissivity of 100 to 250m^2/d
[3] Environment Agency zone mapped with a transmissivity of 20 to 100 m^2/d

3 Results

3.1 Construction

Baseline construction scenario

3.1.1 The construction scenario includes the following:

a. North Portal excavation final elevation (including 1m buffer for 'over excavation')

b. HFB flow barriers representing diaphragm walls

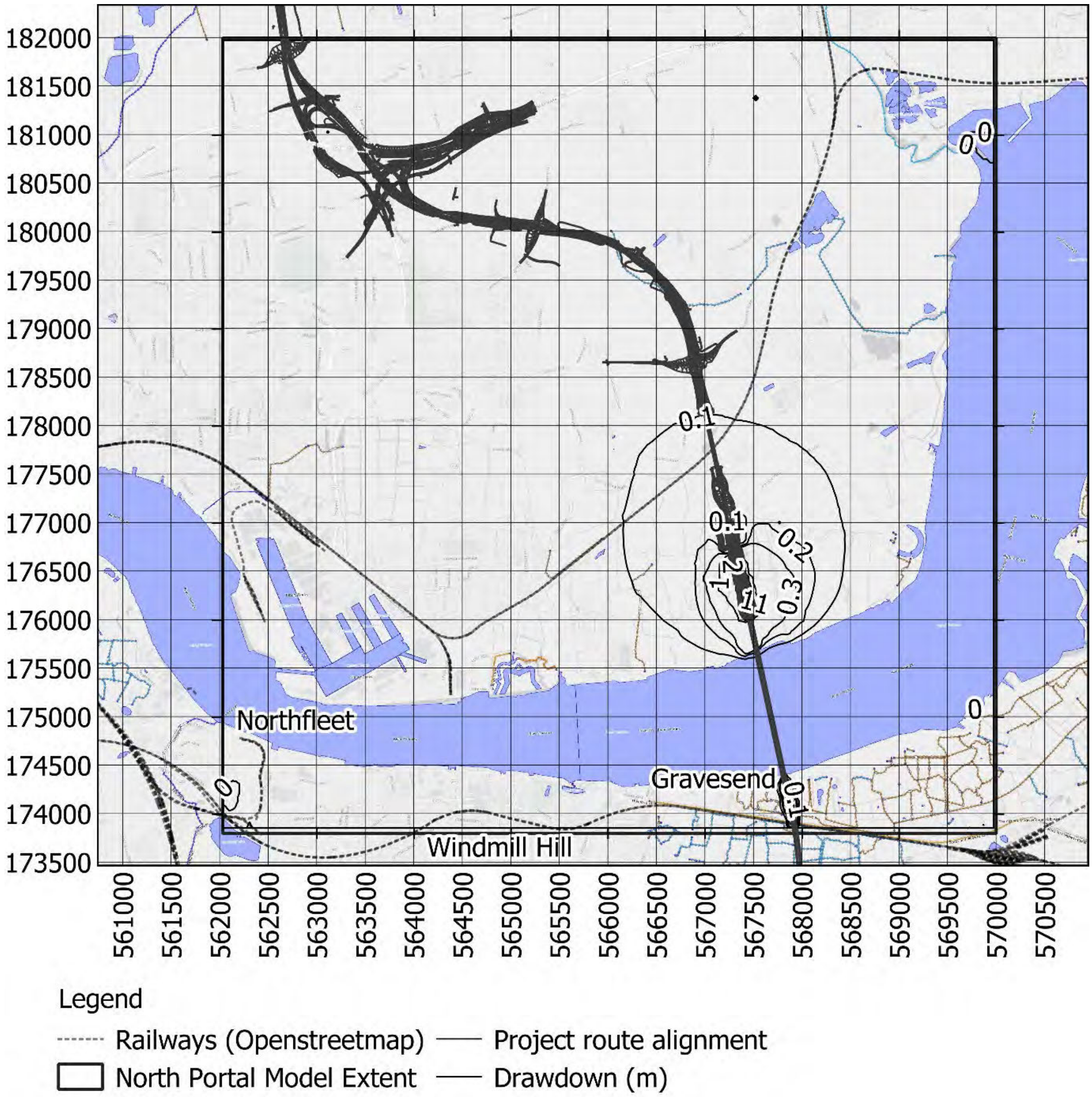
c. 5m thick grout plug with a hydraulic conductivity of $1x10^{-7}$m/s where the base of the diaphragm wall is above -27.5m AOD (informed by the Project Tunnel and Portals Team)

d. 10m thick grout plug with a hydraulic conductivity of $1x10^{-7}$m/s where the base of the diaphragm wall is below -27.5m AOD (informed by the Tunnel and Portals Team)

Drawdown

3.1.2 Plate 3.1 shows the predicted drawdown of the water table for the construction phase, in steady state conditions. Steady state is the worst-case condition as the drawdown has an infinite amount of time to propagate. In reality, the construction phase would be limited, and during operation the excavation would be watertight. The plate shows that the 0.1m drawdown contour extends 1km to the west, north and east. The axis of the drawdown cone is orientated parallel to the axis of the portal ramp.

Plate 3.1 Drawdown of the water table from the construction phase



3.1.3 The total inflow rate for the portal and associated ramps is expected to be 10.5L/s (914m^3/d) though a range of between 9.4 and 11.7L/s is predicted (Section 3.3). The flow rate is very low due to the effectiveness of the mitigation measures incorporated into the design and modelled.

Saline interface movement

3.1.4 Annex D provides a cross-section showing the saline interface through a north–south line along the route of the main tunnel. The results show that the saline interface extends further southwards in the high transmissivity aquifers (RTD and CKD).

3.1.5 Annex D shows the predicted change in concentration at various depths between the natural and baseline construction scenario. The results are presented for 5m bgl (Alluvium), 15m bgl (RTD/CKD) and 29m bgl (Chalk) and show the following:

e. No saline interface movement predicted in the Chalk

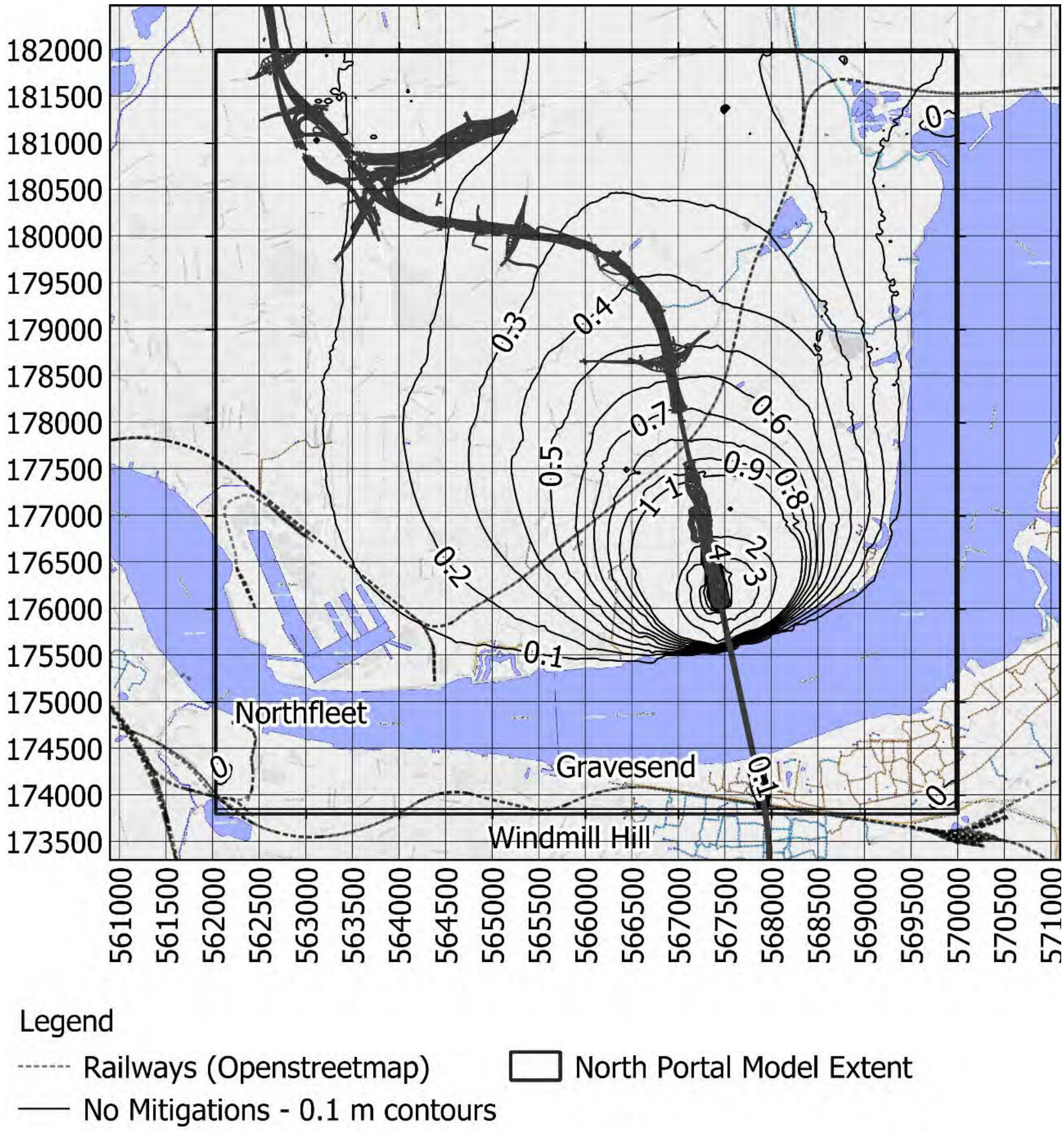
f. Changes in salinity of <0.1g/L in the Alluvium between the Project and the Thames

Scenario with no embedded mitigations (drainage of an open void)

3.1.6 This scenario does not include any of the embedded mitigations, including the grout plug and diaphragm walls. It is therefore a simulation of inflow into an open void.

3.1.7 Plate 3.2 shows the predicted drawdown with none of the embedded mitigation measures. In this scenario drawdown is widespread. The predicted inflow rate without the mitigation measures is 90L/s.

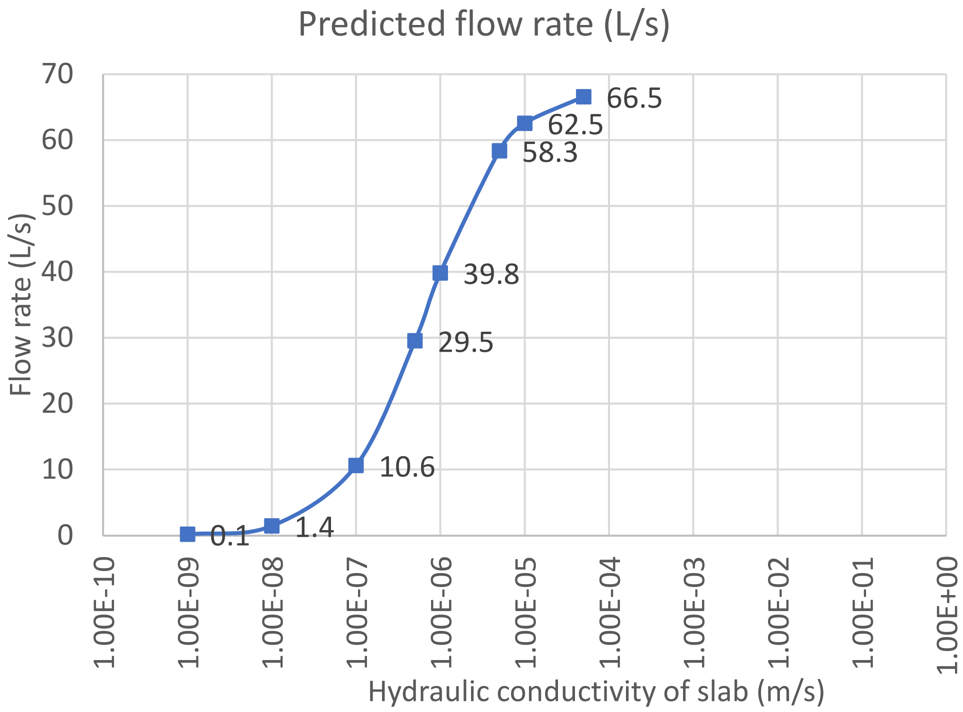
Plate 3.2 Predicted drawdown during construction if design embedded mitigations are not in place



Sensitivity to the grout plug hydraulic conductivity

3.1.8 Plate 3.3 shows the results of a sensitivity assessment for the hydraulic conductivity of the grout plug. The results show that the predicted inflow is very sensitive to the hydraulic conductivity of the in-place grout plug. An order of magnitude increase from 1×10^{-7}m/s to 1×10^{-6}m/s is shown to increase the flow rate from 11L/s to 40L/s.

Plate 3.3 Sensitivity of grout plug hydraulic conductivity



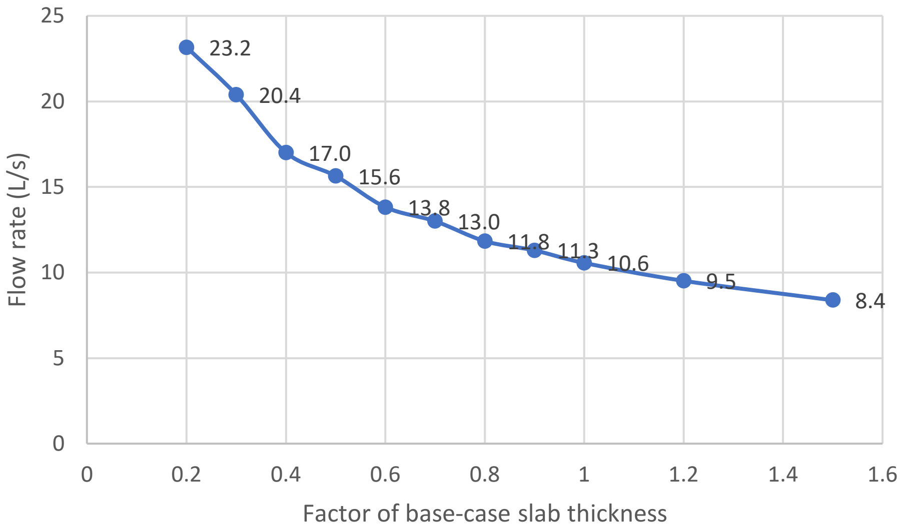
Sensitivity of grout plug thickness

3.1.9 Plate 3.4 shows the results of a sensitivity assessment of grout plug thickness. This was achieved by applying a factor onto the thickness in the base-case, thereby reducing or increasing the thickness. The base-case setup has two zones with differing plug thickness: 5m thick where the diaphragm wall base is above -27.5m AOD and 10m thick where it is below -28m AOD. The result showed:

a. a decrease in plug thickness of 50% increases the inflow rate by 56%

b. an increase in plug thickness of 50% decreases the inflow rate by less than 20%

Plate 3.4 Sensitivity of the groundwater inflow to the grout plug thickness



Diaphragm wall depth

3.1.10 For the simulations in this section the depth of the diaphragm wall is varied. The grout plug remains in place as discussed in Section 2.4 (Table 2.6).

3.1.11 Table 3.1 shows 36 variations of the base case design that have differing diaphragm depths and the results of the simulations. Plate 3.5 shows the locations of the zones.

Table 3.1 Simulated diaphragm wall elevation scenarios

Diaphragm wall elevation (m AOD)			Flow rate (L/s)		
Zone A	Zone B	Zone C[1]	-37m AOD elevation	-42m AOD elevation	-47m AOD elevation
-20	-27.5	a	10.57	10.52	10.46
-20	-32.5	b	8.85	8.85	8.81
-20	-37.5	c	8.81	8.81	8.77
-25	-27.5	d	10.52	10.47	10.40
-25	-32.5	e	8.82	8.82	8.78
-25	-37.5	f	8.78	8.78	8.74
-30	-27.5	g	10.11	10.04	9.96
-30	-32.5	h	8.63	8.63	8.60
-30	-37.5	i	8.57	8.57	8.53

[1] Letter refers to curve on Plate 3.6

Plate 3.5 Variations to the diaphragm wall elevations

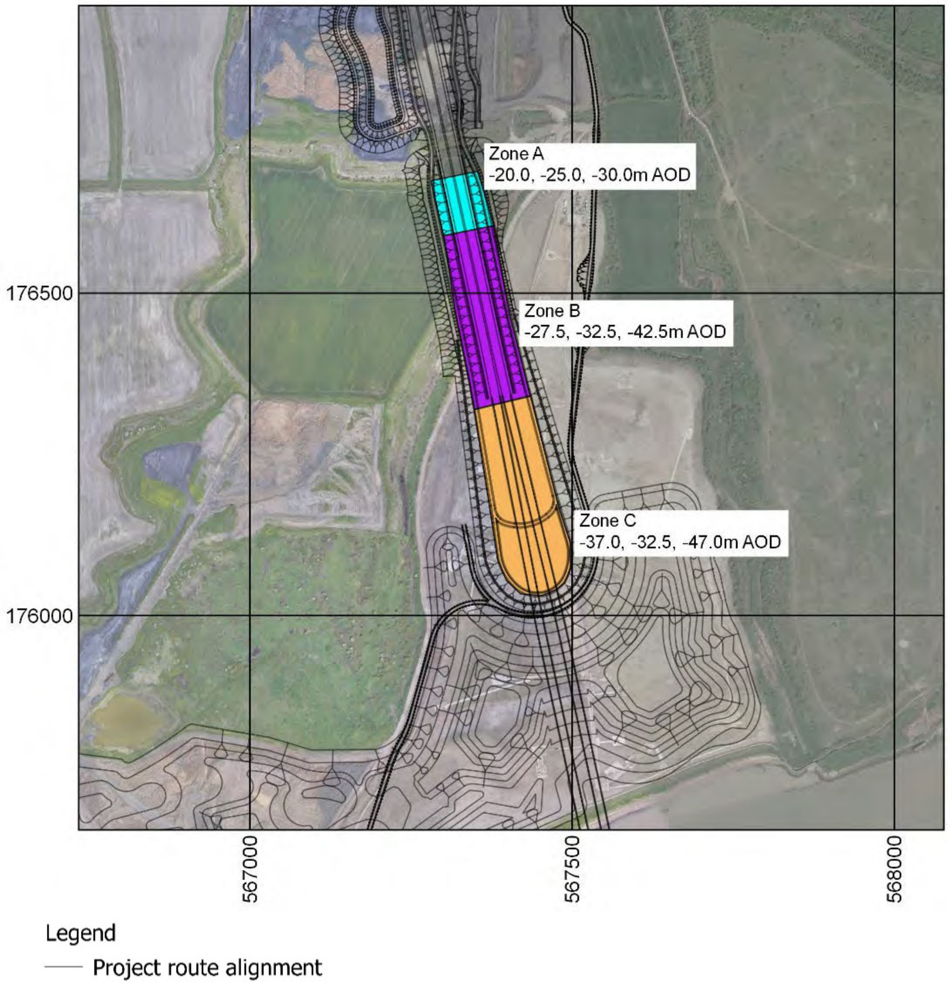
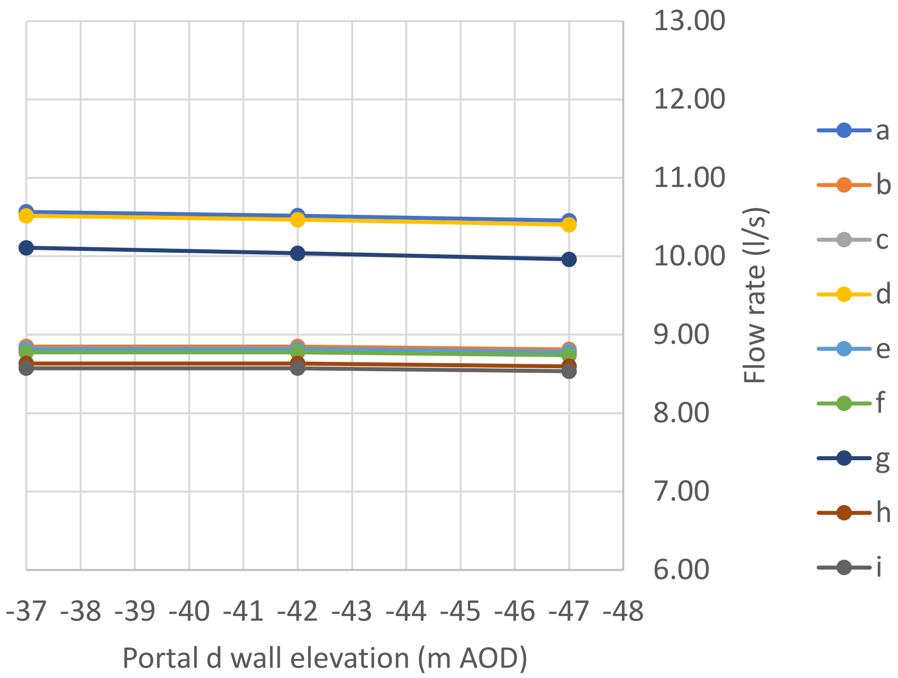


Plate 3.6 Changes in diaphragm wall depth



3.1.12 Plate 3.6 shows the results of the simulations. The highest inflows are in scenarios a, d and g, in which the Zone B diaphragm wall has a bottom elevation of -27.5m AOD. For setups where Zone B is at -32.5m AOD, a decrease in inflow of approximately 20% is predicted. There is only a very small additional benefit to deepening this zone to -37.5m AOD. The slope of the curves plotted is flat, showing that the effect of deepening Zone C on the predicted flow rate is negligible. This is because the depth of the cut-off in Zone C is deep enough to cut-off the bulk of the transmissive Chalk.

Linford abstraction

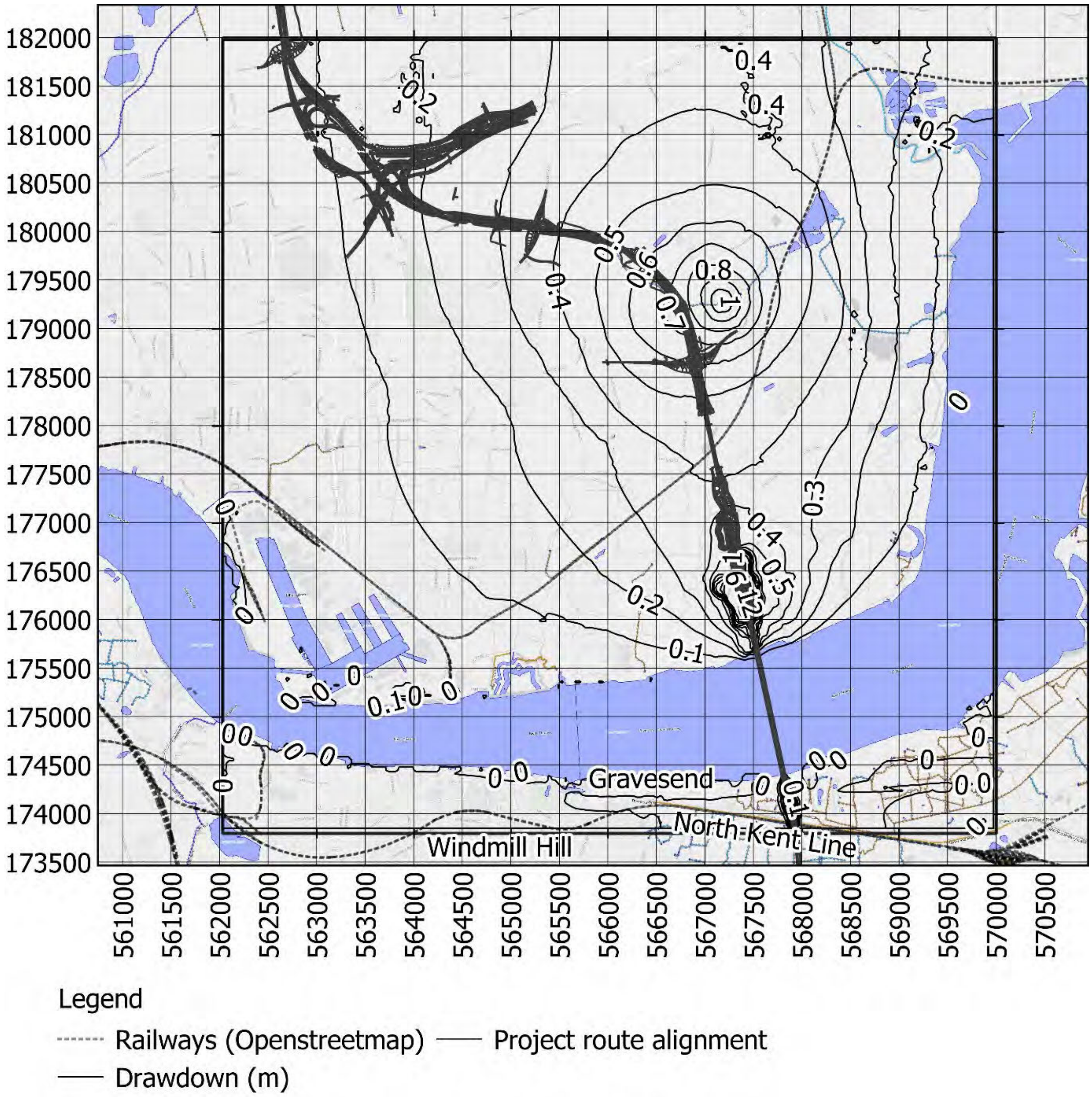
3.1.13 Linford Public Water Supply is in the model domain, approximately 3km north of the Project. The site has an existing licence from the Environment Agency for water supply. The Applicant may choose to use the site for water supply at rates within the already licensed condition. Simulations of the drawdown and saline intrusion (SEAWAT) have been produced for abstraction rates of 1ML/d, 3.5ML/d and 6ML/d.

1ML/d

3.1.14 This scenario is like that described under the ‘baseline construction scenario’ heading, above, except it includes the Linford abstraction borehole operating at 1ML/d.

3.1.15 Plate 3.7 shows the predicted drawdown of the water table in the Chalk for this scenario for steady state conditions. This is calculated by subtracting the scenario water table from the baseline water table. The baseline does not include the Linford abstraction. It is noted that the predicted impacts of the Linford abstraction well extend out of the model domain to the north. At the Linford abstraction site, the predicted drawdown is 1.0m.

Plate 3.7 Predicted drawdown for the construction phase with Linford operating at 1ML/d



3.1.16 Annex E shows the predicted change in chloride concentration at various depths between the natural and baseline construction scenario. The results are presented for 5m bgl (ALV), 15m bgl (ALV/RTD), 21m bgl (CKD) and 29m bgl (Chalk) and show the following:

a. Within the CKD, a slim strip approximately 70m wide at the edge of the Thames is predicted to increase in concentration by <0.1g/L.

b. As with the scenario without Linford operating, there were changes in salinity of <0.1g/L in the Alluvium between the Project and the Thames.

3.5ML/d

3.1.17 Northumbrian Water Limited, which operates the Linford water supply as Essex and Suffolk Water, has advised that, based on historical pumping data, the sustainable yield is 3.5ML/d.

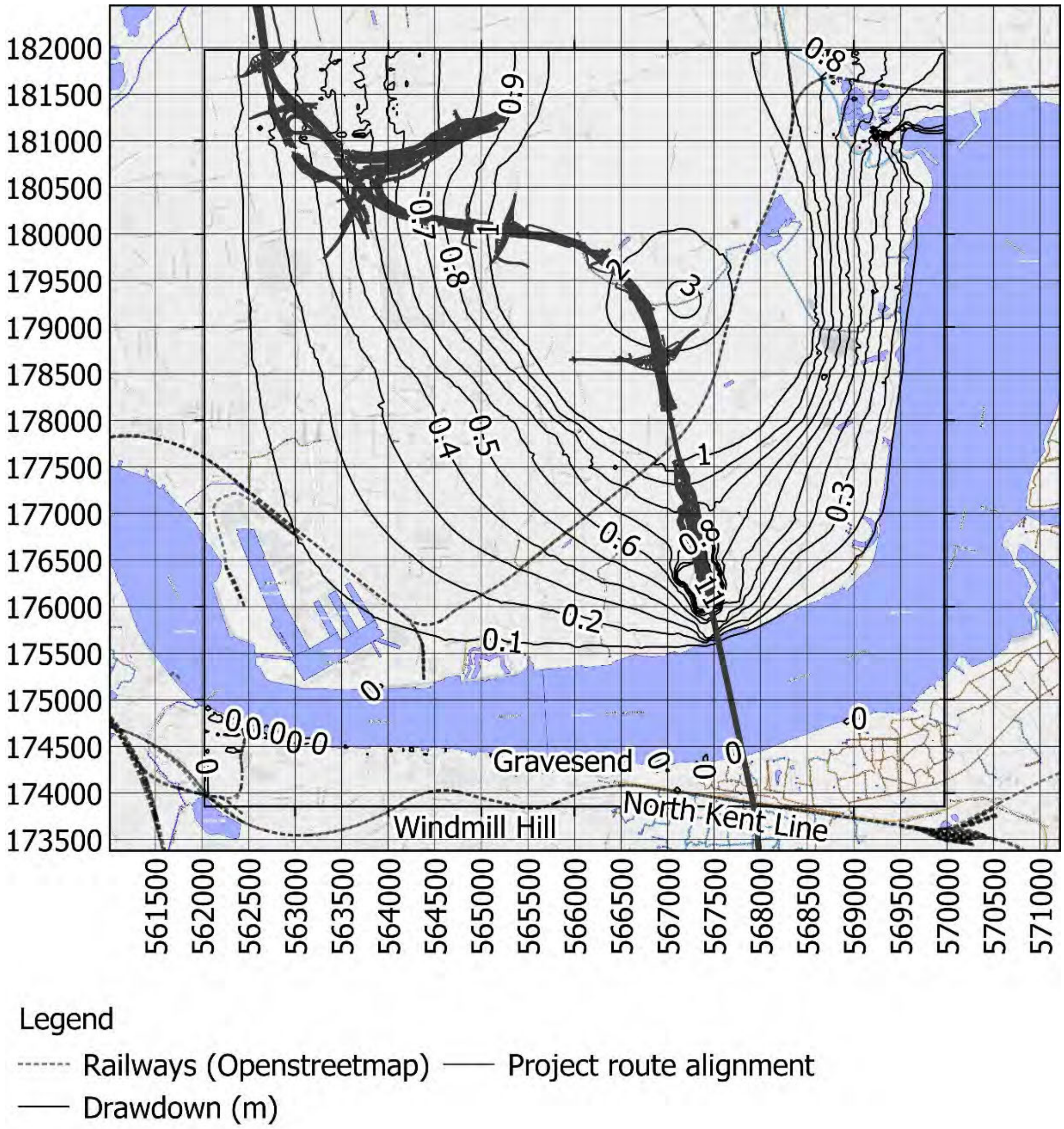
3.1.18 This scenario is like that described under the ‘baseline construction scenario’ heading, above, except:

a. the abstraction rate of the Linford abstraction well is 3.5ML/d

b. the model domain was extended 3km northwards

3.1.19 Plate 3.8 shows the predicted drawdown of the water table for this scenario. This is calculated by subtracting the scenario water table from the baseline water table. The baseline does not include the Linford abstraction. It is noted that the predicted impacts of the Linford abstraction continue out of the model domain to the north. A peak drawdown of 3m of the water table is predicted, located at the Linford abstraction.

Plate 3.8 Predicted drawdown for the construction phase with Linford operating at 3.5ML/d



3.1.20 Annex F shows the predicted change in chloride concentration at various depths between the natural and baseline construction scenario. The results are presented for 5m bgl (ALV), 15m bgl (ALV/RTD), 21m bgl (CKD) and 29m bgl (Chalk) and show the following:

a. Within the CKD, a slim strip approximately 150m wide at the edge of the Thames is predicted to increase in concentration by <0.1g/L.

b. As with the scenario without Linford operating, there were changes in salinity of <0.1g/L in the Alluvium between the Project and the Thames.

6ML/d

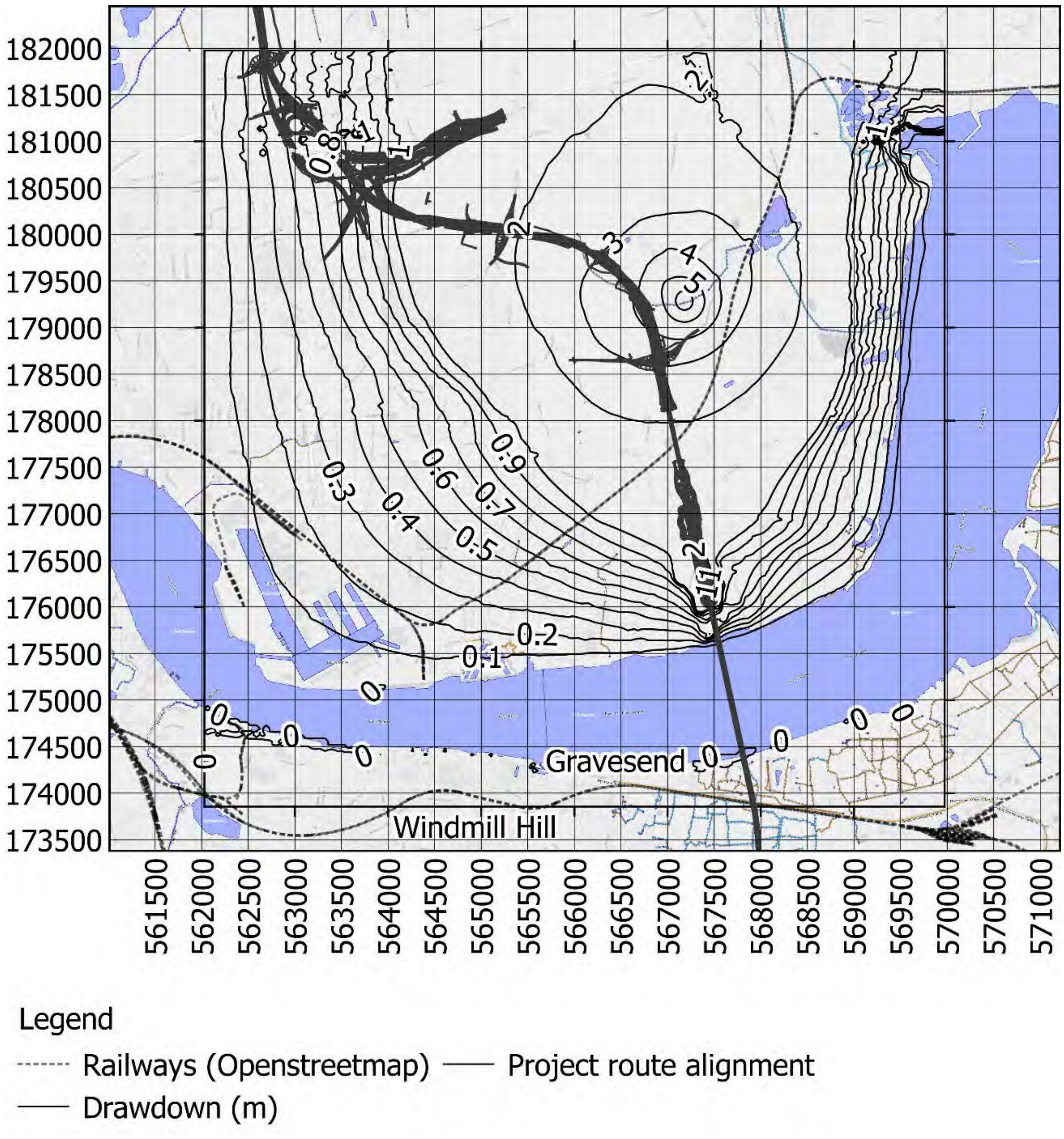
3.1.21 This scenario is like that described under the ‘‘baseline construction scenario’ heading, above, except:

a. the abstraction rate of the Linford abstraction well is 6ML/d

b. the model domain was extended 3km northwards

3.1.22 Plate 3.9 shows the predicted drawdown of the water table for this scenario. This is calculated by subtracting the scenario water table from the baseline water table. The baseline does not include the Linford abstraction. The predicted impacts of the Linford abstraction continue out of the model domain to the north-east. A peak drawdown of 5m of the water table is predicted located at the Linford abstraction.

Plate 3.9 Predicted drawdown for the construction phase with Linford operating at 6ML/d



3.1.23 Annex G shows the predicted change in chloride concentration at various depths between the natural and baseline construction scenario. The results are presented for 5m bgl (ALV), 15m bgl (ALV/RTD), 21m bgl (CKD) and 29m bgl (Chalk) and show the following:

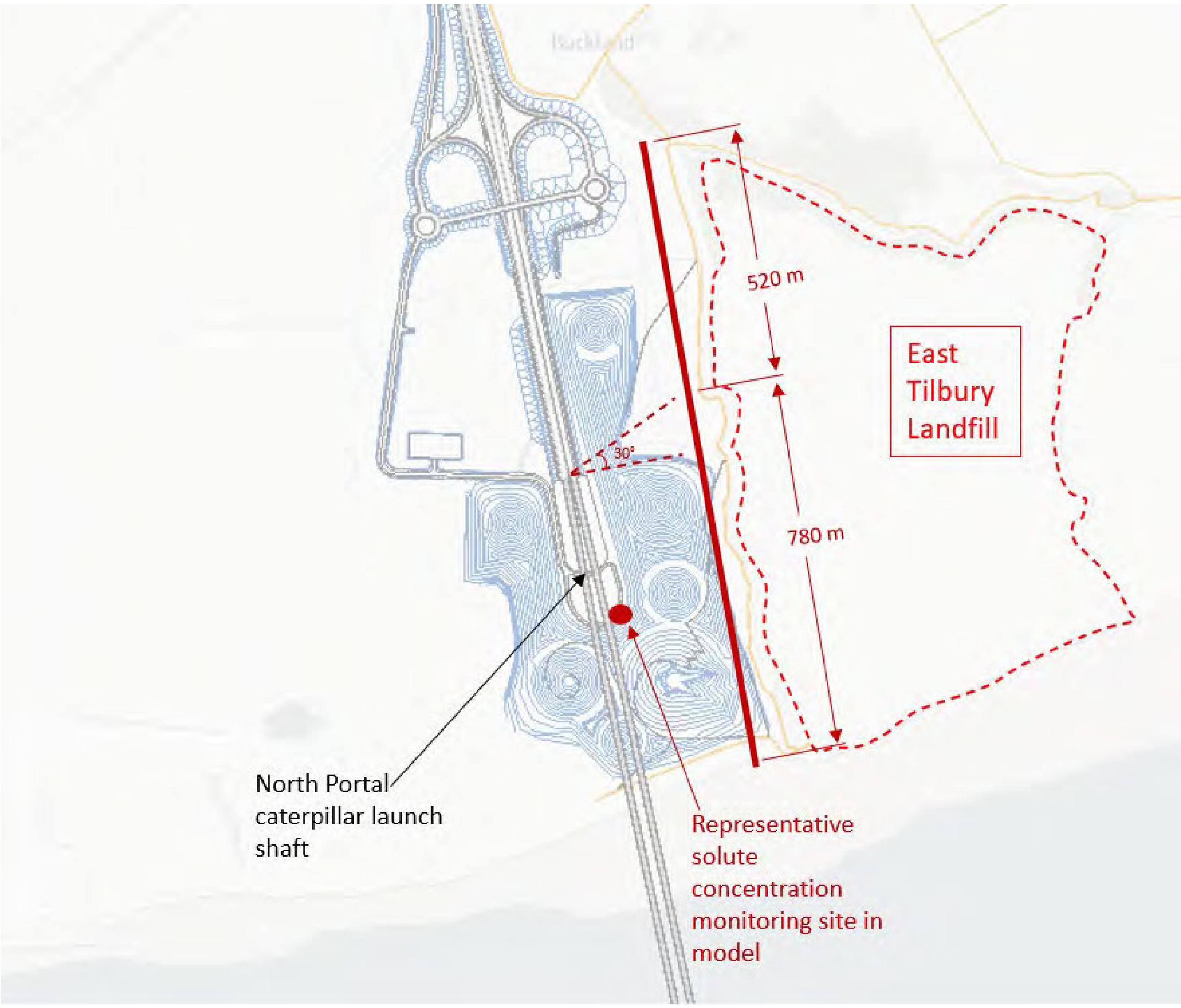
a. Within the CKD, a slim strip approximately 150m to 300m wide at the edge of the Thames is predicted to increase in concentration by <0.1g/L.

b. As with the scenario without Linford operating, there were changes in salinity of <0.1g/L in the Alluvium between the Project and the Thames.

Slurry wall and solute transport from East Tilbury Landfill

3.1.24 Plate 3.10 shows the layout of the potential slurry wall option The slurry wall is one of a suite of possible supplementary mitigation measures. The objective of the slurry wall would be to slow or prevent the movement of potential historical contamination in groundwater, including that associated with historical land uses. The slurry wall options assessed included construction to an elevation of -22m AOD, but an option to deepen this to -30m AOD has also been tested. The hydraulic conductivity of the slurry wall is set to $1x10^{-9}$m/s, in line with industry standards.

Plate 3.10 Layout of potential slurry wall option



3.1.25 The groundwater model has been supplemented with MT3D to simulate movement of solute away from the East Tilbury Landfill. The assumptions in the model include the following:

a. A construction period of three years, as advised by the Tunnels Team.

b. The embedded mitigations in the baseline model (grout plug and diaphragm walls) are included.

c. The largest, deepest excavation extent is in place from the start (worst case).

d. The initial concentration of solute in groundwater below the landfill site is assumed to be 0.1g/L. This is set in all layers above 26m bgl and simulates a potential historical dissolved phase contaminant in the ALV, RTD and CKD. There has been no targeted intrusive investigation for the Project into any pollution potentially present in groundwater beneath the landfill site, to avoid the risk of mobilising landfill leachate into groundwater.

e. The contaminant transport simulation is conservative, that is, advection-dispersion with no sorption or retardation.

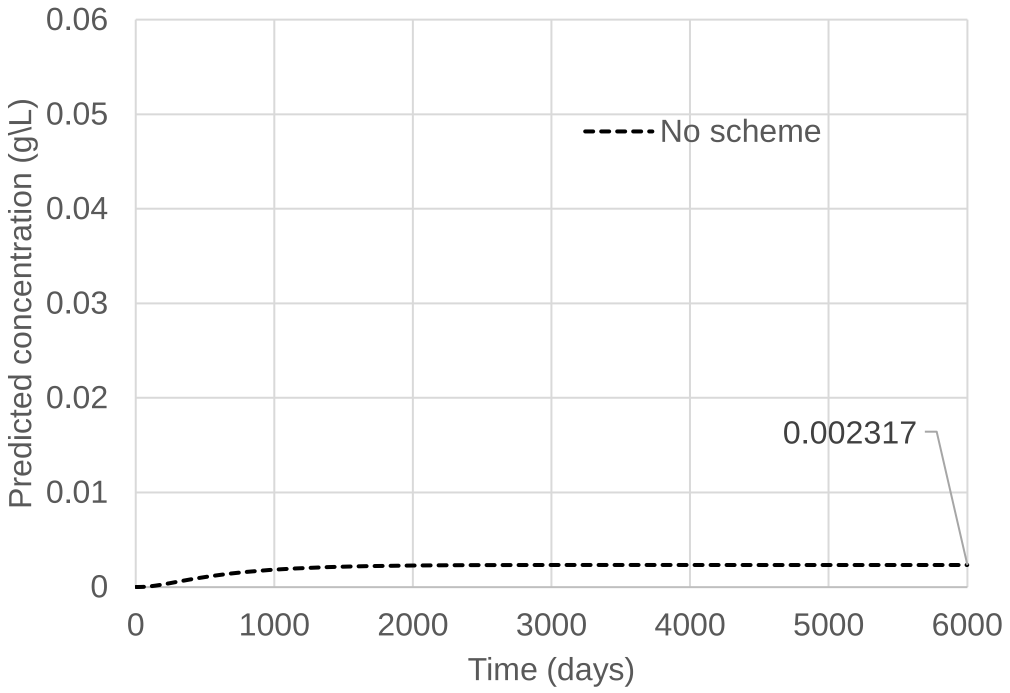
f. Recharge passing through the landfill has a concentration of 0.1g/L.

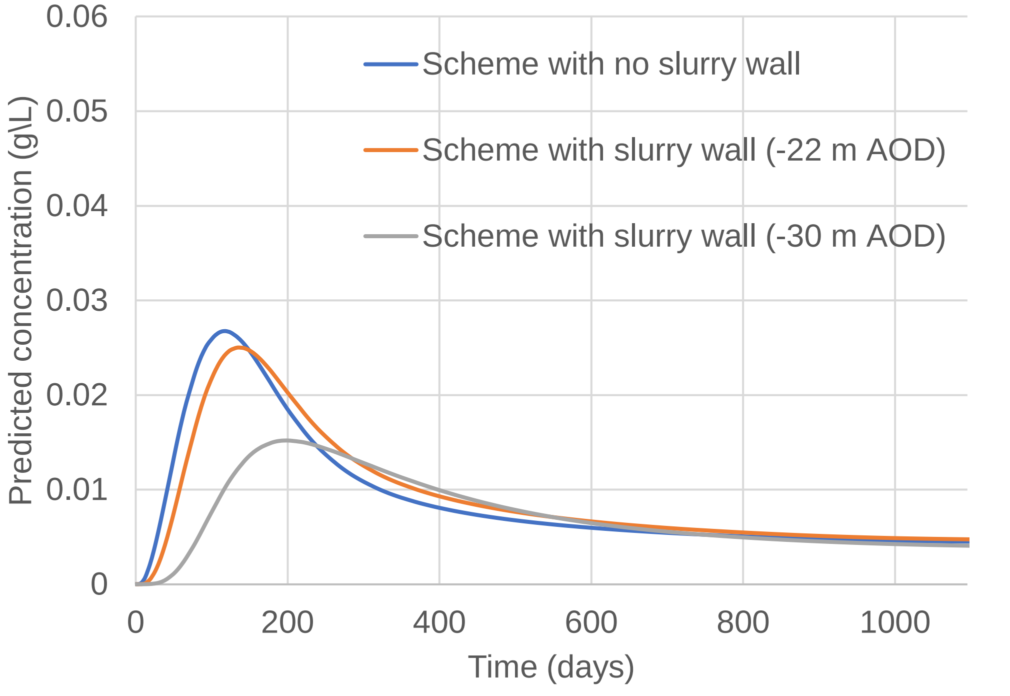
g. Recharge rates are not enhanced or reduced compared to the baseline model.

h. Dispersion is set to 10m over the whole domain, with a factor of 0.1 metres per metre for dispersion in the vertical or transverse planes.

3.1.26 Plate 3.11 shows the predicted results. Simulations were done for scenarios with no slurry wall, a slurry wall to -22m AOD and a slurry wall to -30m AOD.

Plate 3.11 Predicted concentration at the south-east corner of the North Portal





3.1.27 The results show the following:

<u>No Project (no dewatering)</u>

a. There is a very slow increase in concentration over time due to the lateral dispersion away from the landfill site. This reflects the existing gradient causing flow to be southwards to the River Thames.

b. The concentration would ultimately stabilise at 0.0023g/L.

No slurry wall

a. Without a slurry wall, the peak concentration is 0.026g/L, approximately a quarter of the initial concentration.

b. The peak occurs at 110 days.

c. The concentration subsides to 0.01g/L at 330 days.

Slurry wall to -22m AOD

a. The peak concentration is 0.024g/L.

b. The peak concentration occurs at 152 days.

c. The concentration subsides to 0.01g/L at 400 days.

Slurry wall to -30m AOD

a. The peak concentration is 0.015g/L, 15% of the initial concentration.

b. The peak concentration occurs at 200 days.

c. The concentration subsides to 0.01g/L at 400 days.

3.1.28 In natural conditions, without the Project, it is predicted that the concentration at the site of the Project would be just 0.2% of the possible source concentration.

3.1.29 With the Project, it is predicted a nearby part of the plume would move towards the portal area, causing the concentration here to rise. The slurry wall is more effective because it has a lower bottom elevation but the shallower option (-22m AOD) has minimal effect. This option is not deep enough to penetrate the high transmissivity shallow Chalk layers (CKD) present in boreholes. The deepest option (-30m AOD) is more effective as it penetrates through these high transmissivity zones but does not fully extend to low transmissivity Chalk.

3.1.30 It is noted that this simulation assumes an ideal conservative tracer. Should contamination be present, then, alternative solutes may be present with different dispersion and retardation characteristics. Regardless of the above, this work is superseded by later work presented in Appendix 10.7: East Tilbury Landfill Risk Assessment Technical Memorandum (Application Document 6.3). The latter confirms that there are no significant risks posed by East Tilbury Landfill as a result of the Project.

3.2 Operation

Operation baseline scenario

3.2.1 The operation baseline scenario includes the following:

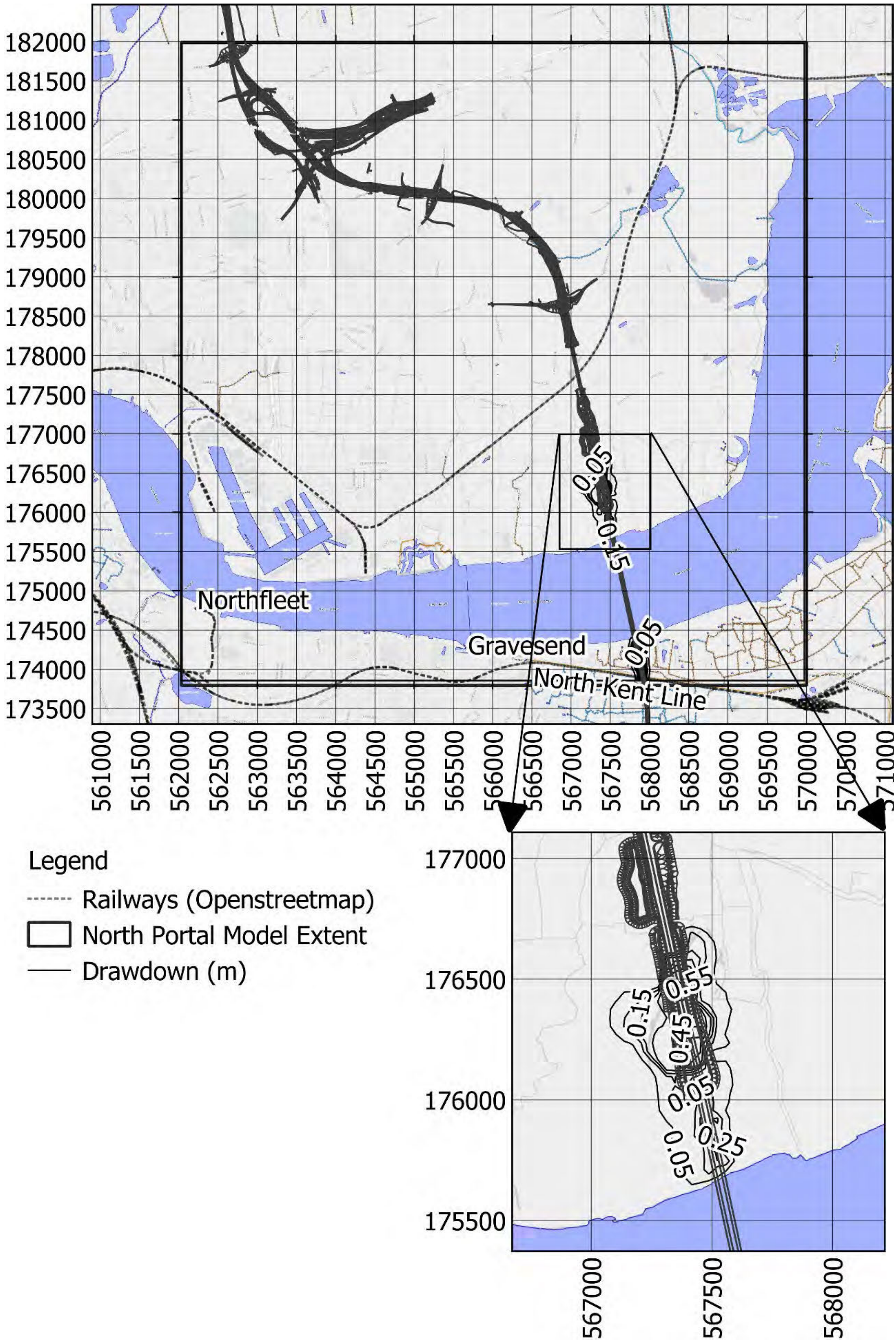
a. The portal and ramp are assumed to be impermeable. This is because the design includes water-proofing; and

b. The Project main tunnels and cross-passages would have a minimal inflow rate of 0.1L/s/m^2 as defined by the British Tunnelling Society standards (British Tunnelling Society and Institution of Civil Engineers, 2010).

3.2.2 Plate 3.12 shows the predicted drawdown of the water table in the operation scenario. The drawdown follows the line of the main tunnels. In general, it dissipates to less than 0.05m within 200m of the tunnel. Next to the portal ramp, drawdown is predicted to extend 300m westwards, along higher transmissivity zones. The predicted flow rate in the scenario is 0.5L/s (45m^3/d).

3.2.3 Such a small predicted drawdown is likely an artefact of uncertainty within the model due to emplacement of boundaries. It is unlikely that this drawdown would manifest in an observable way in observation boreholes. The confidence in predictions of drawdowns so small is likely to be quite low and within the resolution of the model.

Plate 3.12 Predicted drawdown due to the Project main tunnels (operation)



3.2.4 The inflow rate is controlled by the prescribed leakage rate into the main tunnels of 0.1L/d/m^2 (British Tunnelling Society and Institution of Civil Engineers, 2010).

3.2.5 Annex H shows the predicted change in salinity at 5m bgl, 15m bgl, 21m bgl and 29m bgl, corresponding to Alluvium, Alluvium/RTD, RTD/CKD, and Chalk strata. The results show that no significant saline intrusion is predicted. A minor change of <0.1g/L is predicted along the line of the Project route at 21m bgl within the RTD/CKD. Other depths do not show any change.

Operation baseline scenario including ground improvement

3.2.6 Ground improvement in the form of soil mixing is likely to be necessary to support the construction activities of the tunnel approach ramp, North Portal and tunnel. Soil mixing includes mixing of in-situ material with cementitious binders to form a material with improved strength and lower compressibility than the original soil. The ground improvement includes zones of shallow and deep soil mixing. Plate 3.13 shows the ground improvement conceptualisation in cross section. It has the following features:

- Shallow soil mixing forming a continuous block of treatment. A maximum depth of 7m is assumed.
- Deep soil mixing (DSM) columns with a diameter of 1.5 m and a spacing of 2.5m, to reach the base of the RTD. Between deep columns continuous pathways through natural material remain present. The ground improvement volume so makes up 26 % of the model cell volume. As 74 % of a model cell remains as pre-existing material, it is not expected that deep soil mixing zones will have significant impact on the hydraulic conductivity or connectivity of existing higher hydraulic conductivity zones, such as the RTD.
- For deep ground improvement, the shallow ground improvement zone is also applied.
- The hydraulic conductivity of ground improvement zones is assumed to be $1x10^{-7}$ m/s and is isotropic.

3.2.7 The ground improvement zones are applied to the model by:

- Referencing a map of shallow and deep soil mixing zones, shown in Plate 3.14 and Plate 3.15; and
- Modifying the hydraulic conductivity of the model cell as follows:
  - For shallow zones of ground improvement, the hydraulic conductivity of ground improvement is applied directly, since the shallow ground improvement is laterally continuous;
  - For deep ground improvement, a new bulk average is calculated for the model cell, that include 26 % of ground improvement and 74 % of pre-existing natural material.

Plate 3.13 Ground Improvement concept

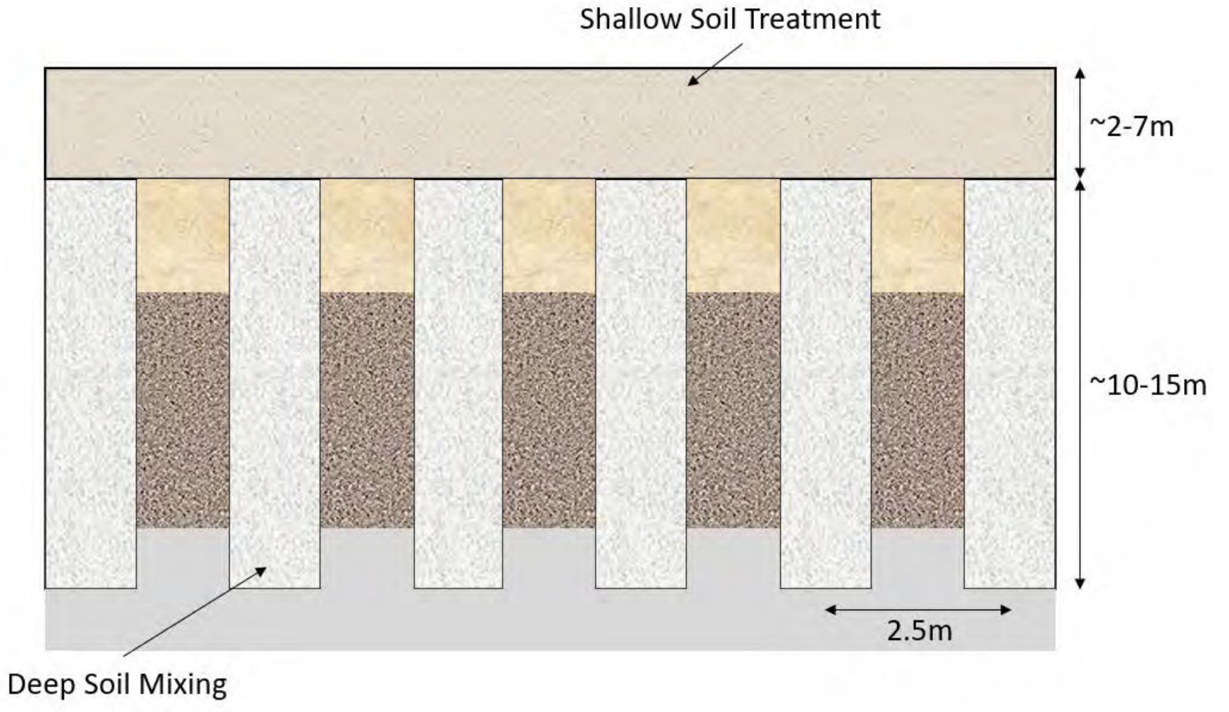


Plate 3.14 Ground Improvement layout

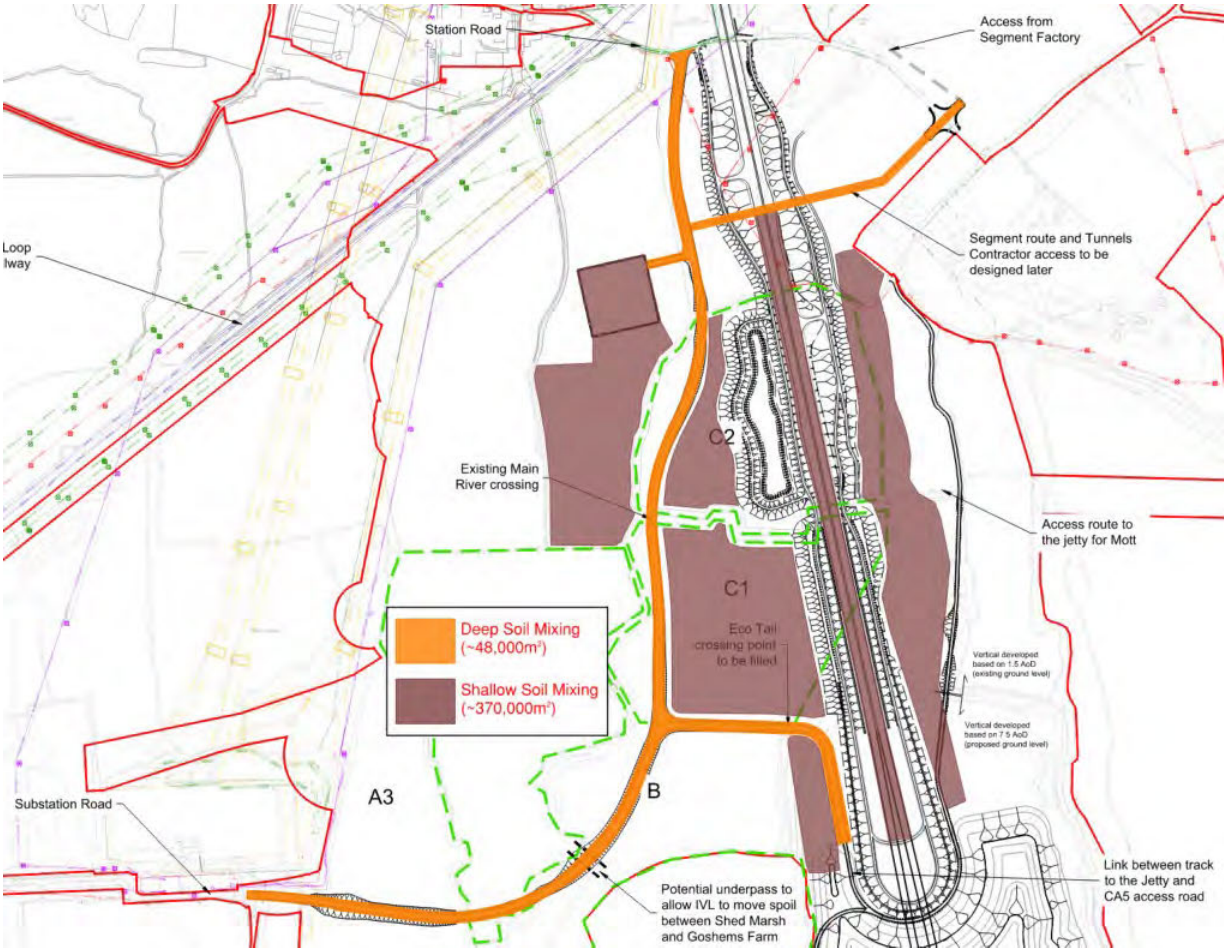
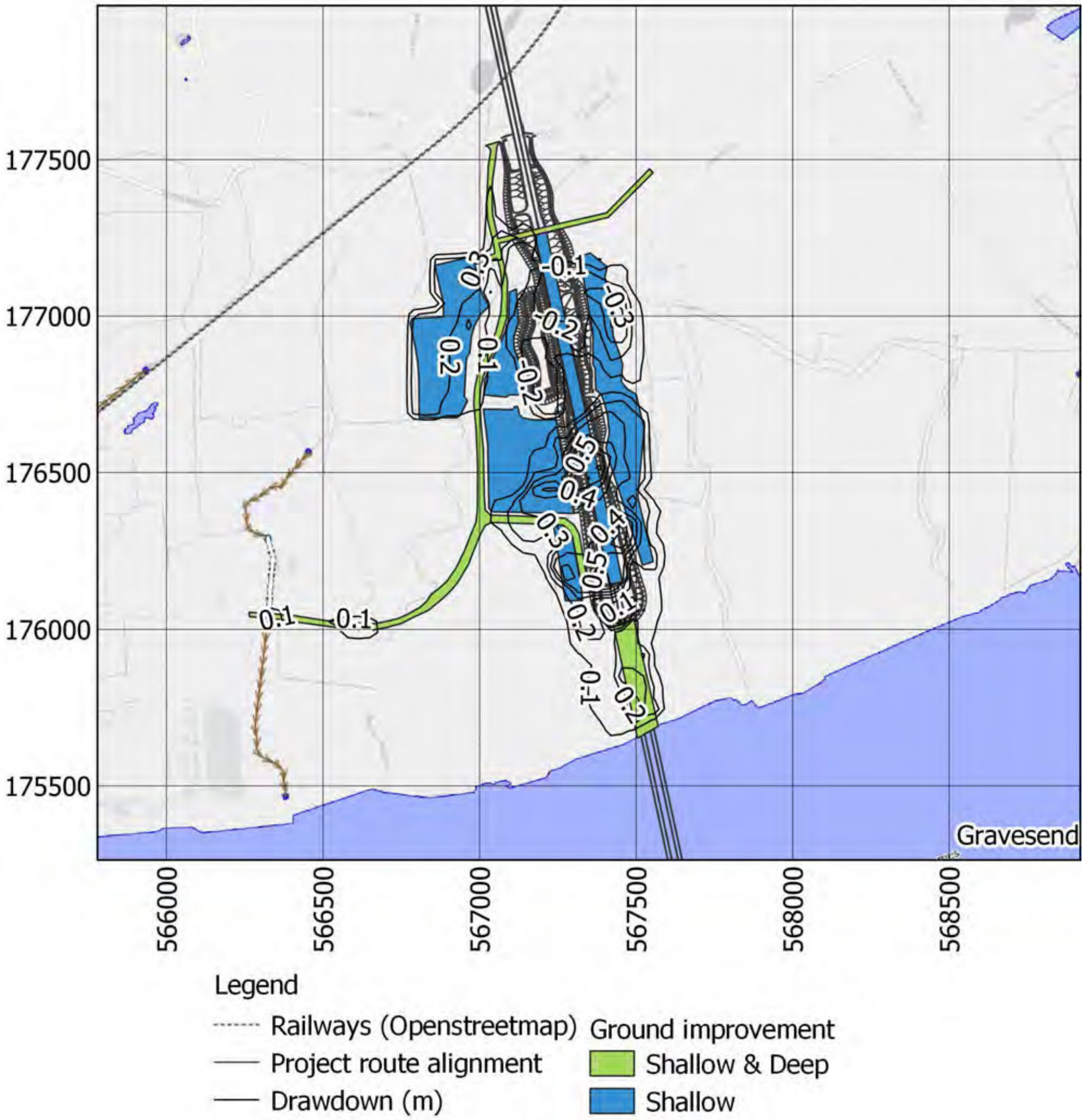


Plate 3.15 Ground Improvement layout. Tunnel ring stability DSM

3.2.8 Plate 3.16 shows the predicted drawdown when the ground improvement is included in the operations scenario inclusive of mitigations at the North Portal, such as the grout plug and diaphragm wall. The results show that the drawdown remains constrained to an area very proximal to North Portal location. The ground improvement is predicted to result in a minor decrease in the groundwater level. This is likely because the assumed hydraulic conductivity of the ground improvement zones is marginally higher than clay within the alluvium superficial deposits. No notable changes in the groundwater salinity of the area are predicted (Annex I).

Plate 3.16 Ground Improvement drawdown



3.3 Parameter sensitivity – Monte Carlo assessment

Monte Carlo assessment inputs

3.3.1 It can be the case that a single calibration is fixed upon during groundwater modelling by manual iteration, when many may be available within the pre-defined parameter ranges. A Monte Carlo analysis tested 1,600 parameter combinations. Each simulation included a steady state and time-variant calibration assessment followed by the Project infrastructure scenario if the calibration was suitable. The assessment was completed using FloPy. For each simulation, the SRMSE and parameters applied were recorded and assessed for the calibration data discussed in Section 2.5

3.3.2 The recharge was 'fixed' at the values discussed in paragraph 2.4.19. Parameters varied in the analysis included the horizontal (k_h) and vertical (k_z) hydraulic conductivity (in a pre-defined ratio) for the following:

a. Alluvium (ratio of $k_z / k_h = 0.1$)

b. RTD (ratio of $k_z / k_h = 0.1$)

c. CKD (unstructured granular Chalk/core loss zones ($k_z = k_h$)

d. Belle Tout beds within the Seaford Formation Chalk (a zone within approx. 35m bgl, ratio of $k_z / k_h = 0.02$)

e. Bulk Chalk – deeper Chalk, making up the thickness of the saturated Chalk (ratio of $k_z / k_h = 0.02$). Split into three zones, depending on whether the Belle Tout beds are present and on the estimate of transmissivity (Environment Agency, 2016).

3.3.3 Table 3.2 provides the distribution ranges from which parameters were selected at random.

Table 3.2 Log-normal distributions of hydraulic conductivity for the Monte Carlo simulations.

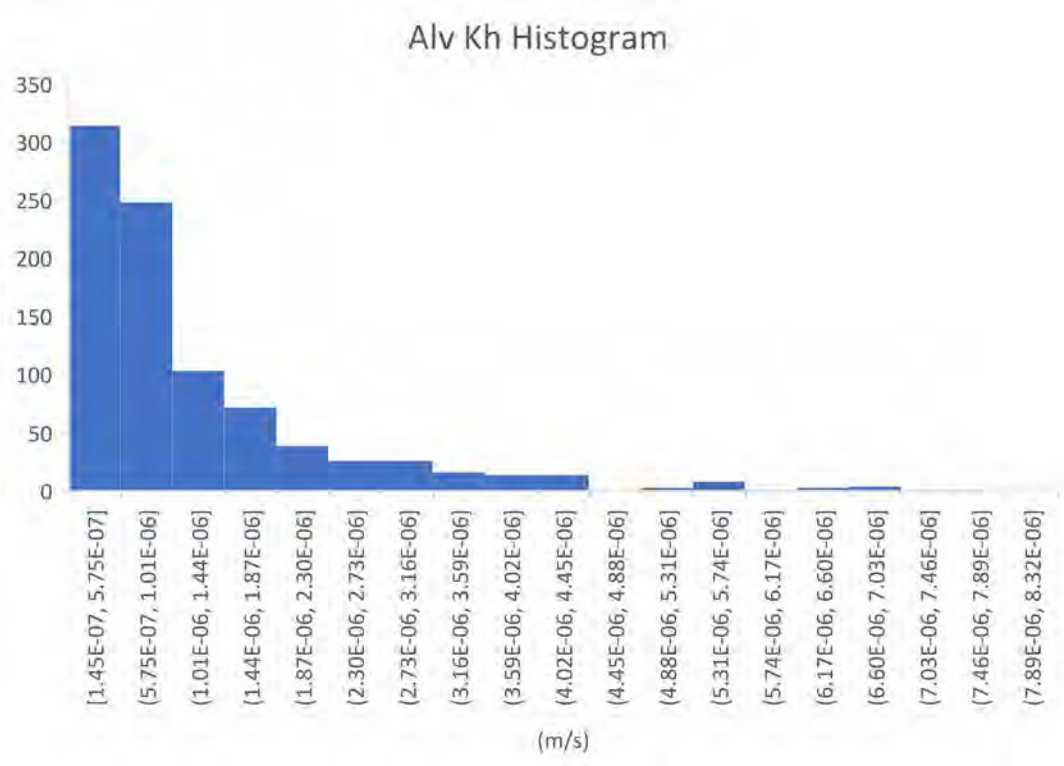
Geological unit	Hydraulic conductivity (m/s)		
	Mean	Standard deviation	Max and min tested
Alluvium	$4x10^{-7}$	1.25	$1.29x10^{-8}$ to $9.95x10^{-5}$
RTD	$7.30x10^{-4}$	1	$5x10^{-5}$ to $2x10^{-3}$
Unstructured Chalk (CKD/AZCL)	$1x10^{-2}$	0.1	$6.93x10^{-3}$ to $1.39x10^{-2}$
Belle Tout Formation	$5x10^{-4}$	0.25	$1.00x10^{-3}$ to $5.40x10^{-2}$
Bulk Chalk[1] (m^2/d) Environment Agency zone (T<250)	50	0.25	22 to 112
Bulk Chalk[1] (m^2/d) Environment Agency zone (100<T<250)	33	0.25	13 to 74
Bulk Chalk[1] (m^2/d) Environment Agency zone (20<T<100)	25	0.25	11-69

[1] The modelled transmissivity does not include the transmissivity of the Belle Tout Formation and unstructured Chalk zones. These make up the top 35m of the Chalk (approximately) in the model area. Hence, the values are lower than those given by the Environment Agency, which would include these more transmissive zones.

Alluvium

3.3.4 Plate 3.13 shows a histogram for Alluvium k_h (horizontal hydraulic conductivity). The result shows that the majority of calibrated Alluvium models have a low hydraulic conductivity. The 50th percentile of the Monte Carlo results is $7.46x10^{-7}$m/s. The hydraulic conductivity tends towards the lowest values simulated. Plate 3.13 shows that the calibrated values for the Alluvium skew towards the lower end of the range tested.

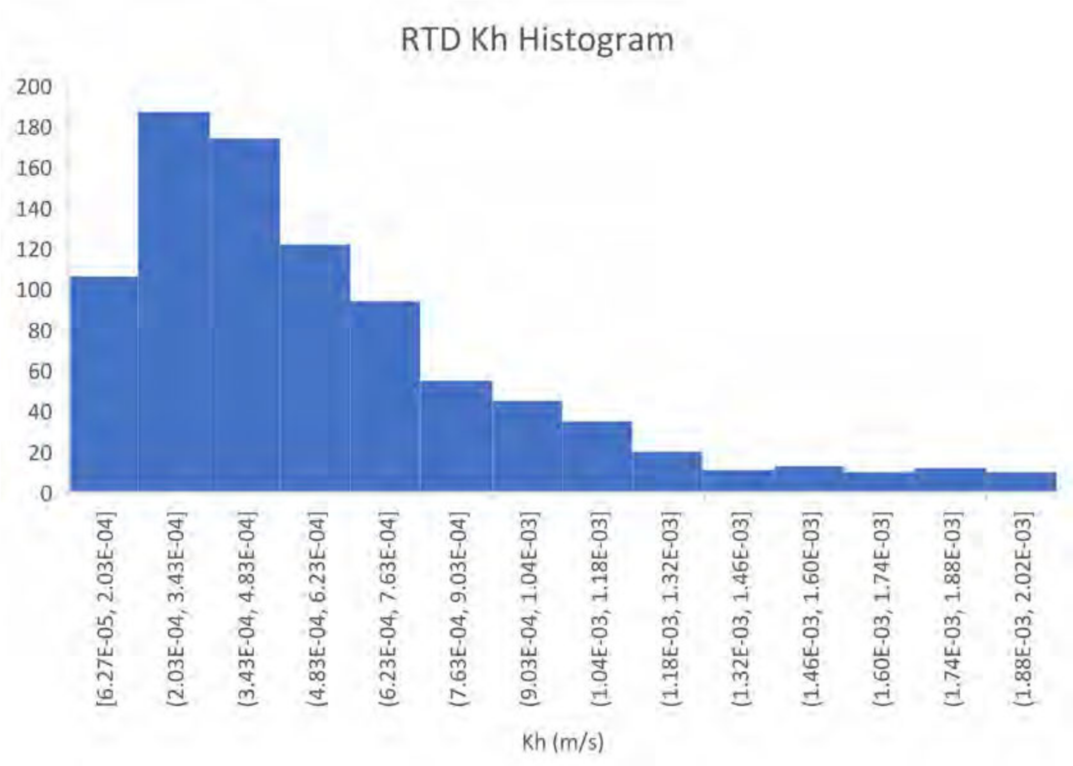
Plate 3.16 Alluvium k_h



River Terrace Deposits (RTD)

3.3.5 Plate 3.14 shows a histogram of the results for the RTD. The results are skewed towards the lower end of the tested range, generally less than $8.7x10^{-4}$m/s. The 50^{th} percentile of the results is $4x10^{-4}$m/s.

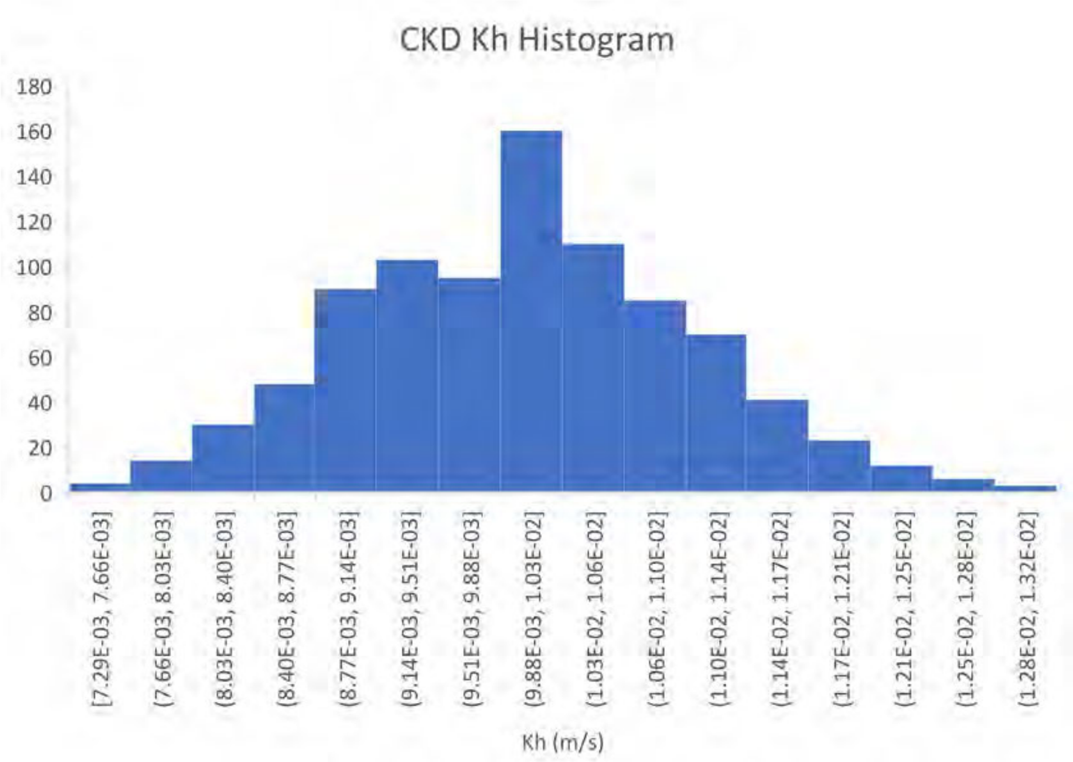
Plate 3.17 Monte Carlo results for the RTD



CKD

3.3.6 Plate 3.15 shows that the extremes of the range tested for the CKD are much less likely to occur than the central range of between 8.5x10^{-3}m/s and 1.8x10^{-2}m/s. Once in the central value range, there is little additional sensitivity, except for a significant spike in calibrated scenarios with a hydraulic conductivity of the CKD of 1x10^{-2}m/s. This value (1x10^{-2}m/s) is also the 50th percentile of the results. This is slightly lower than values reported by the Channel Tunnel Rail Link project (Bevan *et al*., 2010), where it was found that a hydraulic conductivity of up to 7x10^{-3}m/s was applicable. In practice, if lower hydraulic conductivity values are used for this parameter, the tidal response is too small.

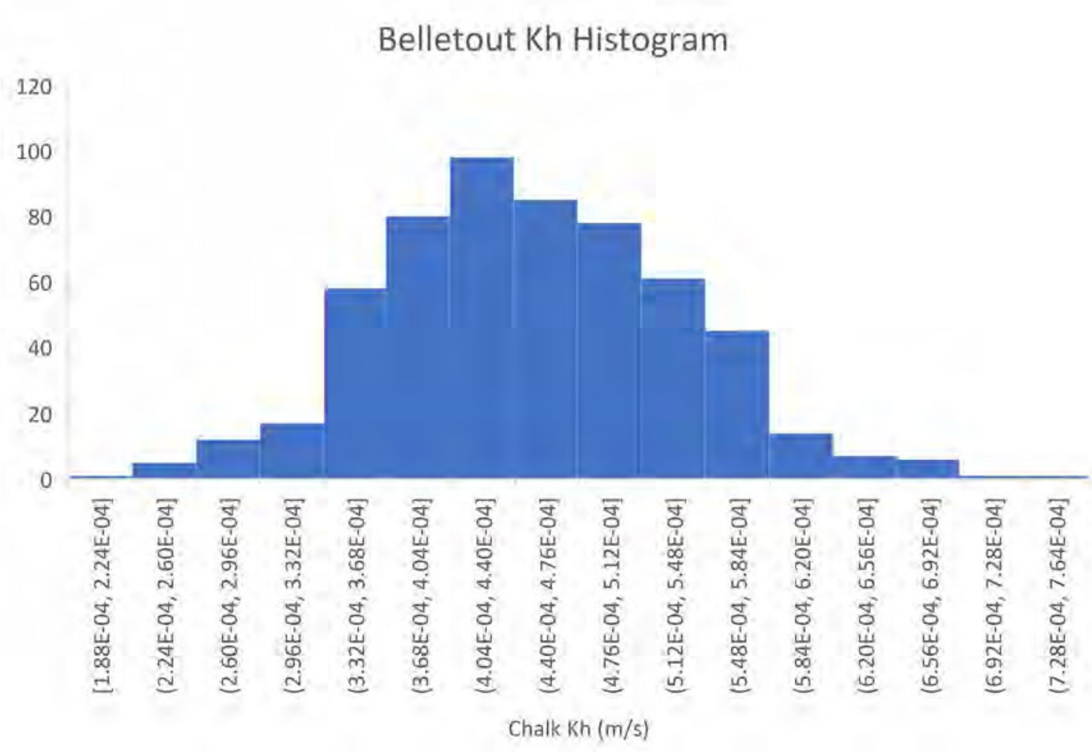
Plate 3.18 Monte Carlo results for the CKD



Belle Tout Formation (upper part of Chalk)

3.3.7 Plate 3.16 shows that the calibrated values for the Belle Tout layer that forms the upper part of the Chalk, form a normal distribution with a skew to higher values. The 50th percentile is $8x10^{-4}$m/s. Lower hydraulic conductivities cause hydraulic gradient between the Thames and the hinterlands to become too steep. This causes the calibration of the observed Chalk water levels in borehole to become poorer. Higher hydraulic conductivity values do not affect the observed Chalk water levels but cause the hinterland regions to drain too freely. This causes the steady state calibration against the February 2014 regional water levels to fail.

Plate 3.19 Monte Carlo results for the Belle Tout Formation



Bulk Chalk (buried structured chalk, low transmissivity)

3.3.8 Plate 3.17 to Plate 3.19 show the calibrated values for the Chalk layer that forms the remaining aquifer beneath the Belle Tout layer (approx. 35m bgl) to the base of the model (170m bgl). This has been done by varying the transmissivity of the aquifer within three zones, matching Plate 2.7 as follows:

a. T>250m^2/d (Plate 3.17)

b. 100<T<250m^2/d (Plate 3.18)

c. 20<T<100m^2/d (Plate 3.19)

3.3.9 The transmissivity calibrated in the model is for the deeper Chalk and excludes the transmissivity of the shallow Belle Tout and unstructured Chalk zones.

Plate 3.20 Monte Carlo results for the bulk Chalk rock (Environment Agency Zone T>250m²/d)

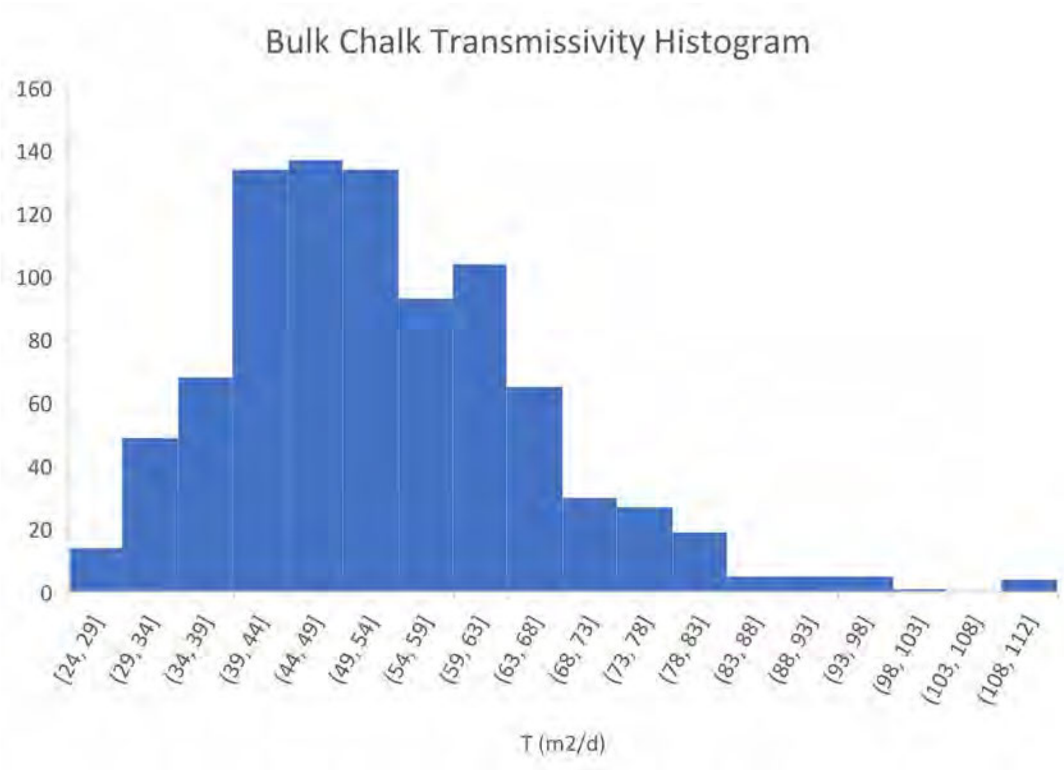


Plate 3.21 Monte Carlo results for the bulk Chalk rock (Environment Agency Zone 100<T<250m²/d)

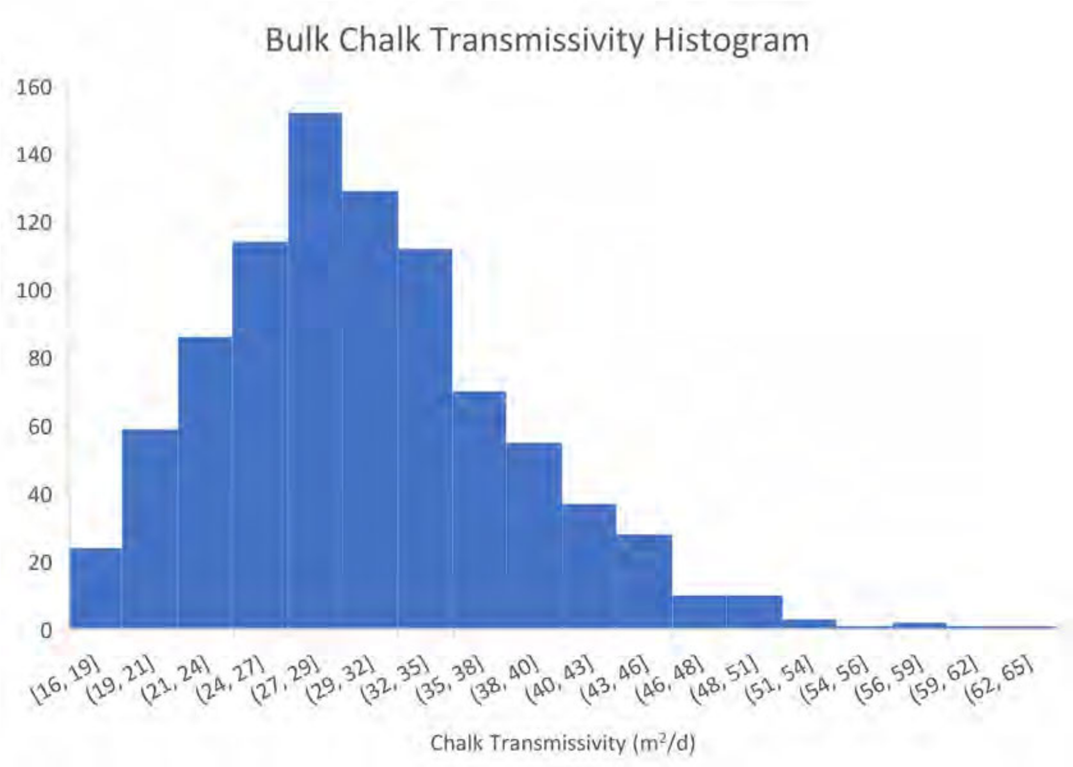
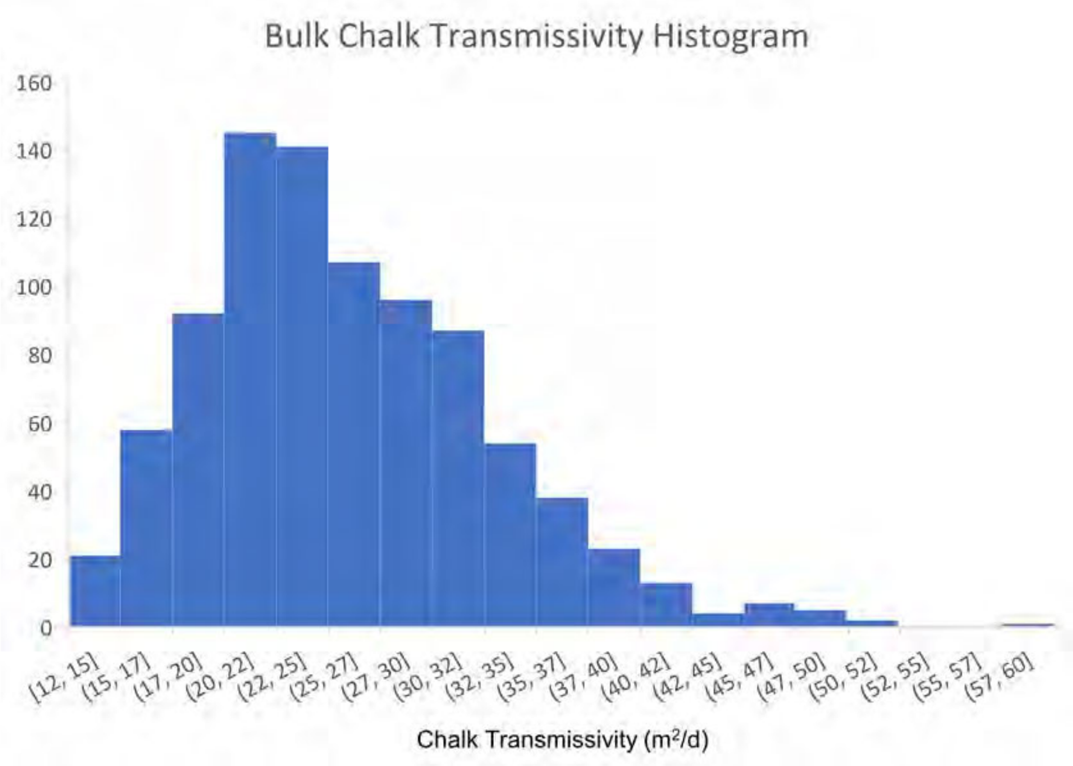


Plate 3.22 Monte Carlo results for the bulk Chalk rock (Environment Agency Zone 20<T<100m^2/d)



Representative 50th percentile model

3.3.10 Table 3.3 presents the results for the 50th and 95th percentile parameters from the Monte Carlo simulation.

Table 3.3 Material permeability for different percentiles

<table>
<tr><th>Material</th><th>Hydraulic conductivity 50th percentile (m/s)</th><th>Hydraulic conductivity 5th percentile (m/s)</th><th>Hydraulic conductivity 95th percentile (m/s)</th></tr>
<tr><td>[1]Made Ground</td><td colspan="3">1.0x10^{-5}</td></tr>
<tr><td>[1]Head Deposits</td><td colspan="3">5.0x10^{-7}</td></tr>
<tr><td>Alluvium</td><td>7.7x10^{-7}</td><td>2.6x10^{-7}</td><td>3.7x10^{-6}</td></tr>
<tr><td>RTD</td><td>4.67x10^{-4}</td><td>1.41x10^{-5}</td><td>1.45x10^{-3}</td></tr>
<tr><td>[1,2]London Clay</td><td colspan="3">1.0x10^{-7}</td></tr>
<tr><td>[1]Lambeth Group</td><td colspan="3">1.0x10^{-7}</td></tr>
<tr><td>[1]Harwich Formation</td><td colspan="3">1.0x10^{-5}</td></tr>
<tr><td>[1,3]Thanet Formation</td><td colspan="3">1.0x10^{-4}</td></tr>
<tr><td>CKD (unstructured Chalk)</td><td>1.0x10^{-2}</td><td>8.4x10^{-3}</td><td>1.1x10^{-2}</td></tr>
<tr><td>Belle Tout Chalk layer</td><td>4.5x10^{-4}</td><td>3.3x10^{-4}</td><td>5.9x10^{-3}</td></tr>
</table>

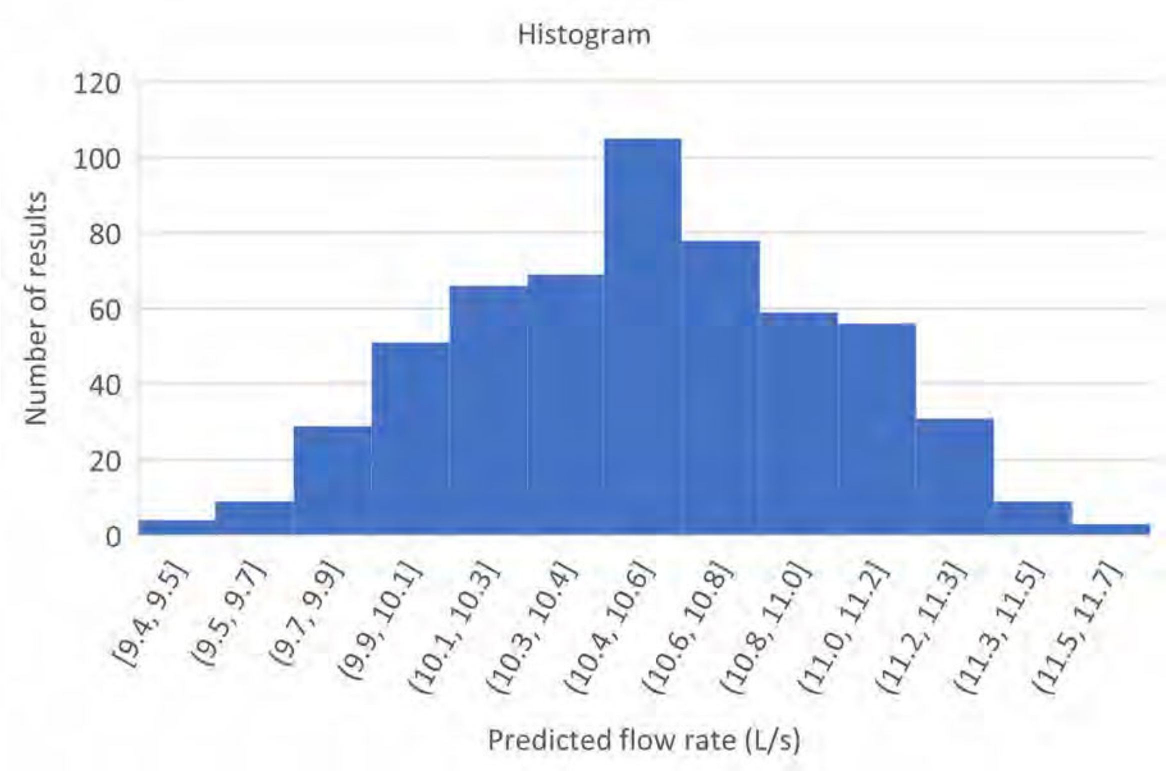
Material	Hydraulic conductivity 50th percentile (m/s)	Hydraulic conductivity 5th percentile (m/s)	Hydraulic conductivity 95th percentile (m/s)
Bulk Chalk transmissivity (m^2/d) (Environment Agency Zone T<250)	50.31 (transmissivity)	32.87 (transmissivity)	76.28 (transmissivity)
Bulk Chalk transmissivity (m^2/d) (Environment Agency Zone 100<T<250)	29.85 (transmissivity)	19.85 (transmissivity)	43.65 (transmissivity)
Bulk Chalk transmissivity (m^2/d) (Environment Agency Zone 20<T<100)	23.67 (transmissivity)	16.61 (transmissivity)	37.20 (transmissivity)

[1] Manual calibration and not varied in assessment.
[2] This is relatively high for London Clay, but it is sufficiently low that it is a non-aquifer within the model.
[3] This is at the upper end of the range for the Thanet Sands and reflects sandier parts of the formation. The model is insensitive to it and it is distant from the Project and the impact of the Project.

Groundwater inflow during construction with grout plug

3.3.11 For each parameter setup that had an SRMSE of less than 10% compared to the February 2014 water levels and observed water level data, a scenario run was completed. The scenario was for the baseline construction, with grout plug and diaphragm walls. Plate 3.20 shows the results for 569 successful parameter combinations. The 50th percentile of the predicted inflow rate result is 10.5L/s and the 95th percentile is 11.2L/s.

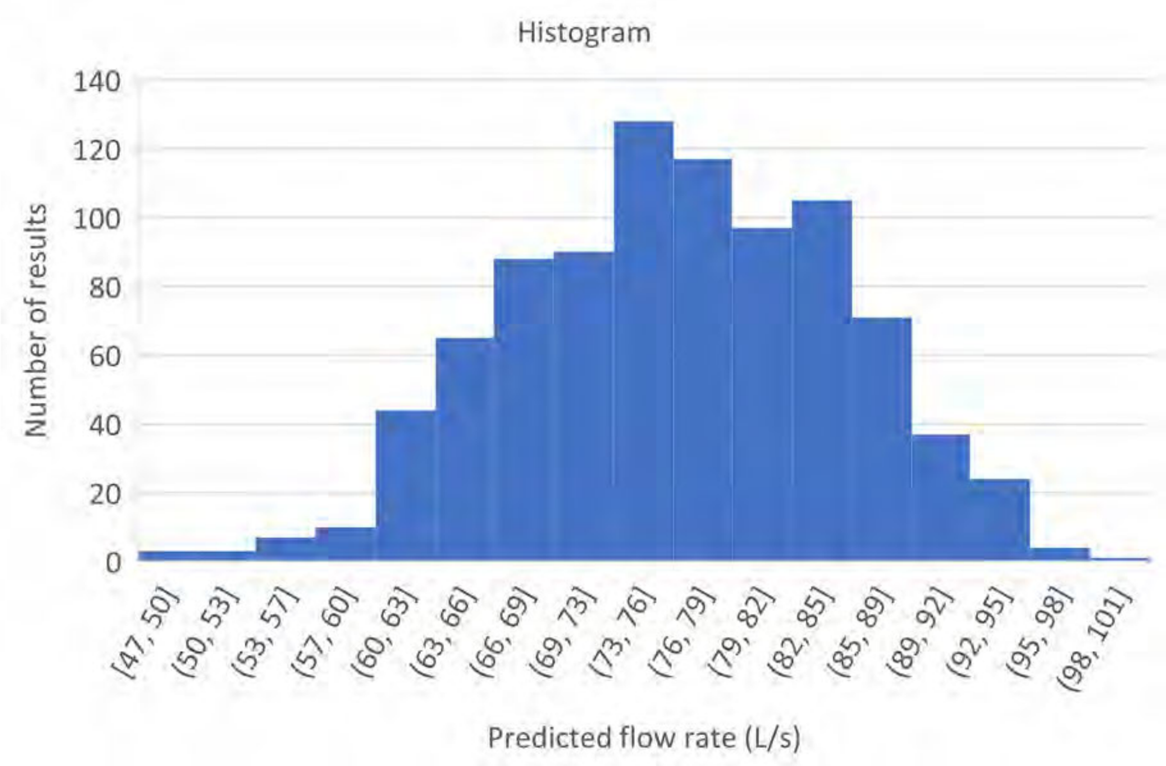
Plate 3.23 Monte Carlo assessment results for Project inflow rate



Groundwater inflow during construction without a grout plug

3.3.12 A second Monte Carlo simulation was completed for the baseline construction scenario but without a grout plug below the portal excavation. The diaphragm walls were included in the simulations. Of the 1,700 parameter setups that were simulated, 899 had a chalk SRMSE of less than 10%. Plate 3.21shows the expected flows from the 899 parameter setups. The 50th percentile of the predicted inflow rate result is 73L/s and the 95th percentile is 90.5L/s.

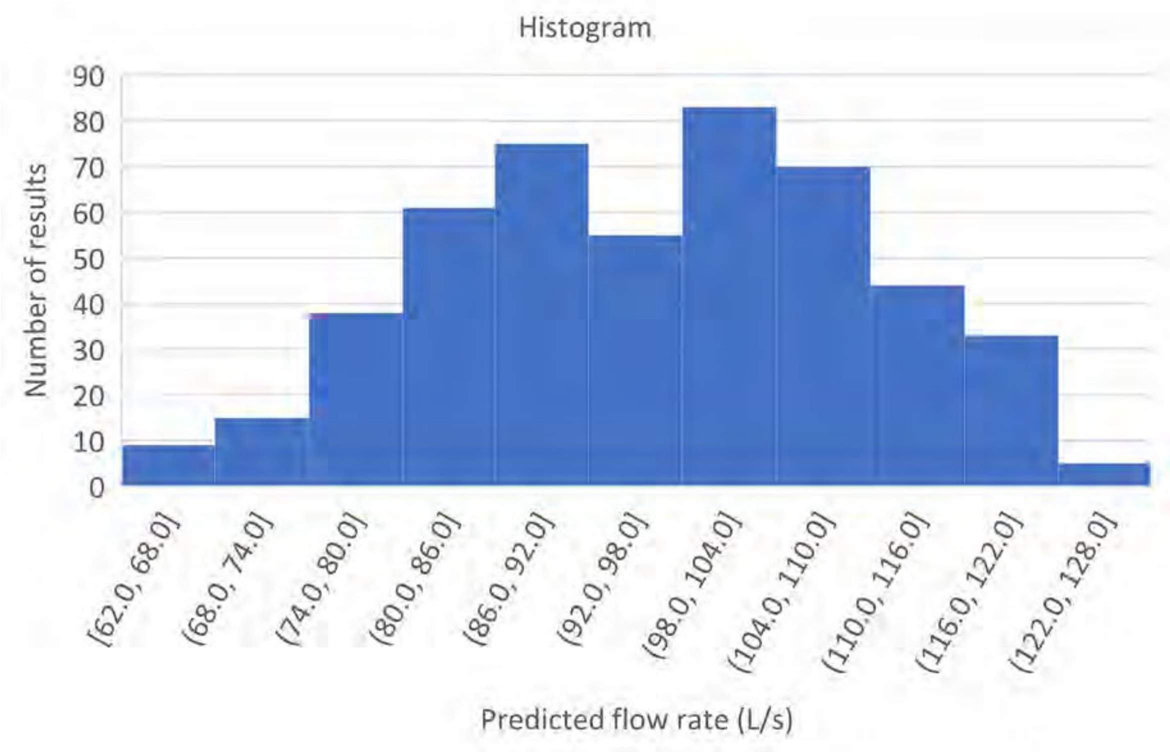
Plate 3.24 Monte Carlo assessment results for Project inflow rate without a grout plug



Groundwater inflow during construction without any mitigation measures

3.3.13 A Monte Carlo simulation was completed for the baseline construction scenario without any mitigation measures (either diaphragm walls, grout plug or slurry wall). Up to 1,153 parameter setups were simulated, of which 493 had a Chalk SRMSE of less than 10%. Plate 3.22 shows the expected flows from the 493 combinations. The 50th percentile of the predicted inflow rate result is 97L/s and the 95th percentile is 117L/s.

Plate 3.25 Monte Carlo assessment results for Project inflow rate, without grout plug, diaphragm walls or slurry wall



4 Summary

4.1.1 Groundwater modelling has been completed for the proposed North Portal and main tunnels, to the north of the River Thames.

4.1.2 The groundwater model included a 3D geological model supplied by the BGS, supplemented with site-specific information gained from ground investigations completed for the Project. This data included material type, stratigraphy and RQD information from boreholes, packer test data and variable head test data. The North Portal model was developed in conjunction with the Ramsar model. The geological and numerical layering is the same for both, though the extents, boundary conditions and calibrated parameters are different.

4.1.3 Groundwater level data from the Project site boreholes was used to calibrate the steady state model and a time-variant tidal response model. As a result of calibration to the new data, adjustments were made to the conceptual model. These included a zone of high transmissivity associated with RQD of less than 0.1, zones of core loss and Chalk weathering of CIRIA grade Dc. This zone enables a strong hydraulic, confined response within the Chalk to the River Thames tide. These high transmissivity layers exist at a shallow elevation within the Chalk, in a thin layer beneath the RTD.

4.1.4 A manual calibration was completed, followed by a Monte Carlo assessment, in which parameters were varied within ranges to determine the potential combinations of parameters that maintain a reasonable calibration.

4.1.5 Prediction of drawdown was completed using the manual calibration.

4.1.6 The predictive scenarios included the following:

a. Construction – excavation of ramp and portal, with variations of the following mitigation measures:

   i. Diaphragm walls

   ii. Grout plug

   iii. Slurry wall with grout plug and diaphragm walls

b. Operation – main tunnels:

   i. Prescription of main tunnel inflows using British Tunnelling Society standards (British Tunnelling Society and Institution of Civil Engineers, 2010)

c. Operation – main tunnels with ground improvement

   i. As per previous scenario but with shallow soil mixing and deep soil columns (DSM) included

4.1.7 The baseline construction scenario has a grout plug 5m thick in the ramp area and 10m thick in the portal area. It has also diaphragm walls installed at varying depths to a maximum of -37.5m AOD. The predicted groundwater drainage is between 9.4L/s and 11.7L/s. Outside of the diaphragm walls, long-term drawdown within the RTD/Chalk aquifer is predicted to be below 0.3m at a radius of approximately 500m and below 0.1m at approximately 1km radius from the site. A SEAWAT simulation was completed and showed that no notable saline interface movement would be caused by the Project.

4.1.8 A Monte Carlo assessment was used to investigate the range of potential inflows, which found the following:

a. Using the baseline construction scenario, the groundwater drainage is predicted to be between 9.4L/s and 11.7L/s.

b. Without the basal grout plug, the groundwater drainage is predicted to be between 47L/s and 99L/s.

c. Without the basal grout plug and diaphragm walls, the groundwater drainage rate is predicted to be between 62L/s to 124L/s.

4.1.9 A sensitivity assessment of mitigation measures was completed using variations of the baseline construction scenario, which found the following:

a. The resultant flow is quite sensitive to small changes in the hydraulic conductivity of the grout plug. For a hydraulic conductivity range of between $1x10^{-8}$m/s and $1x10^{-6}$m/s, a flow rate of between 1.4L/s and 39.8L/s was predicted respectively.

b. The thickness of the grout plug was varied from 20% to 150% of its thickness in the baseline scenario setup. The result found that:

   i. a decrease in grout plug thickness of 50% would increase the groundwater inflow rate by 56%

   ii. an increase in grout plug thickness of 50% would decrease the groundwater inflow rate by less than 20%.

c. The depth of the diaphragm wall was varied in three zones. This showed that deepening the central zone (Zone B) of diaphragm wall from -27.5m AOD to -32.5m AOD could further decrease the groundwater inflow by approximately 20%. Deepening the other zones of the wall made no difference to the result, suggesting they are sufficiently deep.

4.1.10 Should there be a need to mitigate against movement of potentially contaminated groundwater to the site from historical land uses, then a slurry wall could be one supplementary mitigation measure option. This would be potentially located between the portal, ramp and the East Tilbury Landfill. Modelling results of different slurry wall depths are presented in this report and show that with slurry wall, the magnitude of a potential contamination peak would be reduced and occur later. However, this work is superseded by later work presented in Appendix 10.7: East Tilbury Landfill Risk Assessment Technical Memorandum (Application Document 6.3). The latter confirms that there are no significant risks posed by East Tilbury Landfill as a result of the Project.

4.1.11 The Linford Public Water Supply, operated by Essex and Suffolk Water, is within the model domain, approximately 3km north of the Project. The use of this site for water supply is licensed by the Environment Agency. The Applicant may agree with Essex and Suffolk Water to use the construction site for water supply at rates within the licensed condition. Simulations were made of the combined effects of drawdown and saline interface movement. The simulations showed the following:

a. When pumping at 3.5ML/d or 6ML/d, a small amount of saline interface movement would occur within RTD and structured Chalk aquifers. This is located in a strip 150m to 300m thick along the edge of the River Thames. The magnitude of the increase was less than 0.1g/L salinity.

b. The saline interface was not predicted to impact upon the Project or the Linford abstraction well.

c. With the baseline scenario mitigation measures in place, drawdown from the Project does not affect the Linford site, even if the construction inflows were permanent (steady state).

4.1.12 The operations models simulated the inflows to the Project main tunnels only. It is assumed that the ramp and portal area would be sealed from groundwater ingress during operation. The inflow to the tunnels would be controlled to $0.1L/d/m^2$ as the tunnels would be constructed to meet pre-defined minimum design standards. The results showed that drawdown in general is less than 0.05m when further than 150m from the Project. Close to the diaphragm wall, immediately above the tunnel next to the portal, drawdown may be larger, due to boundary effects with the diaphragm wall. Overall, drawdown is really limited to the area immediately above the tunnel itself and may not be detectable in the field or may be on top of tidal fluctuations.

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Annexes

Annex A Packer and variable head tests included in the model

Borehole ID	Elevation (m AOD)	Screen (m AOD)	Hydraulic conductivity (m/s)	Easting	Northing	Screen length (m)	Ground investigation phase	Type (from AGS record)	Screen bottom (m bgl)	Screen top (m bgl)
BH2322	2.28	-13.32	2.40E-06	567883.4	173842.1	0.5	562289_V9-Final AGS2-Phase1A	Rising head	15.6	15.6
BH2322	2.28	-13.32	2.80E-05	567883.4	173842.1	0.5	562289_V9-Final AGS2-Phase1A	Falling head	15.6	15.6
BH2384	8.79	-18.11	8.00E-07	567348.3	176334.8	0.5	562289_V9-Final AGS2-Phase1A	Falling head	27.15	26.65
BH2384	8.79	-24.19	1.50E-06	567348.3	176334.8	0.5	562289_V9-Final AGS2-Phase1A	Falling head	33.23	32.73
BH2384	8.79	-22.86	2.00E-06	567348.3	176334.8	0.5	562289_V9-Final AGS2-Phase1A	Falling head	31.9	31.4
BH2385	7.14	-18.28	9.70E-07	567407.8	176463.1	0.5	562289_V9-Final AGS2-Phase1A	Falling head	25.67	25.17
BH2392A	5.36	-16.64	4.90E-06	567363.5	176631.4	0.5	562289_V9-Final AGS2-Phase1A	Falling head	22	22
BH2392A	5.36	-16.64	5.60E-04	567363.5	176631.4	0.5	562289_V9-Final AGS2-Phase1A	Rising head	22	22

Borehole ID	Elevation (m AOD)	Screen (m AOD)	Hydraulic conductivity (m/s)	Easting	Northing	Screen length (m)	Ground investigation phase	Type (from AGS record)	Screen bottom (m bgl)	Screen top (m bgl)
BH2384	8.79	-2.61	2.20E-06	567348.3	176334.8	0.6	562289_V9-Final AGS2-Phase1A	Falling head	11.7	11.1
BH2385	7.14	-20.46	3.50E-07	567407.8	176463.1	0.6	562289_V9-Final AGS2-Phase1A	Falling head	27.9	27.3
BH2385	7.14	-22.81	6.50E-07	567407.8	176463.1	0.6	562289_V9-Final AGS2-Phase1A	Falling head	30.25	29.65
BH2308	2.2	-1.7	6.00E-06	568082.9	173268.7	1	562289_V9-Final AGS2-Phase1A	Rising head	4.4	3.4
BH2308	2.2	-6.8	2.70E-05	568082.9	173268.7	1	562289_V9-Final AGS2-Phase1A	Rising head	9.5	8.5
BH02002	48.6	-6.9	5.08E-07	567807.4	171508.1	1.5		Packer		
BH02002	48.6	29.1	1.63E-06	567807.4	171508.1	1.5		Packer		
BH02002	48.6	38.35	1.73E-06	567807.4	171508.1	1.5		Packer		
BH2301	9.17	-39.28	4.97E-06	568028	173026.3	1.5		Packer		
BH2301	9.17	-9.28	1.00E-05	568028	173026.3	1.5		Packer		
BH2301	9.17	-27.28	2.02E-05	568028	173026.3	1.5		Packer		
BH2301	9.17	-21.28	3.27E-05	568028	173026.3	1.5		Packer		
BH2301	9.17	-13.28	3.89E-05	568028	173026.3	1.5		Packer		

Borehole ID	Elevation (m AOD)	Screen (m AOD)	Hydraulic conductivity (m/s)	Easting	Northing	Screen length (m)	Ground investigation phase	Type (from AGS record)	Screen bottom (m bgl)	Screen top (m bgl)
BH04009	5.8	-12.2	1.20E-05	567926	173142.8	1.5	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	18.75	17.25
BH04009	5.8	-12.2	1.25E-05	567926	173142.8	1.5		Packer		
BH04009	5.8	-12.2	1.30E-05	567926	173142.8	1.5	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	18.75	17.25
BH04009	5.8	-12.2	1.40E-05	567926	173142.8	1.5	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	18.75	17.25
BH04009	5.8	-12.2	1.50E-05	567926	173142.8	1.5	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	18.75	17.25
BH04009	5.8	-12.2	1.60E-05	567926	173142.8	1.5	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	18.75	17.25
BH04009	5.8	-12.2	1.80E-05	567926	173142.8	1.5	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	18.75	17.25
BH04009	5.8	-15.2	2.40E-05	567926	173142.8	1.5		Packer		
BH04009	5.8	-15.2	2.40E-05	567926	173142.8	1.5	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	21.75	20.25
BH04009	5.8	-15.2	3.00E-05	567926	173142.8	1.5	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	21.75	20.25

Borehole ID	Elevation (m AOD)	Screen (m AOD)	Hydraulic conductivity (m/s)	Easting	Northing	Screen length (m)	Ground investigation phase	Type (from AGS record)	Screen bottom (m bgl)	Screen top (m bgl)
BH04009	5.8	-15.2	3.10E-05	567926	173142.8	1.5	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	21.75	20.25
BH04009	5.8	-15.2	3.20E-05	567926	173142.8	1.5	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	21.75	20.25
OH07022	7.24	-36.01	9.30E-06	567341	176009	1.5	B-AGSF-X-X-X-D-X-X-X-0003-02012083	Water Pressure	44	42.5
OH07022	7.24	-36.01	9.70E-06	567341	176009	1.5	B-AGSF-X-X-X-D-X-X-X-0003-02012082	Water Pressure	44	42.5
OH07022	2.33	-36.01	1.00E-05	567341	176009	1.5		Packer		
OH07022	7.24	-36.01	1.00E-05	567341	176009	1.5	B-AGSF-X-X-X-D-X-X-X-0003-02012081	Water Pressure	44	42.5
OH07022	7.24	-36.01	1.00E-05	567341	176009	1.5	B-AGSF-X-X-X-D-X-X-X-0003-02012084	Water Pressure	44	42.5
OH07022	7.24	-36.01	1.10E-05	567341	176009	1.5	B-AGSF-X-X-X-D-X-X-X-0003-02012080	Water Pressure	44	42.5
OH07022	7.24	-29.01	3.00E-05	567341	176009	1.5	B-AGSF-X-X-X-D-X-X-X-0003-02012075	Water Pressure	37	35.5

Borehole ID	Elevation (m AOD)	Screen (m AOD)	Hydraulic conductivity (m/s)	Easting	Northing	Screen length (m)	Ground investigation phase	Type (from AGS record)	Screen bottom (m bgl)	Screen top (m bgl)
OH07022	7.24	-29.01	3.30E-05	567341	176009	1.5	B-AGSF-X-X-X-D-X-X-X-0003-02012076	Water Pressure	37	35.5
OH07022	7.24	-29.01	4.40E-05	567341	176009	1.5	B-AGSF-X-X-X-D-X-X-X-0003-02012077	Water Pressure	37	35.5
OH07022	7.24	-29.01	4.50E-05	567341	176009	1.5	B-AGSF-X-X-X-D-X-X-X-0003-02012078	Water Pressure	37	35.5
OH07022	2.33	-29.01	4.73E-05	567341	176009	1.5		Packer		
OH07022	7.24	-29.01	5.30E-05	567341	176009	1.5	B-AGSF-X-X-X-D-X-X-X-0003-02012079	Water Pressure	37	35.5
OH07022	2.33	-32.51	5.48E-05	567341	176009	1.5		Packer		
OH07021	7.64	-57.86	1.60E-07	567530	176062	1.5	B-AGSF-X-X-X-D-X-X-X-0003-02012072	Water Pressure	66.25	64.75
OH07021	7.64	-57.86	1.60E-07	567530	176062	1.5	B-AGSF-X-X-X-D-X-X-X-0003-02012074	Water Pressure	66.25	64.75
OH07021	7.64	-57.86	2.30E-07	567530	176062	1.5	B-AGSF-X-X-X-D-X-X-X-0003-02012073	Water Pressure	66.25	64.75
OH07021	2.33	-57.86	2.40E-07	567530	176062	1.5		Packer		

Borehole ID	Elevation (m AOD)	Screen (m AOD)	Hydraulic conductivity (m/s)	Easting	Northing	Screen length (m)	Ground investigation phase	Type (from AGS record)	Screen bottom (m bgl)	Screen top (m bgl)
OH07021	7.64	-57.86	3.30E-07	567530	176062	1.5	B-AGSF-X-X-X-D-X-X-X-0003-02012070	Water Pressure	66.25	64.75
OH07021	7.64	-57.86	4.90E-07	567530	176062	1.5	B-AGSF-X-X-X-D-X-X-X-0003-02012071	Water Pressure	66.25	64.75
OH07040	2.33	-35.52	7.24E-06	567379	176105	1.5		Packer		
OH07040	2.33	-32.02	9.00E-06	567379	176105	1.5		Packer		
OH07040	2.33	-28.52	4.24E-05	567379	176105	1.5		Packer		
BH1306	7.4	-27.8	3.61E-06	567449.8	175700.3	1.6		Packer		
BH1306	7.4	-33.8	4.89E-06	567449.8	175700.3	1.6		Packer		
BH1306	7.4	-39.8	2.27E-05	567449.8	175700.3	1.6		Packer		
OW06016	26.21	-45.7	2.65E-06	567608.5	175545.6	2		Packer		
OW06016	26.21	-41.7	2.76E-06	567608.5	175545.6	2		Packer		
OW06016	26.21	-33.7	1.52E-05	567608.5	175545.6	2		Packer		
BH13002	23.66	9.16	4.20E-07	564805.2	180074.9	2	C-AGSF-X-X-X-D-X-X-X-0004-02012064	Falling Head	15.5	13.5
BH01003	68.85	-1.15	2.60E-07	570033	169729.1	3	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	71.5	68.5
BH01003	68.85	-1.15	2.70E-07	570033	169729.1	3	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	71.5	68.5

Borehole ID	Elevation (m AOD)	Screen (m AOD)	Hydraulic conductivity (m/s)	Easting	Northing	Screen length (m)	Ground investigation phase	Type (from AGS record)	Screen bottom (m bgl)	Screen top (m bgl)
BH01003	68.85	-1.15	2.72E-07	570033	169729.1	3		Packer		
BH01003	68.85	-1.15	2.80E-07	570033	169729.1	3	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	71.5	68.5
BH01003	68.85	-1.15	2.90E-07	570033	169729.1	3	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	71.5	68.5
BH01003	68.85	2.85	5.40E-07	570033	169729.1	3	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	67.5	64.5
BH01003	68.85	2.85	5.60E-07	570033	169729.1	3	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	67.5	64.5
BH01003	68.85	2.85	5.86E-07	570033	169729.1	3		Packer		
BH01003	68.85	2.85	5.90E-07	570033	169729.1	3	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	67.5	64.5
BH01003	68.85	2.85	6.00E-07	570033	169729.1	3	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	67.5	64.5
BH01003	68.85	2.85	6.40E-07	570033	169729.1	3	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	67.5	64.5
BH01003	68.85	6.85	8.90E-07	570033	169729.1	3	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	63.5	60.5

Borehole ID	Elevation (m AOD)	Screen (m AOD)	Hydraulic conductivity (m/s)	Easting	Northing	Screen length (m)	Ground investigation phase	Type (from AGS record)	Screen bottom (m bgl)	Screen top (m bgl)
BH01003	68.85	6.85	9.90E-07	570033	169729.1	3	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	63.5	60.5
BH01003	68.85	6.85	1.04E-06	570033	169729.1	3		Packer		
BH01003	68.85	6.85	1.10E-06	570033	169729.1	3	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	63.5	60.5
BH01025	70.9	9.4	1.20E-07	567177.8	170977.2	3	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	63	60
BH01025	70.9	15.4	1.20E-07	567177.8	170977.2	3	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	57	54
BH01025	70.9	9.4	1.65E-07	567177.8	170977.2	3		Packer		
BH01025	70.9	9.4	2.10E-07	567177.8	170977.2	3	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	63	60
BH01025	70.9	15.4	2.60E-07	567177.8	170977.2	3	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	57	54
BH01025	70.9	9.4	2.70E-07	567177.8	170977.2	3	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	63	60
BH01025	70.9	15.4	2.70E-07	567177.8	170977.2	3		Packer		

Borehole ID	Elevation (m AOD)	Screen (m AOD)	Hydraulic conductivity (m/s)	Easting	Northing	Screen length (m)	Ground investigation phase	Type (from AGS record)	Screen bottom (m bgl)	Screen top (m bgl)
BH01025	70.9	9.4	2.90E-07	567177.8	170977.2	3	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	63	60
BH01025	70.9	15.4	2.90E-07	567177.8	170977.2	3	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	57	54
BH01025	70.9	15.4	3.10E-07	567177.8	170977.2	3	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	57	54
BH01025	70.9	12.4	4.10E-07	567177.8	170977.2	3	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	60	57
BH01025	70.9	12.4	4.30E-07	567177.8	170977.2	3	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	60	57
BH01025	70.9	12.4	4.40E-07	567177.8	170977.2	3		Packer		
BH01025	70.9	12.4	4.60E-07	567177.8	170977.2	3	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	60	57
BH01025	70.9	12.4	4.70E-07	567177.8	170977.2	3	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	60	57
BH02002	48.6	20.1	3.30E-07	567807.4	171508.1	3		Packer		
BH02002	48.6	7.1	4.20E-07	567807.4	171508.1	3		Packer		
BH02002	48.6	0.1	6.90E-07	567807.4	171508.1	3		Packer		
BH02002	48.6	14.1	8.65E-07	567807.4	171508.1	3		Packer		

Borehole ID	Elevation (m AOD)	Screen (m AOD)	Hydraulic conductivity (m/s)	Easting	Northing	Screen length (m)	Ground investigation phase	Type (from AGS record)	Screen bottom (m bgl)	Screen top (m bgl)
BH04009	5.8	-25.2	2.30E-06	567926	173142.8	3	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	32.5	29.5
BH04009	5.8	-25.2	2.50E-06	567926	173142.8	3	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	32.5	29.5
BH04009	5.8	-25.2	2.52E-06	567926	173142.8	3		Packer		
BH04009	5.8	-25.2	2.60E-06	567926	173142.8	3	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	32.5	29.5
BH04009	5.8	-25.2	2.70E-06	567926	173142.8	3	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	32.5	29.5
BH04009	5.8	-20.2	7.50E-06	567926	173142.8	3	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	27.5	24.5
BH04009	5.8	-20.2	8.00E-06	567926	173142.8	3		Packer		
BH04009	5.8	-20.2	8.50E-06	567926	173142.8	3	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	27.5	24.5
BH04009	5.8	-20.2	8.60E-06	567926	173142.8	3	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	27.5	24.5
BH04009	5.8	-20.2	9.20E-06	567926	173142.8	3	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	27.5	24.5

Borehole ID	Elevation (m AOD)	Screen (m AOD)	Hydraulic conductivity (m/s)	Easting	Northing	Screen length (m)	Ground investigation phase	Type (from AGS record)	Screen bottom (m bgl)	Screen top (m bgl)
BH04009	5.8	-20.2	9.60E-06	567926	173142.8	3	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	27.5	24.5
BH04015	1.95	-42.05	2.10E-07	568028.6	173521.8	3	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	45.5	42.5
BH04015	1.95	-42.05	2.15E-07	568028.6	173521.8	3		Packer		
BH04015	1.95	-42.05	2.20E-07	568028.6	173521.8	3	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	45.5	42.5
BH04015	1.95	-42.05	2.40E-07	568028.6	173521.8	3	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	45.5	42.5
BH04015	1.95	-42.05	2.60E-07	568028.6	173521.8	3	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	45.5	42.5
BH04015	1.95	-42.05	2.90E-07	568028.6	173521.8	3	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	45.5	42.5
BH04015	1.95	-34.85	3.90E-06	568028.6	173521.8	3		Packer		
BH04015	1.95	-34.85	3.90E-06	568028.6	173521.8	3	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	38.3	35.3
BH04015	1.95	-30.05	3.90E-06	568028.6	173521.8	3	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	33.5	30.5

Borehole ID	Elevation (m AOD)	Screen (m AOD)	Hydraulic conductivity (m/s)	Easting	Northing	Screen length (m)	Ground investigation phase	Type (from AGS record)	Screen bottom (m bgl)	Screen top (m bgl)
BH04015	1.95	-30.05	4.10E-06	568028.6	173521.8	3		Packer		
BH04015	1.95	-30.05	4.30E-06	568028.6	173521.8	3	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	33.5	30.5
BH04015	1.95	-34.85	4.40E-06	568028.6	173521.8	3	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	38.3	35.3
BH04015	1.95	-30.05	4.80E-06	568028.6	173521.8	3	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	33.5	30.5
BH04015	1.95	-30.05	5.00E-06	568028.6	173521.8	3	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	33.5	30.5
BH04015	1.95	-34.85	5.20E-06	568028.6	173521.8	3	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	38.3	35.3
BH04015	1.95	-30.05	5.90E-06	568028.6	173521.8	3	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	33.5	30.5
BH04015	1.95	-34.85	6.60E-06	568028.6	173521.8	3	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	38.3	35.3
BH04015	1.95	-34.85	7.90E-06	568028.6	173521.8	3	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	38.3	35.3

Borehole ID	Elevation (m AOD)	Screen (m AOD)	Hydraulic conductivity (m/s)	Easting	Northing	Screen length (m)	Ground investigation phase	Type (from AGS record)	Screen bottom (m bgl)	Screen top (m bgl)
BH04015	1.95	-25.25	8.80E-06	568028.6	173521.8	3	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	28.7	25.7
BH04015	1.95	-25.25	1.10E-05	568028.6	173521.8	3	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	28.7	25.7
BH04015	1.95	-25.25	1.14E-05	568028.6	173521.8	3		Packer		
BH04015	1.95	-25.25	1.20E-05	568028.6	173521.8	3	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	28.7	25.7
BH04015	1.95	-25.25	1.30E-05	568028.6	173521.8	3	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	28.7	25.7
BH2316	2.18	-16.32	7.00E-07	568038.2	173653.4	3	562289_V9-Final AGS2-Phase1A	Falling head	20	17
BH2316	2.18	-29.82	1.70E-06	568038.2	173653.4	3	562289_V9-Final AGS2-Phase1A	Falling head	33.5	30.5
BH2316	2.18	-37.97	7.78E-06	568038.2	173653.4	3		Packer		
BH2316	2.18	-31.97	1.53E-05	568038.2	173653.4	3		Packer		
BH2316	2.18	-25.97	1.54E-05	568038.2	173653.4	3		Packer		
OW05002	-7.72	-29.02	6.70E-06	567742.3	174496.4	3	E-AGSF-X-X-X-D-X-X-X-0002-02012020	Packer Test	22.8	19.8

Borehole ID	Elevation (m AOD)	Screen (m AOD)	Hydraulic conductivity (m/s)	Easting	Northing	Screen length (m)	Ground investigation phase	Type (from AGS record)	Screen bottom (m bgl)	Screen top (m bgl)
OW05002	-7.72	-29.02	6.90E-06	567742.3	174496.4	3	E-AGSF-X-X-X-D-X-X-X-0002-02012020	Packer Test	22.8	19.8
OW05002	-7.72	-29.02	7.10E-06	567742.3	174496.4	3	E-AGSF-X-X-X-D-X-X-X-0002-02012020	Packer Test	22.8	19.8
OW05002	26.21	-29.02	7.12E-06	567742.3	174496.4	3		Packer		
OW05002	-7.72	-29.02	7.30E-06	567742.3	174496.4	3	E-AGSF-X-X-X-D-X-X-X-0002-02012020	Packer Test	22.8	19.8
OW05002	-7.72	-47.32	7.40E-06	567742.3	174496.4	3	E-AGSF-X-X-X-D-X-X-X-0002-02012020	Packer Test	41.1	38.1
OW05002	26.21	-47.32	7.40E-06	567742.3	174496.4	3		Packer		
OW05002	-7.72	-29.02	7.60E-06	567742.3	174496.4	3	E-AGSF-X-X-X-D-X-X-X-0002-02012020	Packer Test	22.8	19.8
OW05002	-7.72	-41.32	8.30E-06	567742.3	174496.4	3	E-AGSF-X-X-X-D-X-X-X-0002-02012020	Packer Test	35.1	32.1
OW05002	-7.72	-47.32	8.40E-06	567742.3	174496.4	3	E-AGSF-X-X-X-D-X-X-X-0002-02012020	Packer Test	41.1	38.1
OW05002	-7.72	-47.32	9.10E-06	567742.3	174496.4	3	E-AGSF-X-X-X-D-X-X-X-0002-02012020	Packer Test	41.1	38.1

Borehole ID	Elevation (m AOD)	Screen (m AOD)	Hydraulic conductivity (m/s)	Easting	Northing	Screen length (m)	Ground investigation phase	Type (from AGS record)	Screen bottom (m bgl)	Screen top (m bgl)
OW05002	-7.72	-41.32	9.50E-06	567742.3	174496.4	3	E-AGSF-X-X-X-D-X-X-X-0002-02012020	Packer Test	35.1	32.1
OW05002	-7.72	-47.32	1.00E-05	567742.3	174496.4	3	E-AGSF-X-X-X-D-X-X-X-0002-02012020	Packer Test	41.1	38.1
OW05002	-7.72	-41.32	1.10E-05	567742.3	174496.4	3	E-AGSF-X-X-X-D-X-X-X-0002-02012020	Packer Test	35.1	32.1
OW05002	26.21	-41.32	1.10E-05	567742.3	174496.4	3		Packer		
OW05002	-7.72	-47.32	1.20E-05	567742.3	174496.4	3	E-AGSF-X-X-X-D-X-X-X-0002-02012020	Packer Test	41.1	38.1
OW05002	-7.72	-35.32	1.90E-05	567742.3	174496.4	3	E-AGSF-X-X-X-D-X-X-X-0002-02012020	Packer Test	29.1	26.1
OW05002	26.21	-35.32	1.90E-05	567742.3	174496.4	3		Packer		
OW05002	-7.72	-35.32	2.20E-05	567742.3	174496.4	3	E-AGSF-X-X-X-D-X-X-X-0002-02012020	Packer Test	29.1	26.1
OW05002	-7.72	-35.32	2.50E-05	567742.3	174496.4	3	E-AGSF-X-X-X-D-X-X-X-0002-02012020	Packer Test	29.1	26.1
OW05007	-12.22	-54.12	1.10E-06	567781.6	174776.4	3	E-AGSF-X-X-X-D-X-X-X-0002-02012020	Packer Test	43.4	40.4

Borehole ID	Elevation (m AOD)	Screen (m AOD)	Hydraulic conductivity (m/s)	Easting	Northing	Screen length (m)	Ground investigation phase	Type (from AGS record)	Screen bottom (m bgl)	Screen top (m bgl)
OW05007	-12.22	-54.12	1.30E-06	567781.6	174776.4	3	E-AGSF-X-X-X-D-X-X-X-0002-02012020	Packer Test	43.4	40.4
OW05007	-12.22	-54.12	1.50E-06	567781.6	174776.4	3	E-AGSF-X-X-X-D-X-X-X-0002-02012020	Packer Test	43.4	40.4
OW05007	-12.22	-54.12	1.60E-06	567781.6	174776.4	3	E-AGSF-X-X-X-D-X-X-X-0002-02012020	Packer Test	43.4	40.4
OW05007	26.21	-54.12	1.60E-06	567781.6	174776.4	3		Packer		
OW05007	-12.22	-39.26	1.80E-06	567781.6	174776.4	3	E-AGSF-X-X-X-D-X-X-X-0002-02012020	Packer Test	28.54	25.54
OW05007	-12.22	-54.12	1.90E-06	567781.6	174776.4	3	E-AGSF-X-X-X-D-X-X-X-0002-02012020	Packer Test	43.4	40.4
OW05007	-12.22	-39.26	1.90E-06	567781.6	174776.4	3	E-AGSF-X-X-X-D-X-X-X-0002-02012020	Packer Test	28.54	25.54
OW05007	-12.22	-32.96	1.90E-06	567781.6	174776.4	3	E-AGSF-X-X-X-D-X-X-X-0002-02012020	Packer Test	22.24	19.24
OW05007	26.21	-39.26	1.98E-06	567781.6	174776.4	3		Packer		
OW05007	-12.22	-39.26	2.00E-06	567781.6	174776.4	3	E-AGSF-X-X-X-D-X-X-X-0002-02012020	Packer Test	28.54	25.54

Borehole ID	Elevation (m AOD)	Screen (m AOD)	Hydraulic conductivity (m/s)	Easting	Northing	Screen length (m)	Ground investigation phase	Type (from AGS record)	Screen bottom (m bgl)	Screen top (m bgl)
OW05007	-12.22	-32.96	2.10E-06	567781.6	174776.4	3	E-AGSF-X-X-X-D-X-X-X-0002-02012020	Packer Test	22.24	19.24
OW05007	-12.22	-39.26	2.30E-06	567781.6	174776.4	3	E-AGSF-X-X-X-D-X-X-X-0002-02012020	Packer Test	28.54	25.54
OW05007	-12.22	-32.96	2.30E-06	567781.6	174776.4	3	E-AGSF-X-X-X-D-X-X-X-0002-02012020	Packer Test	22.24	19.24
OW05007	-12.22	-32.96	2.50E-06	567781.6	174776.4	3	E-AGSF-X-X-X-D-X-X-X-0002-02012020	Packer Test	22.24	19.24
OW05007	26.21	-32.96	2.53E-06	567781.6	174776.4	3		Packer		
OW05007	-12.22	-32.96	2.80E-06	567781.6	174776.4	3	E-AGSF-X-X-X-D-X-X-X-0002-02012020	Packer Test	22.24	19.24
OW05007	-12.22	-48.12	4.60E-06	567781.6	174776.4	3	E-AGSF-X-X-X-D-X-X-X-0002-02012020	Packer Test	37.4	34.4
OW05007	26.21	-48.12	4.60E-06	567781.6	174776.4	3		Packer		
OW05007	-12.22	-48.12	4.90E-06	567781.6	174776.4	3	E-AGSF-X-X-X-D-X-X-X-0002-02012020	Packer Test	37.4	34.4
OW05007	-12.22	-48.12	5.40E-06	567781.6	174776.4	3	E-AGSF-X-X-X-D-X-X-X-0002-02012020	Packer Test	37.4	34.4

Borehole ID	Elevation (m AOD)	Screen (m AOD)	Hydraulic conductivity (m/s)	Easting	Northing	Screen length (m)	Ground investigation phase	Type (from AGS record)	Screen bottom (m bgl)	Screen top (m bgl)
OW05007	-12.22	-48.12	5.50E-06	567781.6	174776.4	3	E-AGSF-X-X-X-D-X-X-X-0002-02012020	Packer Test	37.4	34.4
OW05007	-12.22	-32.96	6.30E-06	567781.6	174776.4	3	E-AGSF-X-X-X-D-X-X-X-0002-02012020	Packer Test	22.24	19.24
OW05007	26.21	-32.96	6.30E-06	567781.6	174776.4	3		Packer		
OW05007	-12.22	-48.12	6.80E-06	567781.6	174776.4	3	E-AGSF-X-X-X-D-X-X-X-0002-02012020	Packer Test	37.4	34.4
OW05007	-12.22	-32.96	9.70E-06	567781.6	174776.4	3	E-AGSF-X-X-X-D-X-X-X-0002-02012020	Packer Test	22.24	19.24
OW05007	-12.22	-32.96	1.10E-05	567781.6	174776.4	3	E-AGSF-X-X-X-D-X-X-X-0002-02012020	Packer Test	22.24	19.24
OW05007	-12.22	-32.96	1.30E-05	567781.6	174776.4	3	E-AGSF-X-X-X-D-X-X-X-0002-02012020	Packer Test	22.24	19.24
OW05007	-12.22	-32.96	1.50E-05	567781.6	174776.4	3	E-AGSF-X-X-X-D-X-X-X-0002-02012020	Packer Test	22.24	19.24
OW06001	-13.15	-32.99	3.90E-07	567659.3	174856.3	3	E-AGSF-X-X-X-D-X-X-X-0002-02012020	Packer Test	21.34	18.34

Borehole ID	Elevation (m AOD)	Screen (m AOD)	Hydraulic conductivity (m/s)	Easting	Northing	Screen length (m)	Ground investigation phase	Type (from AGS record)	Screen bottom (m bgl)	Screen top (m bgl)
OW06001	-13.15	-32.99	4.10E-07	567659.3	174856.3	3	E-AGSF-X-X-X-D-X-X-X-0002-02012020	Packer Test	21.34	18.34
OW06001	-13.15	-32.99	4.30E-07	567659.3	174856.3	3	E-AGSF-X-X-X-D-X-X-X-0002-02012020	Packer Test	21.34	18.34
OW06001	-13.15	-32.99	4.70E-07	567659.3	174856.3	3	E-AGSF-X-X-X-D-X-X-X-0002-02012020	Packer Test	21.34	18.34
OW06001	-13.15	-32.99	4.80E-07	567659.3	174856.3	3	E-AGSF-X-X-X-D-X-X-X-0002-02012020	Packer Test	21.34	18.34
OW06001	26.21	-32.99	9.00E-06	567659.3	174856.3	3		Packer		
OW06001	-13.15	-39.55	9.30E-06	567659.3	174856.3	3	E-AGSF-X-X-X-D-X-X-X-0002-02012020	Packer Test	27.9	24.9
OW06001	-13.15	-39.55	9.90E-06	567659.3	174856.3	3	E-AGSF-X-X-X-D-X-X-X-0002-02012020	Packer Test	27.9	24.9
OW06001	-13.15	-39.55	1.00E-05	567659.3	174856.3	3	E-AGSF-X-X-X-D-X-X-X-0002-02012020	Packer Test	27.9	24.9
OW06001	26.21	-39.55	1.00E-05	567659.3	174856.3	3		Packer		
OW06001	-13.15	-45.55	1.10E-05	567659.3	174856.3	3	E-AGSF-X-X-X-D-X-X-X-0002-02012020	Packer Test	33.9	30.9

Borehole ID	Elevation (m AOD)	Screen (m AOD)	Hydraulic conductivity (m/s)	Easting	Northing	Screen length (m)	Ground investigation phase	Type (from AGS record)	Screen bottom (m bgl)	Screen top (m bgl)
OW06001	-13.15	-39.55	1.10E-05	567659.3	174856.3	3	E-AGSF-X-X-X-D-X-X-X-0002-02012020	Packer Test	27.9	24.9
OW06001	-13.15	-51.55	1.40E-05	567659.3	174856.3	3	E-AGSF-X-X-X-D-X-X-X-0002-02012020	Packer Test	39.9	36.9
OW06001	-13.15	-45.55	1.40E-05	567659.3	174856.3	3	E-AGSF-X-X-X-D-X-X-X-0002-02012020	Packer Test	33.9	30.9
OW06001	-13.15	-51.55	1.50E-05	567659.3	174856.3	3	E-AGSF-X-X-X-D-X-X-X-0002-02012020	Packer Test	39.9	36.9
OW06001	26.21	-51.55	1.52E-05	567659.3	174856.3	3		Packer		
OW06001	-13.15	-51.55	1.60E-05	567659.3	174856.3	3	E-AGSF-X-X-X-D-X-X-X-0002-02012020	Packer Test	39.9	36.9
OW06001	-13.15	-45.55	1.60E-05	567659.3	174856.3	3	E-AGSF-X-X-X-D-X-X-X-0002-02012020	Packer Test	33.9	30.9
OW06001	-13.15	-51.55	1.70E-05	567659.3	174856.3	3	E-AGSF-X-X-X-D-X-X-X-0002-02012020	Packer Test	39.9	36.9
OW06001	-13.15	-45.55	1.70E-05	567659.3	174856.3	3	E-AGSF-X-X-X-D-X-X-X-0002-02012020	Packer Test	33.9	30.9
OW06001	26.21	-45.55	1.70E-05	567659.3	174856.3	3		Packer		

Borehole ID	Elevation (m AOD)	Screen (m AOD)	Hydraulic conductivity (m/s)	Easting	Northing	Screen length (m)	Ground investigation phase	Type (from AGS record)	Screen bottom (m bgl)	Screen top (m bgl)
OW06001	-13.15	-45.55	1.80E-05	567659.3	174856.3	3	E-AGSF-X-X-X-D-X-X-X-0002-02012020	Packer Test	33.9	30.9
OW06006	26.21	-41.8	3.76E-06	567692.3	175144	3		Packer		
OW06006	26.21	-47.84	4.72E-06	567692.3	175144	3		Packer		
OW06006	26.21	-41.8	5.48E-06	567692.3	175144	3		Packer		
OW06006	26.21	-35.8	7.43E-06	567692.3	175144	3		Packer		
OW06016	26.21	-37.7	9.18E-06	567608.5	175545.6	3		Packer		
OH07022	7.24	-40.26	1.10E-06	567341	176009	3	B-AGSF-X-X-X-D-X-X-X-0003-02012086	Water Pressure	49	46
OH07022	7.24	-40.26	1.10E-06	567341	176009	3	B-AGSF-X-X-X-D-X-X-X-0003-02012087	Water Pressure	49	46
OH07022	7.24	-40.26	1.20E-06	567341	176009	3	B-AGSF-X-X-X-D-X-X-X-0003-02012088	Water Pressure	49	46
OH07022	7.24	-40.26	1.20E-06	567341	176009	3	B-AGSF-X-X-X-D-X-X-X-0003-02012089	Water Pressure	49	46
OH07022	2.33	-40.26	1.22E-06	567341	176009	3		Packer		
OH07022	7.24	-40.26	1.50E-06	567341	176009	3	B-AGSF-X-X-X-D-X-X-X-0003-02012085	Water Pressure	49	46

Borehole ID	Elevation (m AOD)	Screen (m AOD)	Hydraulic conductivity (m/s)	Easting	Northing	Screen length (m)	Ground investigation phase	Type (from AGS record)	Screen bottom (m bgl)	Screen top (m bgl)
OH07021	7.64	-52.86	3.10E-07	567530	176062	3	B-AGSF-X-X-X-D-X-X-X-0003-02012066	Water Pressure	62	59
OH07021	7.64	-52.86	3.30E-07	567530	176062	3	B-AGSF-X-X-X-D-X-X-X-0003-02012065	Water Pressure	62	59
OH07021	7.64	-47.86	1.30E-06	567530	176062	3	B-AGSF-X-X-X-D-X-X-X-0003-02012060	Water Pressure	57	54
OH07021	7.64	-47.86	1.80E-06	567530	176062	3	B-AGSF-X-X-X-D-X-X-X-0003-02012061	Water Pressure	57	54
OH07021	7.64	-47.86	2.30E-06	567530	176062	3	B-AGSF-X-X-X-D-X-X-X-0003-02012062	Water Pressure	57	54
OH07021	7.64	-47.86	2.40E-06	567530	176062	3	B-AGSF-X-X-X-D-X-X-X-0003-02012063	Water Pressure	57	54
OH07021	7.64	-47.86	2.60E-06	567530	176062	3	B-AGSF-X-X-X-D-X-X-X-0003-02012064	Water Pressure	57	54
OH07021	2.33	-47.86	2.83E-06	567530	176062	3		Packer		
OH07021	7.64	-52.86	3.20E-06	567530	176062	3	B-AGSF-X-X-X-D-X-X-X-0003-02012067	Water Pressure	62	59

Borehole ID	Elevation (m AOD)	Screen (m AOD)	Hydraulic conductivity (m/s)	Easting	Northing	Screen length (m)	Ground investigation phase	Type (from AGS record)	Screen bottom (m bgl)	Screen top (m bgl)
OH07021	7.64	-52.86	3.20E-06	567530	176062	3	B-AGSF-X-X-X-D-X-X-X-0003-02012068	Water Pressure	62	59
OH07021	7.64	-38.86	3.50E-06	567530	176062	3	B-AGSF-X-X-X-D-X-X-X-0003-02012058	Water Pressure	48	45
OH07021	7.64	-38.86	3.60E-06	567530	176062	3	B-AGSF-X-X-X-D-X-X-X-0003-02012057	Water Pressure	48	45
OH07021	7.64	-38.86	3.60E-06	567530	176062	3	B-AGSF-X-X-X-D-X-X-X-0003-02012059	Water Pressure	48	45
OH07021	2.33	-38.86	3.65E-06	567530	176062	3		Packer		
OH07021	7.64	-38.86	3.90E-06	567530	176062	3	B-AGSF-X-X-X-D-X-X-X-0003-02012056	Water Pressure	48	45
OH07021	2.33	-52.86	4.00E-06	567530	176062	3		Packer		
OH07021	7.64	-52.86	4.00E-06	567530	176062	3	B-AGSF-X-X-X-D-X-X-X-0003-02012069	Water Pressure	62	59
OH07021	7.64	-34.86	4.00E-06	567530	176062	3	B-AGSF-X-X-X-D-X-X-X-0003-02012052	Water Pressure	44	41
OH07021	7.64	-34.86	4.10E-06	567530	176062	3	B-AGSF-X-X-X-D-X-X-X-0003-02012051	Water Pressure	44	41

Borehole ID	Elevation (m AOD)	Screen (m AOD)	Hydraulic conductivity (m/s)	Easting	Northing	Screen length (m)	Ground investigation phase	Type (from AGS record)	Screen bottom (m bgl)	Screen top (m bgl)
OH07021	7.64	-34.86	4.50E-06	567530	176062	3	B-AGSF-X-X-X-D-X-X-X-0003-02012050	Water Pressure	44	41
OH07021	7.64	-34.86	4.50E-06	567530	176062	3	B-AGSF-X-X-X-D-X-X-X-0003-02012053	Water Pressure	44	41
OH07021	2.33	-42.86	4.58E-06	567530	176062	3		Packer		
OH07021	7.64	-34.86	5.20E-06	567530	176062	3	B-AGSF-X-X-X-D-X-X-X-0003-02012054	Water Pressure	44	41
OH07021	7.64	-38.86	5.50E-06	567530	176062	3	B-AGSF-X-X-X-D-X-X-X-0003-02012055	Water Pressure	48	45
OH07021	7.64	-30.86	4.70E-05	567530	176062	3	B-AGSF-X-X-X-D-X-X-X-0003-02012045	Water Pressure	40	37
OH07021	7.64	-30.86	4.90E-05	567530	176062	3	B-AGSF-X-X-X-D-X-X-X-0003-02012048	Water Pressure	40	37
OH07021	7.64	-30.86	5.00E-05	567530	176062	3	B-AGSF-X-X-X-D-X-X-X-0003-02012047	Water Pressure	40	37
OH07021	7.64	-30.86	5.10E-05	567530	176062	3	B-AGSF-X-X-X-D-X-X-X-0003-02012046	Water Pressure	40	37
OH07021	2.33	-30.86	5.12E-05	567530	176062	3		Packer		

Borehole ID	Elevation (m AOD)	Screen (m AOD)	Hydraulic conductivity (m/s)	Easting	Northing	Screen length (m)	Ground investigation phase	Type (from AGS record)	Screen bottom (m bgl)	Screen top (m bgl)
OH07021	7.64	-30.86	5.90E-05	567530	176062	3	B-AGSF-X-X-X-D-X-X-X-0003-02012049	Water Pressure	40	37
OH07021	7.64	-26.86	8.00E-05	567530	176062	3	B-AGSF-X-X-X-D-X-X-X-0003-02012041	Water Pressure	36	33
OH07021	7.64	-26.86	8.40E-05	567530	176062	3	B-AGSF-X-X-X-D-X-X-X-0003-02012040	Water Pressure	36	33
OH07021	7.64	-26.86	8.40E-05	567530	176062	3	B-AGSF-X-X-X-D-X-X-X-0003-02012042	Water Pressure	36	33
OH07021	2.33	-26.86	8.70E-05	567530	176062	3		Packer		
OH07021	7.64	-26.86	8.80E-05	567530	176062	3	B-AGSF-X-X-X-D-X-X-X-0003-02012043	Water Pressure	36	33
OH07021	7.64	-26.86	9.90E-05	567530	176062	3	B-AGSF-X-X-X-D-X-X-X-0003-02012044	Water Pressure	36	33
OH07040	2.33	-38.77	3.88E-06	567379	176105	3		Packer		
OH07012	7.45	-34.05	1.10E-07	567559	176233	3	B-AGSF-X-X-X-D-X-X-X-0003-02012033	KPO	43	40
OH07012	7.45	-34.05	1.40E-07	567559	176233	3	B-AGSF-X-X-X-D-X-X-X-0003-02012032	KPO	43	40

Borehole ID	Elevation (m AOD)	Screen (m AOD)	Hydraulic conductivity (m/s)	Easting	Northing	Screen length (m)	Ground investigation phase	Type (from AGS record)	Screen bottom (m bgl)	Screen top (m bgl)
OH07012	7.45	-34.05	1.60E-07	567559	176233	3	B-AGSF-X-X-X-D-X-X-X-0003-02012034	KPO	43	40
OH07012	7.45	-38.05	1.70E-07	567559	176233	3	B-AGSF-X-X-X-D-X-X-X-0003-02012039	KPO	47	44
OH07012	2.33	-38.05	1.75E-07	567559	176233	3		Packer		
OH07012	7.45	-38.05	1.80E-07	567559	176233	3	B-AGSF-X-X-X-D-X-X-X-0003-02012035	KPO	47	44
OH07012	7.45	-34.05	1.80E-07	567559	176233	3	B-AGSF-X-X-X-D-X-X-X-0003-02012031	KPO	43	40
OH07012	7.45	-34.05	1.90E-07	567559	176233	3	B-AGSF-X-X-X-D-X-X-X-0003-02012030	KPO	43	40
OH07012	7.45	-30.05	3.40E-07	567559	176233	3	B-AGSF-X-X-X-D-X-X-X-0003-02012027	KPO	39	36
OH07012	2.33	-30.05	3.60E-07	567559	176233	3		Packer		
OH07012	7.45	-30.05	3.60E-07	567559	176233	3	B-AGSF-X-X-X-D-X-X-X-0003-02012028	KPO	39	36
OH07012	7.45	-30.05	3.80E-07	567559	176233	3	B-AGSF-X-X-X-D-X-X-X-0003-02012026	KPO	39	36

Borehole ID	Elevation (m AOD)	Screen (m AOD)	Hydraulic conductivity (m/s)	Easting	Northing	Screen length (m)	Ground investigation phase	Type (from AGS record)	Screen bottom (m bgl)	Screen top (m bgl)
OH07012	7.45	-30.05	4.80E-07	567559	176233	3	B-AGSF-X-X-X-D-X-X-X-0003-02012025	KPO	39	36
OH07012	7.45	-30.05	4.90E-07	567559	176233	3	B-AGSF-X-X-X-D-X-X-X-0003-02012029	KPO	39	36
OH07012	7.45	-38.05	6.60E-07	567559	176233	3	B-AGSF-X-X-X-D-X-X-X-0003-02012036	KPO	47	44
OH07012	7.45	-38.05	1.20E-06	567559	176233	3	B-AGSF-X-X-X-D-X-X-X-0003-02012038	KPO	47	44
OH07012	7.45	-38.05	1.50E-06	567559	176233	3	B-AGSF-X-X-X-D-X-X-X-0003-02012037	KPO	47	44
OH07012	7.45	-26.05	7.40E-06	567559	176233	3	B-AGSF-X-X-X-D-X-X-X-0003-02012023	Water Pressure	35	32
OH07012	2.33	-26.05	7.97E-06	567559	176233	3		Packer		
OH07012	7.45	-26.05	8.00E-06	567559	176233	3	B-AGSF-X-X-X-D-X-X-X-0003-02012021	Water Pressure	35	32
OH07012	7.45	-26.05	8.50E-06	567559	176233	3	B-AGSF-X-X-X-D-X-X-X-0003-02012022	Water Pressure	35	32

Borehole ID	Elevation (m AOD)	Screen (m AOD)	Hydraulic conductivity (m/s)	Easting	Northing	Screen length (m)	Ground investigation phase	Type (from AGS record)	Screen bottom (m bgl)	Screen top (m bgl)
OH07012	7.45	-26.05	1.10E-05	567559	176233	3	B-AGSF-X-X-X-D-X-X-X-0003-02012020	Water Pressure	35	32
OH07012	7.45	-26.05	1.10E-05	567559	176233	3	B-AGSF-X-X-X-D-X-X-X-0003-02012024	Water Pressure	35	32
BH09002	3.38	-1.62	1.20E-04	567046.2	177958.1	3	C-AGSF-X-X-X-D-X-X-X-0004-02012021	Falling Head	6.5	3.5
BH09002	3.38	-1.62	6.60E-04	567046.2	177958.1	3	C-AGSF-X-X-X-D-X-X-X-0004-02012020	Rising Head	6.5	3.5
BH09006	12.37	-2.63	1.60E-06	566928	178336.7	3	C-AGSF-X-X-X-D-X-X-X-0004-02012023	Rising Head	16.5	13.5
BH09006	12.37	-2.63	1.70E-06	566928	178336.7	3	C-AGSF-X-X-X-D-X-X-X-0004-02012022	Falling Head	16.5	13.5
BH10003	6.64	-33.86	1.40E-06	566824.3	179204.7	3	C-AGSF-X-X-X-D-X-X-X-0004-02012046	Packer	42	39
BH10003	6.64	-33.86	1.40E-06	566824.3	179204.7	3	C-AGSF-X-X-X-D-X-X-X-0004-02012047	Packer	42	39
BH10003	6.64	-33.86	1.60E-06	566824.3	179204.7	3	C-AGSF-X-X-X-D-X-X-X-0004-02012048	Packer	42	39

Borehole ID	Elevation (m AOD)	Screen (m AOD)	Hydraulic conductivity (m/s)	Easting	Northing	Screen length (m)	Ground investigation phase	Type (from AGS record)	Screen bottom (m bgl)	Screen top (m bgl)
BH10003	6.64	-26.86	1.60E-06	566824.3	179204.7	3	C-AGSF-X-X-X-D-X-X-X-0004-02012042	Packer	35	32
BH10003	6.64	-26.86	1.60E-06	566824.3	179204.7	3	C-AGSF-X-X-X-D-X-X-X-0004-02012043	Packer	35	32
BH10003	6.64	-33.86	1.70E-06	566824.3	179204.7	3	C-AGSF-X-X-X-D-X-X-X-0004-02012045	Packer	42	39
BH10003	6.64	-26.86	1.70E-06	566824.3	179204.7	3	C-AGSF-X-X-X-D-X-X-X-0004-02012041	Packer	35	32
BH10003	6.64	-26.86	1.70E-06	566824.3	179204.7	3	C-AGSF-X-X-X-D-X-X-X-0004-02012044	Packer	35	32
BH10003	6.64	-26.86	1.80E-06	566824.3	179204.7	3	C-AGSF-X-X-X-D-X-X-X-0004-02012040	Packer	35	32
BH10003	6.64	-33.86	2.00E-06	566824.3	179204.7	3	C-AGSF-X-X-X-D-X-X-X-0004-02012049	Packer	42	39
BH10003	6.64	-20.86	2.70E-06	566824.3	179204.7	3	C-AGSF-X-X-X-D-X-X-X-0004-02012036	Packer	29	26
BH10003	6.64	-20.86	2.70E-06	566824.3	179204.7	3	C-AGSF-X-X-X-D-X-X-X-0004-02012037	Packer	29	26

Borehole ID	Elevation (m AOD)	Screen (m AOD)	Hydraulic conductivity (m/s)	Easting	Northing	Screen length (m)	Ground investigation phase	Type (from AGS record)	Screen bottom (m bgl)	Screen top (m bgl)
BH10003	6.64	-20.86	2.70E-06	566824.3	179204.7	3	C-AGSF-X-X-X-D-X-X-X-0004-02012038	Packer	29	26
BH10003	6.64	-20.86	2.80E-06	566824.3	179204.7	3	C-AGSF-X-X-X-D-X-X-X-0004-02012035	Packer	29	26
BH10003	6.64	-20.86	2.80E-06	566824.3	179204.7	3	C-AGSF-X-X-X-D-X-X-X-0004-02012039	Packer	29	26
BH10003	6.64	-15.86	5.70E-06	566824.3	179204.7	3	C-AGSF-X-X-X-D-X-X-X-0004-02012032	Packer	24	21
BH10003	6.64	-15.86	6.00E-06	566824.3	179204.7	3	C-AGSF-X-X-X-D-X-X-X-0004-02012033	Packer	24	21
BH10003	6.64	-39.86	6.10E-06	566824.3	179204.7	3	C-AGSF-X-X-X-D-X-X-X-0004-02012050	Packer	48	45
BH10003	6.64	-39.86	6.10E-06	566824.3	179204.7	3	C-AGSF-X-X-X-D-X-X-X-0004-02012051	Packer	48	45
BH10003	6.64	-15.86	6.20E-06	566824.3	179204.7	3	C-AGSF-X-X-X-D-X-X-X-0004-02012031	Packer	24	21
BH10003	6.64	-15.86	6.50E-06	566824.3	179204.7	3	C-AGSF-X-X-X-D-X-X-X-0004-02012034	Packer	24	21

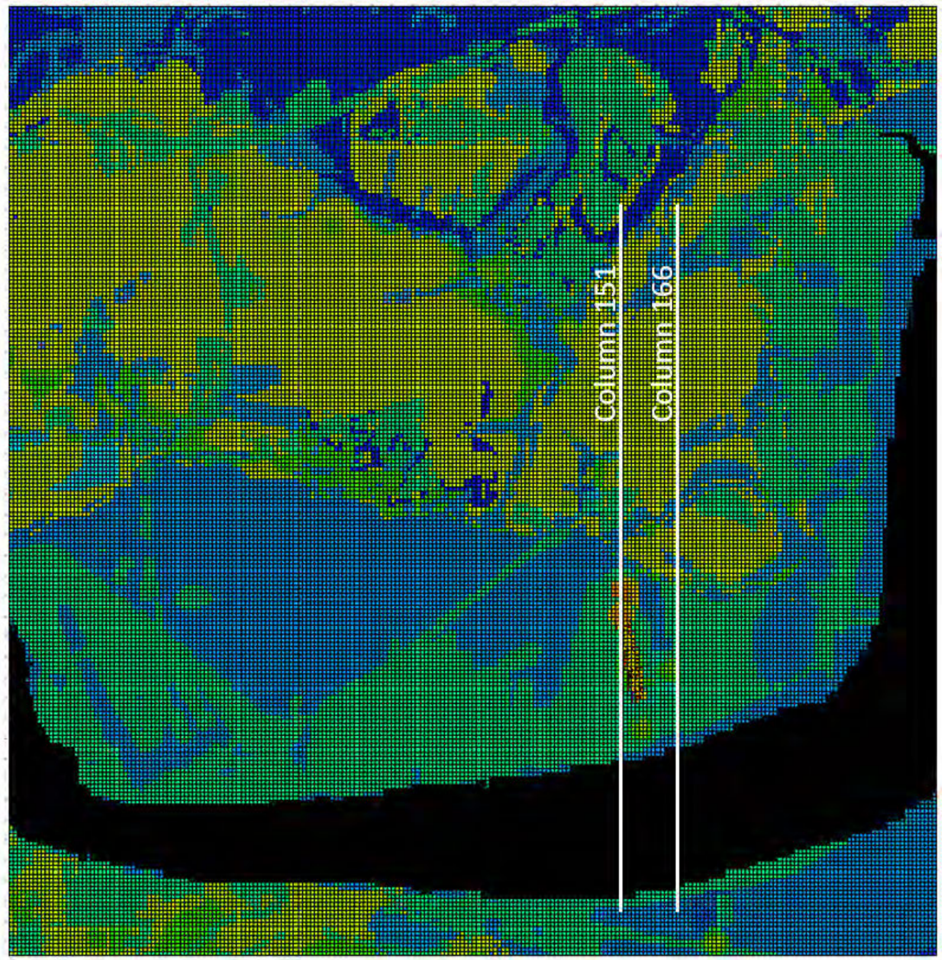
Borehole ID	Elevation (m AOD)	Screen (m AOD)	Hydraulic conductivity (m/s)	Easting	Northing	Screen length (m)	Ground investigation phase	Type (from AGS record)	Screen bottom (m bgl)	Screen top (m bgl)
BH10003	6.64	-15.86	6.70E-06	566824.3	179204.7	3	C-AGSF-X-X-X-D-X-X-X-0004-02012030	Packer	24	21
BH10003	6.64	-39.86	6.90E-06	566824.3	179204.7	3	C-AGSF-X-X-X-D-X-X-X-0004-02012052	Packer	48	45
BH10003	6.64	-39.86	7.30E-06	566824.3	179204.7	3	C-AGSF-X-X-X-D-X-X-X-0004-02012053	Packer	48	45
BH10003	6.64	-39.86	8.30E-06	566824.3	179204.7	3	C-AGSF-X-X-X-D-X-X-X-0004-02012054	Packer	48	45
BH10003	6.64	-10.86	1.80E-05	566824.3	179204.7	3	C-AGSF-X-X-X-D-X-X-X-0004-02012026	Packer	19	16
BH10003	6.64	-10.86	1.90E-05	566824.3	179204.7	3	C-AGSF-X-X-X-D-X-X-X-0004-02012025	Packer	19	16
BH10003	6.64	-10.86	1.90E-05	566824.3	179204.7	3	C-AGSF-X-X-X-D-X-X-X-0004-02012027	Packer	19	16
BH10003	6.64	-10.86	2.00E-05	566824.3	179204.7	3	C-AGSF-X-X-X-D-X-X-X-0004-02012028	Packer	19	16
BH10003	6.64	-10.86	2.00E-05	566824.3	179204.7	3	C-AGSF-X-X-X-D-X-X-X-0004-02012029	Packer	19	16

Borehole ID	Elevation (m AOD)	Screen (m AOD)	Hydraulic conductivity (m/s)	Easting	Northing	Screen length (m)	Ground investigation phase	Type (from AGS record)	Screen bottom (m bgl)	Screen top (m bgl)
BH10004	7.63	2.13	2.70E-07	566645.5	179312.2	3	C-AGSF-X-X-X-D-X-X-X-0004-02012056	Rising Head	7	4
BH10004	7.63	2.13	2.80E-07	566645.5	179312.2	3	C-AGSF-X-X-X-D-X-X-X-0004-02012055	Falling Head	7	4
BH11004	20.3	2.3	2.50E-07	566276	179707	3	C-AGSF-X-X-X-D-X-X-X-0004-02012058	Rising Head	19.5	16.5
BH11004	20.3	2.3	2.60E-07	566276	179707	3	C-AGSF-X-X-X-D-X-X-X-0004-02012057	Falling Head	19.5	16.5
BH11007	17.88	4.38	1.00E-07	565801.6	179927.6	3	C-AGSF-X-X-X-D-X-X-X-0004-02012060	Rising Head	15	12
BH11007	17.88	4.38	4.10E-07	565801.6	179927.6	3	C-AGSF-X-X-X-D-X-X-X-0004-02012059	Falling Head	15	12
BH2302	3.77	-30.53	5.77E-06	568094.5	173178.4	3.2		Packer		
BH2302	3.77	-42.53	6.74E-06	568094.5	173178.4	3.2		Packer		
BH2302	3.77	-18.53	1.14E-05	568094.5	173178.4	3.2		Packer		
BH2302	3.77	-36.53	1.28E-05	568094.5	173178.4	3.2		Packer		
BH2302	3.77	-12.53	3.58E-05	568094.5	173178.4	3.2		Packer		
BH2374	8.51	-38.09	1.16E-06	567426.1	175994.4	3.2		Packer		
BH2374	8.51	-41.39	1.66E-06	567426.1	175994.4	3.2		Packer		

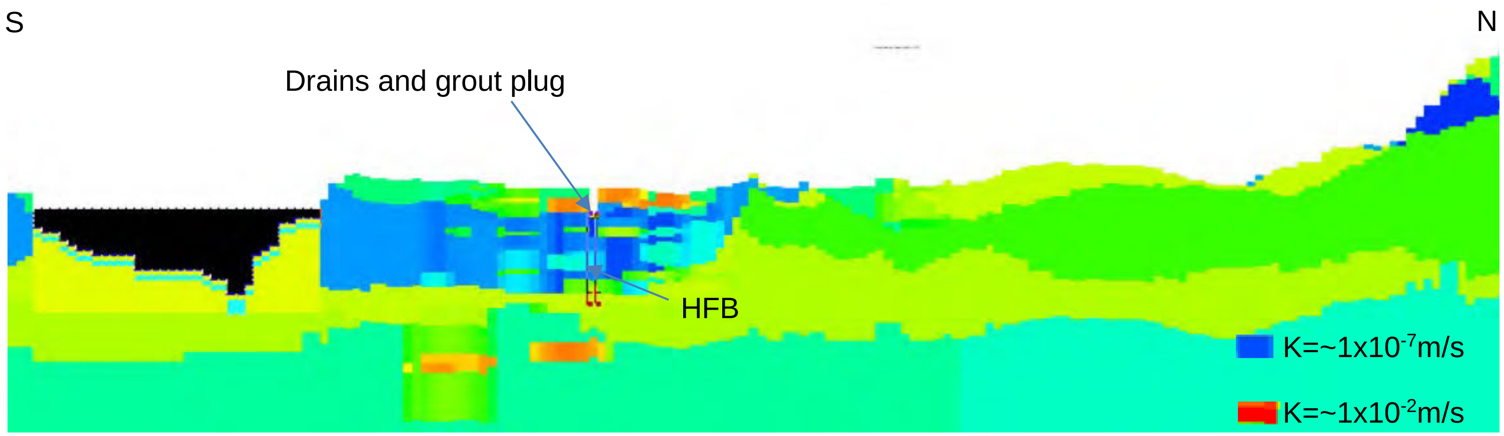
Borehole ID	Elevation (m AOD)	Screen (m AOD)	Hydraulic conductivity (m/s)	Easting	Northing	Screen length (m)	Ground investigation phase	Type (from AGS record)	Screen bottom (m bgl)	Screen top (m bgl)
BH2374	8.51	-33.09	2.56E-06	567426.1	175994.4	3.2		Packer		
BH2374	8.51	-31.09	3.29E-06	567426.1	175994.4	3.2		Packer		
BH2374	8.51	-28.59	9.78E-06	567426.1	175994.4	3.2		Packer		
BH2374	8.51	-26.09	2.15E-05	567426.1	175994.4	3.2		Packer		
BH2385	7.14	-45.96	6.39E-07	567407.8	176463.1	3.2		Packer		
BH2385	7.14	-38.96	6.99E-07	567407.8	176463.1	3.2		Packer		
BH2385	7.14	-42.46	7.87E-07	567407.8	176463.1	3.2		Packer		
BH2385	7.14	-35.46	3.28E-06	567407.8	176463.1	3.2		Packer		
BH2385	7.14	-31.96	4.36E-06	567407.8	176463.1	3.2		Packer		
BH2385	7.14	-27.96	5.76E-06	567407.8	176463.1	3.2		Packer		
OH07012	2.33	-34.05	1.35E-07	567559	176233	4		Packer		
BH12005	23.82	-3.18	2.50E-06	564462.1	180123.4	6	C-AGSF-X-X-X-D-X-X-X-0004-02012062	Rising Head	30	24
BH12005	23.82	-3.18	4.30E-06	564462.1	180123.4	6	C-AGSF-X-X-X-D-X-X-X-0004-02012061	Falling Head	30	24

.

Annex B Infrastructure boundary conditions



Plot showing the location of the range of cross-sections showed in this section



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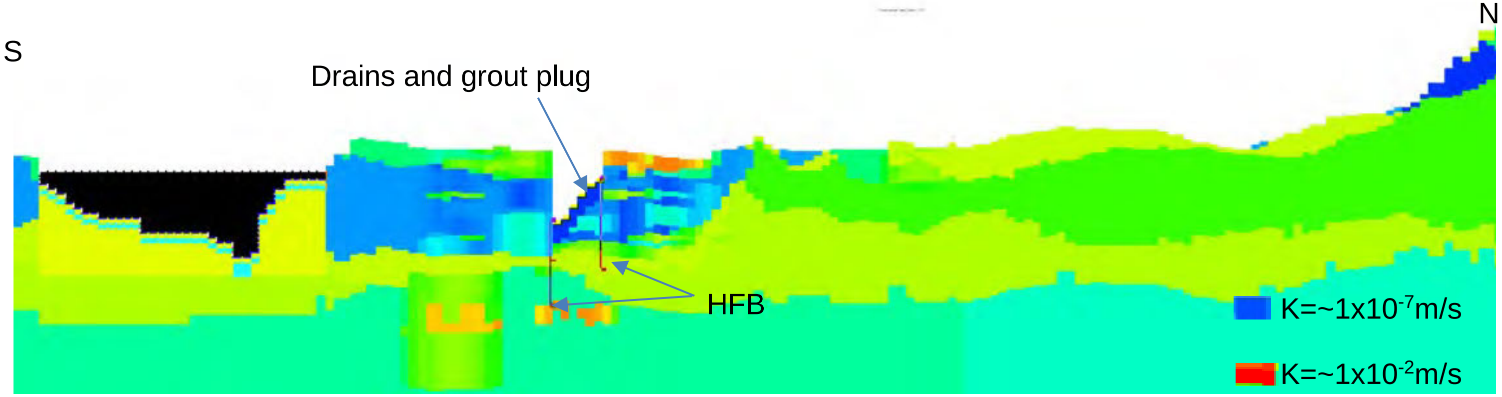

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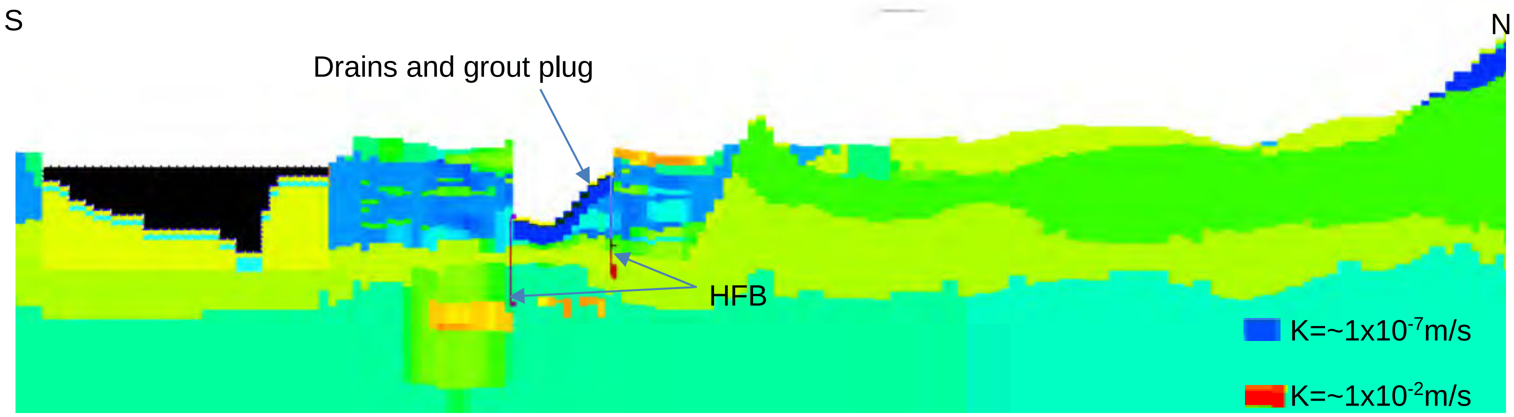

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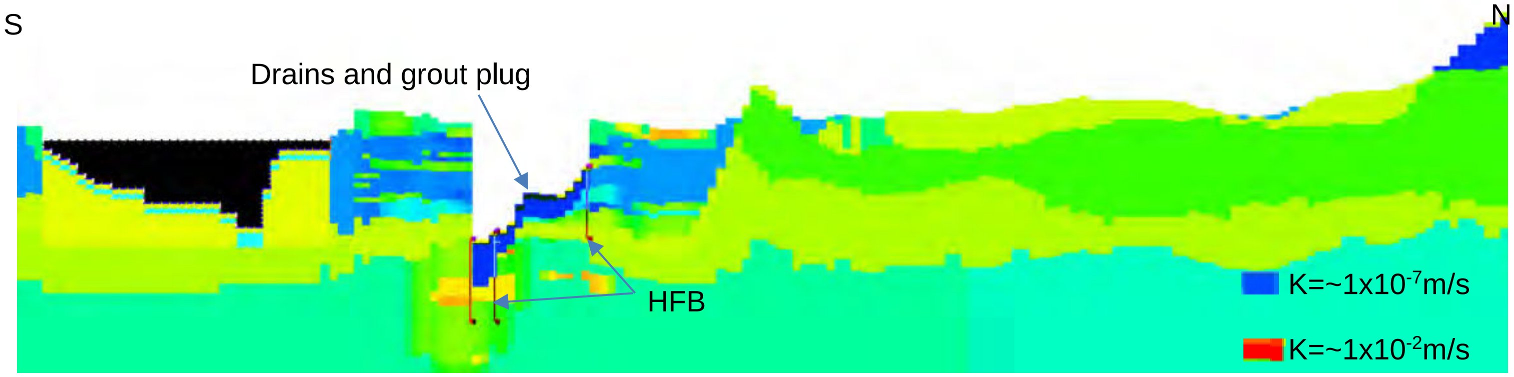

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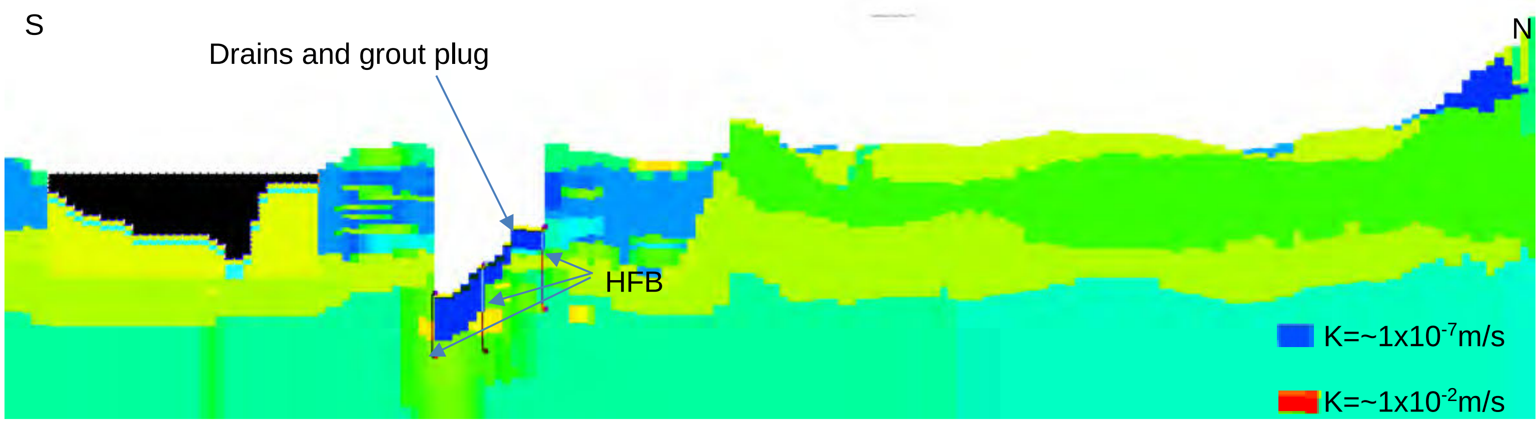

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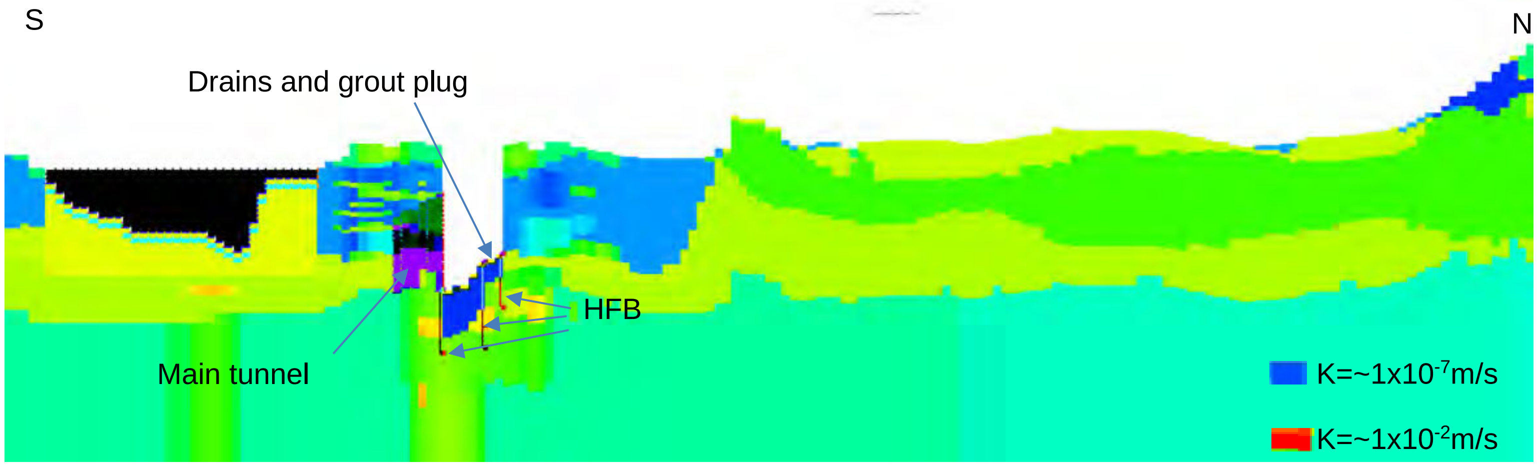

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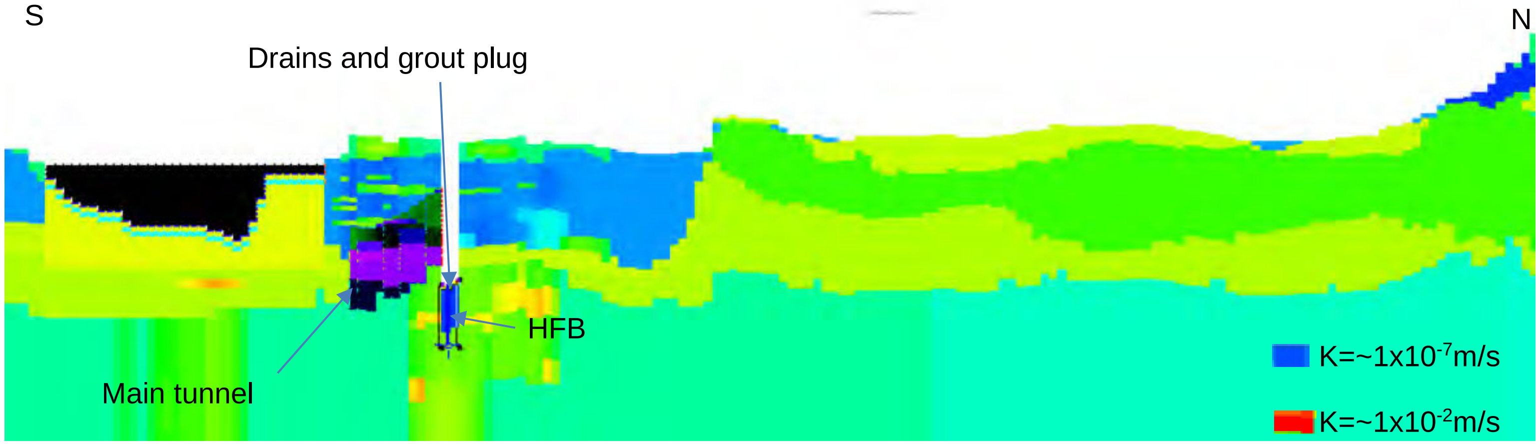

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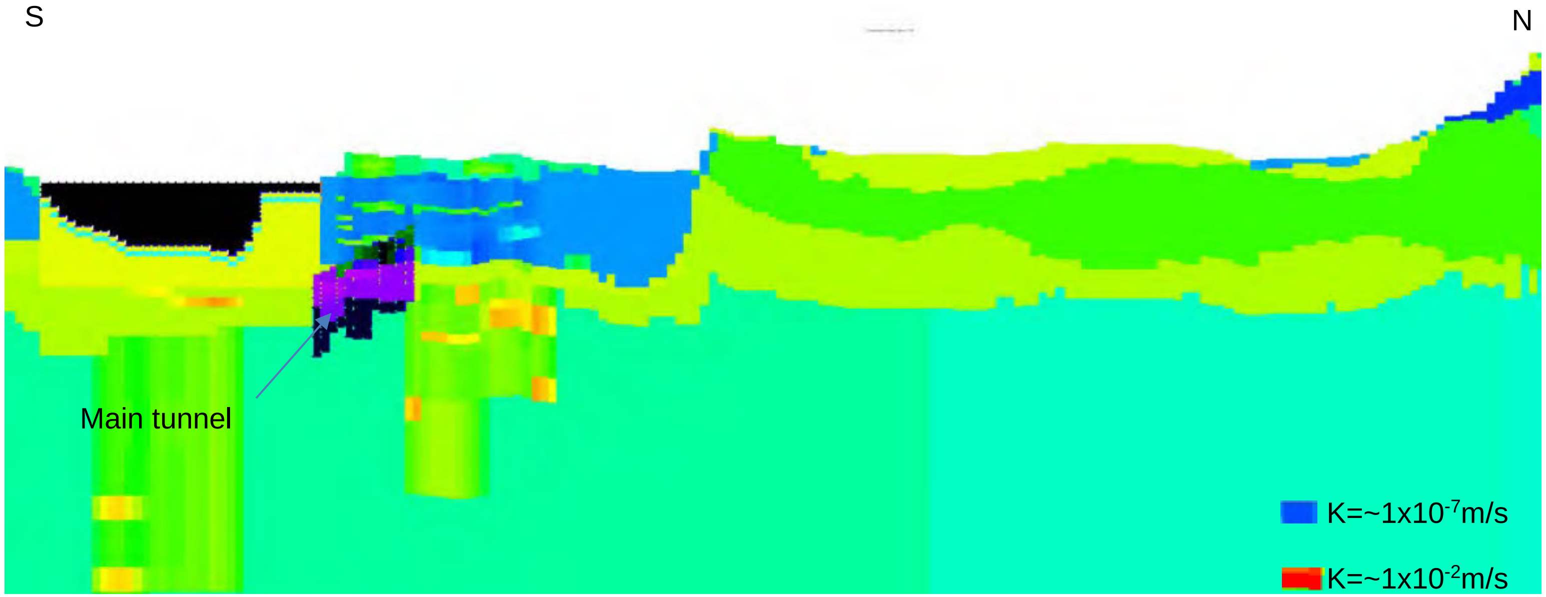

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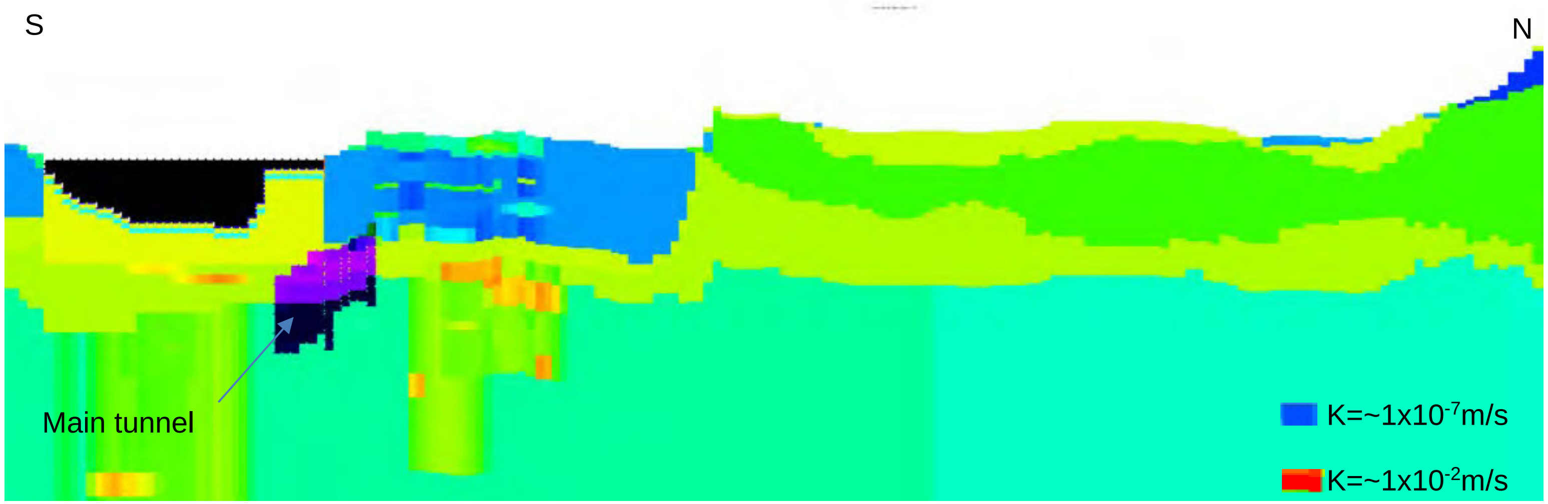

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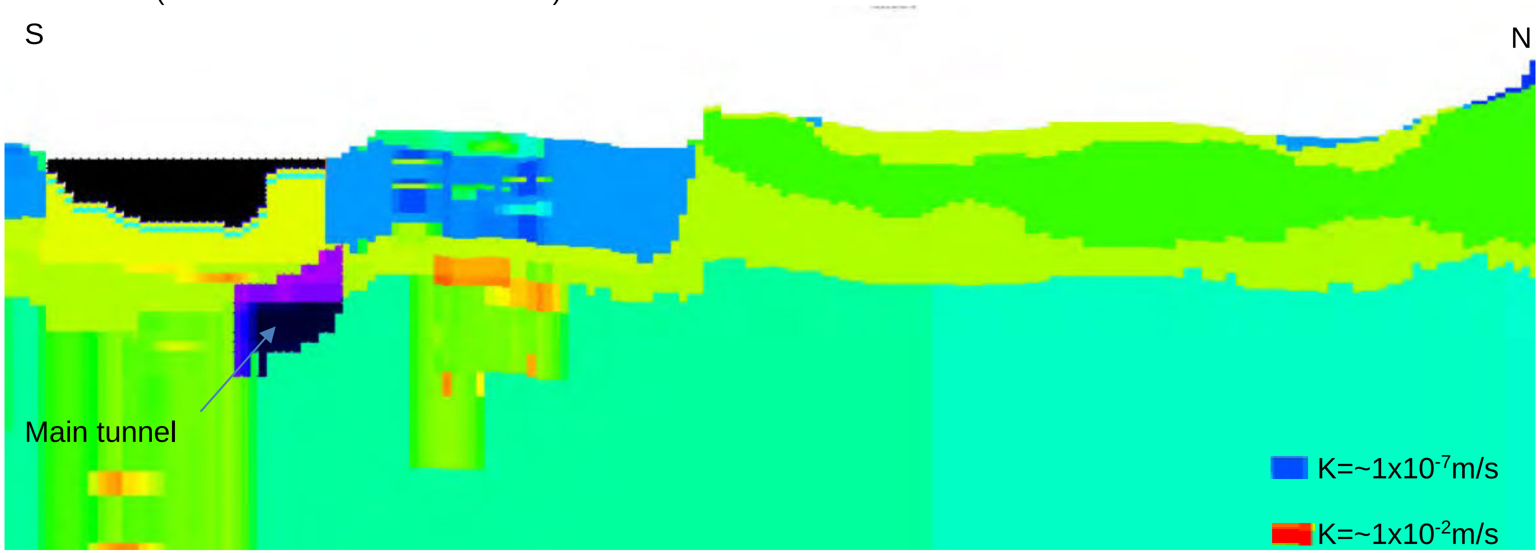

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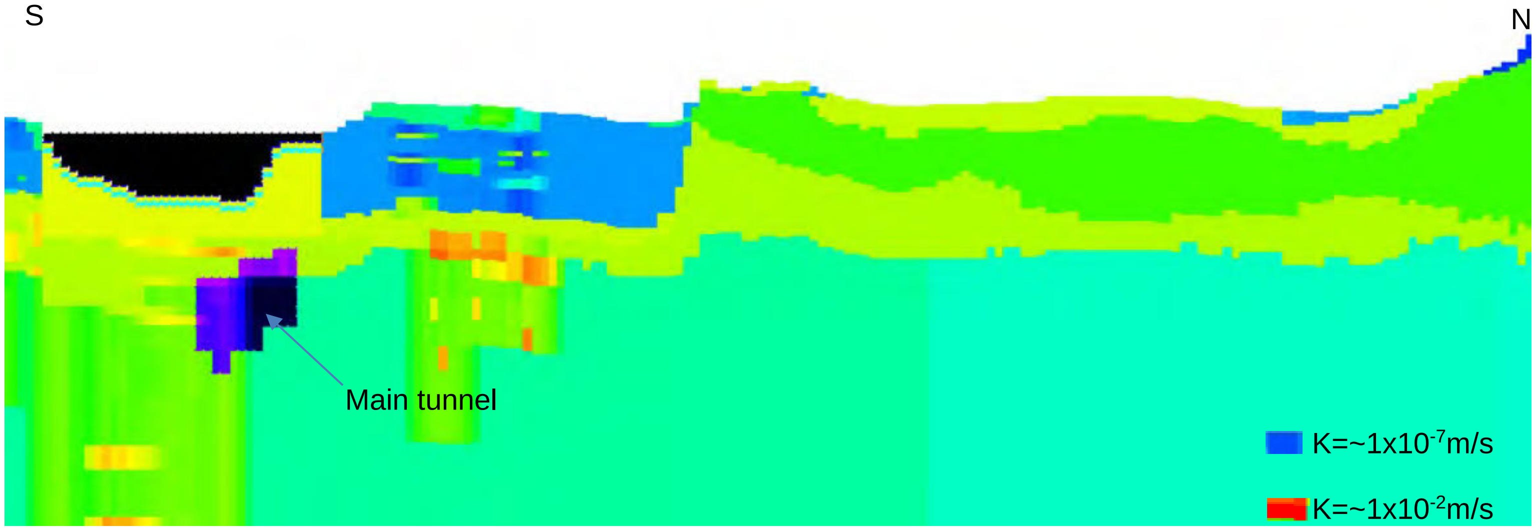

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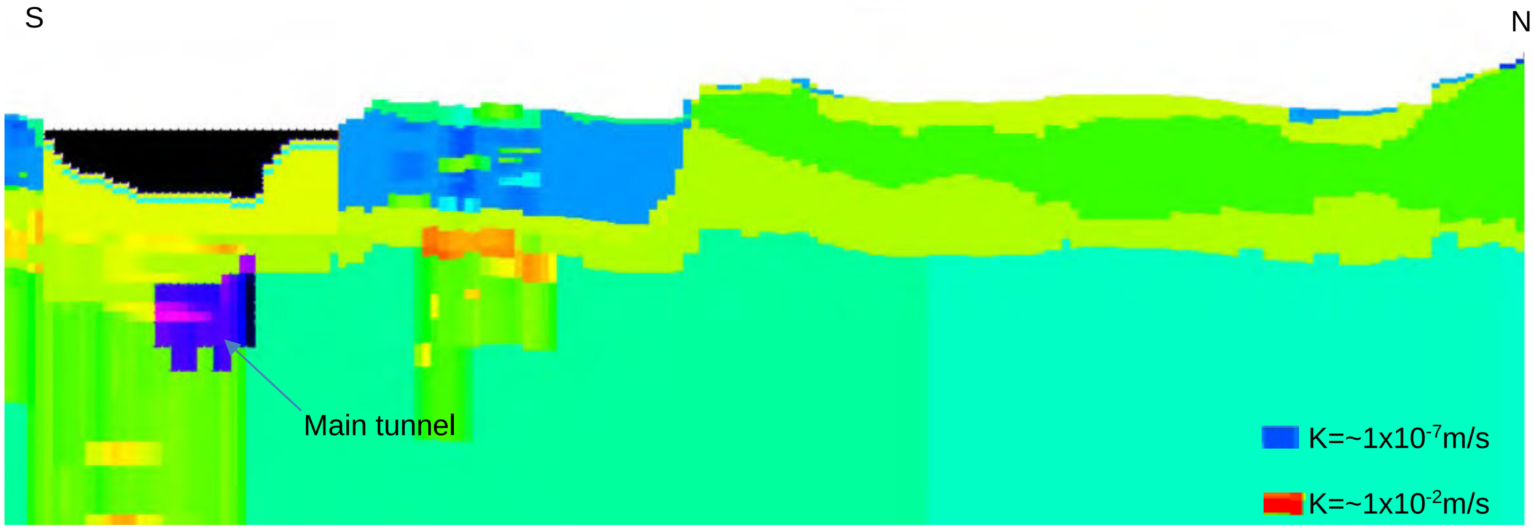

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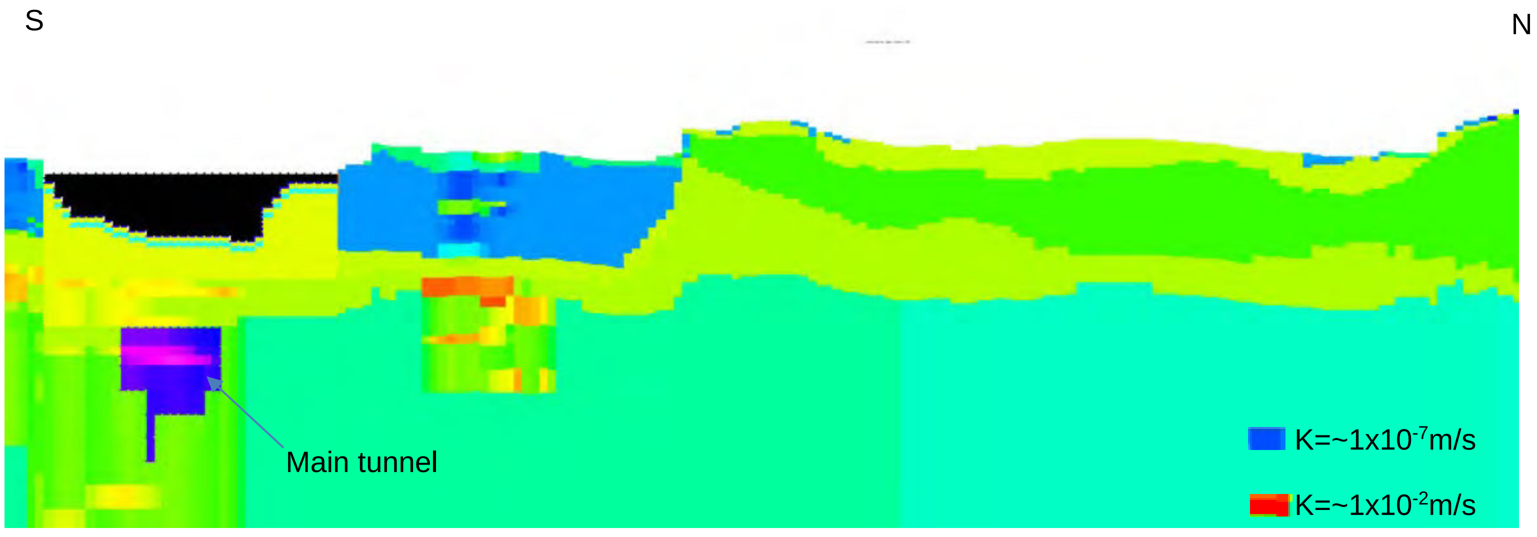

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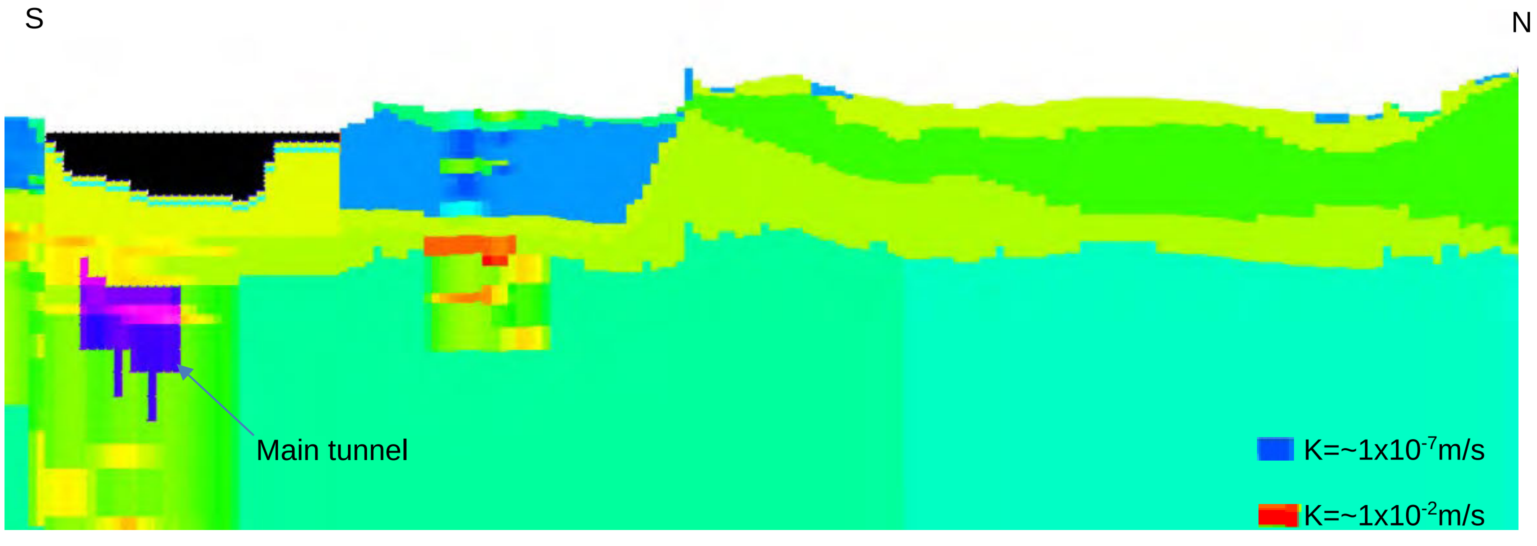

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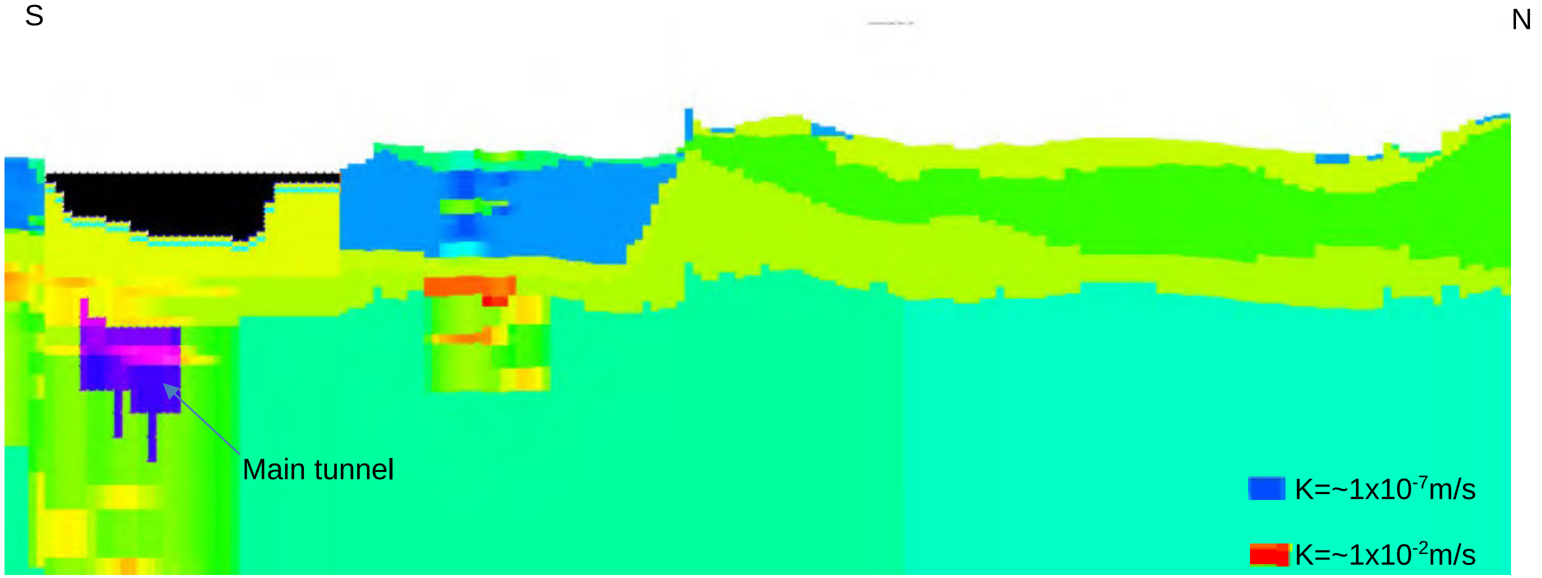

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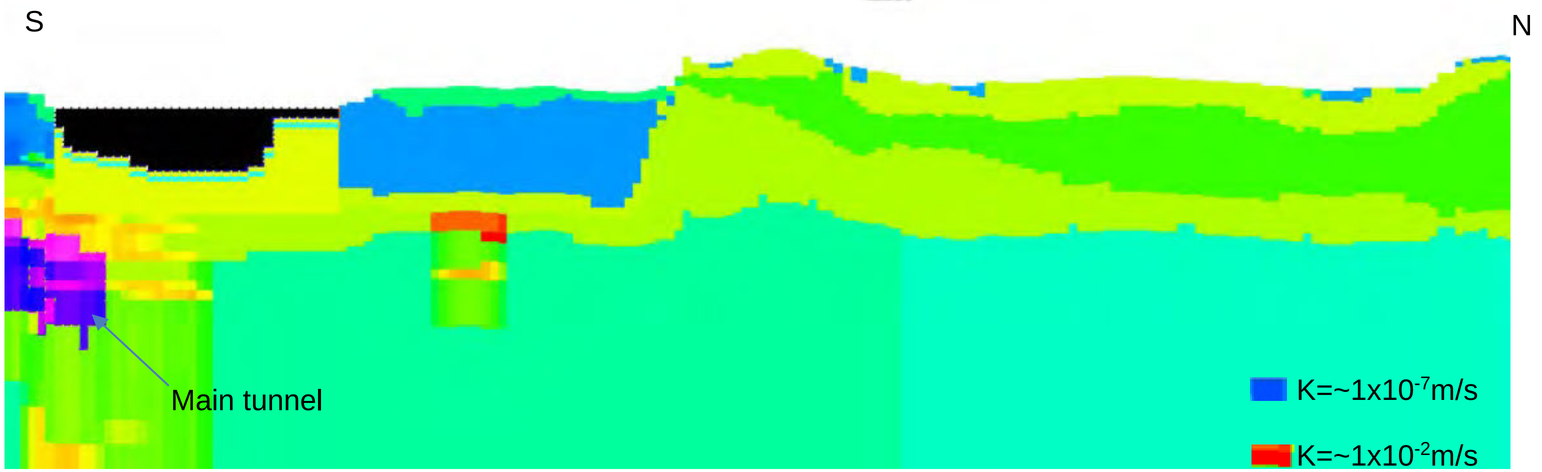


Column 166 (vertical resolution 20 x horizontal)

Annex C SEAWAT saline interface modelling description and parameters

C.1 Method

C.1.1 SEAWAT V4 (Langevin *et al*., 2008) is used via the FloPy interface to do saline interface modelling. SEAWAT is a coupled version of MODFLOW and MT3DMS designed to simulate three-dimensional, variable density, saturated ground-water flow. The model is solved using a finite difference approximation similar to the one solved by MODFLOW-2000.

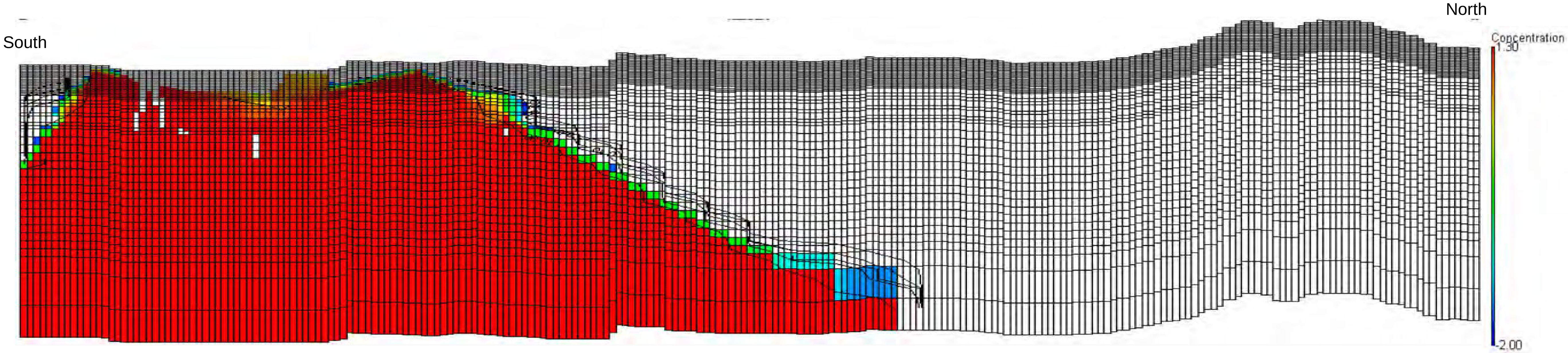
C.1.2 Table C.1 provides the additional parameters that are implemented for SEAWAT for the baseline model.

Table C.1 SEAWAT parameters

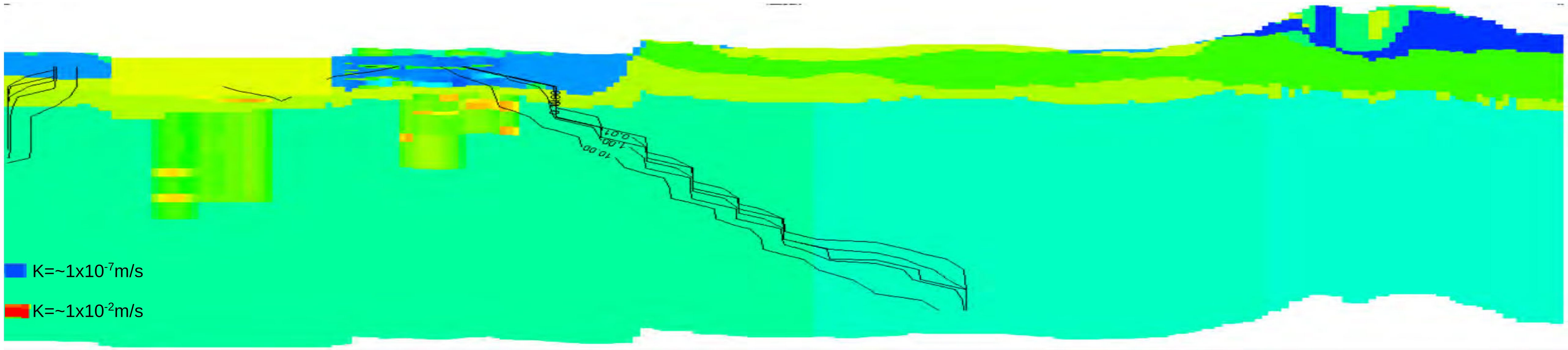
Applied to all models	Parameter	Value	Unit
Dt0	Timestep length	Steady state Initial timestep length of $1x10^{-3}$d	d
dmcoef	Molecular diffusion coefficient	0.57	m^2/d From Henry Problem
al	Longitudinal dispersivity	Kh*3	m
trpt	Transverse dispersivity	0.1*longitudinal dispersivity	m
trpv	Vertical dispersivity	0.05*longitudinal dispersivity	m
River boundary concentration		20	g/l
denseref	Reference density of water	1,000	g/l
denseslp	The slope of the linear equation of state that relates fluid density to solute concentration	0.7143	From Henry Problem
iwtable	Flag	0	Water table correction for density not applied
densemin densemax	Flag	0	No limitation
Sconc	Initial concentration	Initial distribution concentration	g/l

Applied to all models	Parameter	Value	Unit
		calculated based on Ghyben-Herzberg approximation, with a maximum of 20 g/l	
InitHds	Initial Heads	Topography	m AOD
Perlen	Length of simulation	Steady state	d
nstp	Number of stress periods	1	
dt0		5,000	days per time period

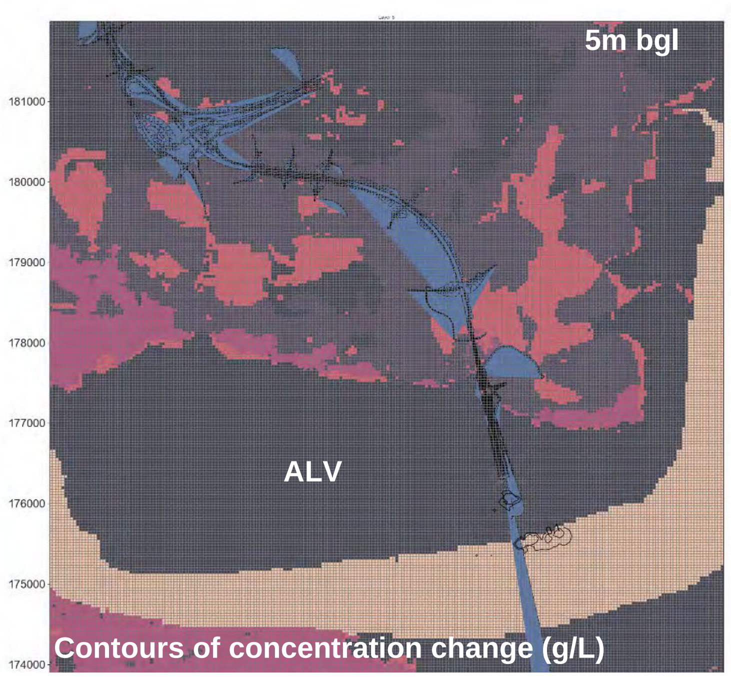
Annex D Saline interface results – baseline (natural) model

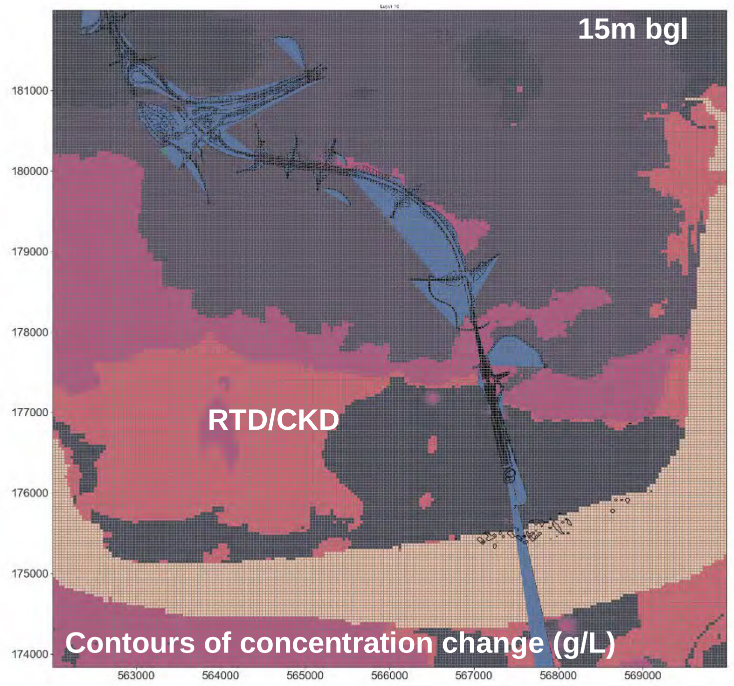


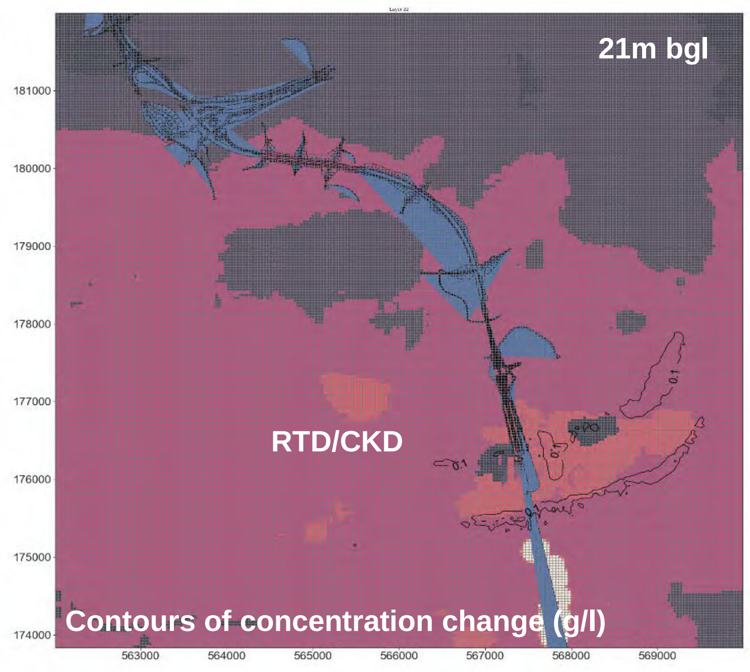
Cross-section showing the calculated saline interface along the Project route

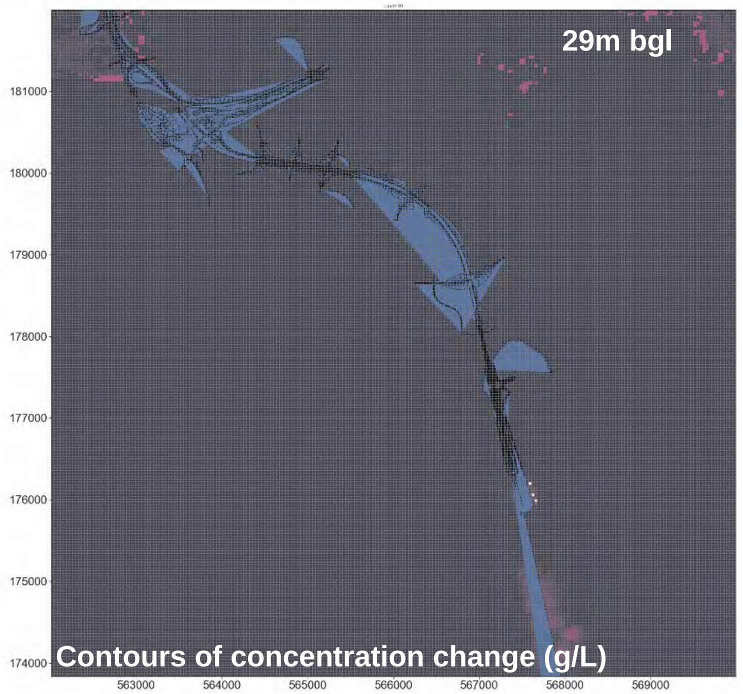


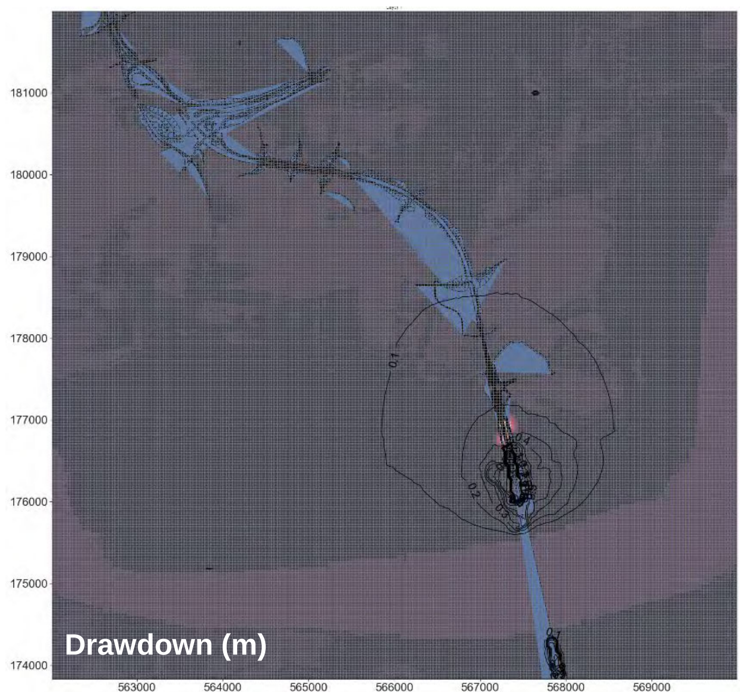
Cross-section showing concentration and hydraulic conductivity (red – high, blue – low)











Alluvium – 5m bgl

- nil saline intrusion compared to the salinity of the Thames
- <0.1g/L change present in area of Project excavation

RTD/CKD 15m bgl

- Negligible/nil salinity increase

RTD/CKD 21m bgl

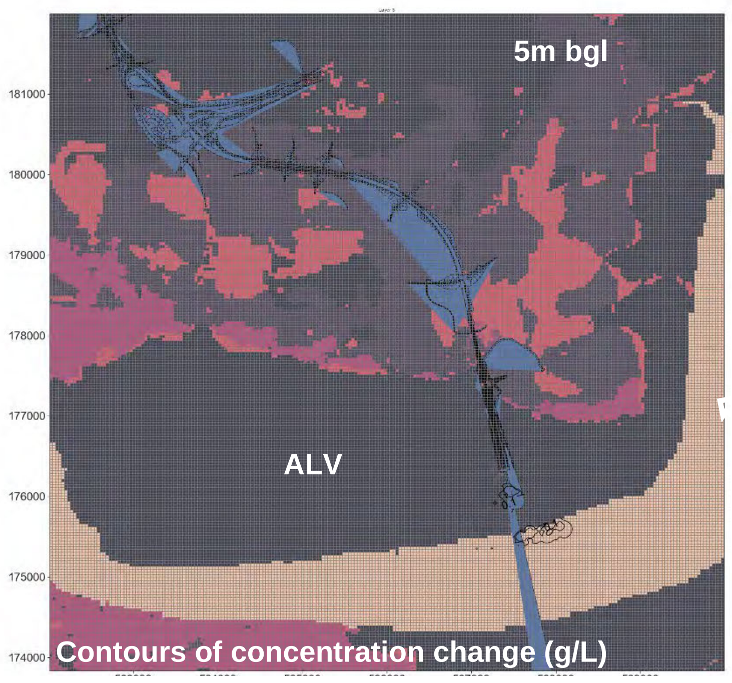
- Approximately 0.1g/L increase in salinity due to up-coning

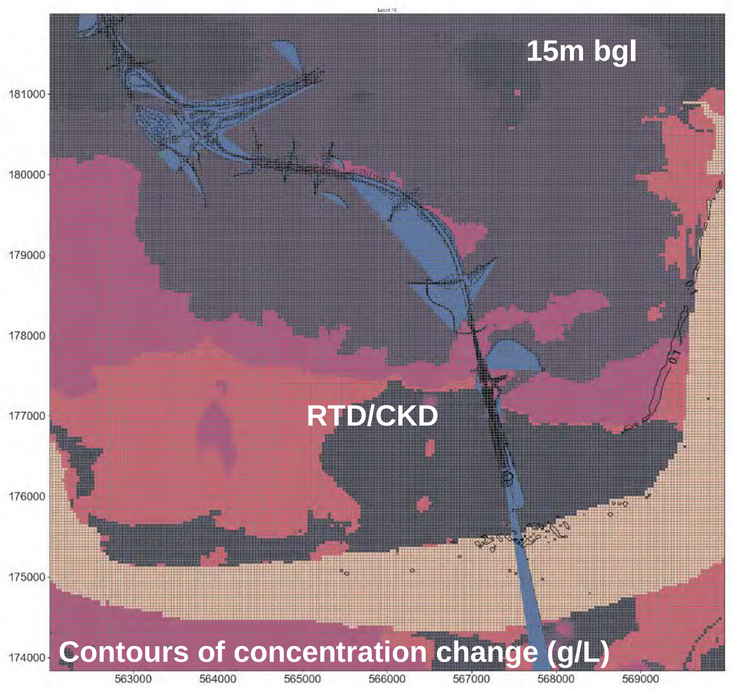
Chalk 29m bgl

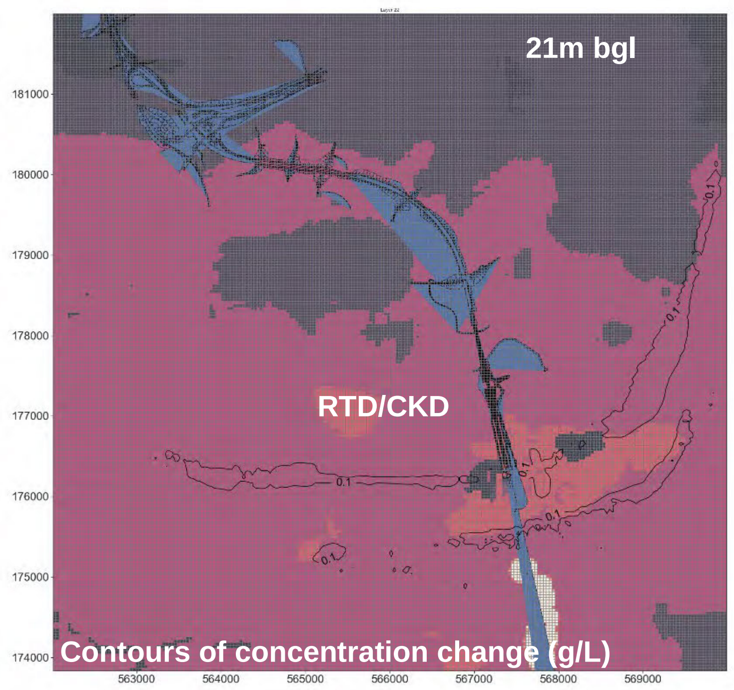
- Negligible/nil salinity increase

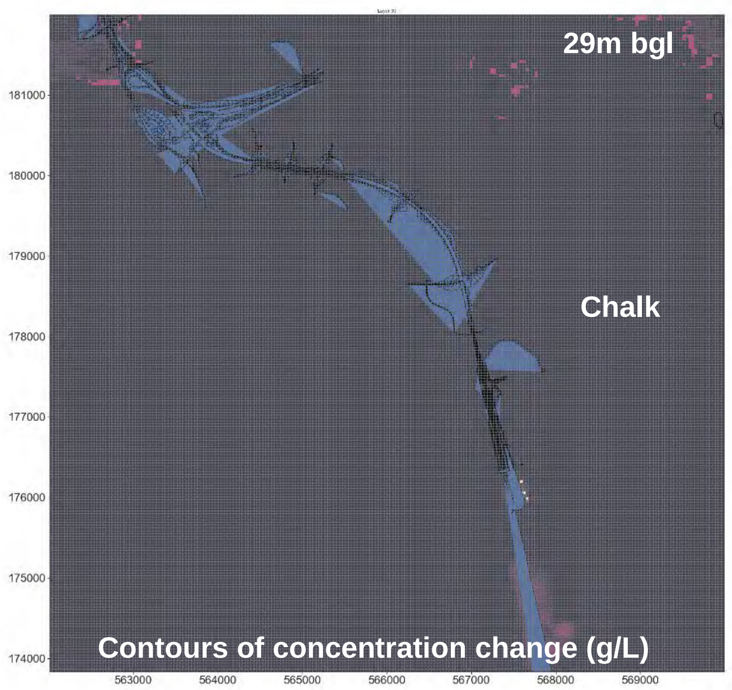
The figures show the statutory consultation route

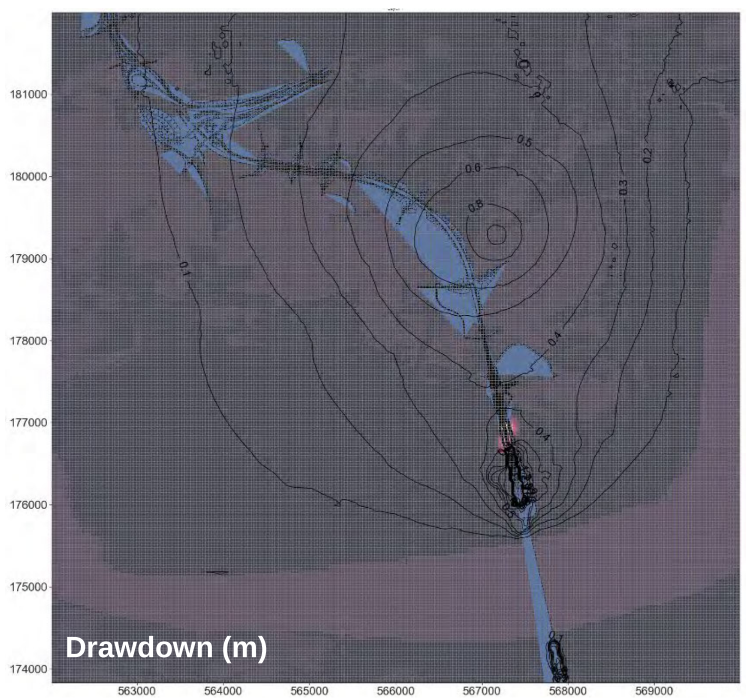
Annex E Saline interface results – baseline construction model + Linford abstraction (1ML/d)











5m bgl

- almost negligible saline intrusion compared to Thames salinity
- <0.1g/L change present in area due south of Project ramp and portals

15 and 21m bgl

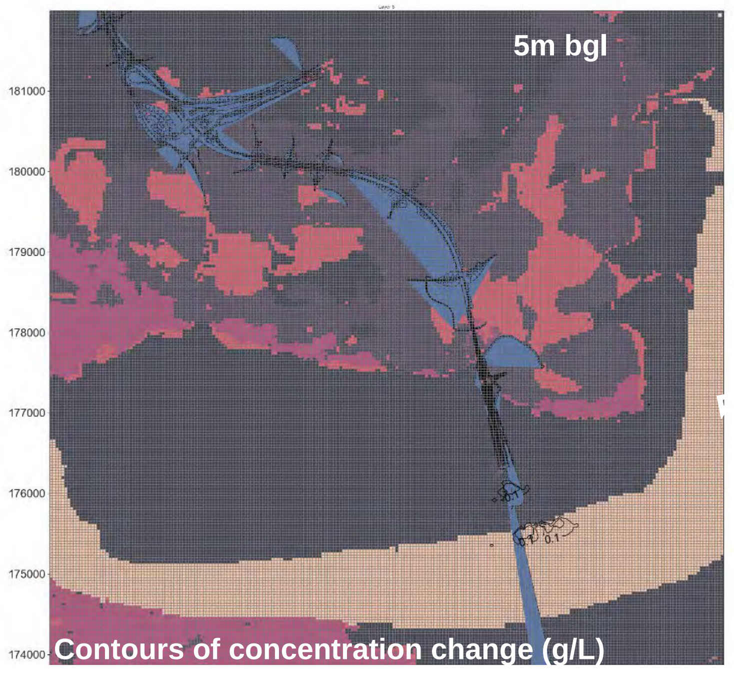
- Slight increase in salinity up to 0.1g/L caused by regional drawdown and up-coning due to Linford operation
- Limited to higher permeability RTD and TAB (Thanet Formation) deposits

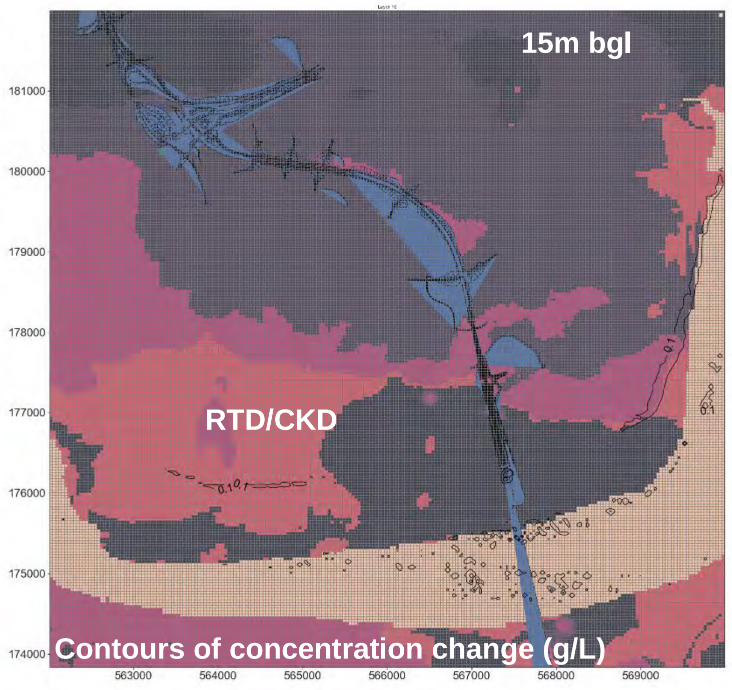
29m bgl

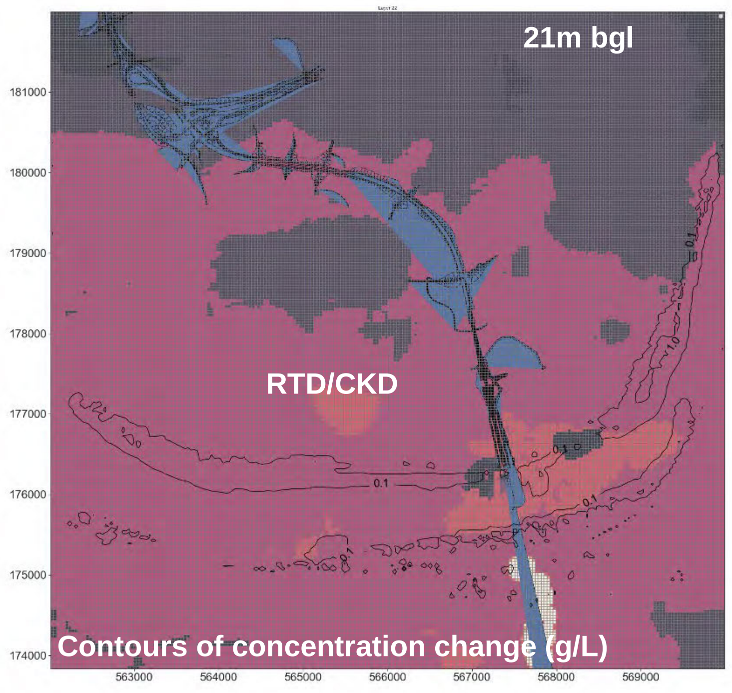
- Chalk
- Negligible saline intrusion

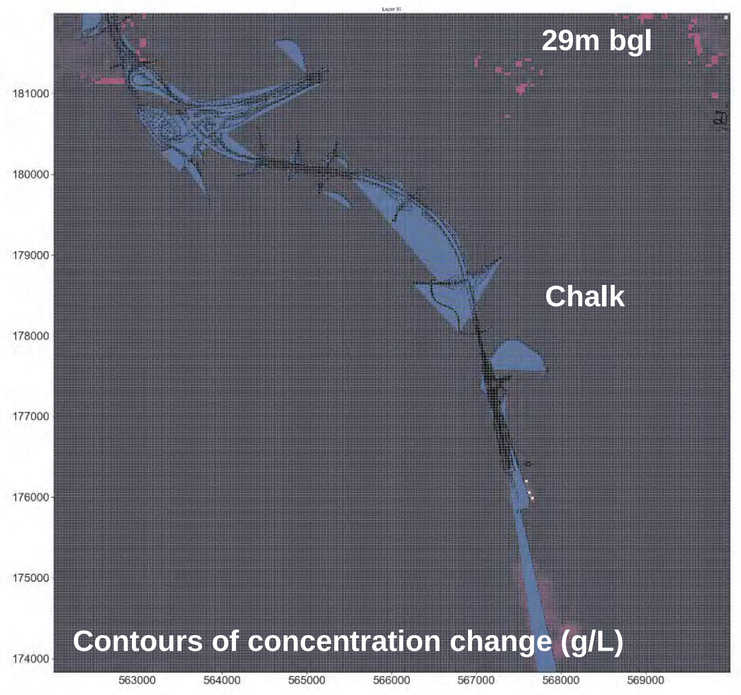
The figures show the statutory consultation route

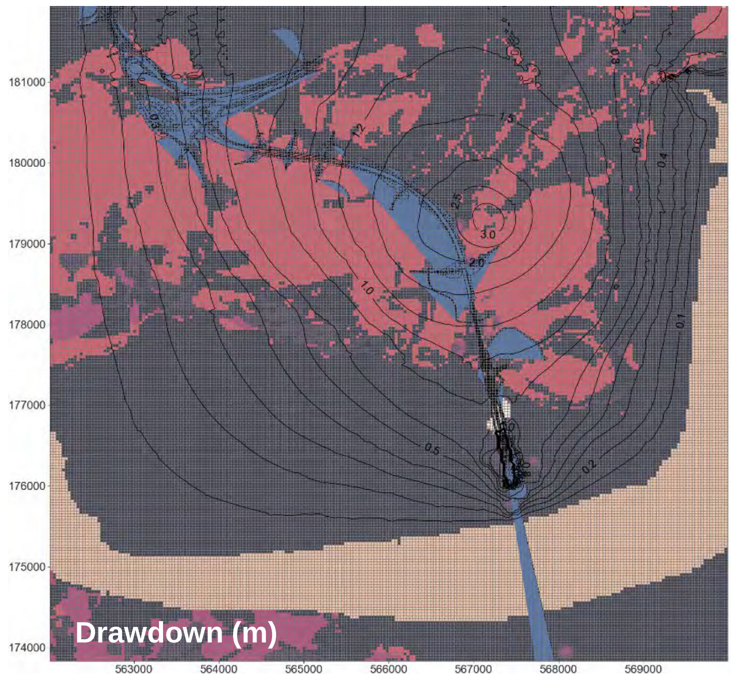
Annex F Saline interface results – baseline construction model + Linford abstraction (3.5ML/d)











5m bgl

- almost negligible saline intrusion compared to Thames salinity
- <0.1g/L change present in area due south of Project ramp and portals

15 and 21m bgl

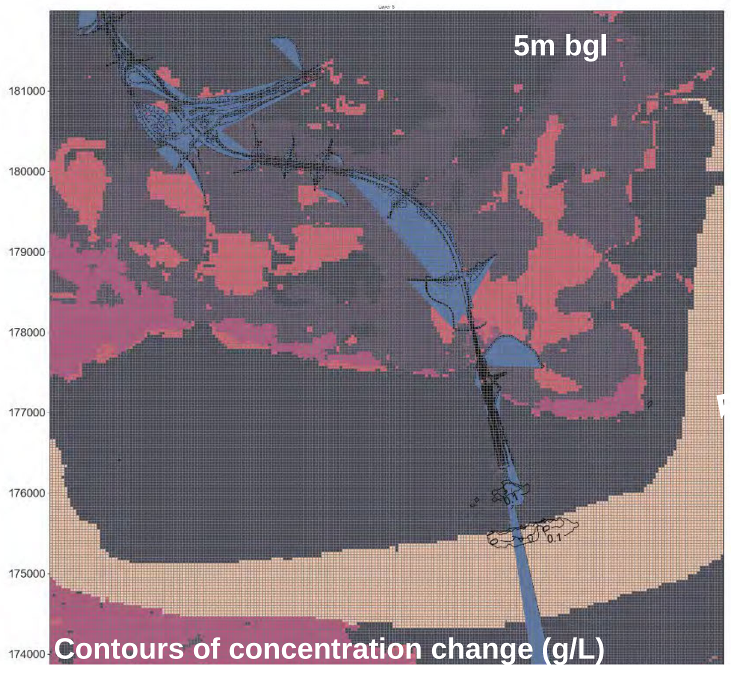
- Slight increase in salinity up to 1g/L caused by regional drawdown and up-coning due to Linford operation
- Limited to higher permeability RTD and TAB (Thanet Formation) deposits

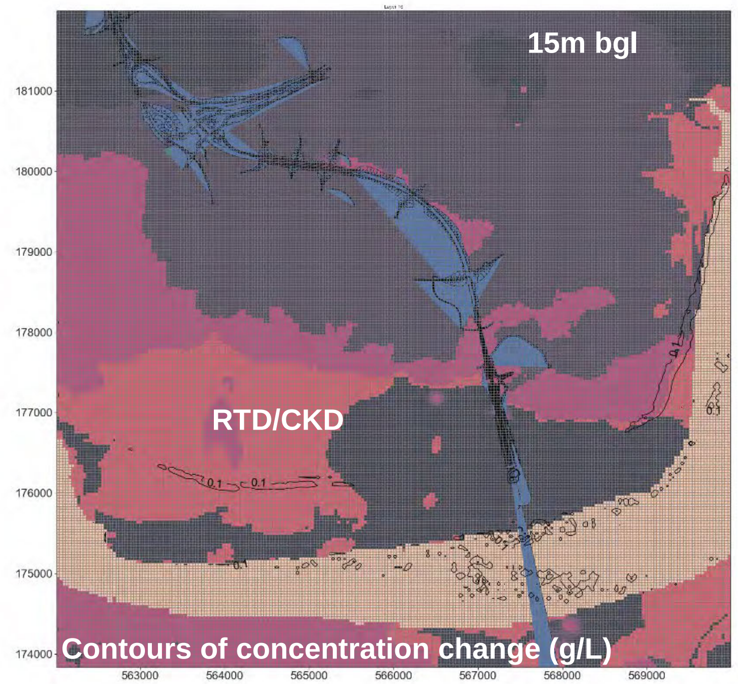
29m bgl

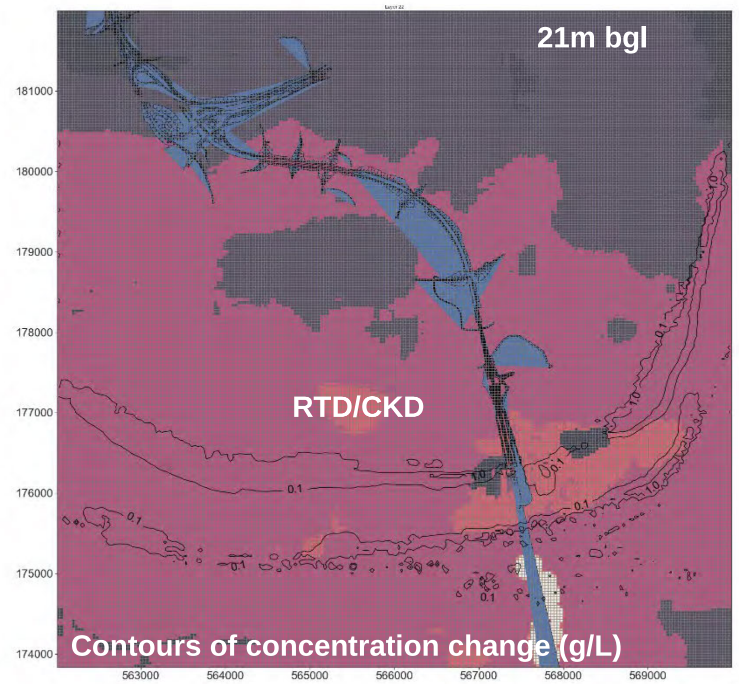
- Chalk
- Negligible saline intrusion

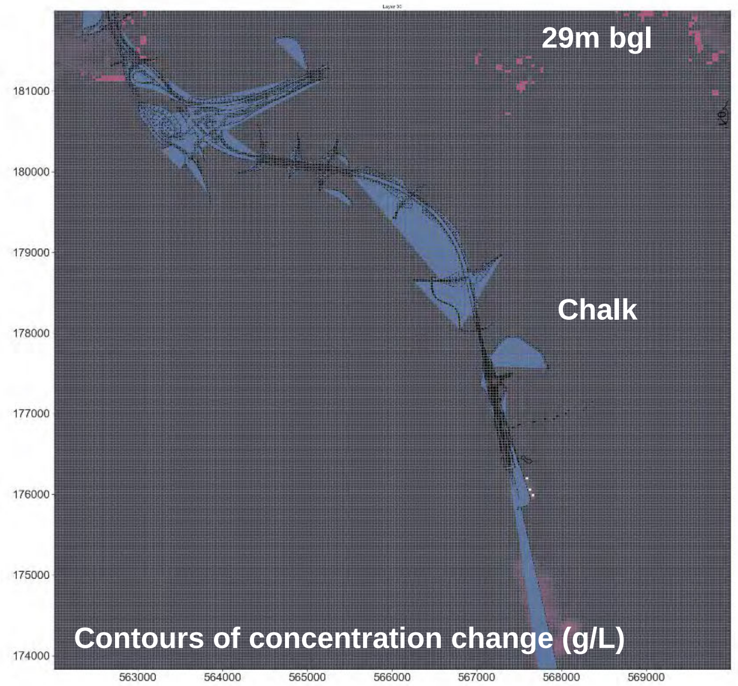
The figures show the statutory consultation route.

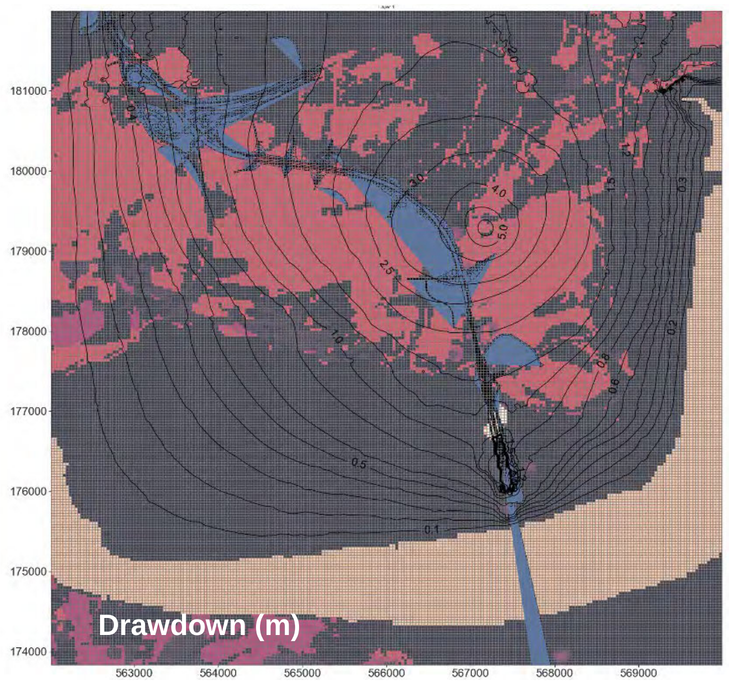
Annex G Saline interface results – baseline construction model + Linford abstraction (6ML/d)











5m bgl

- almost negligible saline intrusion compared to Thames salinity
- <0.1g/L change present in area due south of Project ramp and portals

15 and 21m bgl

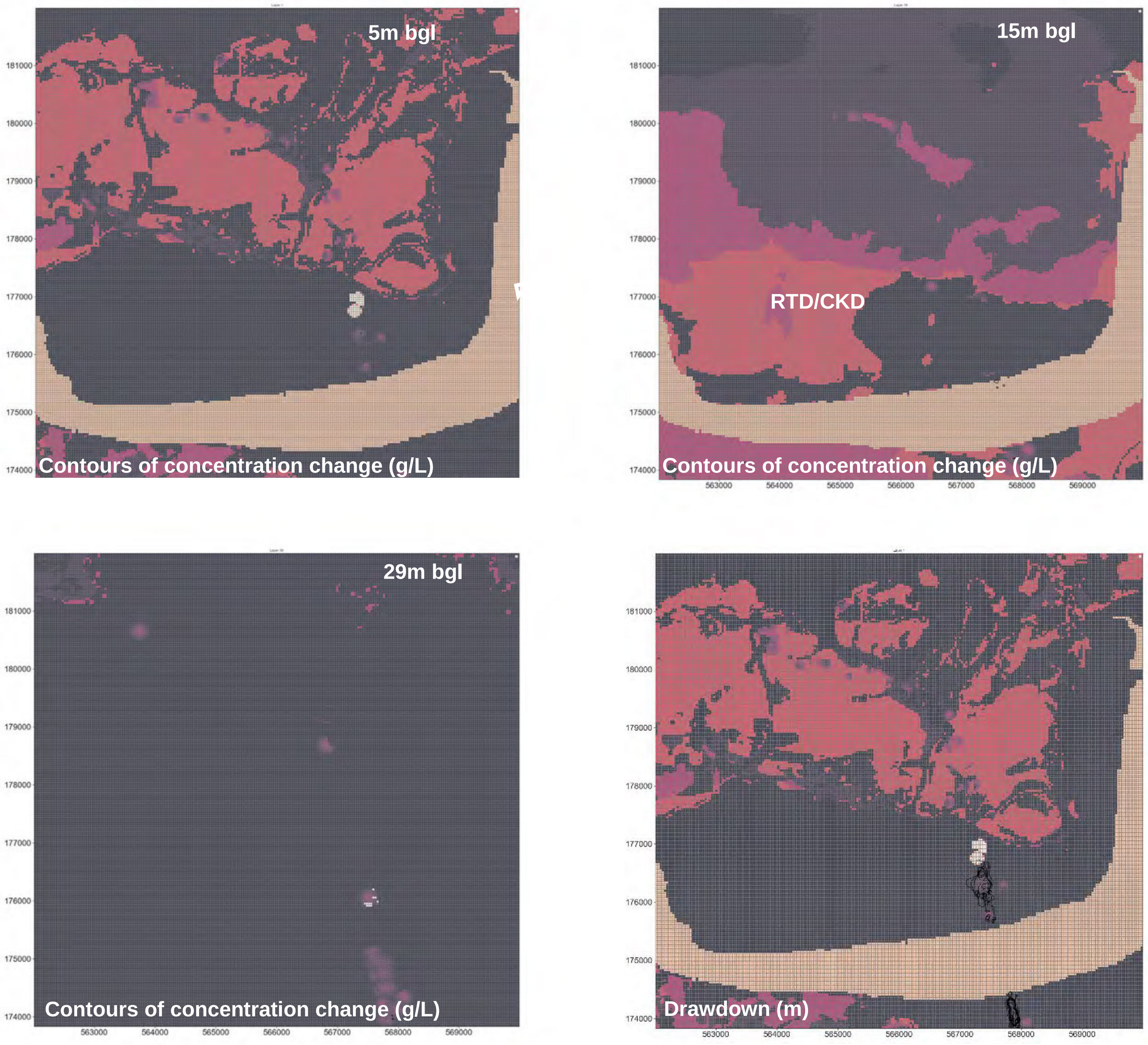
- Slight increase in salinity up to 1g/L caused by regional drawdown and up-coning due to Linford operation
- Limited to higher permeability RTD and TAB (Thanet Sand) deposits

29m bgl

- Chalk
- Negligible saline intrusion

The figures show the statutory consultation route.

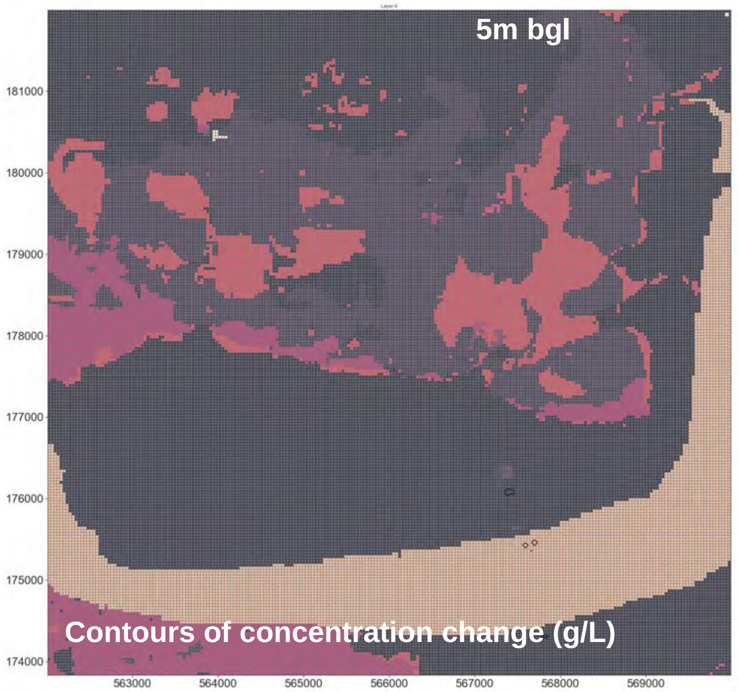
Annex H Saline interface results – operations model

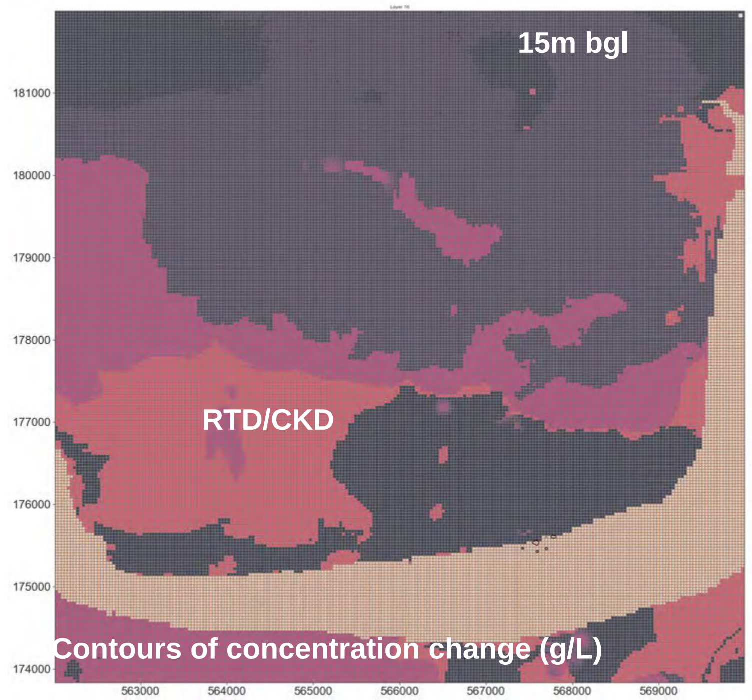


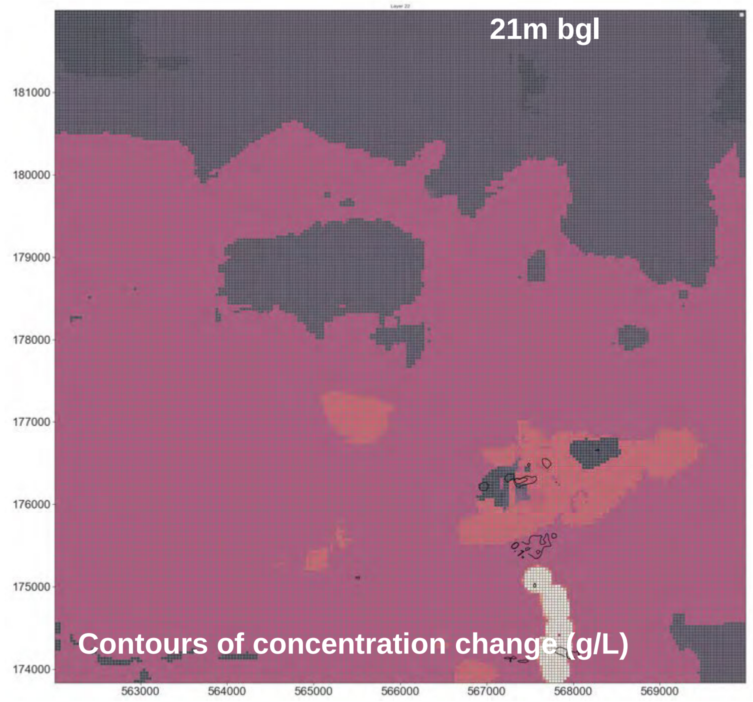
- Negligible saline interface movement at 5m bgl or 15m bgl
- At 21m bgl (CKD), minor increases in salinity of <0.1g/L
- This is steady state, long-term result

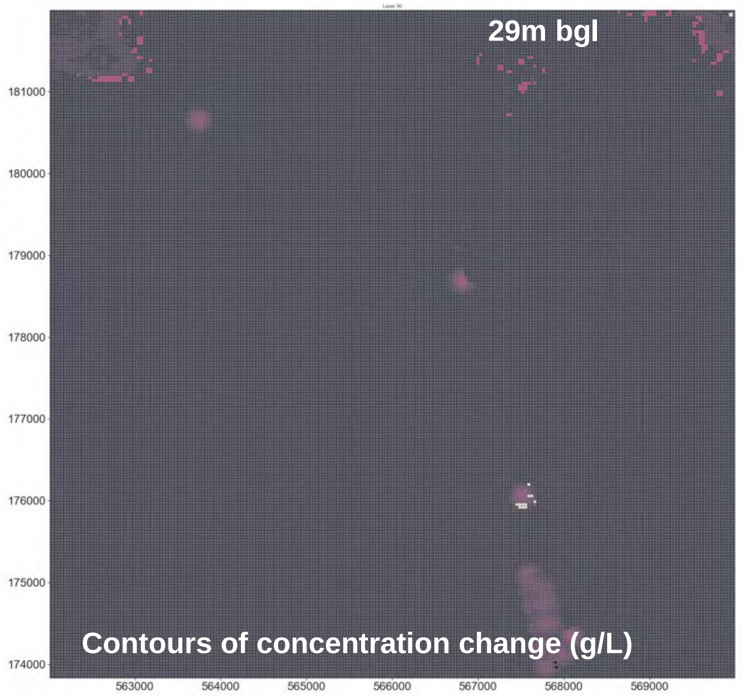
The figures show the statutory consultation route.

Annex I Saline interface results – operations model with ground improvement









- Negligible saline interface movement at 5m bgl or 15m bgl
- At 21m bgl (CKD), minor increases in salinity of <0.1g/L

Annex L A122 Lower Thames Crossing/M25 junction groundwater impact assessment numerical model – technical note

Lower Thames Crossing

Annex L A122 Lower Thames Crossing/M25 Junction Groundwater Impact Assessment Numerical Model – Technical Note

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1 Introduction

1.1 Overview

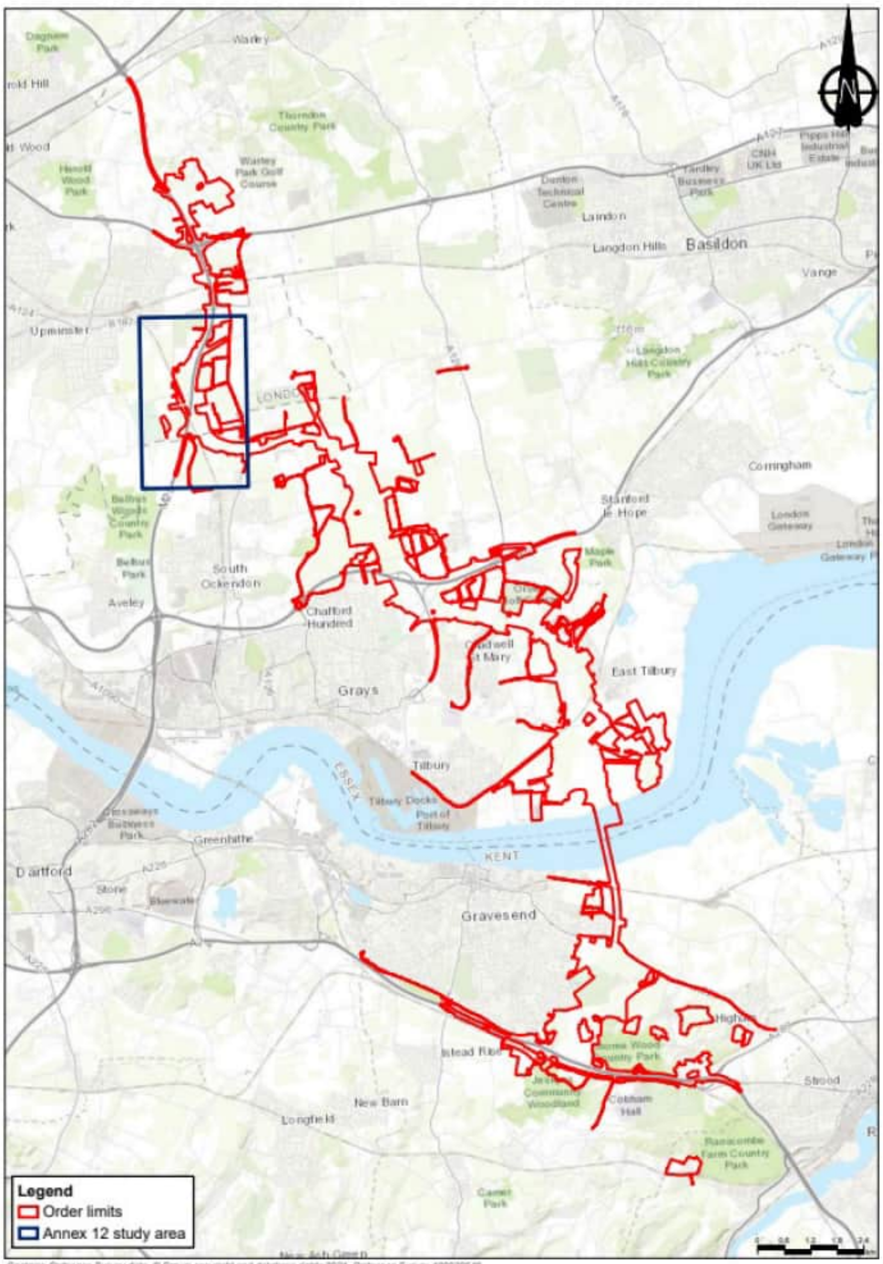
1.1.1 The A122 Lower Thames Crossing (the Project) would provide a connection between the A2 and M2 in Kent, east of Gravesend, crossing under the River Thames through a tunnel, before joining the M25 south of junction 29. The Project route is presented in Plate 1.1.

1.1.2 The A122 road would be approximately 23km long, 4.25km of which would be in tunnel. On the south side of the River Thames, the Project route would link the tunnel to the A2 and M2. On the north side, it would link to the A13 and junction 29 of the M25. The tunnel entrances would be located to the east of the village of Chalk on the south of the River Thames and to the west of East Tilbury on the north side.

1.1.3 The focus of this technical note is on the Project/M25 junction, where the proposed A122 northbound carriageway crosses under the existing M25, and its likely impact on the hydrogeological system surrounding the earthworks area.

1.1.4 The top of the underpass would be approximately 21.3m above ordnance datum (AOD), with the base varying between 15.25m AOD and 15.8m AOD. The proposed underpass is approximately 80m long, 20m wide and 5.5m high.

Plate 1.1 The Lower Thames Crossing corridor (Order Limits)



1.2 Reporting and modelling objectives

1.2.1 This technical note describes the modelling of groundwater flows for the construction of the Project/M25 junction and estimates the potential impact of this development on the surrounding hydrogeological regime.

1.2.2 This technical note includes the following:

a. Assessment of the groundwater seepage into the excavation during construction

b. Estimation of the drawdown and assessment of the temporary impact during construction

c. Estimation of the drawdown and assessment of the permanent impact during operation

d. Assessment of potential mitigation measures and respective impacts

1.2.3 Particular attention was given to the local springs, spring-fed ponds and Cranham Marsh Local Nature Reserve (LNR) that may have partial groundwater dependency to the north-west of the cutting.

2 Conceptual site model

2.1 Sources of information

2.1.1 This technical note is based on the available ground and groundwater data from British Geological Survey (BGS), historical investigations, Project ground investigation data and long-term monitoring data.

2.1.2 The BGS 3D lithostratigraphic model (Cascade, 2019a) was used to determine geological relationships in this region. In addition, Project geological and geomorphological interpretation was used in this respect.

2.1.3 Information regarding groundwater levels consists of the Project Phase 2 ground investigation works, Phase 3 ground investigation works and long-term monitoring data (December 2019 to January 2021). No historical groundwater levels were available in the Project.

2.2 Regional geology

2.2.1 BGS geological mapping shows that the superficial deposits mainly relate to former positions of the River Thames and are variable in their type and extent (Cascade, 2019). Deposits in this region comprise the Boyn Hill Gravel Member and Lynch Hill Gravel Member deposited by former Thames channels, with Head on some slopes and intermittent coverage of Alluvium in valley bottoms.

2.2.2 The former River Thames deposits are typically sand and gravel, deposited in braided streams during cold climate phases of the Quaternary Period. However, beds or lenses of finer-grained sometimes peaty sediments, deposited in warmer climate phases, are locally preserved within the sand and gravel units (Cascade, 2019). Individual members are differentiated on the basis of their elevation, subtle variation in gravel lithology and age. They are geotechnically identical and cannot be differentiated by particle size distribution or other index tests. In ground investigation reports they are usually described as River Terrace Deposits (RTD).

2.2.3 The bedrock comprises the London Clay Formation throughout.

2.2.4 The area of the proposed Project alignment and cutting intercepts both the Boyn Hill and Lynch Hill gravels, and Head Deposits, as well as the underlying London Clay. The cutting is not expected to encounter Alluvium, but localised Alluvium is mapped by the BGS approximately 770m west of the nearest limit of the proposed cutting.

2.3 Hydrogeological setting

2.3.1 Maps provided by the Environment Agency have been used to determine aquifer designations (Cascade, 2018).

2.3.2 Aquifer classification mapping by the Environment Agency shows the London Clay Formation is defined as an unproductive stratum, with low permeability that has negligible significance for water supply or river base flow (Cascade, 2018).

2.3.3 The overlying superficial deposits are mapped as Secondary A and Secondary Undifferentiated aquifers. The Environment Agency defines Secondary A aquifers 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. The term Secondary Undifferentiated aquifer is assigned where it has not been possible to attribute either Secondary A or Secondary B to a rock type. There is therefore potential for shallow groundwater, likely to be perched on the underlying clay in this region (Cascade, 2018).

2.3.4 There are no prominent rivers or watercourses next to the alignment. However, data received from the Environment Agency shows the River Ingrebourne is located further west, and tributaries of the Mardyke to the east. Small-scale features labelled as drains are located closer to the west. Levels and flows at these locations are not well understood.

2.3.5 Several additional features have been identified as of relevance in building conceptual understanding. These include surface water abstractions, historic and current springs, local surface water bodies, and Cranham Marsh which is a LNR.

2.3.6 The nearest Environment Agency monitoring borehole is located more than 2km from the alignment and monitors the Chalk. It is therefore not representative of groundwater levels at this part of the alignment, or within the layers in and above London Clay.

2.4 Site data and interpretation

Phase 2 ground investigation

2.4.1 Five observation holes have been completed, in a cluster, to the west of the proposed Project route during the Phase 2 ground investigation. These boreholes were completed between December 2019 and January 2020. Table 2.1 shows a summary of the geology recorded at the five observation holes, as provided on the preliminary engineers' logs.

2.4.2 Plate 2.1 provides a plan view of these observation holes and their location with respect to the alignment.

Table 2.1 Summary of Phase 2 ground conditions

Borehole ID	Borehole datum (m AOD)	Depth and geology	Recorded groundwater level
OH20001	24.58	• 0–0.30m below ground level (bgl): Made Ground (MGR) • 0.30–2.20m bgl: Alluvium • 2.20–10.60m bgl: RTD • 10.60–15.20m bgl: London Clay	No groundwater strikes recorded
OH20002	24.51	• 0–0.40m bgl: Topsoil • 0.40–3.70m bgl: Alluvium • 3.70–10.0m bgl: RTD • 10.00–15.20m bgl: London Clay	Strike recorded at 9.20m bgl, rising to 8.00m bgl after 20 minutes

Borehole ID	Borehole datum (m AOD)	Depth and geology	Recorded groundwater level
OH20003	24.13	• 0–0.35m bgl: Topsoil • 0.35–2.15m bgl: Alluvium • 2.15–10.10m bgl: RTD • 10.10–11.20m bgl: London Clay	Strike at 8.20m bgl, rising to 7.55m bgl after 20 minutes
OH20004	21.65	• 0–0.30m bgl: Made Ground (MGR) • 0.30–6.10m bgl: Alluvium • 6.10–11.10m bgl: RTD • 11.10–15.15m bgl: London Clay	Strike at 6.10m bgl, rising to 4.50m bgl after 20 minutes
OH20005	22.08	• 0–0.35m bgl: Topsoil • 0.35–10.80m bgl: Alluvium • 10.80–15.00m bgl: London Clay	Strike at 3.50m bgl, rising to 3.30m bgl after 20 minutes

Phase 3 ground investigation

2.4.3 An additional six boreholes were drilled in August to October 2020 and monitored for water level as part of Phase 3 ground investigation and long-term monitoring. Table 2.2 shows a summary of the geology recorded as provided on the preliminary engineers' logs.

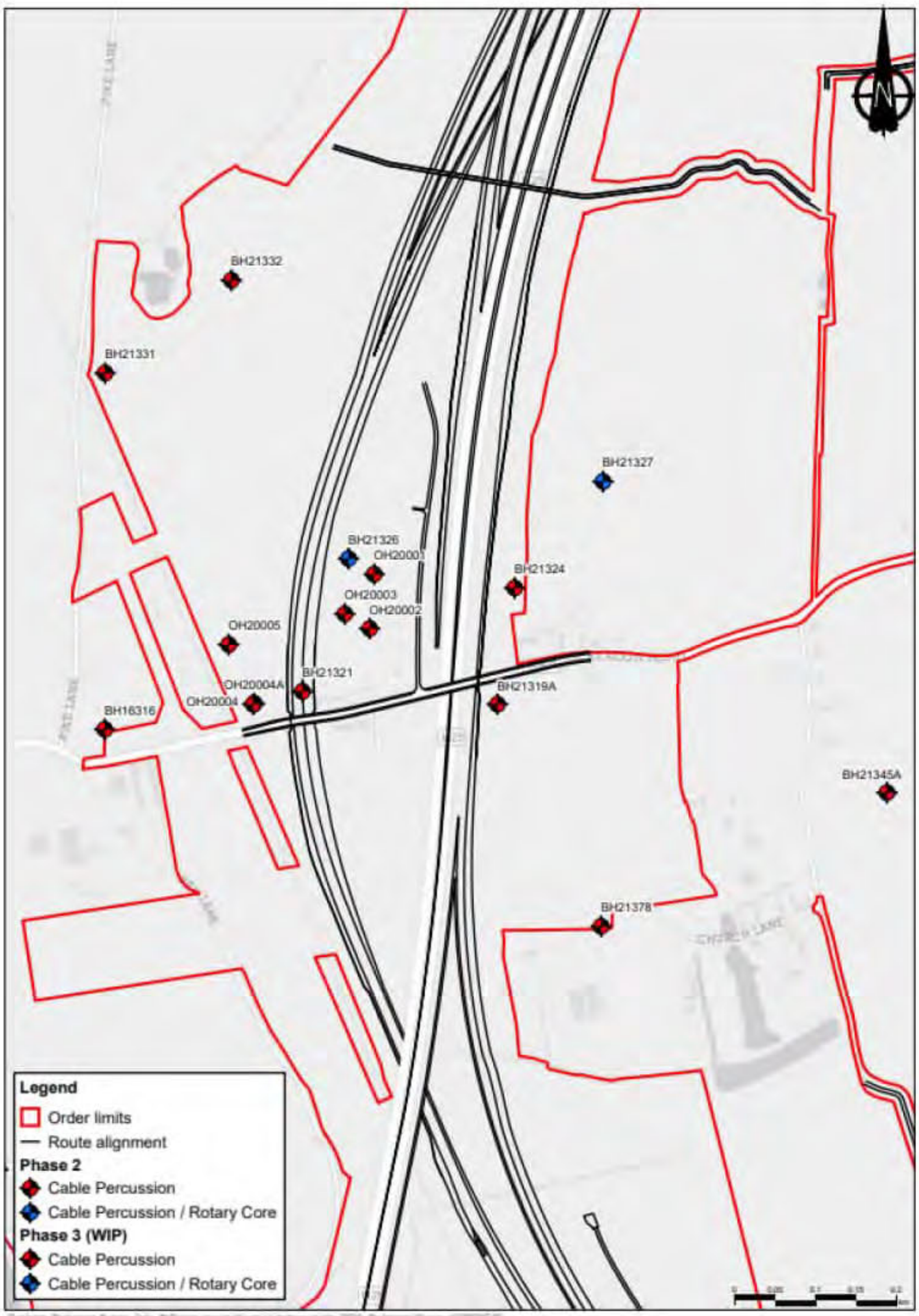
2.4.4 Plate 2.1 provides a plan view of these boreholes and their location with respect to the alignment.

Table 2.2 Summary of Phase 3 ground conditions

Borehole ID	Borehole datum (m AOD)	Depth and geology	Recorded groundwater level
BH21379	18.8	• 0–0.30m bgl: Topsoil • 0.30–0.50m bgl: Head • 0.50–4.90m bgl: RTD • 4.90–10.00m bgl: Alluvium • 10.00–20.00m bgl: London Clay	Strike at 2.1m bgl rising to 1.7m bgl after 20 minutes
BH21306	20.4	• 0–0.35m bgl: Topsoil • 0.35–0.50m bgl: Head • 0.50–7.10m bgl: RTD • 7.10–14.70m bgl: Alluvium • 14.70–36.60m bgl: London Clay • 36.60–48.35m bgl: Lambeth Group • 48.35–55.80m bgl: Upnor Formation • 55.80–75.67m bgl: Thanet Formation • 75.67–144.00m bgl: Chalk	Not recorded

Borehole ID	Borehole datum (m AOD)	Depth and geology	Recorded groundwater level
BH21309	19.2	• 0–0.30m bgl: Topsoil • 0.30–1.70m bgl: Head • 1.70–2.90m bgl: RTD • 2.90–6.60m bgl: Alluvium • 6.60–20.00m bgl: London Clay	Strike at 1.8m bgl rising to 1.55m bgl after 20 minutes
BH21310	23.8	• 0–2.70m bgl: Made Ground (MGR) • 2.70–12.45m bgl: RTD • 12.45–18.50m bgl: Alluvium • 18.50–20.50m bgl: London Clay	Groundwater not encountered prior to use of water flush
BH21332	19.5	• 0–0.15m bgl: Topsoil • 0.15–1.10m bgl: Head • 1.10–3.70m bgl: RTD • 3.70–20.00m bgl: London Clay	Resting water at 2.1m bgl overnight
BH21333	27.2	• 0–0.40m bgl: Topsoil • 0.40–0.60m bgl: Head • 0.60–30.00m bgl: London Clay	Strike at 2.7m bgl rising to 2.55m bgl after 20 minutes

Plate 2.1 Location plan of Project Phase 2 and Phase 3 boreholes in the M25 region



2.4.5 Local borehole logs have recorded Alluvium, which the BGS geological maps record as deposits of Head. Since there are no prominent existing or past watercourses located in this region to support the presence of Alluvium, the materials have been interpreted as Head for the purposes of this report. Also noted is that the preliminary log for OH20005 does not record any thickness of RTD when the logs for nearby locations do. The log instead records over 10m of Alluvium. Additionally, where RTD have been recorded, the Project ground investigation data has not differentiated which gravel member is present, indicating only 'River Terrace Deposits'. This reflects the difficulty of differentiating RTD on the basis of geotechnical data.

2.4.6 In order to provide a more refined interpretation of the RTD, appropriate to support hydrogeological modelling, the data has been reviewed in detail by a geomorphologist using 3D modelling tools. This has resulted in a more accurate ground model that differentiates sand and gravel members and identifies the location and depth of finer grained material.

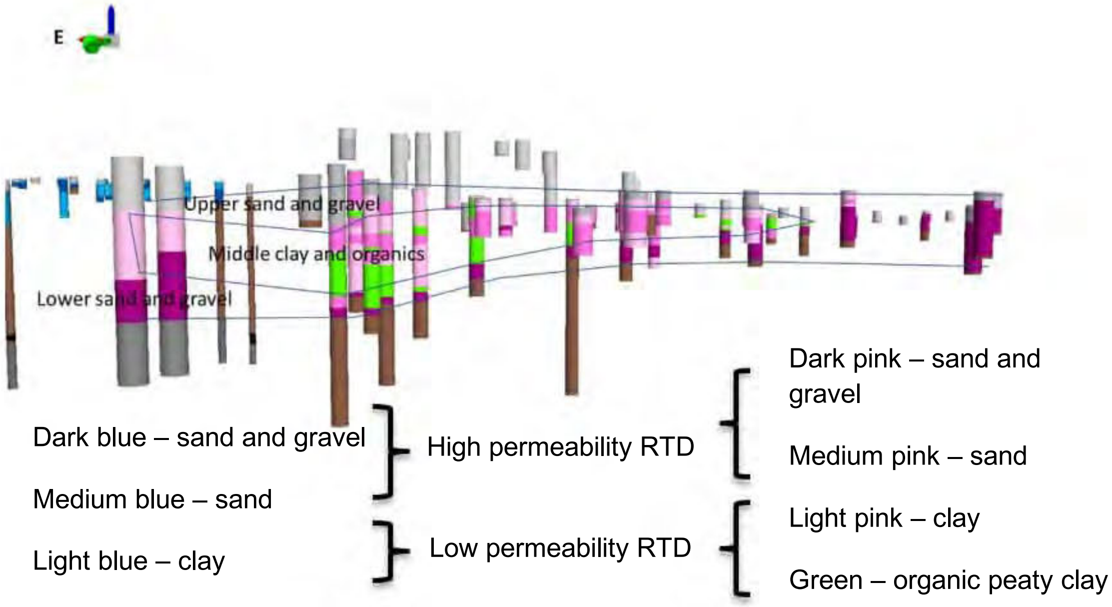
Interpretation

2.4.7 The River Thames has deposited bodies of sand and gravel that often include beds of organic silts. Progressive phases of incision and deposition, in response to uplift and climate change over the last 500,000 years, have formed a 'staircase' of river terraces that are underlain by aggradations of river deposits. Academic research shows the aggradations often comprise sedimentary triplets of lower sand and gravel, organic silts and upper sand and gravel that reflect the river's sedimentary response to changes in climate and sea-level, between glacial and interglacial phases of the Quaternary Period (Cascade, 2019). The sediments that underly each terrace surface have been classified by BGS into different geological members. Former positions of the Thames are reconstructed by correlating remnants of terrace surfaces and/or associated sedimentary members in the landscape.

2.4.8 The study area lies near a former river meander known as the 'Ockendon Loop'. The palaeogeography of this feature has been the subject of academic research and is associated with the outcrop of the Lynch Hill Gravel Member (also known in the literature as the Corbets Tay Gravel). The Ockendon Loop meander incised into older river deposits of the Lynch Hill Gravel Member, which are preserved at higher elevations.

2.4.9 The Project's geomorphological interpretation is based on recent and historical ground investigation data that has been evaluated through detailed review of the sediment descriptions, supported by 3D visualisation. Particularly attention was paid to the lithological descriptions of RTDs in borehole logs, which were classified as sand and gravel or sand (high permeability), or clay, silty clay or organic clay (low permeability). In certain cases, classifications of Alluvium and Head were also revised. Borehole data was then visualised in 3D and coloured by lithology allowing lithostratigraphic horizons to be traced between different boreholes in the region and classification of the deposits to member level. Plate 2.2 shows the widespread presence of a low permeability bed of clay-rich, sometimes organic, material that is bound within high permeability sand and gravel units. The bed can be traced through the landscape using both recent and historical ground investigation data, but it is not present at all locations. The data is interpreted as showing warm climate river sediments that infill a series of localised channels, which were subsequently buried by sand and gravel as the river responded to a cooling climate.

Plate 2.2 Showing how data was assessed to trace defined horizons within each deposit. Blue shades show the Boyn Hill Gravel Member while pink shades show the Lynch Hill Gravel Member.

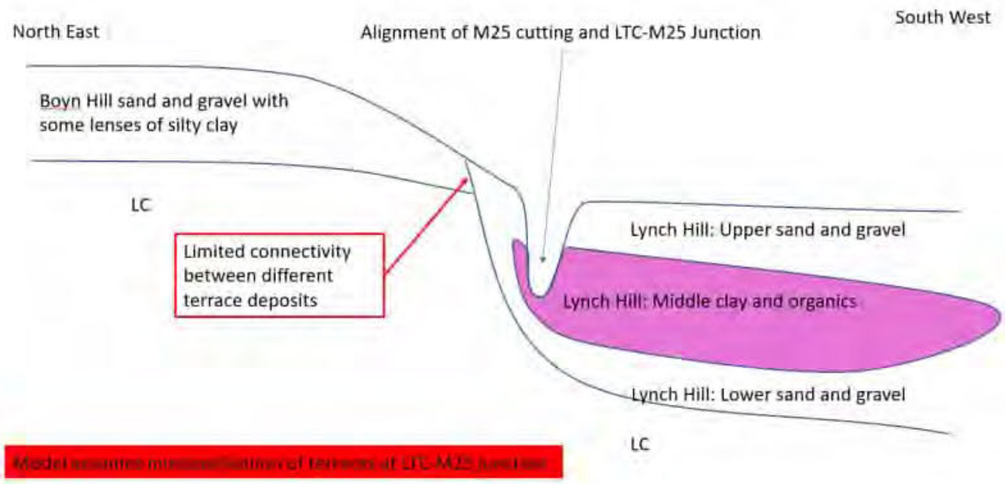


2.4.10 The outputs of the Project's geomorphological interpretation confirm that sediments of the older Boyn Hill Gravel Member are found at higher elevations to the east of the existing M25 cutting. In contrast, the Lynch Hill Gravel Member, which is younger, is found at lower elevations to the west of the existing M25 cutting, where the Project cutting is proposed. Fine-grained beds are identified in both members, but they are more extensive and often rich in organic material in the Lynch Hill Gravel Member.

2.4.11 This interpretation also suggests that historical ground investigation data around the existing M25 cutting and railway bridge (associated with the historical M25 widening scheme) is likely to have been misclassified. The Project's geomorphological interpretation suggests that sediments previously considered to represent the Boyn Hill Gravel Member at this location have an atypically low elevation range and are more likely to represent the Lynch Hill Gravel Member.

2.4.12 Plate 2.3 shows schematic relationships at this part of the alignment. Limited, if any, hydraulic connection is anticipated between these strata due to elevation differences, topographic controls, and because the existing M25 cutting is likely to act as an obstacle to lateral flow. Cross-sections produced using the BGS ground model (Burke *et al.*, 2014), as well as the geomorphological interpretation, support the conclusion of limited connectivity.

Plate 2.3 Schematic relationship between the RTD at the Project/M25 junction



Groundwater

2.4.13 Groundwater level data is available for Phase 2 and Phase 3 boreholes. The groundwater strikes recorded during drilling have been presented in Table 2.2. Additional manual dips, as well as the initial groundwater level measured before the variable head testing, are presented in Table 2.3.

Table 2.3 Summary of groundwater level data

Borehole ID	Response zone	Max. manual dip (m AOD)	Min. manual dip (m AOD)	Average manual dip (m AOD)	Count manual dip reading	Monitoring period
OH20001	RTD	16.6	16.3	16.5	5	05/02/2020 – 05/01/2021
OH20002	RTD	17.2	16.7	16.9	5	24/01/2020 – 05/01/2021
OH20003	RTD	17.6	17.0	17.2	5	24/01/2020 – 05/01/2021
OH20004	RTD	17.7	17.2	17.3	4	30/01/2020 – 18/12/2020
OH20005	Alluvium	17.7	17.1	17.4	4	30/01/2020 – 18/12/2020
BH21306	Chalk	-0.1	-0.3	-0.2	2	27/10/2020 – 05/01/2021
BH21309	RTD	17.4	17.1	17.3	2	09/11/2020 – 07/01/2021
BH21310	RTD	18.3	18.0	18.2	2	27/10/2020 – 07/01/2021

Borehole ID	Response zone	Max. manual dip (m AOD)	Min. manual dip (m AOD)	Average manual dip (m AOD)	Count manual dip reading	Monitoring period
BH21332	RTD	17.8	17.7	17.7	2	17/11/2020 – 05/01/2021
BH21333	London Clay	25.8	25.7	25.8	2	27/10/2020 – 08/01/2021
BH21379	Alluvium	17.0	17.0	17.0	2	27/10/2020 – 11/12/2020

2.4.14 The levels presented in Table 2.1, Table 2.2 and Table 2.3 show shallow groundwater, perched on the underlying London Clay. BH21333 has a higher water level than the other boreholes and is the only monitoring well screening within the London Clay which is thicker in this location. As a result, the standpipe may be acting as a sump and recording a level higher than the surroundings. BH21306 had a deep installation in the Chalk below the London Clay and records the Chalk aquifer water level rather than the level of the water perched on the London Clay

2.4.15 The strikes shown in Table 2.1 are all recorded within the RTD and the overlying material that is labelled Alluvium but assumed to represent Head Deposits. Strikes shown in Table 2.2 are recorded within RTD with one strike in BH21333 recorded within the London Clay.

Permeability

2.4.16 Variable head testing was carried out between 27/01/2020 and 14/11/2020 at the locations shown in Table 2.4. Variable head testing included a rising and a falling head test at all five observation hole locations and either a rising or falling head test in three borehole locations.

2.4.17 Table 2.4 gives a summary of the preliminary results received from the contractor. These preliminary values have been used as guidance on the range of permeability, rather than being used as exact values.

Table 2.4 Summary of permeability results from Project Phase 2 and 3 ground investigation

Borehole ID	Rising head test result (m/s)	Falling head test result (m/s)	Test zone lithology
OH20001	3.9×10^{-5}	5.9×10^{-6}	Fine to medium sand
OH20002	4.6×10^{-6}	2.6×10^{-5}	Gravelly medium to coarse sand
OH20003	No water level drop – permeability not calculated	4.7×10^{-5}	Slightly gravelly medium to coarse sand

Borehole ID	Rising head test result (m/s)	Falling head test result (m/s)	Test zone lithology
OH20004	$4.6x10^{-5}$	$2.1x10^{-6}$	Gravelly medium to coarse sand
OH20005	$4.0x10^{-5}$	$6.7x10^{-6}$	Gravelly fine to coarse sand
BH19300	$3.9x10^{-6}$	Not tested	Gravelly fine to coarse sand
BH19304	$1.3x10^{-7}$	Not tested	Gravelly fine to coarse sand
BH20303	$2.9x10^{-6}$	Not tested	Gravelly fine and medium sand
BH21303	$1.0x10^{-4}$	Not tested	Gravelly fine and medium sand
BH21310	$3.8x10^{-5}$	Not tested	Fine to coarse sand
BH21314	$1.9x10^{-6}$	Not tested	Silty sandy clay
BH21319	$2.4x10^{-7}$	Not tested	Sandy clay
BH21324	$2.8x10^{-5}$	Not tested	Fine to medium sand
BH21378	Not tested	$3.4x10^{-5}$	Very sandy gravel
BH21332	$9.5x10^{-6}$	Not tested	Gravelly fine to coarse sand
BH21345A	$6.0x10^{-5}$	Not tested	Gravelly fine and medium sand

2.4.18 The test zones were all located within the RTD, except OH20005, which the preliminary log suggests the test zone was within Alluvium (as discussed, this is rejected by the Applicant and assumed to be Head). The preliminary logs generally describe the lithology of the test zones as a range between gravelly medium to coarse sands, and fine to coarse gravelly sands. According to Domenico and Schwartz (1990), the following hydraulic conductivity values (all in m/s) are typical for such material:

a. Gravel – $3x10^{-4}$ to $3x10^{-2}$

b. Coarse sand – $9x10^{-7}$ to $6x10^{-3}$

c. Medium sand – $9x10^{-7}$ to $5x10^{-4}$

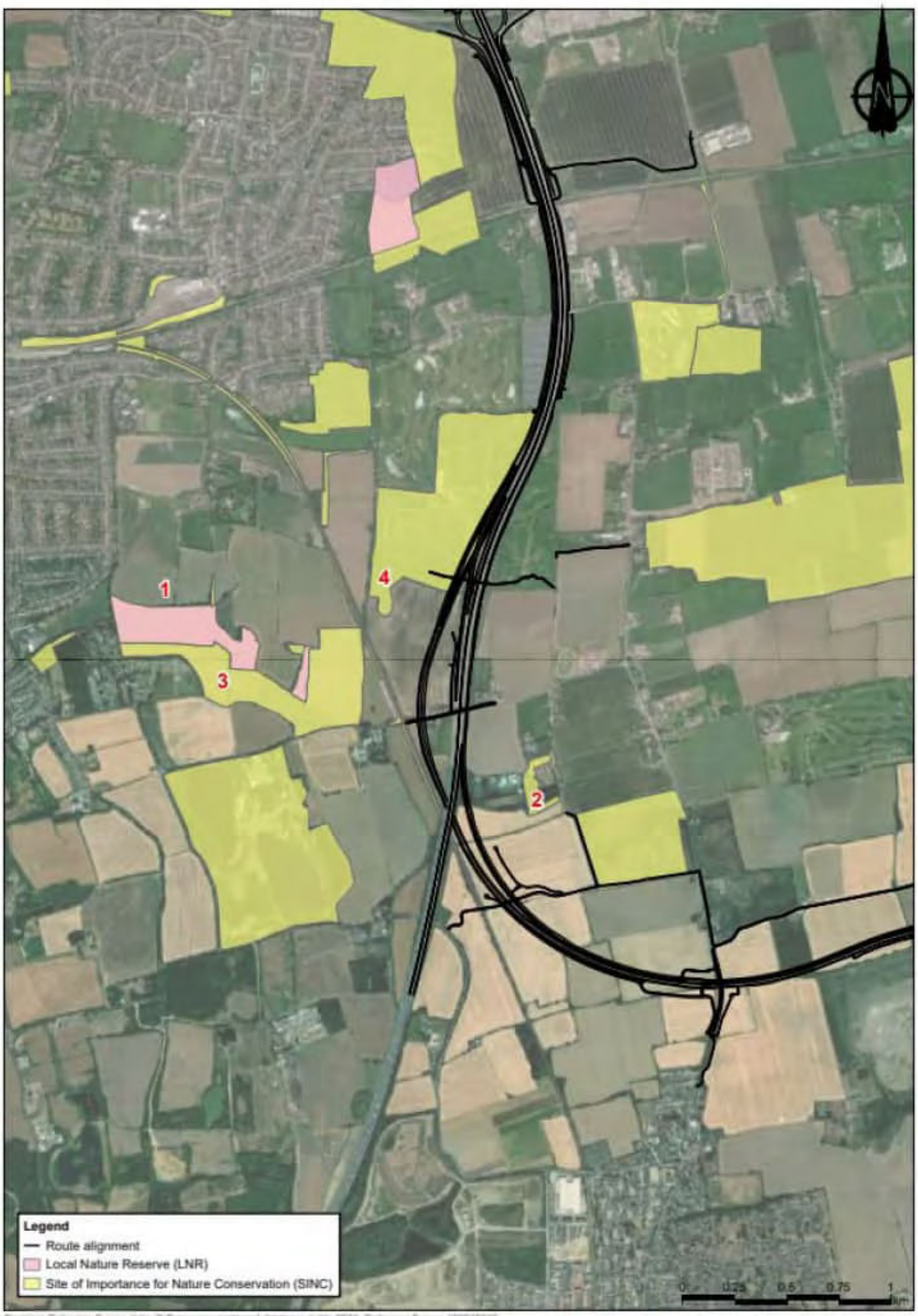
d. Fine sand – $2x10^{-7}$ to $2x10^{-4}$

2.4.19 Bricker and Bloomfield (2014) also report on similar values of hydraulic conductivity.

2.5 Other features

2.5.1 Several features have been identified as being inherent to understanding the hydrogeology in this region and their role in the conceptual site model. These locations are shown spatially in Plate 2.4.

Plate 2.4 Location map showing areas of environmental importance



1. Cranham Marsh LNR – including Spring Wood, Middle Wood and Bonus Wood

2. Hall Farm Moat, paddock and St Mary Magdalene Churchyard, North Ockendon Site of Importance for Nature Conservation (SINC)

3. Fields south of Cranham Marsh SINC

4. Thames Chase Forest Centre SINC – includes Hobbs Hole (pond of mapped historical spring)

Cranham Marsh

2.5.2 Cranham Marsh LNR and vegetation habitats are described in Chapter 14: Road Drainage and the Water Environment (Application Document 6.1) and Appendix 14.5: Hydrogeological Risk Assessment (Application Document 6.3). A key point is that the LNR has been identified as having discrete areas of fen (valley mire), indicating some groundwater dependency. The site is located to the north of Upminster Cemetery. Available Ordnance Survey mapping shows that a series of surface water drains both feed into and exit the site, with small areas of ponding shown.

2.5.3 The LNR is shown to be split over two areas: Bonus Wood and separately, an area including Middle Wood and the larger Spring Wood. Bonus Wood is closest to the Order Limits, approximately 280m away, and approximately 500m from the nearest part of the cutting, to its west. Spring Wood is located further away, approximately 530m from the Order Limits and approximately 750m from the cutting.

2.5.4 Spring Wood is shown to overlie Alluvium. The relationship between the Alluvium, surrounding (and potentially underlying) gravel aquifers, as well as whether the site is dependent on groundwater, is uncertain. No ground investigation (neither historical nor recent) is available in this area.

2.5.5 The BGS ground model shows that, here, shallow Alluvium directly overlies the London Clay, with no gravel underlying. The lateral relationship with any RTD outcropping at surface is not well understood; the superficial geology appears complex. Given its shallow thickness and limited extent, the Alluvium is not likely to be a viable water-bearing aquifer. Therefore, at this stage, groundwater is thought unlikely to be significant in supporting the site.

Surface water abstractions and storage lake

2.5.6 A number of surface water bodies are located near the Project/M25 junction, as shown in Plate 2.4. Two of these are used for recreational purposes (one named Russell’s Lake while the other is unnamed) at Stubbers Adventure Centre.

2.5.7 One of these features is not part of Stubbers Adventure Centre and is understood to be used as a storage facility for water fed from a reported spring. A licensed surface water abstraction abstracts from this reservoir to meet agricultural irrigation needs by a landowner.

2.5.8 The exact location of the spring was not found during a site visit (May 2021). In essence, according to information provided by the landowner, groundwater is collected by series of (deep) land drains and gravity-fed ditches in a general east to west direction, transferred via ducts under the M25, then piped to the landowner’s storage lake next to Stubbers Adventure Centre, where it is stored and the lake used for fishing. Subsequently, this water is pumped out for irrigation purposes, including via pipework back under the M25 to the fields on the east side of the M25.

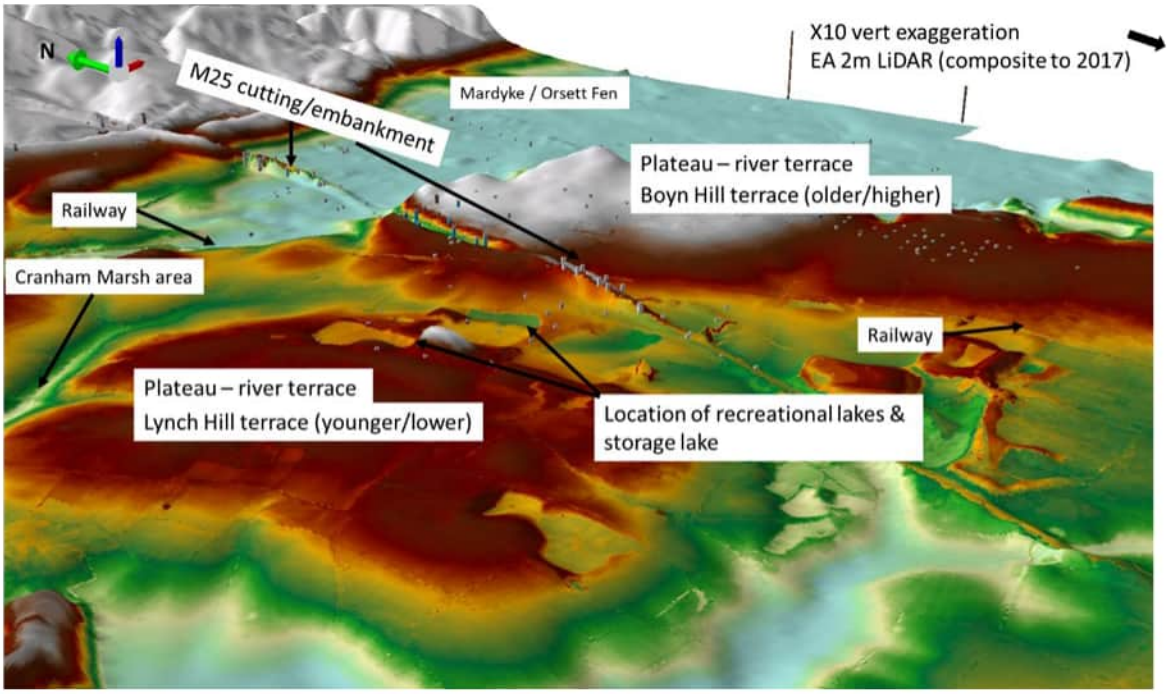
2.5.9 The landowner has informed us that the spring (St Cedd’s Well) at Hall Farm moat, paddock and St Mary Magdalene Churchyard, North Ockendon SINC runs only rarely since the M25 was built, but the nearby moat appears to be full. The source of water is anticipated to be a combination of rainfall directly on the surface, the runoff from the surrounding higher grounds during precipitation events, and potential baseflow from the water table. The latter source may be impacted if drawdown is experienced as a result of new construction activities.

2.5.10 Historical gravel extraction and subsequent infilling of pits has taken place in this region. Geological maps show an absence of superficial deposits in these surface water areas, where material (probably sand and gravel) has been extracted. The BGS ground model (Cascade, 2019) shows Made Ground immediately overlying the London Clay here. Subsequent creation of these surface waters is not well understood; nor whether excavation of any fill material, or lining, occurred, and therefore there is some uncertainty regarding the potential connectivity between them and surrounding RTD.

2.5.11 Based on known information, little to no hydraulic connection is anticipated between these surface waters and underlying material, due to London Clay being encountered at such shallow depths. However, potential lateral flow from surrounding sand and gravel deposits which were not historically quarried may occur into these surface waters. This depends on the composition of material used to create them, which is not currently known.

2.6 Conceptual site model summary

Plate 2.5 3D LiDAR elevation model to show topographic controls on superficial geology, and pertinent features in this region



2.6.1 Plate 2.5 shows a 3D digital elevation model of the region surrounding the Project/M25 junction derived from Light Detection and Ranging (LiDAR) data, visualised in ArcScene software by the Project's geomorphologists. Vertical exaggeration has been applied to emphasise the features. Key features, including Cranham Marsh and the recreational lakes discussed, are shown. The flat river terraces that are underlain by sand and gravel deposits are also indicated.

2.6.2 The river terraces underlain by the Boyn Hill Gravel Member and Lynch Hill Gravel Member can be picked out at distinctly different elevations. The Boyn Hill terrace surface is at a higher elevation to the Lynch Hill, which lies to the west of the existing M25.

2.6.3 No significant hydraulic continuity is expected across the M25 between the two sand and gravel members due to elevation constraints and because of the obstacle that the M25 represents. However, the future cutting would impact both terraces as it is positioned in between Boyn Hill and Lynch Hill.

2.6.4 The interpretation confirms that the Project/M25 junction lies within the area of a former Thames meander known as the ‘Ockendon Loop’. This palaeogeography is associated with terrace gravels known as Lynch Hill Gravel (also known in the literature as the Corbets Tay Gravel).

3 Methodology

3.1 Software

3.1.1 A control-volume finite difference (CVFD) MODFLOW-USG (Panday *et al*., 2013) was used in this assessment. MODFLOW is an industry-standard software maintained by the United States Geological Survey. The model has been created using Groundwater Vistas 7 (Rumbaugh and Rumbaugh, 2017), produced by Environmental Simulations International. AlgoMesh was used to generate an unstructured Voronoi grid (Merrick, 2016). AlgoMesh's primary focus as a model-building tool is producing input files for MODFLOW-USG simulations.

3.2 Model geometry

3.2.1 Varied geology near the existing M25 necessitates a complex model geometry to represent the encountered Made Ground; superficial deposits including Alluvium, Head and several RTD; the Mucking, Corbets Tay and Orsett Heath gravels and the London Clay Formation which underlies the superficial terrace deposits throughout the region.

3.2.2 A lithostratigraphic geological model purchased from the BGS (BGS, 2019) was consulted for developing the model. The BGS data assists the determination of model geometry and the vertical sequence of the terraces of the RTD group in this location in addition to local data acquired from the five local boreholes. Plate 3.1 shows the outcrop geology in plan-view for the model area. The BGS model contains many layers though, there are three key layers in this area and relevant to the anticipated depth of the embankment:

a. Made ground – the high-resolution topography data, form the top surface of the model

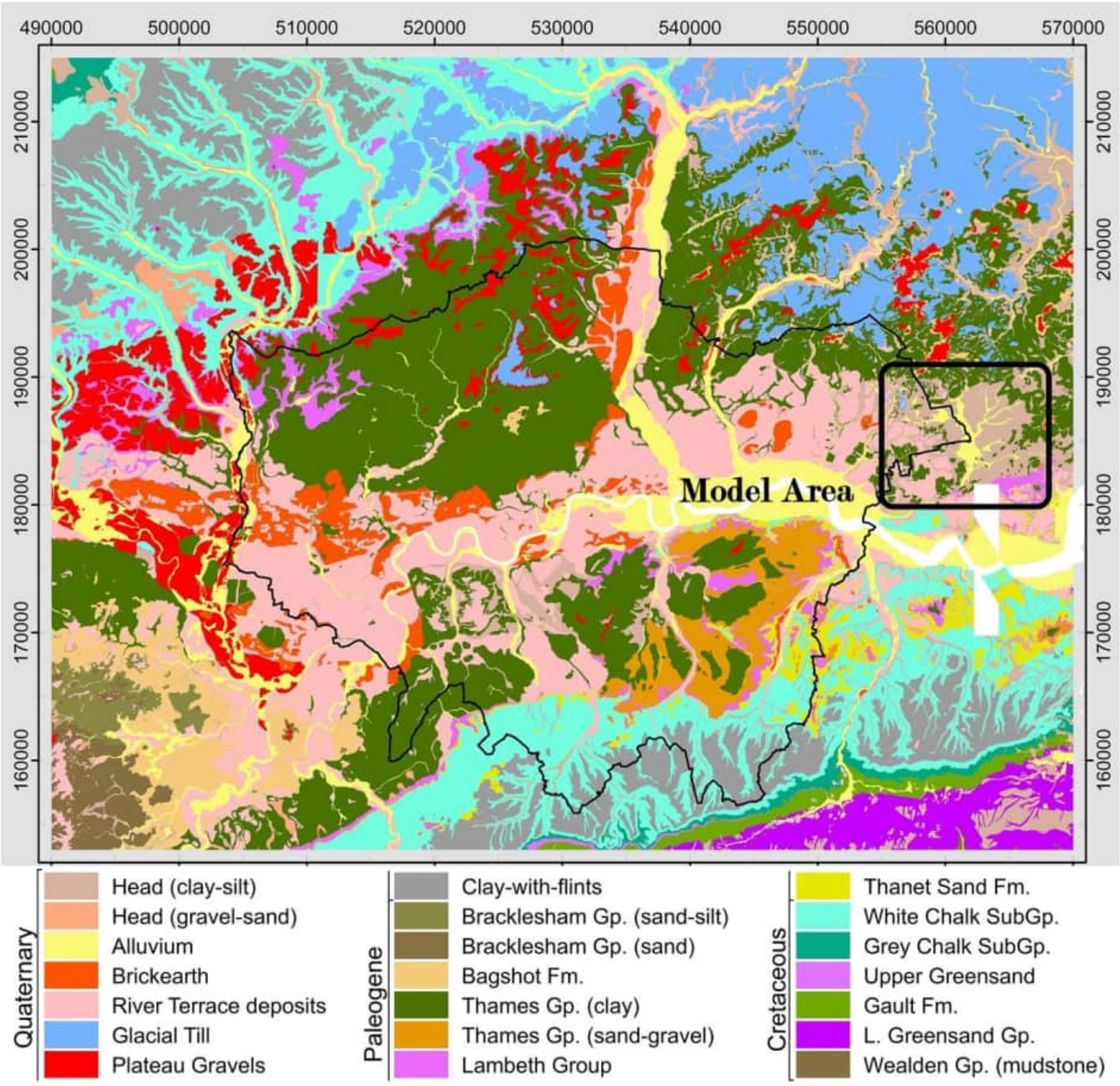
b. Superficial deposits at outcrop including Alluvium, Head Deposits and RTD

c. RTD, underlying the Alluvium

d. London Clay at varying depths

3.2.3 The Eocene deposits, such as the London Clay, outcrop sporadically across the model domain and at higher elevations than the RTD above the water table. London Clay outcrops are also seen in man-made, clean geometrical shapes where previous mining activities have taken place.

Plate 3.1 The topographical model with geological boundaries across the model domain (BGS, 2014)

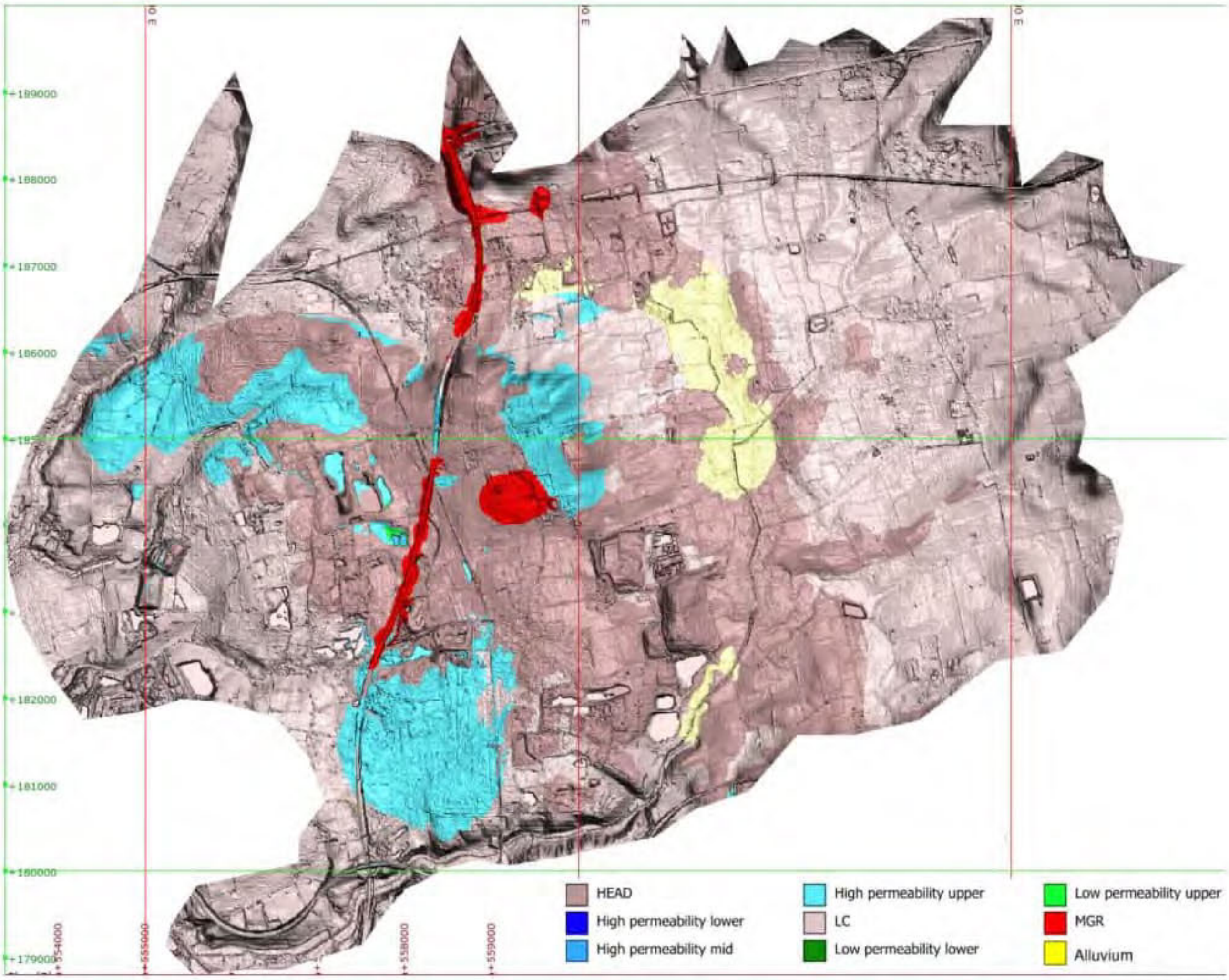


3.2.4 The BGS geological model includes a multitude of DXF data files for each lithological group. The grids include a top elevation, bottom elevation and thickness for each different stratum identified by the BGS.

3.2.5 The BGS model is supplemented with, and reinterpreted based on, local data to inform local conditions regarding lithostratigraphy. The geomorphological interpretation of the local data provides a basis for spatial discretisation, allowing for sub-units of RTDs to be distinguished. The purpose of this exercise is to separate the sub-units with different hydrogeological characteristics within the RTDs for a more accurate predictive modelling of the groundwater regime. Plate 3.2 shows the surface geology of the refined model composed in the ground modelling software Leapfrog Works (Seequent Ltd), as a 3D model and used to produce the model geometry.

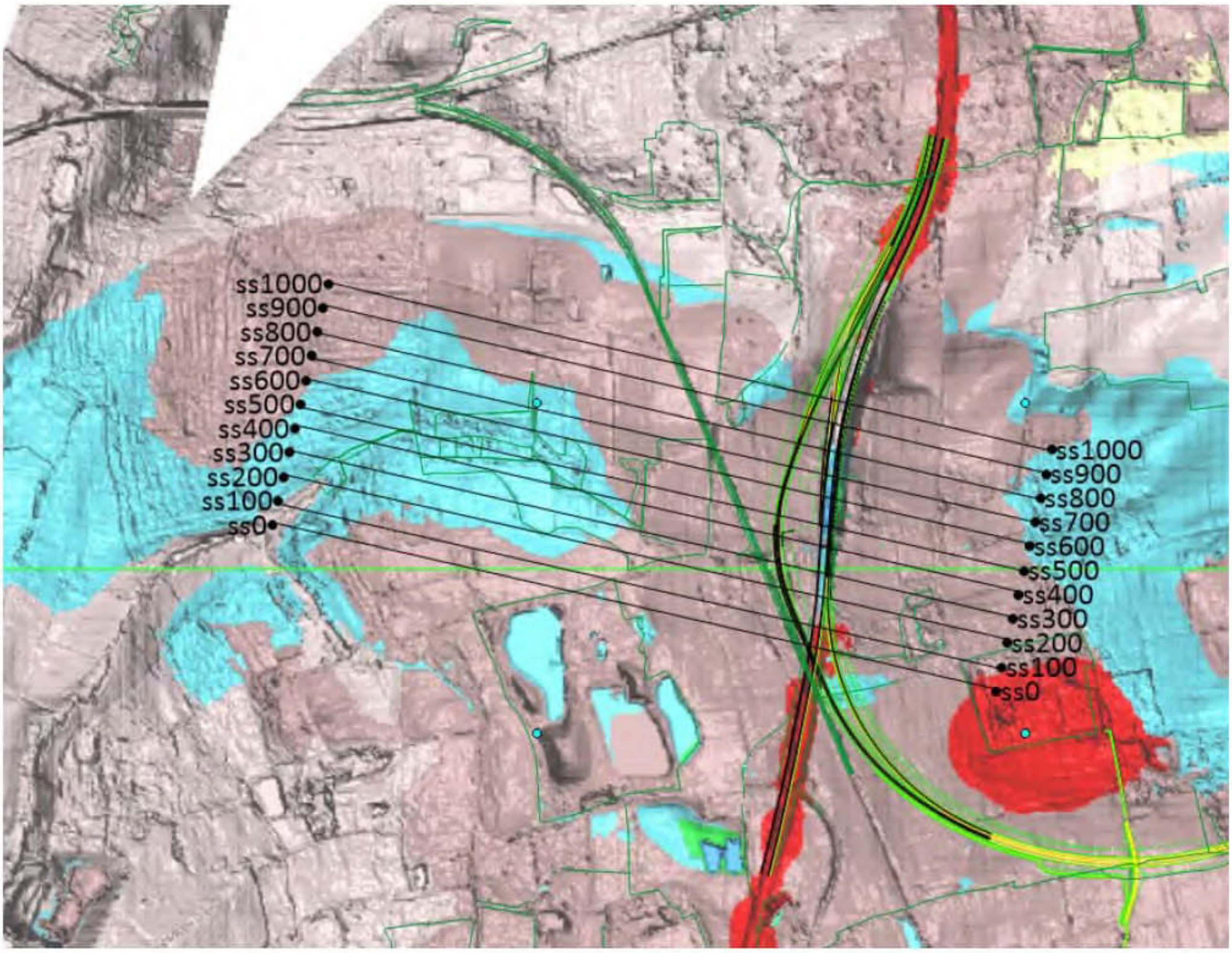
3.2.6 A total of 602 AGS exploratory holes were used in the Leapfrog geology interpretation (Plate 3.2). Data included boreholes, trial pits and window samples from Phase 2 and Phase 3 Project ground investigation, and BGS records.

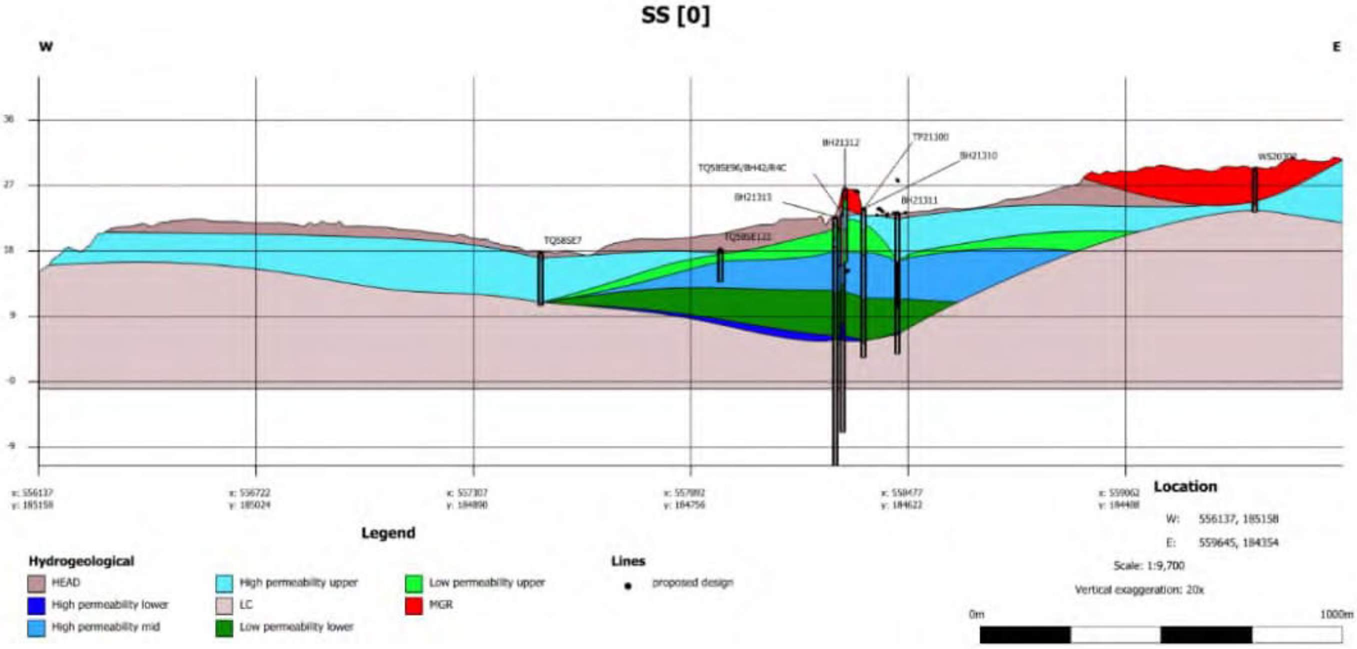
Plate 3.2 The geological refined and interpreted model

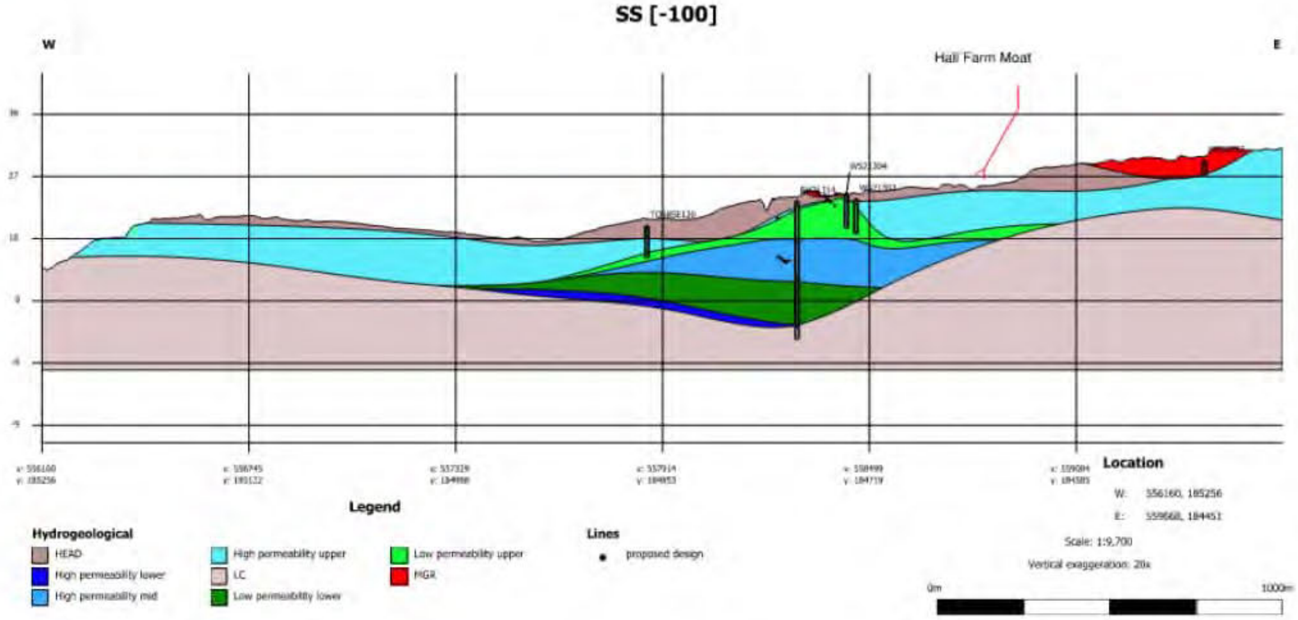


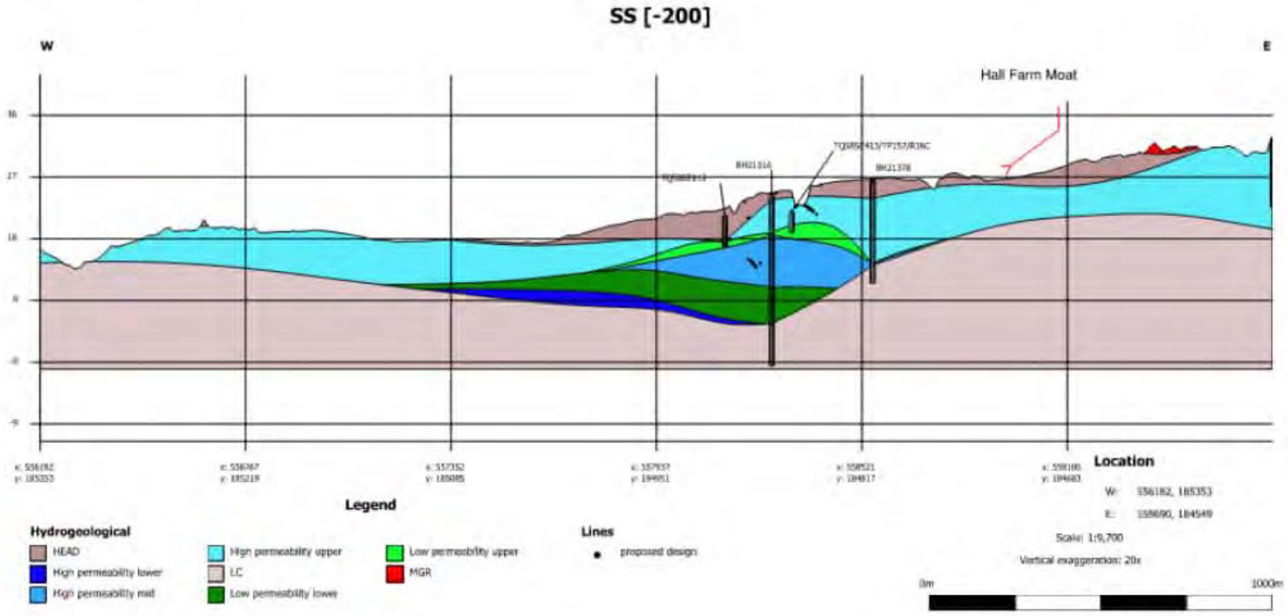
3.2.7 A total of 11 cross-sections were extracted from the model to illustrate the ground conditions in more details. While the model extends significantly away from the cutting to allow for more accurate numerical results, these sections are taken in the area of interest only, covering the main cutting and the surrounding points of importance. Importantly, the sections shed light on the relative position of the current M25 to the RTD hills on both sides of the M25, as well as the position of the proposed cutting (shown with black circles were present). It is evident that much of the RTD hills to the sides of the M25 have been fully, or largely, intercepted during the previous rounds of construction works on the said roadway. The proposed cutting would, in some locations, deepen this interception slightly, while in other places it would rest on the London Clay (shown as LC in Plate 3.2 and Plate 3.3). Sections shown in Plate 3.3 demonstrate these insights visually. Areas of made ground are shown in red and are labelled as MGR (in Plate 3.2 and Plate 3.3).

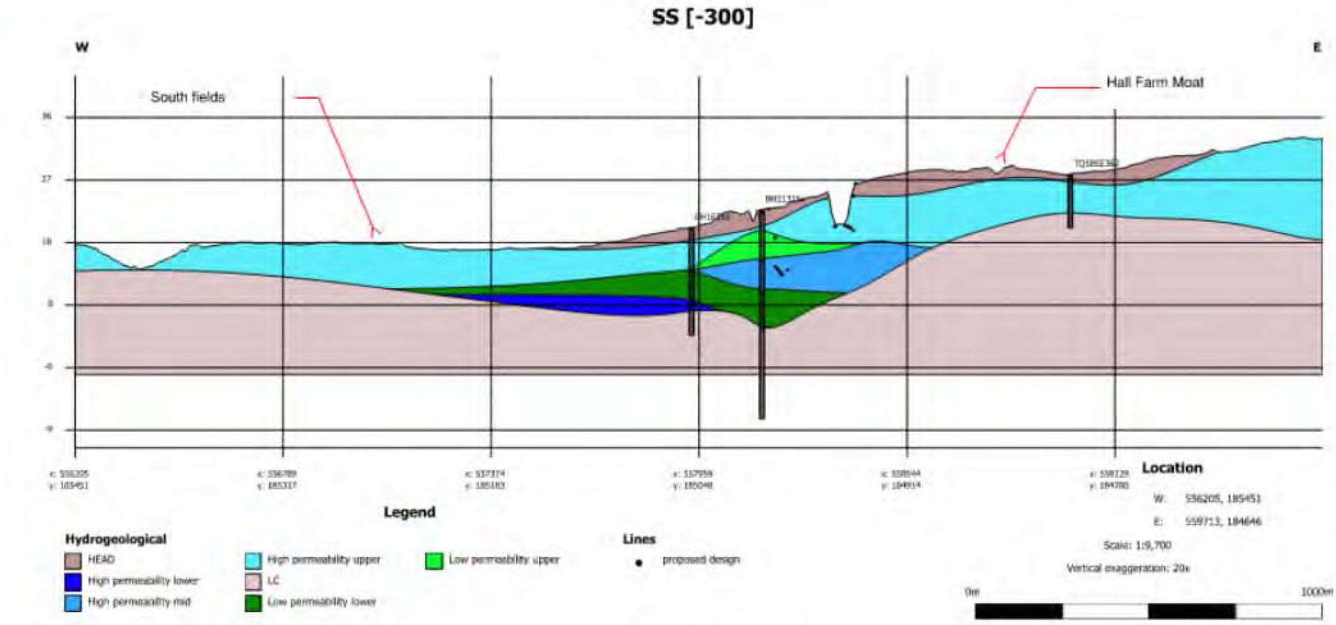
Plate 3.3 The refined and interpreted geological model and sections

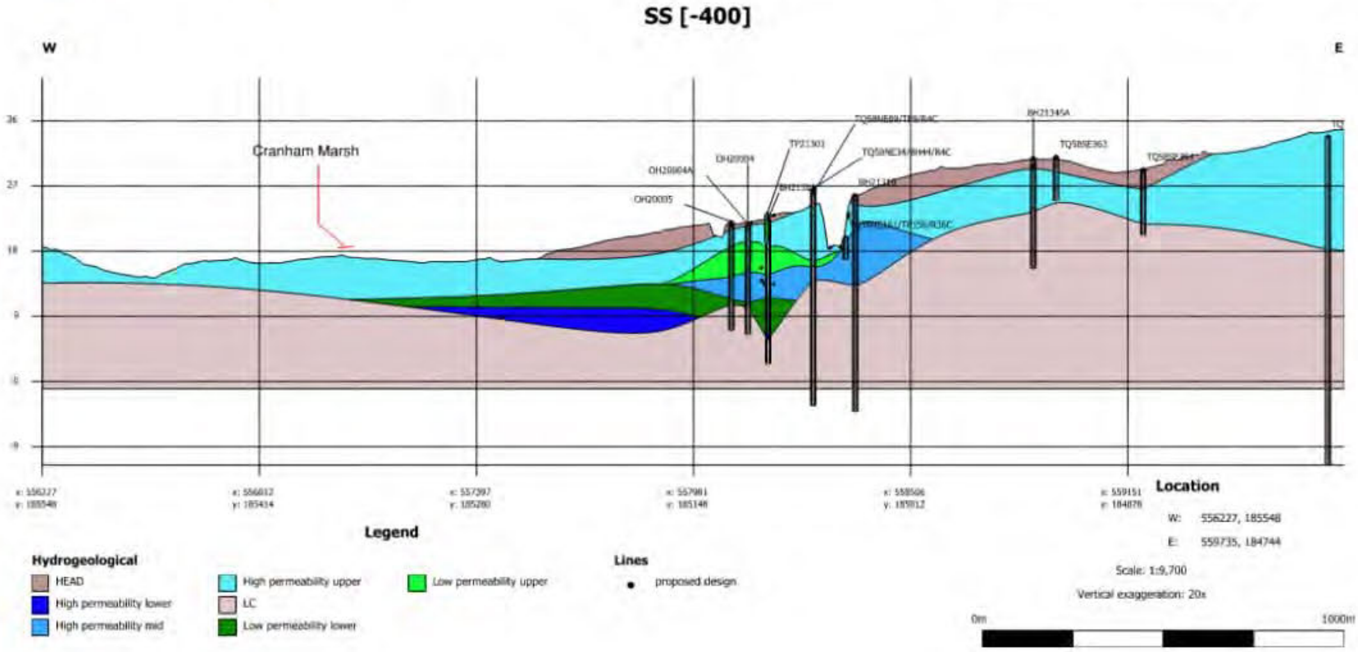




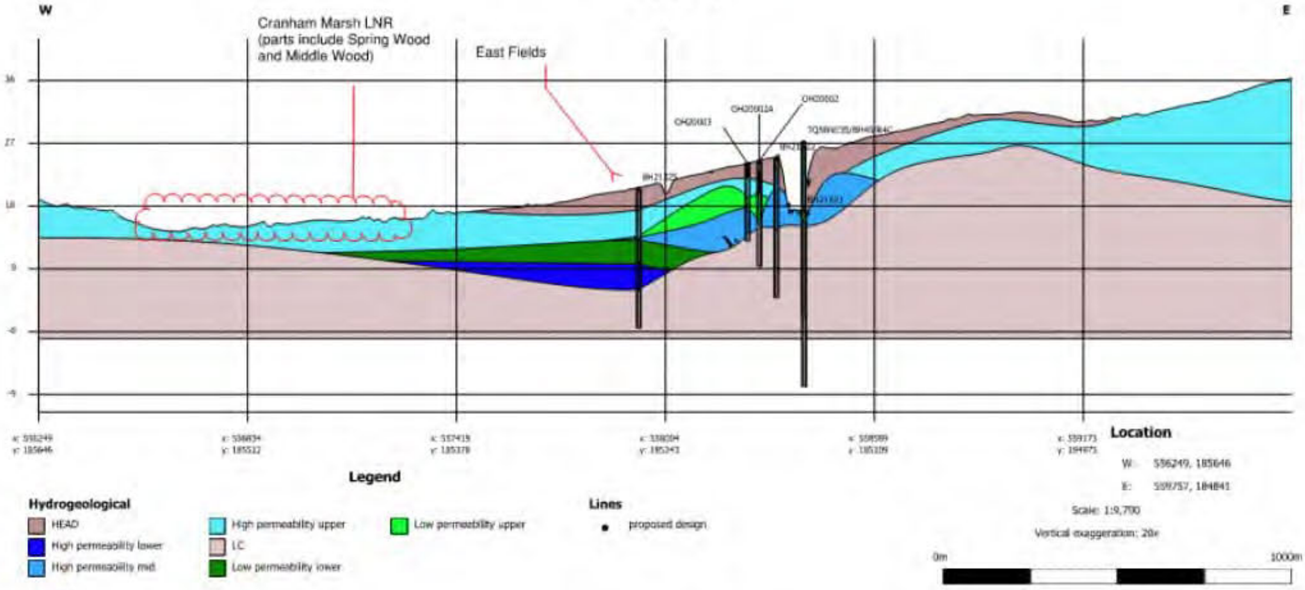

SS [-100]
W
E
Hall Farm Moat
Location
Legend
Hydrogeological
HEAD
High permeability lower
High permeability mid
High permeability upper
LC
Low permeability lower
Low permeability upper
MGR
Lines
proposed design
Scale: 1:9,700
Vertical exaggeration: 20x
0m
1000m


SS [-200]
W
E
Hall Farm Moat
Location
Legend
Hydrogeological
HEAD
High permeability lower
High permeability mid
High permeability upper
LC
Low permeability lower
Low permeability upper
MGR
Lines
proposed design
Scale: 1:9,700
Vertical exaggeration: 20x
0m
1000m

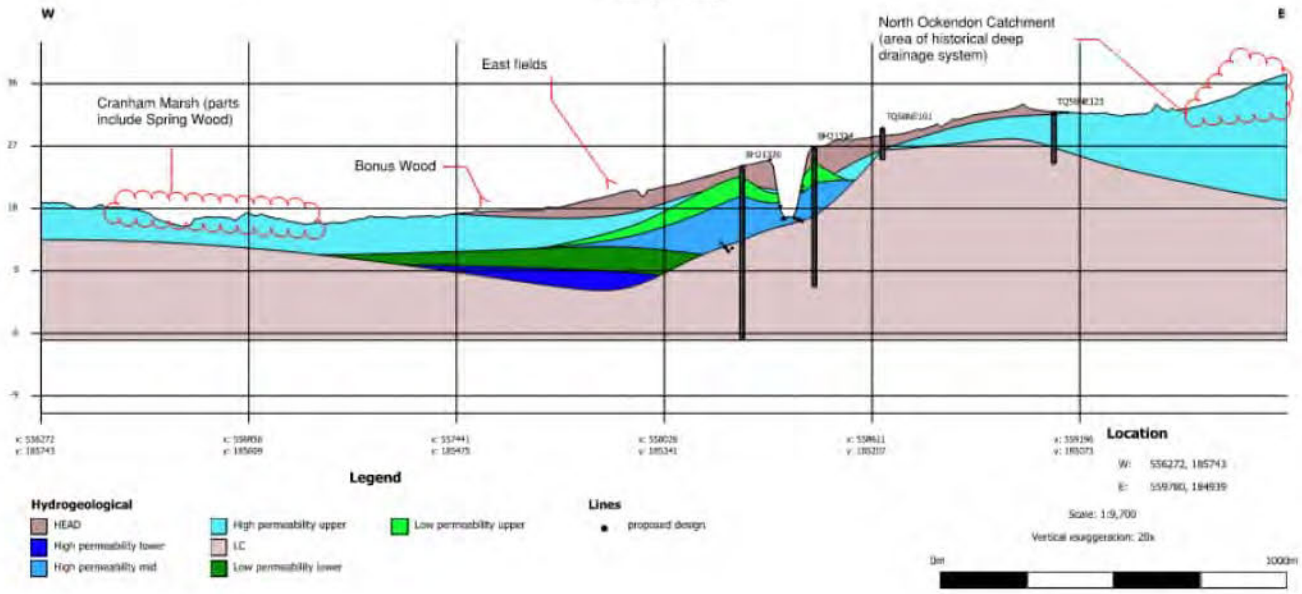

SS [-300]
W
E
South fields
Hall Farm Moat
Location
W: 556205, 185451
E: 559713, 184646
Scale: 1:9,700
Vertical exaggeration: 20x
0m
1000m
Legend
Hydrogeological
HEAD
High permeability lower
High permeability mid
High permeability upper
LC
Low permeability lower
Low permeability upper
Lines
proposed design

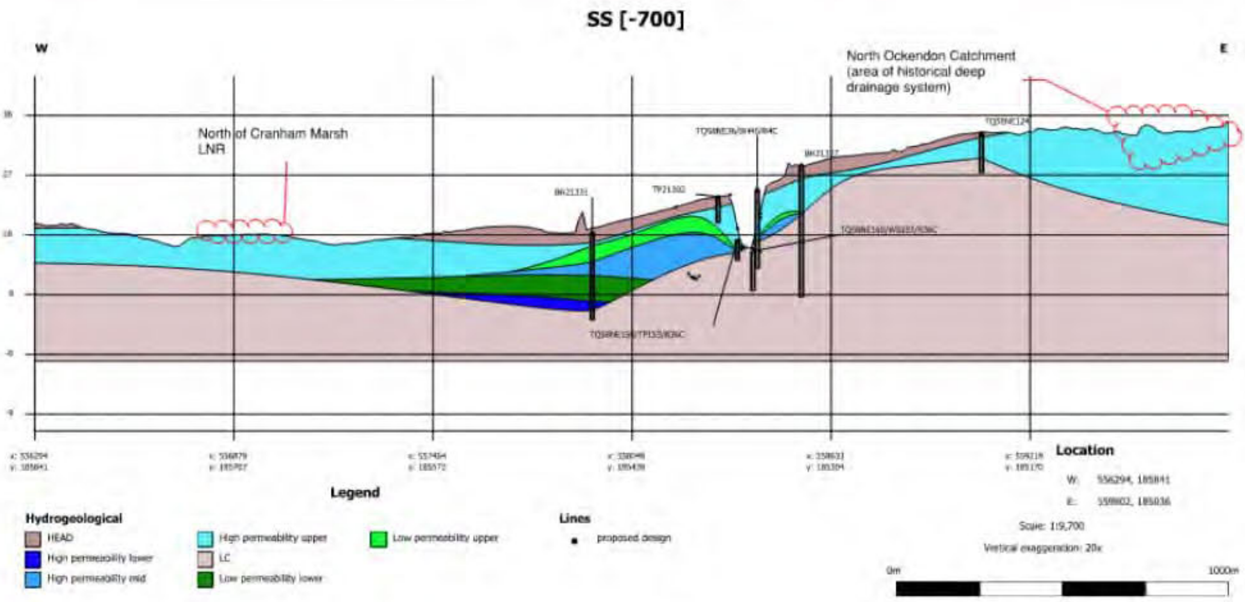

SS [-400]
W
E
Cranham Marsh
Location
W: 556227, 185548
E: 559735, 184744
Scale: 1:9,700
Vertical exaggeration: 20x
0m
1000m
Legend
Hydrogeological
HEAD
High permeability lower
High permeability mid
High permeability upper
LC
Low permeability lower
Low permeability upper
Lines
proposed design

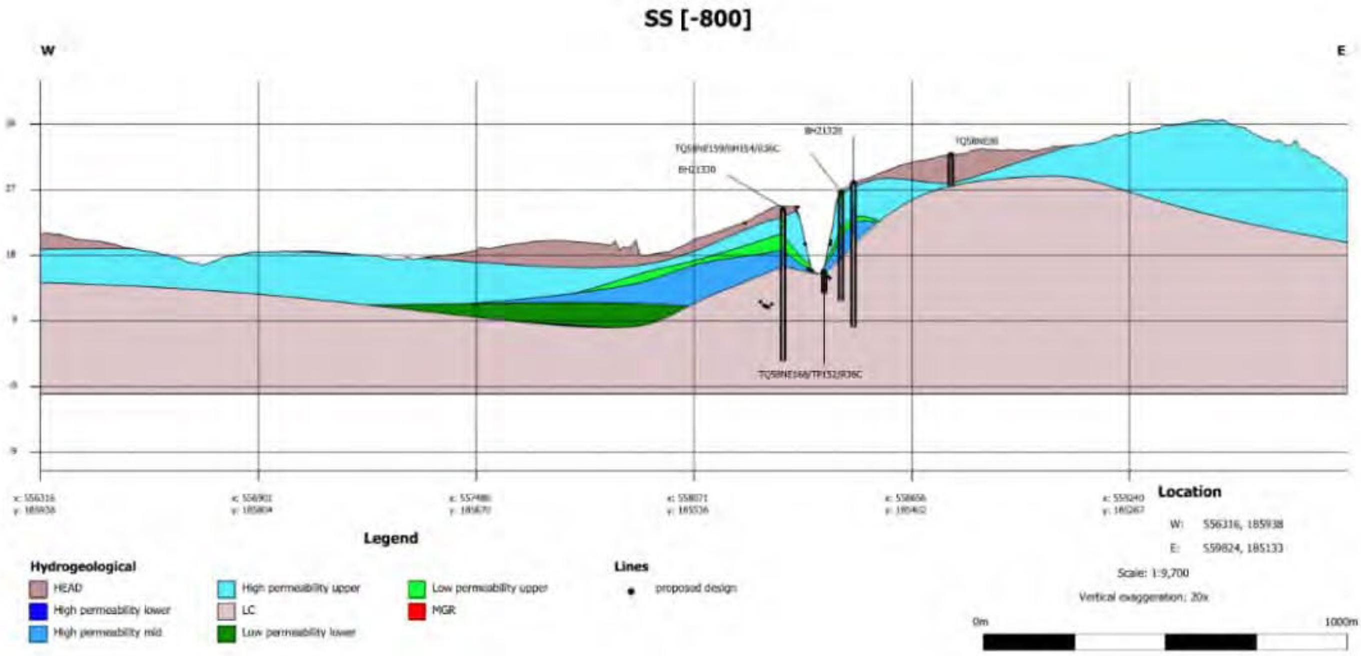
SS [-500]

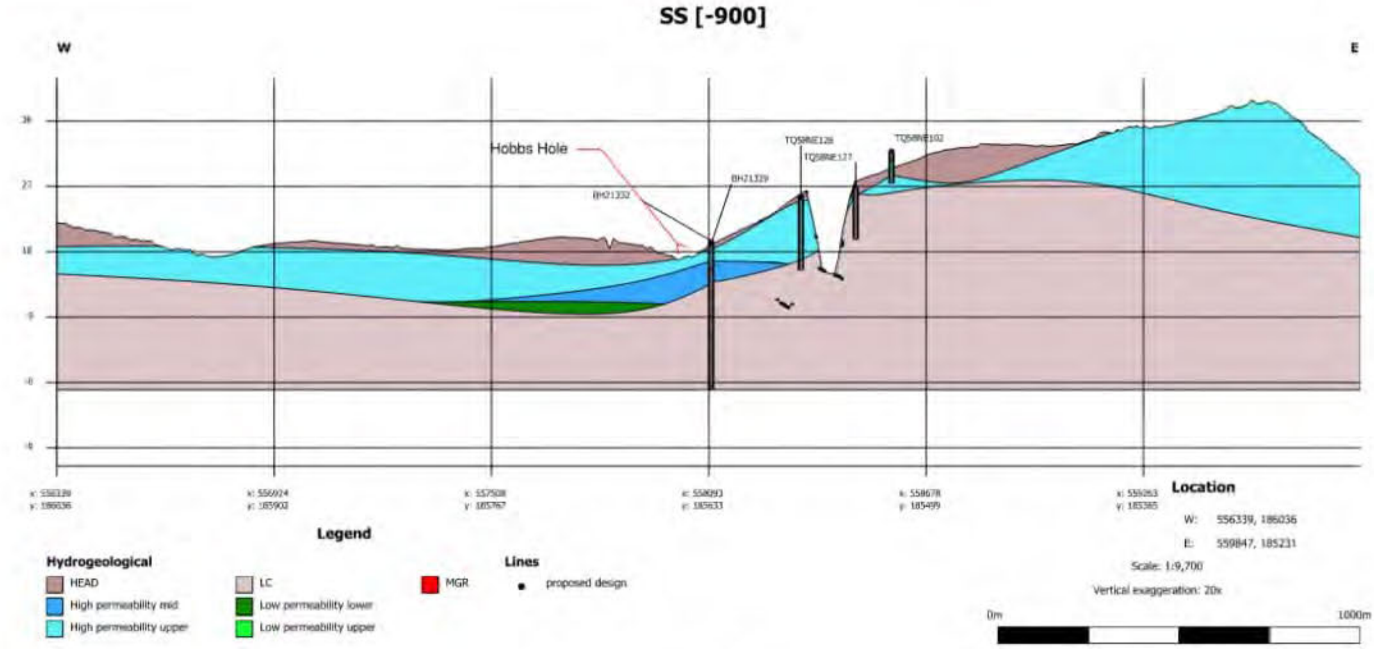

W
E
Cranham Marsh LNR (parts include Spring Wood and Middle Wood)
East Fields
Location
Legend
Hydrogeological
HEAD
High permeability lower
High permeability mid
High permeability upper
LC
Low permeability lower
Low permeability upper
Lines
proposed design
Scale: 1:9,700
Vertical exaggeration: 20x
0m
1000m

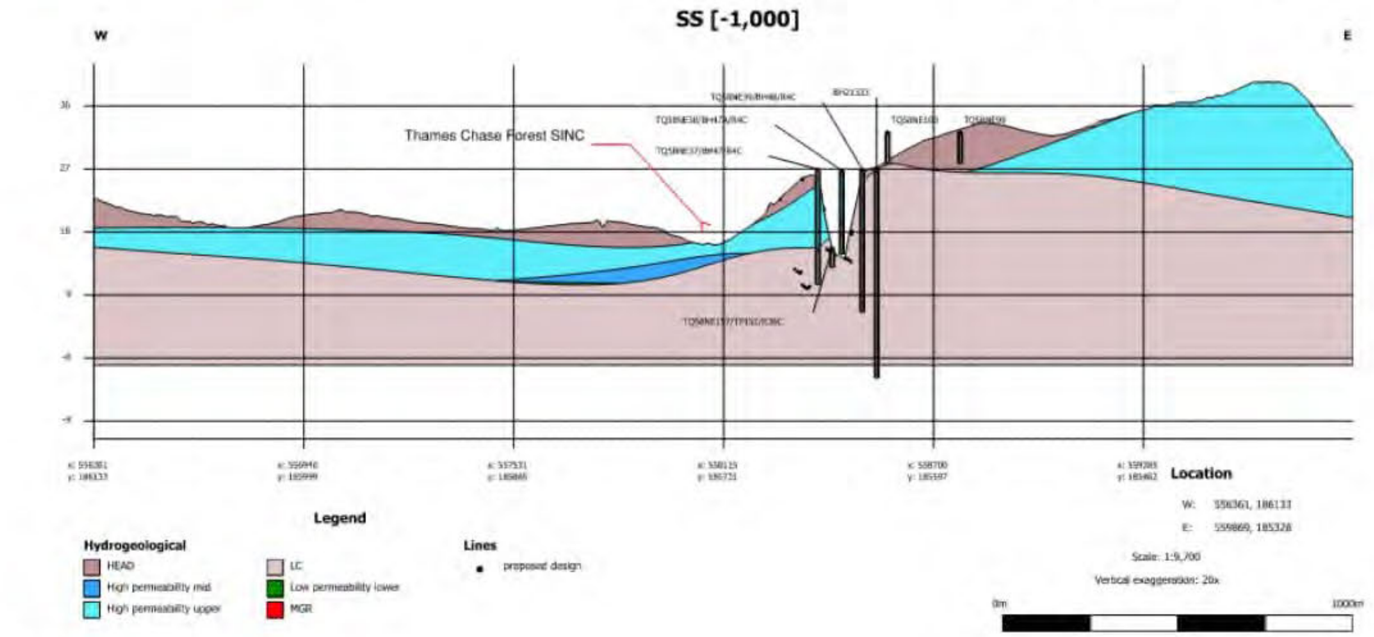
SS [-600]


W
E
Cranham Marsh (parts include Spring Wood)
Bonus Wood
East fields
North Ockendon Catchment (area of historical deep drainage system)
Location
Legend
Hydrogeological
HEAD
High permeability lower
High permeability mid
High permeability upper
LC
Low permeability lower
Low permeability upper
Lines
proposed design
Scale: 1:9,700
Vertical exaggeration: 20x
0m
1000m


SS [-700]
W
E
North Ockendon Catchment (area of historical deep drainage system)
North of Cranham Marsh LNR
Legend
Hydrogeological
HEAD
High permeability lower
High permeability mid
High permeability upper
LC
Low permeability lower
Low permeability upper
Lines
proposed design
Location
Scale: 1:9,700
Vertical exaggeration: 20x
0m
1000m


SS [-800]
W
E
Legend
Hydrogeological
HEAD
High permeability lower
High permeability mid
High permeability upper
LC
Low permeability lower
Low permeability upper
MGR
Lines
proposed design
Location
Scale: 1:9,700
Vertical exaggeration: 20x
0m
1000m





3.2.8 The numerical groundwater model is a CVFD formulation with a node-based, Voronoi mesh, designed with AlgoMesh (Merrick, 2016). The Voronoi elements within the unstructured grid allow for cell geometry that closely follows important geographical, geological, hydrological or man-made features. This enables a more accurate representation of the physical system being modelled, reducing one source of model errors and often mitigating convergence difficulties. In addition, model resolution is focused more heavily in areas of interest (i.e. the cuttings and the nature reserve) and reduced in other areas that are unlikely to significantly affect the model outputs (i.e. Mardyke floodplain). This has the effect of reducing errors due to discretisation (where resolution is increased), while at the same time allowing faster model run times by reducing resolution where it is not needed.

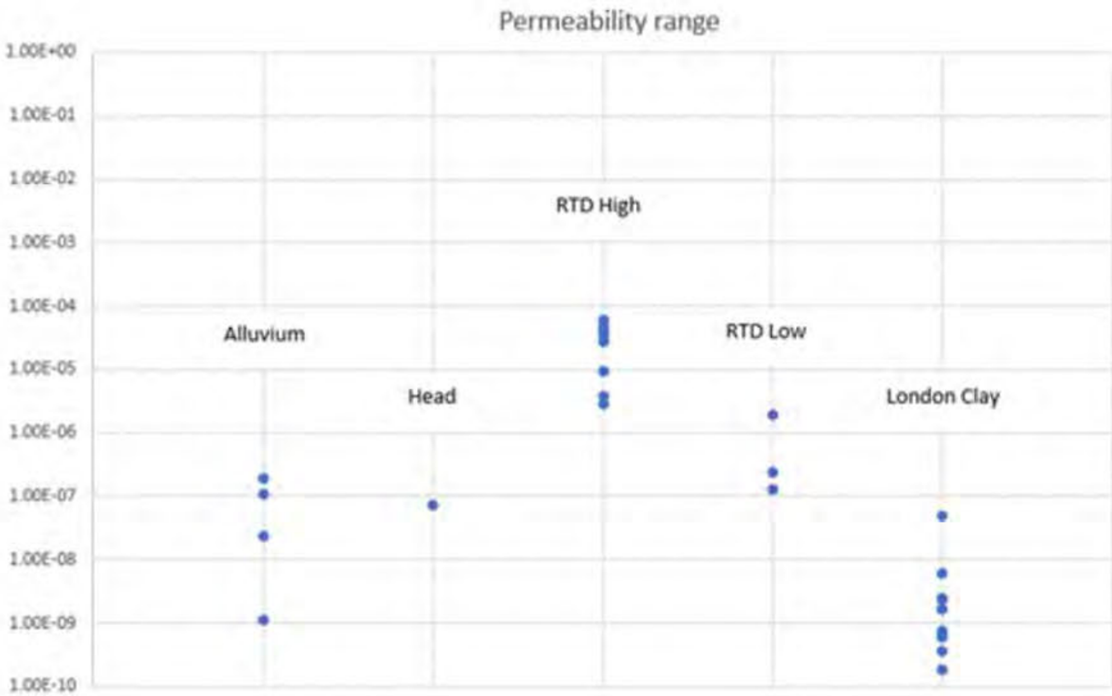
3.2.9 The model grid has seven layers with 11,192 nodes per layer (a total of 78,344 nodes/elements, covering an area of approximately 92,176,768m^2). Layer thickness varies between 1m and 6m. The layer setup allows for defining not only the hydrogeological units, but also built elements to the defined depths.

3.2.10 Element size varies significantly, from approximately 15m² in and around areas of interest to approximately 0.2km² in the flat parts of the mid-valley.

3.3 Model parameters

3.3.1 Hydraulic conductivity (K) ranges are taken from local test data as discussed under the heading 'Permeability' in Section 2.4 and additionally informed by various Project reports, previous modelling, and literature sources (Burke *et al.*, 2014; Cascade, 2018; 2019; 2019b; Perfect Circle, 2018). Material parameters can also be sourced from the Addendum PSSR (Tables 36–38, pages 130–132) (Cascade, 2018). While the Chalk aquifer has been the subject of much interest as a source of water, the information is poor on the various superficial gravel groups (key to this model). The RTD plays a significant role in assessing the impact of the proposed Project's northbound cutting, and hence the RTD's characteristics have a high level of sensitivity. The focus of the recent site tests has therefore been the RTDs, to complement BGS data (see Table 3.1). Plate 3.4 summarises the Project data on the ranges reported by *in situ* testing of hydraulic conductivity.

Plate 3.4 Permeability ranges based on site-specific Project data



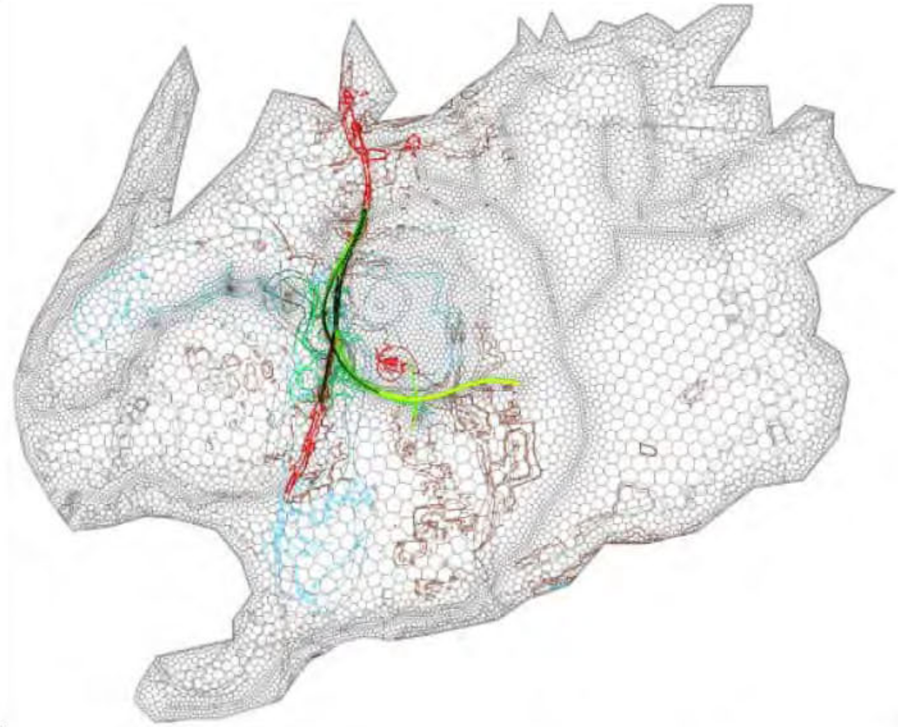
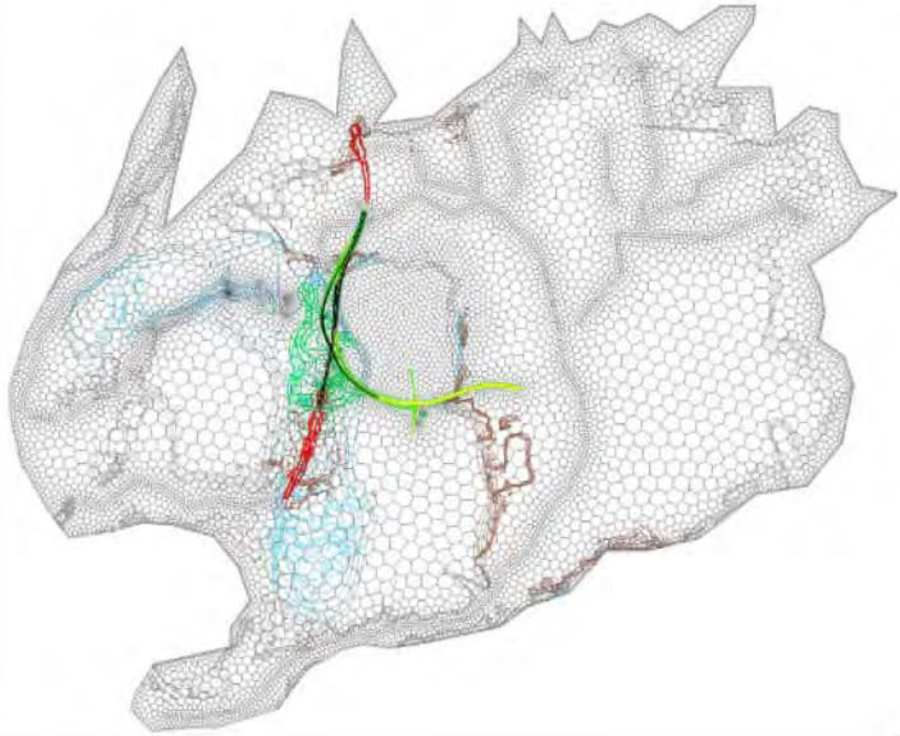
3.3.2 Table 3.1 displays information taken from BGS (Burke *et al.*, 2014) and has been used to cross-check a range of K values for the layers in the model.

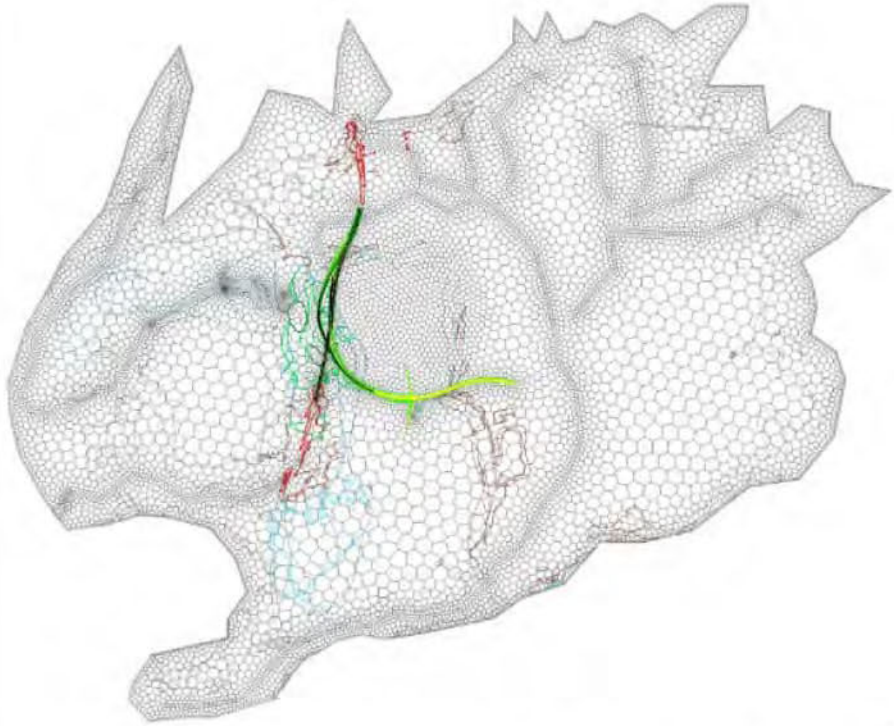
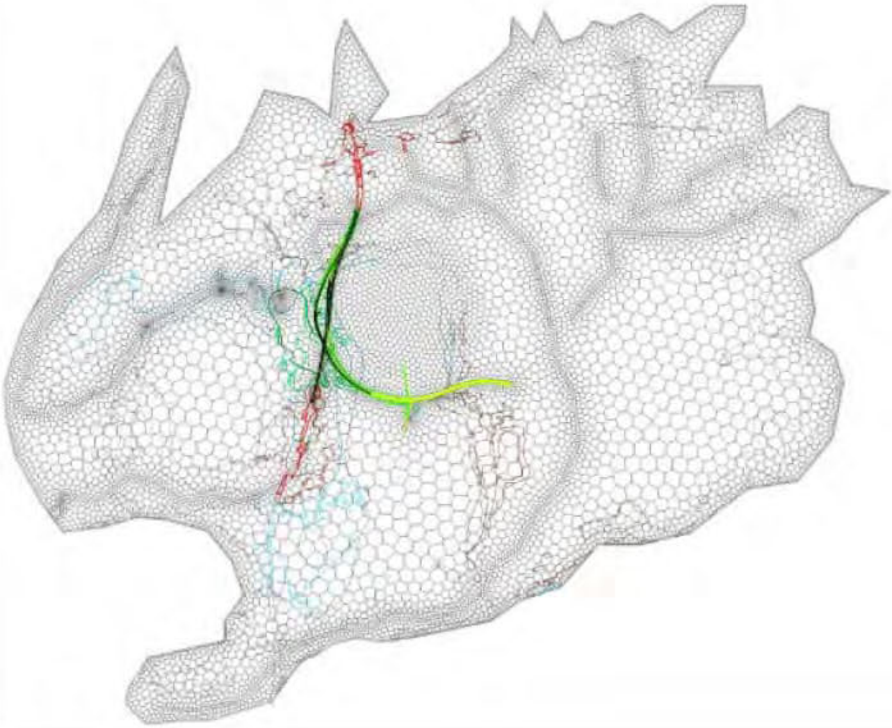
Table 3.1 Summary of BGS hydraulic conductivity data

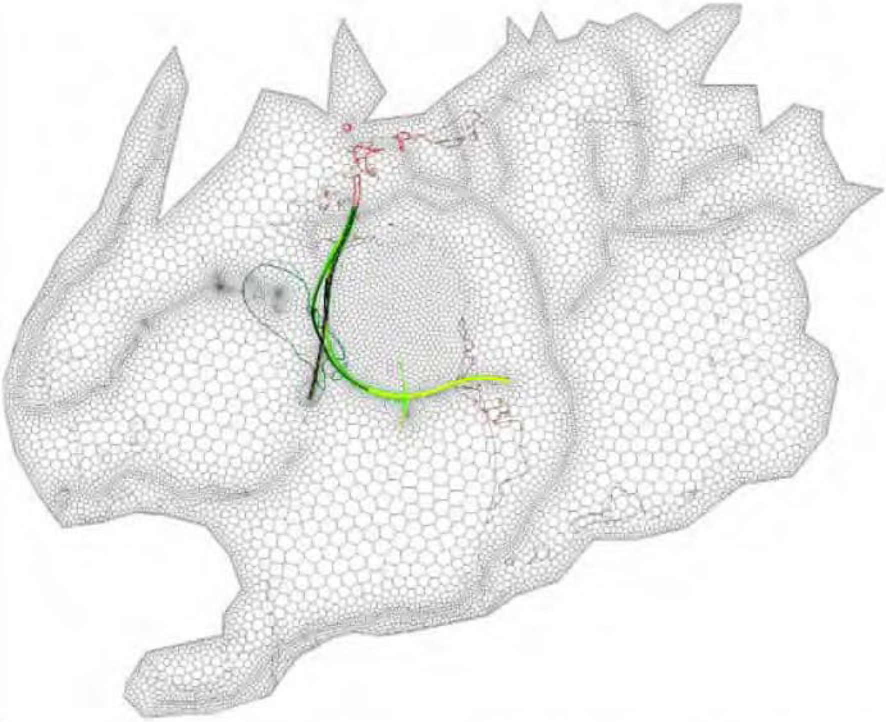
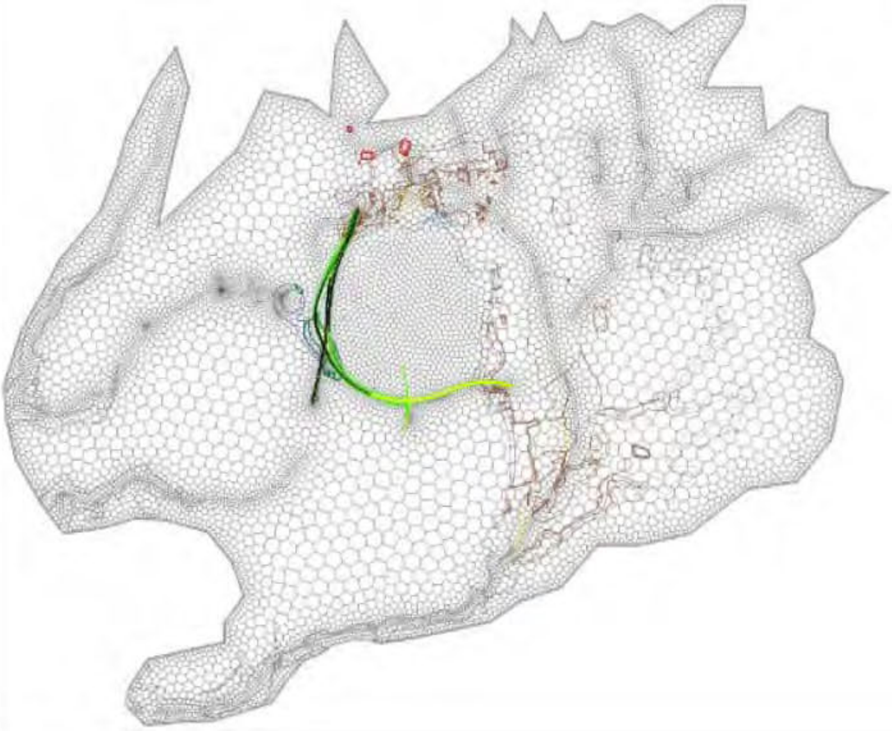
Geological unit	Permeability, maximum (m/s)	Hydrogeological behaviour and influences
Head Deposits	Variable, $1x10^{-8}$ to $1x10^{-6}$	Variable – depends on underlying geology
Alluvium	$k_h = 1x10^{-7}$ $k_v = 1x10^{-8}$	Aquitard or aquifer – depending on whether predominantly clay or granular material in the field but mapped as a single unit with an equivalent bulk permeability.
RTD	$2x10^{-5}$ to $1x10^{-3}$	Aquifer – depends on lateral extent and thickness
London Clay	Non-aquifer	This is a confining unit and has very limited potential to supply a water resource. On a broader scale, it may support underlying aquifers through slow leakage.

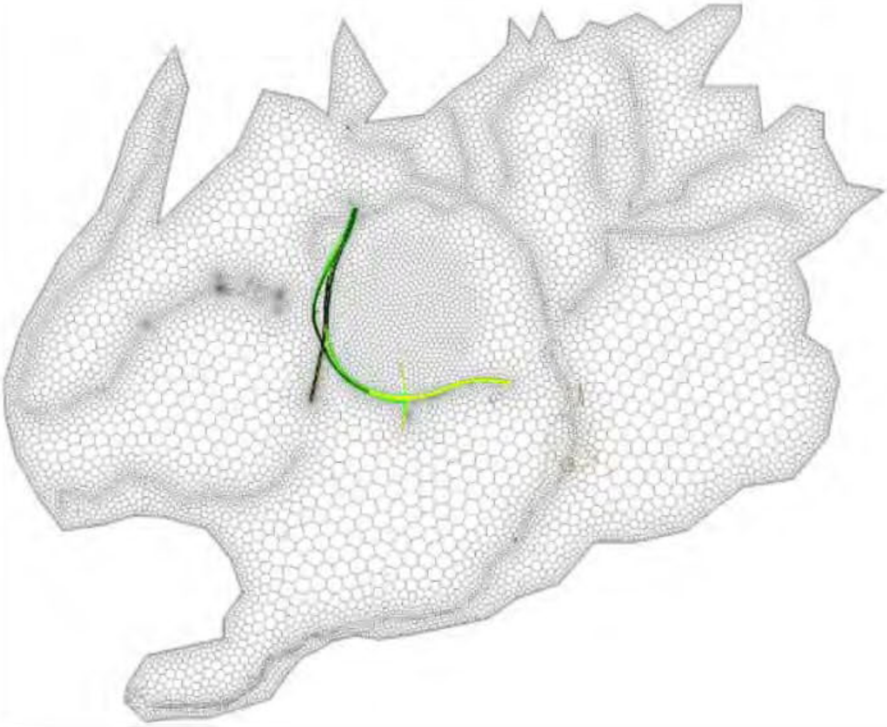
3.3.3 Zoning of the model is determined based on various geological families. This spatial discretisation is supported by a combination of site-specific data, BGS mapping, and well-understood literature on the local geology. Plate 3.5 illustrates zones in each layer, representing the thicknesses of each stratum. These zones have been used to determine the hydraulic characteristics assigned to the model, including hydraulic conductivity and recharge.

Plate 3.5 Model parameterisation and zoning

Layer	Zoning map
1	
2	

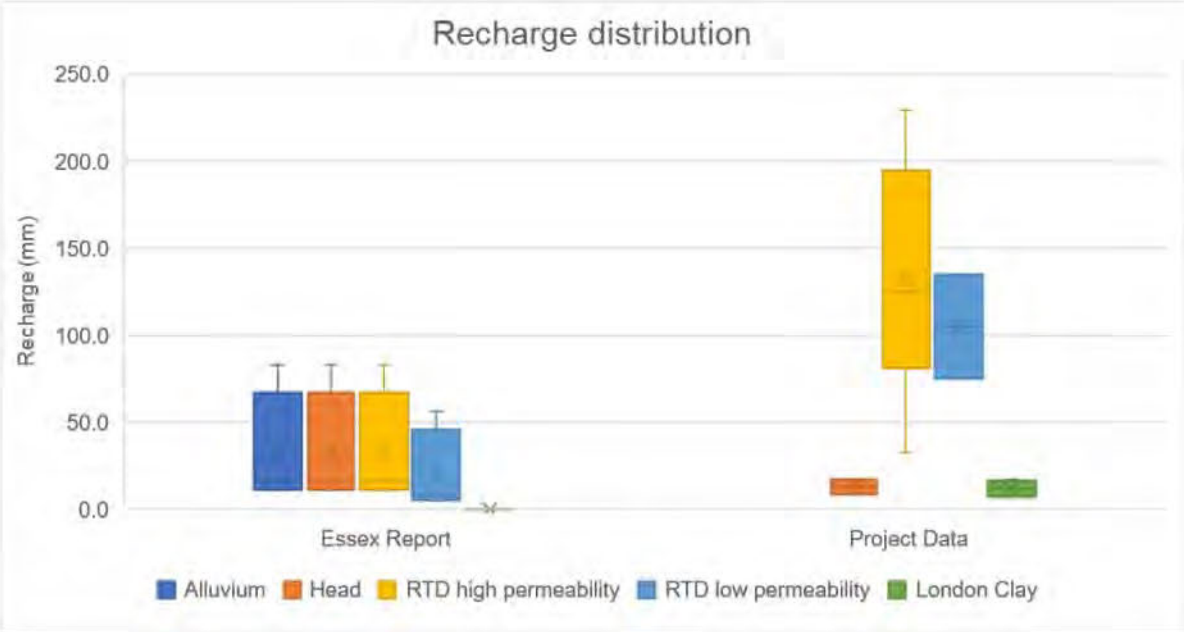
Layer	Zoning map
3	
4	

Layer	Zoning map
5	
6	

Layer	Zoning map
7	
	HEAD
	Alluvium
	Clay
	RTD (high permeability)
	RTD (low permeability)
	Made Ground

3.3.4 Recharge distribution values consulted for the model are shown in Plate 3.6.The median recharge values were used to parameterise the model before the calibration process.

Plate 3.6 Recharge distribution data



3.3.5 Project recharge data was calculated using the water table fluctuation method (United States Geological Survey, 2021):

$$R = S_y \Delta H$$

Where:

R = recharge (L/T)

Sy = specific yield (dimensionless)

H = peak water level rise attributed to the recharge period (L)

3.3.6 The water table fluctuation method is a simplification of a very complex phenomenon, movement of water to and from the water table. The aquifer must be unconfined, and the method is most applicable in areas with shallow water tables that display sharp rises and declines following rainfall events (United States Geological Survey, 2021). The superficial deposits overlying the RTDs near the Project/M25 junction cause semi-confined to confined conditions in parts, likely being the reason for widely ranging recharge values compared to the Essex model report (Environment Agency, 2016).

3.4 Boundary conditions

River (RIV)

3.4.1 Rivers are defined as head-dependent, mixed-type, flux boundaries in MODFLOW, in which a boundary head and conductance are specified as a minimum. Rivers are special forms of the head-dependent boundary condition. In a head-dependent boundary, the model computes the difference in head between the boundary and the model cell where the boundary is defined. The head difference is then multiplied by a conductance term to get the amount of water flowing into or out of the aquifer. In a river boundary, MODFLOW performs an additional check before computing flow rates. If the head in the model cell is below the bottom elevation of the river boundary, the difference in head is computed as the river stage (head) minus the river bottom elevation. This causes flow rates to reach a maximum value when an unsaturated zone exists beneath the river. Note that river stage on the river boundary condition dialogue is the elevation of the water surface in the river. The flux into or out of the cell is then computed as follows:

$$Q = C(H_b - H_m)$$

Where:

Q = flux into or out of boundary cell (L3/T)

H_b = boundary head (L)

H_m = head computed by model (L)

C = boundary conductance (L2/T)

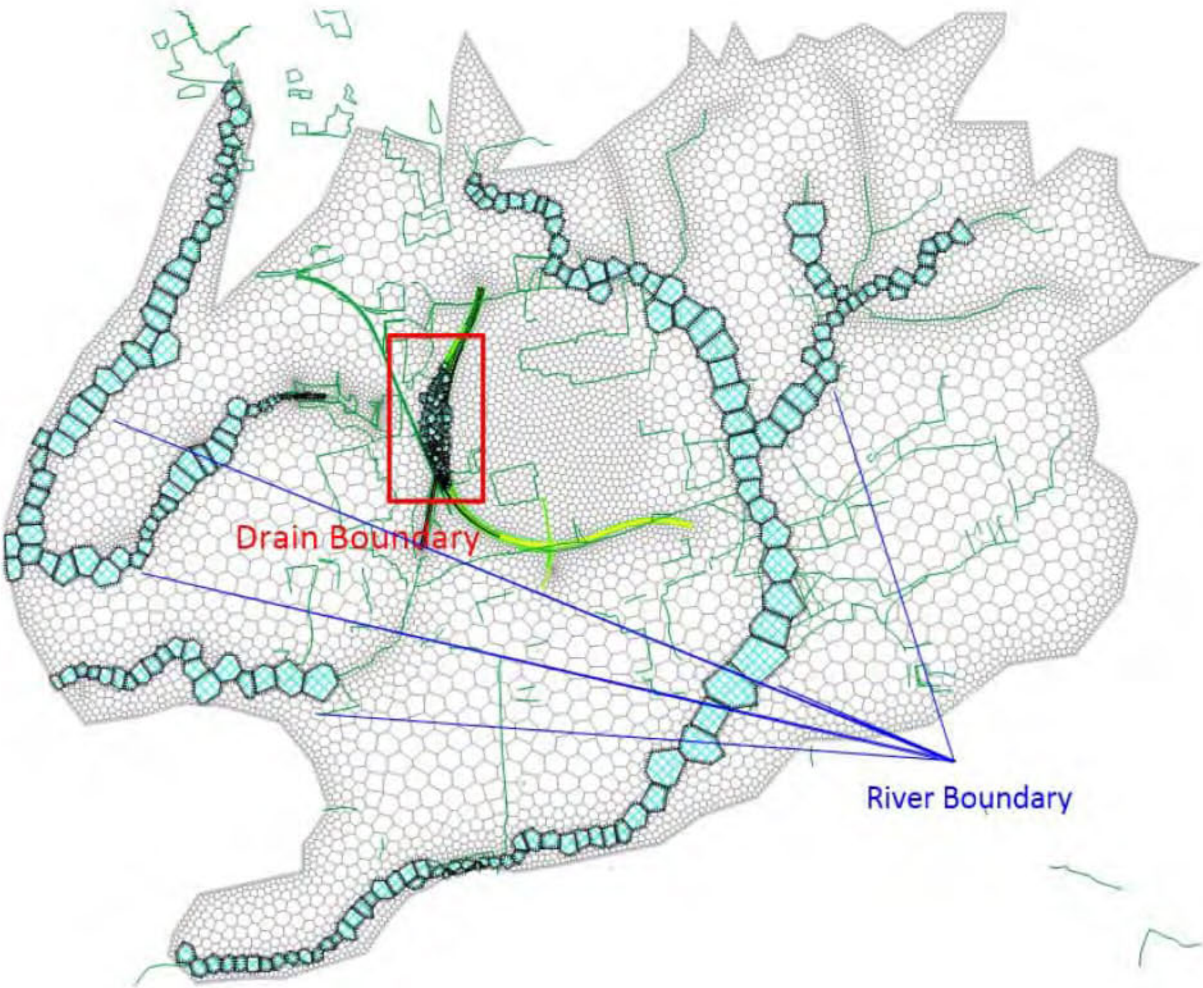
3.4.2 Conductance for rivers is computed as the river width times river length times hydraulic conductivity divided by riverbed thickness. Length and width are measured only within the cell containing the river boundary condition (Rumbaugh and Rumbaugh, 2017).

3.4.3 This boundary condition is used in the model to define significant watercourses to the west of the model domain (River Ingrebourne) and the Mardyke to the east. Some smaller tributaries are also included which are not permanent rivers but allow for ponding above ground level. These watercourses are supported in the alluvial deposits. Plate 3.7 illustrates these boundaries in the model (in blue).

Drains (DRN)

3.4.4 Drains are similar to rivers except that drains will only remove water from the aquifer. If the head in the model cell drops below the drain elevation, the drain will not inject water into the model. Under these conditions, the drain becomes inactive. Note that stage of drain on the drain dialog is the elevation of the water surface or the elevation where water enters the drain, depending on the conceptual model being used. Conductance for drains is computed as the drain width times drain length times hydraulic conductivity divided by drain bed thickness. Length and width are measured only within the cell containing the drain boundary condition (Rumbaough & Rumbaough, 2017). The drain cells are defined based on the elevation of the drain head, presented in the general construction report (Cascade, 2019c). In this model, drain boundary is used to simulate road cuttings (Zaidel *et al.*, 2010). In this model the Drain package is used over six stress periods (total of 2,210 days) to show progressive construction of the cutting, working from south to north (Plate 3.7).

Plate 3.7 Boundary conditions set up



3.5 MODFLOW

Layer set-up

3.5.1 Layer 1 (the uppermost layer) is set as unconfined (Type 1), and so the transmissivity of the layer is calculated based on the saturated thickness and hydraulic conductivity. All remaining layers are Type 3 (fully convertible) and can switch between unconfined and confined conditions. The transmissivity of these layers also varies and is calculated from the layer thickness and hydraulic conductivity.

3.5.2 River, Drain, Recharge, Evapotranspiration (ET), and output control packages were used in the setup of the model run. Preconditioned Conjugate Gradient package 2 (PCG2) was used to solve the model. The edges of the model and the model base are numerically treated as No Flow Boundary.

Initial head

3.5.3 Initial head was set up to the top of layer 1 for the start of the steady state model. The head matrix file of the steady state model was then calibrated using monitoring data and used as the initial head for the subsequent transient run.

3.5.4 Ghost nodes were also used to improve accuracy of the solution.

Ponding

3.5.5 Ponding was allowed in the location of river boundary up to 0.5m to enable watercourse functionality if needed.

Upstream weighting

3.5.6 Upstream weighting was turned on for all convertible layers, keeping cells from desaturating.

4 Model runs

4.1 Steady state

4.1.1 A steady-state model was set up to simulate the baseline (preconstruction) scenario. This model was set up as described in Section 3.5. Initial parameters were taken from literature and guided by site information. Initial head was set to the top of layer 1. In all cases of uncertainty, conservative assumptions have been made and applied to the model.

4.1.2 Calibration of the steady-state model was aided by 17 head targets shown in Plate 4.1. PEST (Doherty, 2015) was used to calibrate against the head targets listed in Table 4.1.

Plate 4.1 Head calibration targets

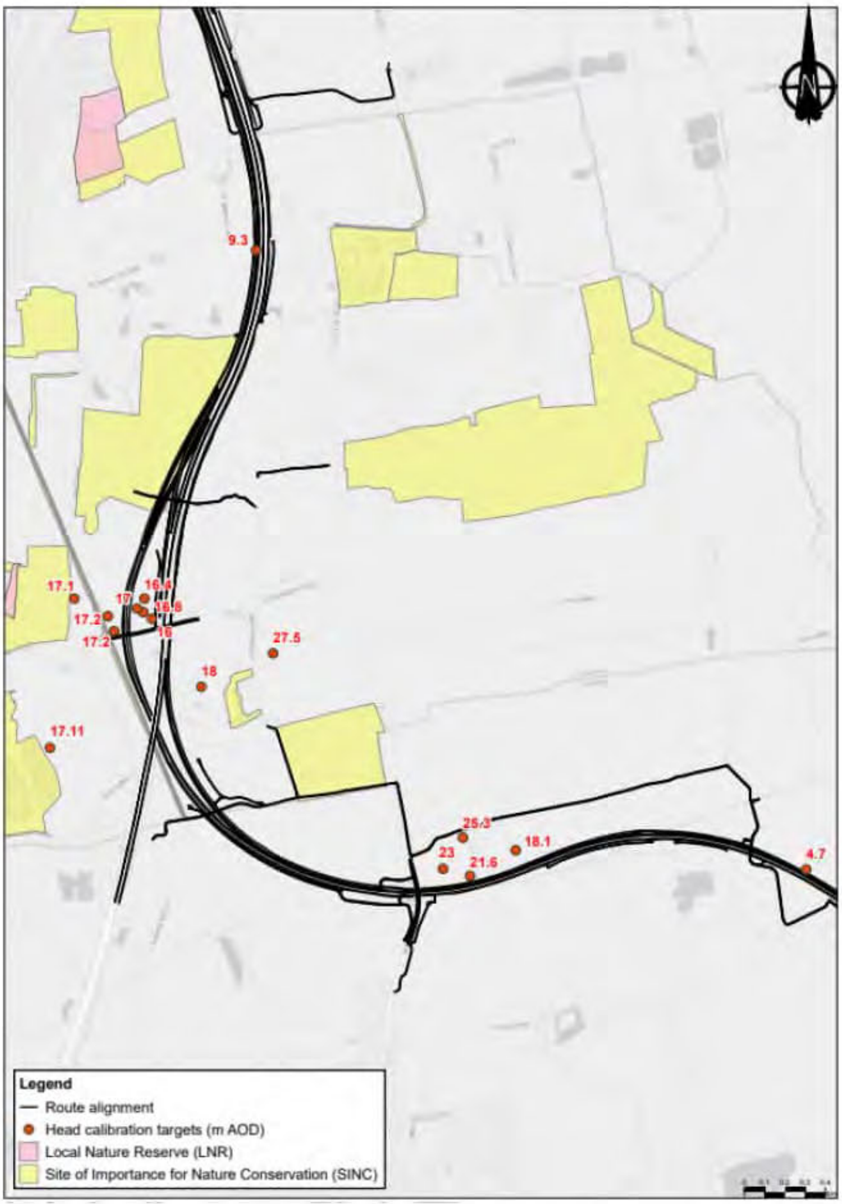


Table 4.1 Head target values (average groundwater level (GWL) from long-term monitoring data)

ID	Easting	Northing	m AOD
BH17312	561535.9	183908.4	4.65
BH19309	560103.1	184003.8	18.09
BH21347	558822.3	186965.4	9.25
BH21378	558552	184810.6	18.03
OH19002	559842	184066.1	25.30
OH19003	559877.7	183876.8	21.63
BH19304	559744.2	183912.5	22.96
BH21309	557805.7	184509.6	17.11
BH21322	558308.3	185146.4	16.00
BH21325	557925.6	185245.9	17.10
BH21345A	558905.6	184976	27.45
OH20001	558271.2	185246.1	16.37
OH20002	558265.6	185178.9	16.77
OH20003	558234.8	185196.9	17.03
OH20004	558121.3	185085.2	17.21
OH20005	558091.2	185159	17.15
BH17312	561535.9	183908.4	4.65

4.1.3 The Standardised Root Mean Squared Error (SRMSE) is the Root Mean Squared Error (RMSE) divided by the range of measured heads and expressed as a percentage. Weights are sometimes introduced to account for different levels of confidence in different measurements. Best modelling practice advises, were possible, to aim for SRMS less than 10% as an indicator of the goodness of fit. This model was calibrated against targets in both RTD and London Clay as depicted above, to achieve an SRMS of 0.04 (4%) overall.

4.1.4 Parameters were updated and the model was re-run for the steady-state conditions. Plate 4.2 illustrates the groundwater contours of this run with calibrated parameters. Note while the cutting outline is shown to depict the location of interest, no disturbance from the Project is yet simulated in this steady-state run.

4.1.5 Calibrated parameters are shown in Table 4.2 and form the basis of the updated model. Note the calibrated hydraulic conductivity values are a good fit to the local ranges shown in Plate 3.4, and calibrated recharge values are closer to the Essex report (Environment Agency, 2016) values than calculated values based on long-term monitoring (Plate 3.6). This is due to the limitations of the method used to back analyse groundwater level changes since confining conditions are present in many locations across the site and many small springs and waterways may receive baseflow with limited time spent flowing through soil before discharge.

4.1.6 The existing M25 has been historically acting as a drain given its relatively low position compared to the RTD hills to its sides. The recently added long-term monitoring data confirms this, as groundwater levels around the proposed cutting location correlate to the existing road level. It is important to note that the difference between the base level of the underpass and the current groundwater rest level is less than 2m.

4.1.7 The Ingrebourne and Mardyke Rivers are also fed by baseflow as signified by groundwater contours, supported in the shallow Alluvium deposits of the rivers themselves as well as their less significant tributaries' flood plains.

Plate 4.2 Steady-state groundwater contours

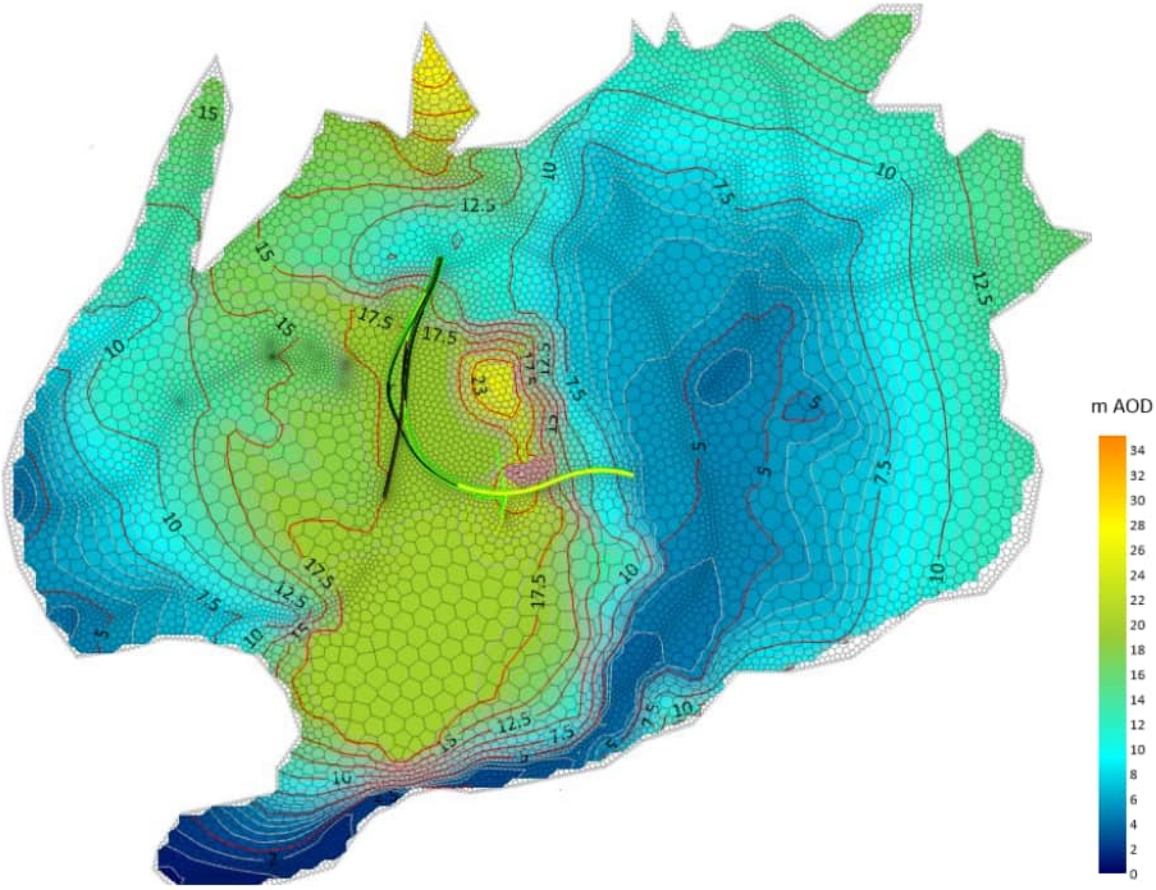


Table 4.2 Calibrated parameters

Zone	Type	$K_{x,y}$	$K_{x,y}$	RCH*	RCH*
	Unit	(m/d)	(m/s)	(m/d)	(mm/year)
1	London Clay	1.65×10^{-4}	1.91×10^{-9}	1.01×10^{-8}	0.004
2	Made Ground	0.008	9.26×10^{-8}	9.75×10^{-9}	0.004
3	HEAD	6.39×10^{-3}	7.40×10^{-8}	1.12×10^{-5}	4.1
4	RTD-High permeability	2.07	2.40×10^{-5}	2.93×10^{-4}	106.9
5	Alluvium	3.03×10^{-3}	3.51×10^{-8}	9.87×10^{-6}	3.6
6	RTD-Low permeability	2.60×10^{-2}	3.01×10^{-7}	3.60×10^{-5}	13.1
7	Retaining walls**	8.64×10^{-5}	1.00×10^{-9}	0	0.0

* Recharge is applied to the top layer only
** Retaining structures are only introduced to the transient model and have been assigned no recharge and zero vertical permeability. Permeability assigned to Zone 7 is based on engineering judgement and is founded on expected installation/material performance.

4.2 Transient

4.2.1 The transient model is set up to simulate the following effects:

a. The impact of construction with a conservative assumption of seven-month duration, and groundwater control at 1m below final excavation level.

b. The impact of development, post completion with an assumed drainage system at 0.5m below base level.

c. The potential benefits of limiting seepage inflow by mitigation measures during and after the construction phase.

4.2.2 The simulation benefits from six stress periods (SPs), first of which is the calibrated steady state (common practice) to allow for accurate initial heads at the start of the transient simulation. The makeup of the time discretisation aims to simulate the construction phases, in four stages, advancing from south to north. SPs 2 to 5 mimic four stages of excavation activities starting from the southern part of the underpass, working northwards, where the deepest cutting is designed. SP6 simulates the operational phase, also set up as steady state.

Table 4.3 Transient run time set up

Stress period	Type	Length (days)	No. time steps
SP*1	SS**	1000	1
SP 2	TR***	30	10
SP 3	TR	30	10
SP 4	TR	60	20
SP 5	TR	90	30

Stress period	Type	Length (days)	No. time steps
SP 6	SS	1000	6

* Stress Period (SP)

**SS (steady state)

***TR (transient)

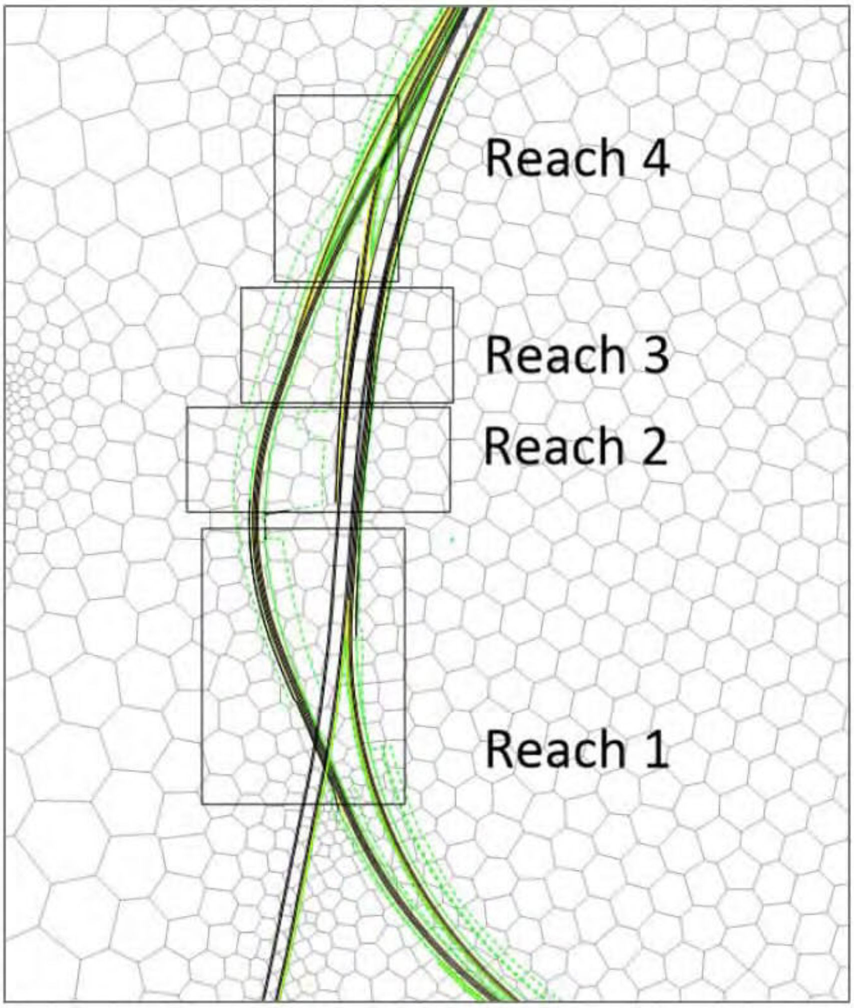
4.2.3 Drain cells are used to simulate the cuttings at various depths and phases.

4.2.4 Drain stage is set to 1m below the base of the cut slope during construction and reduced to 0.5 below the formation level post-construction.

4.2.5 Drain cells are turned off in SP1 and back on during transient periods. The locations of these boundary cells are shown in Plate 4.3.

4.2.6 Diaphragm walls and sheet piles (or similar retaining structures) would be used in parts of the structure to provide slope support. These structures are simulated as low permeability zones and are extended to the deeper layers to replicate the information in hand as marked in Appendix A.

Plate 4.3 Drain set up



4.2.7 Three distinct scenarios are simulated based on this set up:

a. To simulate worst-case impact, each drain reach is progressively left open/active from the time of commencement to the end of the simulation with no specific measures added to limit the seepage inflow.

b. To simulate the best-case impact, drains are effectively turned off during the final stress period (set up as steady state) to mimic a well-isolated cutting.

c. To simulate a more likely impact, a partially mitigated scenario is presented where retaining walls are installed during construction and the conductance of the drain reaches are set to 50% of Scenario B.

4.2.8 Generally, the work stages are simulated by having drain reaches on and off at various times. Table 4.4 summarises how the boundary condition was set up to achieve this.

Table 4.4 Transient drain reaches set up

Stress period* / Scenario	SP1	SP2	SP3	SP4	SP5	SP6
A (no mitigation)	NA	R1*	R1,2	R1,2,3	R1,2,3,4	R1,2,3,4
B (full mitigation)	NA	R1	R1,2	R1,2,3	R1,2,3,4	Off
C***(partial mitigation)	NA	R1	R1,2	R1,2,3	R1,2,3,4	R1,2,3,4

* Stress Period (SP)

**Reach, depicted as R

***In Scenario C, drain conductance is 50% of that in Scenario A.

4.2.9 The three cases display various levels and extents of impact. The dependable accuracy of model data is assessed around 0.3m in accord with the relative accuracy of the geological model at the area of interest, but contours are provided down to 0.1m for the purpose of visual enhancement. Plate 4.4, Plate 4.5, and Plate 4.6 show the drawdown contours of each scenario, respectively.

4.2.10 As anticipated, Scenario A, with no mitigation and free-seeping cutting faces, imposes the largest impact zone as well as the biggest drawdown to a maximum of 1.4m inside the cutting (deepest part of the underpass design).

4.2.11 The contours of drawdown shown in dark and light blue, and quantified by negative integer labels in Scenario B, signify a rise in groundwater table. This is due to the impact of full mitigation where the cutting is effectively tanked from the surroundings and induces damming effect on both sides of the underpass. In this case, the cutting is in the low point between two RTD hills, and the pre-construction flow would have also been towards the M25. This damming effect can result in up to 1m of additional water pressure on retaining walls, or lining. Note these levels are well below ground level. The effect remains very local and does not extend far from the cutting itself. This is due to the relatively small gradient of groundwater at this location and the limited physical extent of the barrier, as water will be flowing to the sides (north and south) driven by the locally increased head.

4.2.12 Scenario C offers an assumed mitigation case where the inflow is controlled to half the amount in Scenario A. It is evident that the zone of impact is significantly reduced while the magnitude remains similar to Scenario A, with approximately 1.4m in the north of the cutting (inside) and just under 1m in the southern part of the cutting.

Plate 4.4 Scenario A; no mitigation

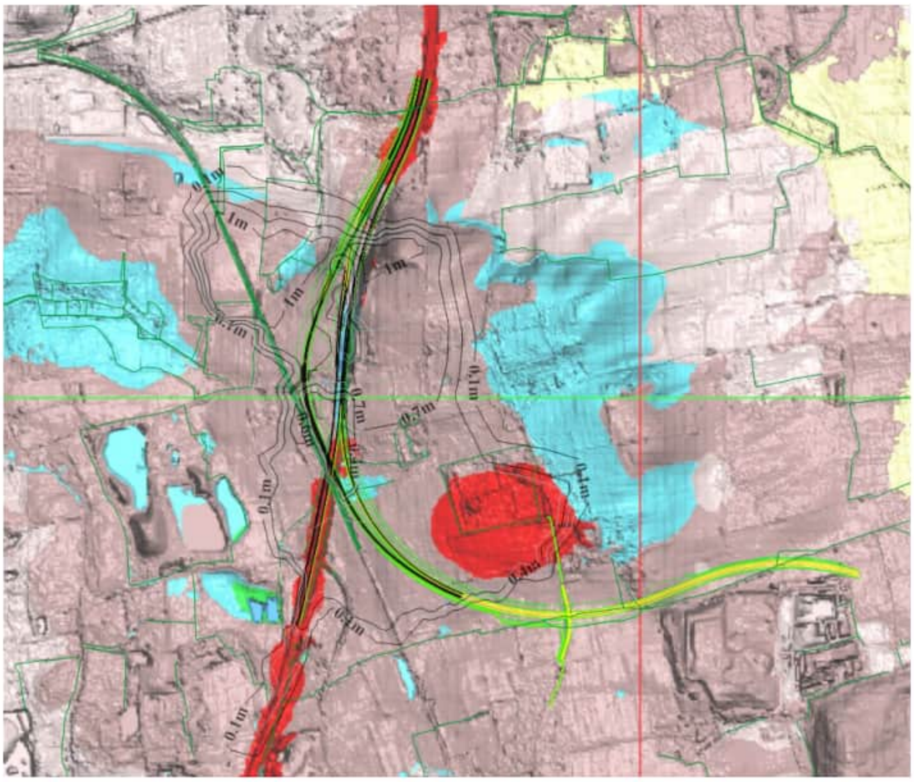


Plate 4.5 Scenario B; full mitigation

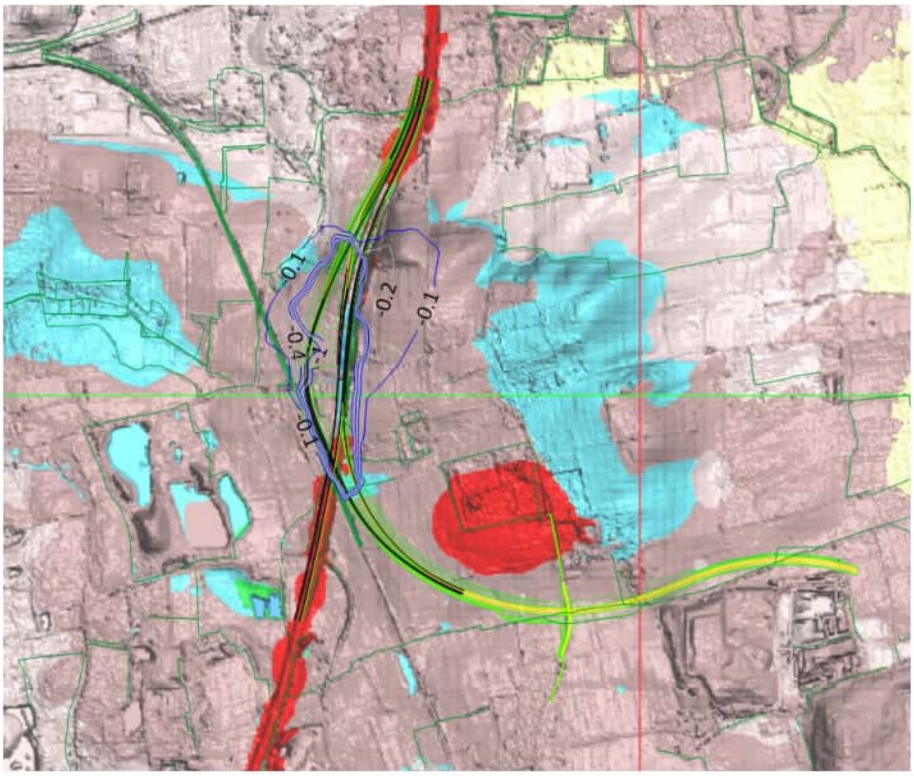
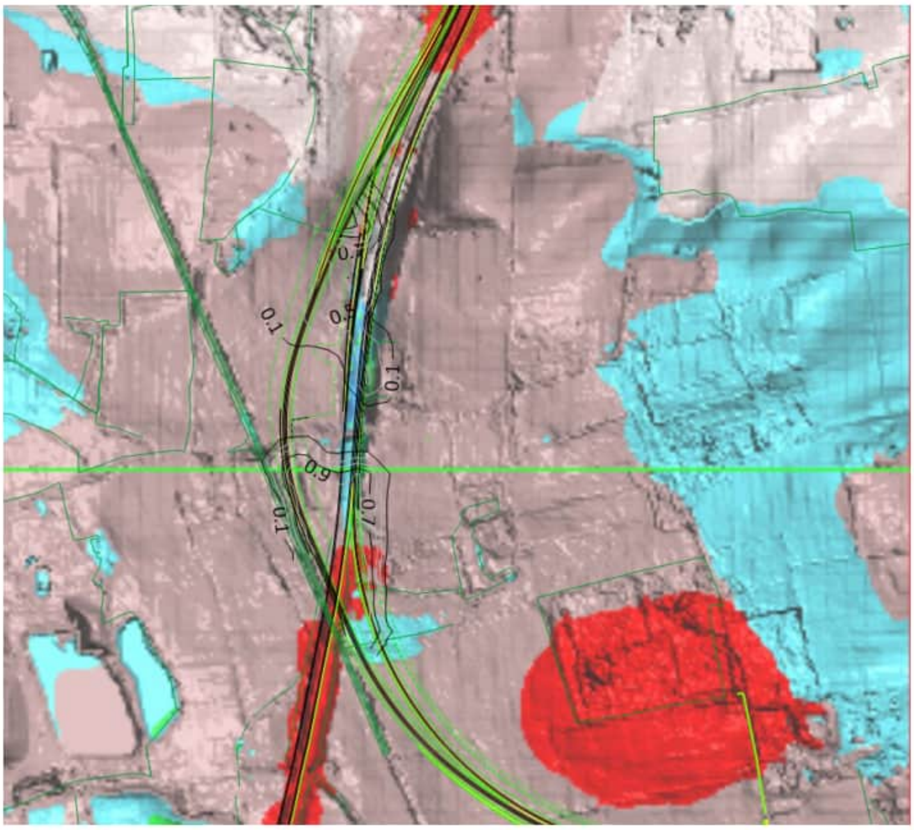


Plate 4.6 Scenario C; partial mitigation



4.2.13 It is essential to emphasise that any measure taken by the Contractors to limit the seepage inflow into the cutting during the construction would positively reduce the impact on the groundwater table in the surrounding area. Design changes to limit the hydraulic communication between the drainage envelope below the underpass and the natural system would also reduce the impact. However, there are many methods of seepage control, and as such, the selection of the mitigation measure is left to the discretion of the Contractors. The purpose of this numerical analysis is not to establish, in detail, the exact methods of mitigation, but merely to offer some insight into the sensitivity of the system to flow reducing measures. This report demonstrates that seepage control measures can prove very effective in reducing the magnitude and extent of the adverse impact on the groundwater table.

4.2.14 Seven virtual monitoring wells (shown as red triangles in Plate 4.7) were placed in the model to allow a closer study of the groundwater table changes at the locations of interest:

d. Cranham Marsh LNR (positioned in the Middle Wood area of the LNR),

e. Hall Farm moat (at the location of St Cedd’s Well which is within part of Hall Farm moat, paddock and St Mary Magdalene Churchyard, North Ockendon SINC),

f. south fields (an area within the Fields south of Cranham Marsh SINC, which at the virtual monitoring well is south of Cranham Marsh LNR),

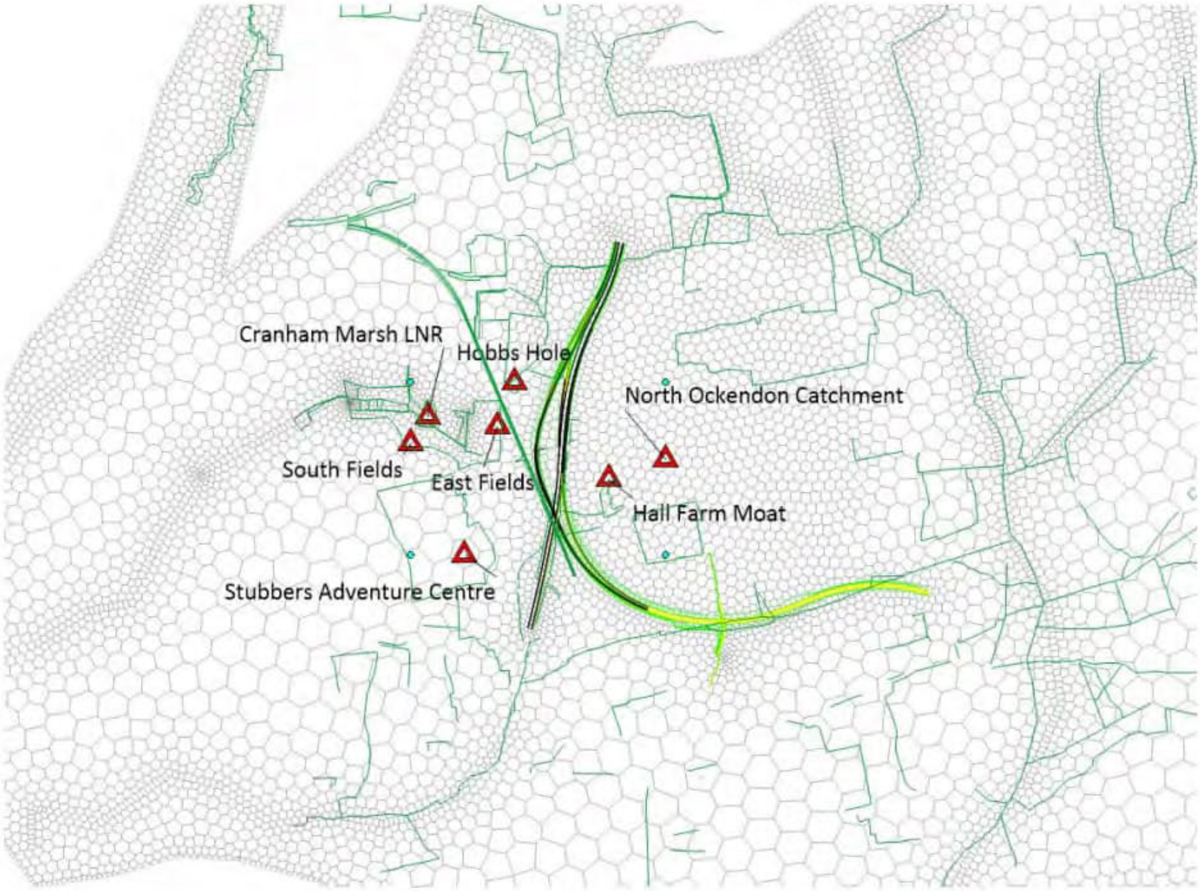
g. east fields (an area within the Fields south of Cranham Marsh SINC, which at the virtual monitoring well is east of Cranham Marsh LNR),

h. Hobbs Hole (Hobbs Hole is part of the Thames Chase Forest Centre SINC),

i. Stubbers Adventure Centre, and the

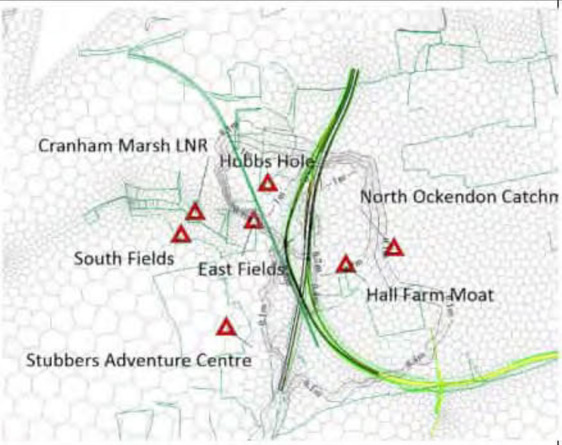
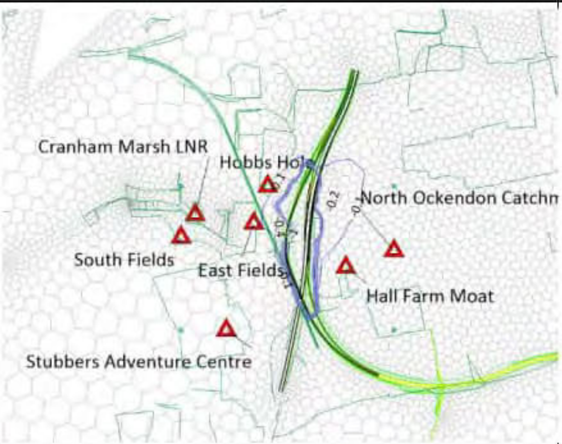
j. North Ockendon catchment area where groundwater feeds into deep land drains/gravity-fed ditches, assisting with irrigation of the land.

Plate 4.7 Location of the virtual observation wells



4.2.15 With respect to these locations of interest, each scenario is examined by determining whether or not these points are within the impact zone. If positive, then the impact is examined for those locations. Table 4.5 provides a visual key to the impact zone in each scenario in relation to the seven selected locations of interest. As evident, Scenario A is the only case in which two of seven locations are within the impact zone, with a third location merely skirting the impact zone.

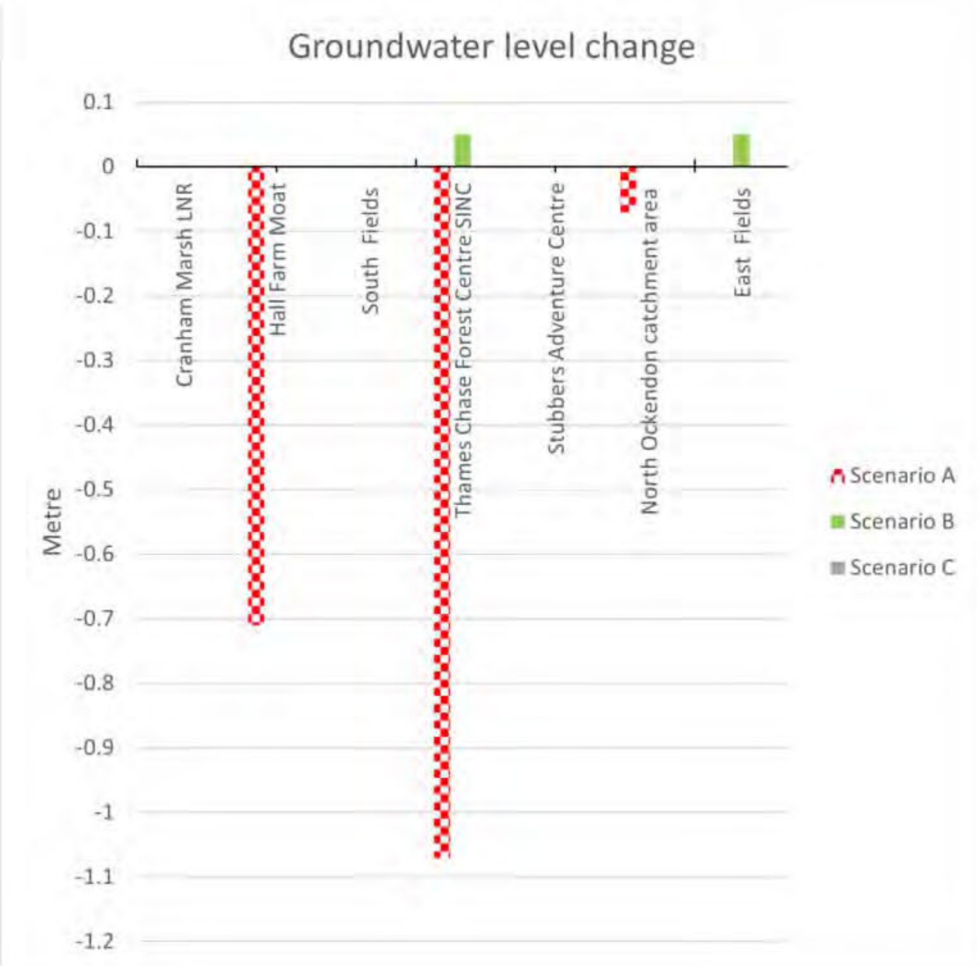
Table 4.5 Drawdown assessment

Impacted Scenario	Potential impact zone	Modelled potential impact at virtual observation well						
		Cranham Marsh LNR	South Fields	East Fields	Hobbs Hole	Stubbers Adventure Centre	Hall Farm Moat	North Ockendon catchment
A (no mitigation)		N	N	N	1.1	N	0.7	0.07
B (full mitigation)		N	N	N	N	N	N	N
C (partial mitigation)		N	N	N	N	N	N	N

Notes: N = no modelled drawdown shown at virtual observation well

4.2.16 To show the magnitude of impact on the locations of interest, data from the three scenarios are plotted in Plate 4.8. Scenario A, shown in red, shows drawdown in groundwater level at three locations. The largest impact is on Thames Chase Forest at 1.1m of drawdown, followed by 0.71m at Hall Farm Moat, and a very small 0.07m impact near the indicative location of the North Ockendon catchment. Scenario B leaves most of locations outside of the impact zone. Scenario C induces no impact, positive or negative, at any of these seven locations.

Plate 4.8 Hydrogeological impact at the virtual observation wells



4.2.17 Mass balance of the model provides the following estimations for seepage inflow and estimated need for drainage collection during temporary construction and permanent conditions:

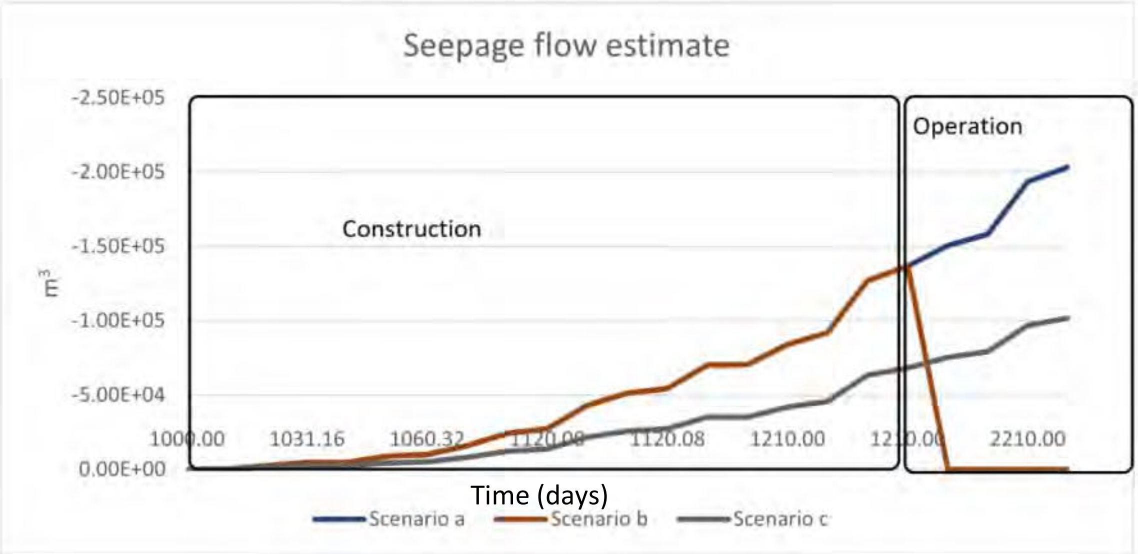
a. Construction, 210-day period and continuous road drainage for an additional 1,000 days, is approximately 1.9L/s.

b. Construction, 210-day period and no seepage post-construction is approximately 1.9L/s, and no volume loss during operational phase.

c. Construction, 210-day period and continuous road drainage for an additional 1,000 days, with reduced conductance factor, is approximately 0.94L/s.

Note these are estimates only and may vary significantly in reality, depending on the mitigation and flow control measures adopted by the Contractor. Plate 4.9 provides a timeline of cumulative volume loss over the active drainage duration in each scenario.

Plate 4.9 Seepage flow estimation, cumulative volumes



*The stepped pattern in the graph during the operational phase is a numerical effect of unequal timesteps defined within the stress period (defined for output control unit)

4.2.18 The seepage calculations into the cuttings are not suitable for use in drainage and/or dewatering design packages as they do not offer enough detail as to the phasing of the construction or the drainage stage in the permanent conditions. These values are purely estimated to demonstrate the anticipated volumes extracted from the superficial aquifers and the aquitard underneath for environmental purposes.

5 Summary

5.1 Results and discussions

5.1.1 A MODFLOW-USG model was set up to aid the assessment of potential impacts of the road cuttings at the Project/M25 junction during and after construction.

5.1.2 The site-specific Project ground investigations and BGS lithostratigraphic models were used to develop a refined 3D ground model. A steady-state, calibrated baseline groundwater model forms the basis of three transient model scenarios examining various outcomes regarding groundwater impact.

5.1.3 The existing M25 intercepts the RTD hills to both sides and is mainly positioned below the shallow groundwater table and acts as a drain. The draining effect is confirmed by the long-term monitoring data.

5.1.4 The results indicate an impact of up to 1.4m of drawdown in Scenario A, simulating the worst-case where no seepage control measures are used during or after construction. The impact footprint is much reduced by assuming a control measure that halves the seepage (Scenario C). In the case of fully lining the cutting (Scenario B), a rise in groundwater is observed on both sides of the cutting. These increased groundwater levels remain well below ground level.

5.1.5 The exact means and methods of mitigation will be determined by the Contractor, so the resultant impact may vary from the scenarios offered in this report.

5.1.6 Seepage flow is time-dependent and reflects the assumed work stages. Care must also be taken with the varying geological profiles since the different ground materials will convey different flows. It is expected that some form of seepage control will be employed by the Contactor during construction to ensure slope stability and site safety.

5.1.7 A close examination of the sensitive and important features near the cutting shows there would be impacts on Hall Farm Moat (approx. 0.7m) and Thames Chase Forest, including Hobbs Hole (up to 1.0m) if no mitigation measure is applied (Scenario A). All sensitive sites are outside of the impact zone for Scenarios B and C, in which mitigation is employed.

5.1.8 This numerical analysis suggests that Cranham Marsh LNR would remain unaffected by the activities related to the underpass during and after construction.

5.1.9 During a coordination meeting in May 2021 with the landowner, his land agent and key members of the Project Team, it was mentioned that, while the spring to the north of Hall Farm Moat has not been productive since the widening of the M25, deep land drains/gravity-fed ditches to the north-west of the moat (named as North Ockendon catchment in this report) have been supplying water for irrigation. These are located on the high grounds of Boyn Hill and are expected to remain untouched by the construction and operation activities. However, it is essential to note this source is expected to be susceptible to increased evaporation in warmer months and possible drought periods, and so generally has low resilience.

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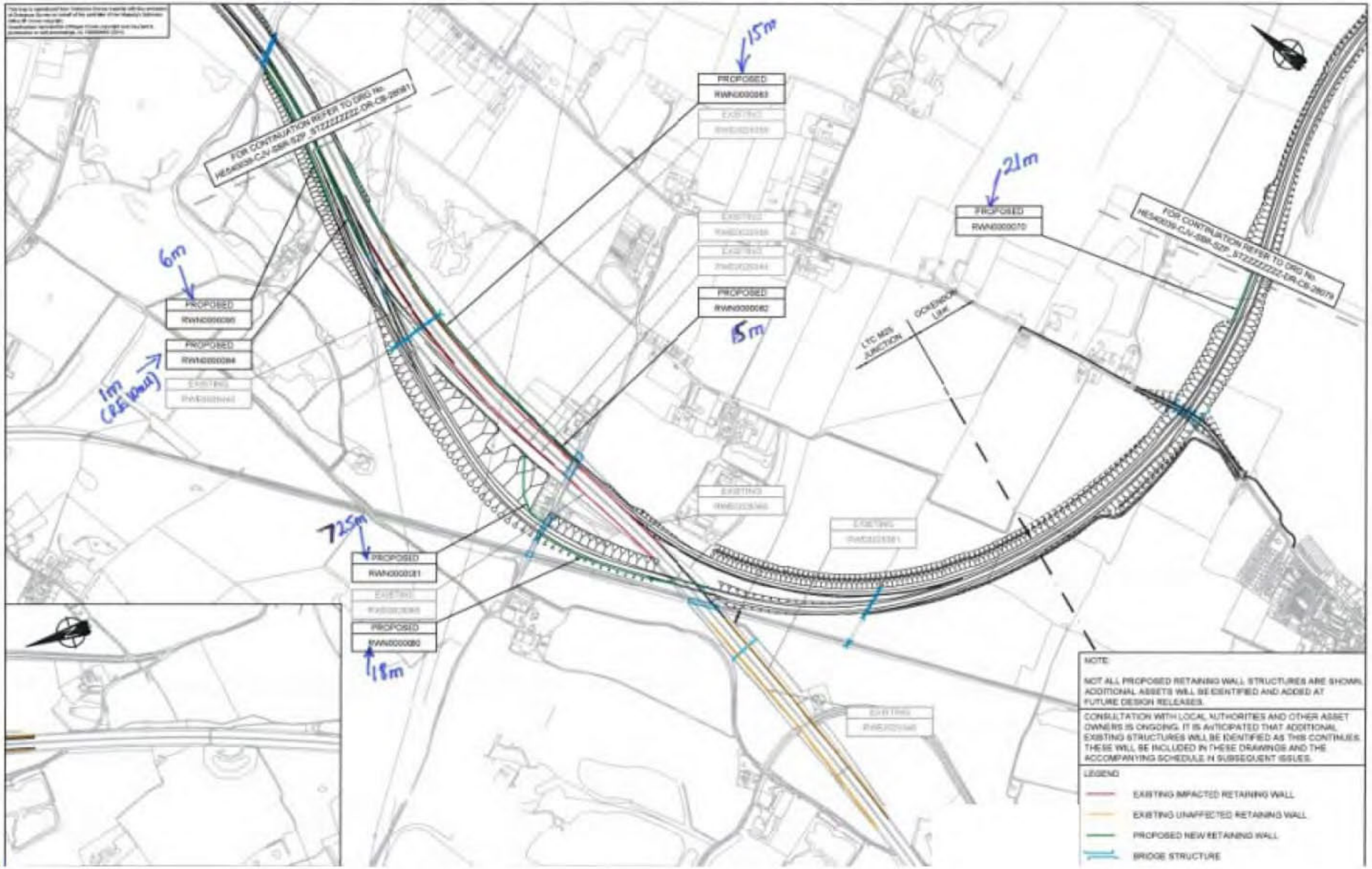
Annex A (Sketch layout of proposed retaining structures, 2021)


15m
PROPOSED
21m
PROPOSED
6m
PROPOSED
PROPOSED
15m
1m (RE)
LTC M25 JUNCTION
7.25m
PROPOSED
PROPOSED
18m
NOTE
NOT ALL PROPOSED RETAINING WALL STRUCTURES ARE SHOWN. ADDITIONAL ASSETS WILL BE IDENTIFIED AND ADDED AT FUTURE DESIGN RELEASES.
CONSULTATION WITH LOCAL AUTHORITIES AND OTHER ASSET OWNERS IS ONGOING. IT IS ANTICIPATED THAT ADDITIONAL EXISTING STRUCTURES WILL BE IDENTIFIED AS THIS CONTINUES. THESE WILL BE INCLUDED IN THESE DRAWINGS AND THE ACCOMPANYING SCHEDULE IN SUBSEQUENT ISSUES.
LEGEND
EXISTING IMPACTED RETAINING WALL
EXISTING UNAFFECTED RETAINING WALL
PROPOSED NEW RETAINING WALL
BRIDGE STRUCTURE

Annex M Infiltration basins detailed assessment south of the River Thames – technical note

Lower Thames Crossing

Annex M Infiltration Basins Detailed Assessment South of the River Thames – Technical Note

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1 Introduction

1.1 Background

1.1.1 The proposed A122 Lower Thames Crossing (the Project) is a new road that would provide a connection between the A2 and the M2 in Kent, east of Gravesend, crossing under the River Thames through two bored tunnels, before joining the M25 south of junction 29. The road is approximately 23km, 4.25km of which is in tunnel. The tunnel crossing is located to the east of the village of Chalk on the south of the Thames and to the west of East Tilbury on the north side. The Project route connects the A2/M2 in Kent, east of Gravesend, crossing under the River Thames through two bored tunnels, before joining the M25 south of junction 29. The route would be approximately 31km with 4km in a twin-bored tunnel. The tunnel would go to a depth of about 30m below the riverbed.

1.1.2 Highway drainage systems are designed to rapidly remove water from the carriageway and accommodate runoff from the highway, to prevent flooding of the carriageway.

1.1.3 The design of the Project highway drainage, south of the River Thames (section between the M2/A2/A122 Lower Thames Crossing junction and the South Portal), is for drainage outfalls to discharge to ground using nine infiltration basins and one swale. The geology and topography mean that there are no significant natural watercourses on the North Downs (south of River Thames). Therefore, existing road drainage networks along the A2, within the Project area, currently discharge to infiltration basins. These allow collected water to drain into a basin and the water to seep into the ground beneath. It is considered that such soakaways work well in this locality where underlain by a Chalk geology. Appropriate pollution control measures would also be proposed.

1.2 Brief and scope

1.2.1 The purpose of this technical note is to present the groundwater appraisal and modelling exercise carried out for the proposed highway drainage by infiltration to ground, for south of the River Thames. This technical note provides specialist hydrogeological information to support the A2/M2 – LTC A2 Junction – Gravesend Link drainage report (Cascade, 2019a).

1.2.2 The objectives of this technical note are to analyse the feasibility of the proposed infiltration basins and swale in terms of likely water infiltration rates into the ground, potential groundwater mounding and risk of pollution from infiltration of routine highway runoff.

1.3 Limitations

1.3.1 Pollution prevention control measures, such as to intercept oils, are discussed in the drainage report (Cascade, 2019a) and are not part of the scope of this technical note.

1.3.2 The presented assessment is based on published and Project ground investigation data.

1.4 Legislation and guidance

1.4.1 For a list of all relevant legislation and guidance, see Chapter 14: Road Drainage and the Water Environment (Application Document 6.1).

2 Review of geology and hydrogeology

2.1 Geology

2.1.1 The geology of the Project route south of the River Thames is summarised in Table 2.1. See Annex A for superficial and bedrock geology maps.

2.1.2 The White Chalk Group dominates the solid geology of the North Downs. Superficial deposits are generally absent on the North Downs except for finger-like outcrops of Head Deposits, within dry valleys.

2.1.3 Palaeogene strata, comprising the London Clay Formation, Lambeth Group and the Thanet Formation, occur locally such as at Shorne Woods and approximately 750m east of the Project crossing beneath the Ramsar site.

2.1.4 Alluvium dominates the superficial deposits on the River Thames floodplain, north of Lower Higham Road. Local outcrops of River Terrace Deposits occur at the border between the North Downs hills and the floodplain.

Table 2.1 Summary of the geology

Strata	General description
Head Deposits	Gravel, sand and clay depending on upslope source.
Alluvium	Marine and estuarine Alluvium. Silt and clay with lenses and beds of peat, and seams of sand and gravel.
River Terrace Deposits (Taplow Gravel Member, Lynch Hill Gravel Member)	River Terrace Deposits – gravel, sandy and clayey in part.
London Clay Formation Harwich Formation	Dark bluish to brownish grey clay, containing variable amounts of fine-grained sand and silt. Cross-bedded shelly sand (the Oldhaven Beds) with a basal pebble bed.
Lambeth Group comprising: Woolwich Formation Reading Formation Upnor Formation	The upper beds are clay with shells, ferruginous sand, lignitic sand and lignite. The lower beds are coarse sand with pale grey clay partings and coarse gravel of black flint.
Thanet Formation	Greenish to brownish grey silty, fine-grained sand, clayey and siltier in the lower part, with a conglomerate of flint pebbles and nodular flints at the base.
White Chalk Group, comprising: Seaford Chalk Formation Lewes Nodular Chalk Formation	Fossiliferous nodular chalk with bands of nodular flints, hardgrounds and marl seams. White chalk with hard nodular beds.

2.2 Hydrogeology

2.2.1 Annex B presents a plan of interpreted Chalk aquifer water level contours (based on data from the Environment Agency monitoring boreholes during February 2014; a period of high-water level) and groundwater flooding potential for south of the River Thames. Groundwater flooding potential is based on rock type, topography and predicted groundwater level after extended rainfall from numerical and statistical modelling (British Geological Survey, 2020).

2.2.2 The Chalk aquifer (North Kent Medway Chalk Water Framework Directive water body) is the dominant groundwater-bearing strata south of the River Thames. The Chalk is an important aquifer due to significant abstraction for public water supplies. Fracture flow is the dominant groundwater flow mechanism. Fractures are the reason for the generally high but spatially variable transmissivity and low storage capacity.

2.2.3 The upper 50m of the saturated zone (that is, the zone below the water table) generally has the highest permeability. Within that top 50m, even higher permeability zones are associated with dry valleys. Most groundwater flow tends to be concentrated in a few large fractures near to the current or historical water table elevation (Adams, 2008).

2.2.4 The Thames Estuary and Marshes areas, within the Medway Catchment Abstraction Management Strategy area, are designated as a Special Protection Area and Ramsar site, and the South Thames Estuary and Marshes Site of Special Scientific Interest.

2.2.5 Groundwater levels, south of the River Thames, are characterised as follows:

a. The North Downs' water table is influenced by the effect of (mostly) public water supply wells.

b. The Chalk aquifer water table is deep (up to 55m below ground level (bgl)) below the high ground of the North Downs.

c. The fall of topography, northwards, means that the water table is shallow near the northern edge of the North Downs, near the South Portal.

d. Diffuse shallow groundwater seepage (depending on groundwater levels and overlying superficial geology) is likely to occur along the southern edge of the North Kent marshes (e.g. at the Ramsar site). However, a preliminary water balance assessment has indicated groundwater input is very low (<2%) compared to the predominance of rainfall at the Filborough Marshes (Cascade, 2019b).

e. Perched groundwater occurs locally, where layered sandy and clay strata are present, e.g. Lambeth Group along parts of the A2.

2.2.6 Areas at risk of potential groundwater flooding are generally low-lying areas where groundwater levels are high. Areas near and north of Lower Higham Road (Ramsar site), north of the South Portal, are shown as having a potential for groundwater flooding risk. The risk is likely a mix of pluvial and groundwater flooding, a result of the low permeability of the Alluvium deposits found at the surface.

2.2.7 East Court Manor and Queen's Farm, south and north of Lower Higham Road respectively, are both areas shown as having potential for groundwater flooding at surface. A possible reason could include the outcrop of River Terrace Deposits (granular superficial deposit) at these locations. The solid geology of Queen's Farm includes sands and clays of the Lower Tertiaries, and these may also influence groundwater flow paths.

2.3 Conceptual model

2.3.1 Groundwater movement and aquifer properties in the Chalk are described in the British Geological Survey report The Chalk Aquifer of the North Downs (Adams, 2008).

2.3.2 The upper 50m of the saturated Chalk generally has higher permeability than the deeper aquifer below 50m depth. Interfluves also generally exhibit lower permeability (than dry valleys).

2.3.3 A summary of aquifer properties obtained from Adams (2008) for the Chalk aquifer of the North Downs is summarised in Table 2.2. It is understood that the summary of data provided better reflects more productive areas of the Chalk, as the data largely includes results from pumping tests carried out for developing production wells. As the infiltration basins are generally sited along dry valleys areas, this summary provides a reasonable starting point for hydraulic conductivity assumptions used in the assessment presented in this report.

Table 2.2 Summary of hydrogeological parameters

	Transmissivity	Hydraulic conductivity		Storativity
	m^2/d	m/d*	m/s	m/m
Minimum	52	1.0	1.2×10^{-5}	1.0×10^{-5}
Maximum	7,400	148	1.7×10^{-3}	0.060
Geometric mean	720	14.4	1.7×10^{-4}	0.003
Median	670	13.4	1.6×10^{-4}	0.004
25^{th} percentile	350	7.0	8.1×10^{-5}	0.001
75^{th} percentile	1,600	32	3.7×10^{-4}	0.015

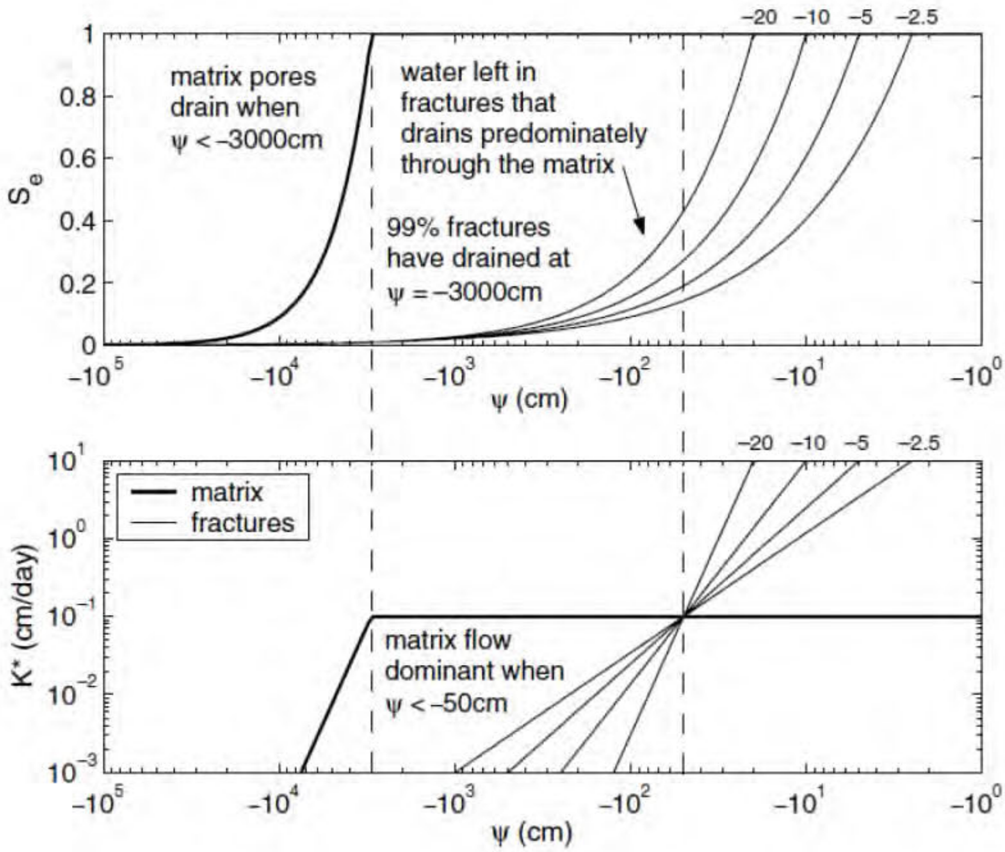
*Adapted from (Adams, 2008)

2.3.4 Two pumping tests were carried out in the Chalk south of the River Thames, as part of the Project Phase 1 ground investigation. Interpretation of the two tests found the hydraulic conductivity of the Chalk to be in the order of 10^{-4} to 10^{-5}m/s, values that fit well within the range provided by Adams (2008). See pumping test factual reports (Cascade, 2020a) and (Cascade, 2020b) for background, results and interpretation.

2.3.5 Groundwater movement in the unsaturated Chalk is characterised by slow piston flow through the matrix and more rapid bypass flow through the fractures. The hydraulic conductivity is therefore low at low matrix potentials, increasing rapidly as matrix potentials rise. The hydraulic properties of the saturated Chalk aquifer are more complex, resulting from a combination of matrix and fracture properties.

2.3.6 Following a literature review of transient simulations of flow and transport in the Chalk unsaturated zone, e.g. (Mathias *et al*., 2006), effective saturation curves and hydraulic conductivity curves were derived for use in the analytical assessment and modelling effort presented in this report (Plate 2.1). The curves produced imply that fracture flow becomes insignificant compared to matrix flow when pressure heads fall below -50cm and that flow through the matrix begins to cease when pressure heads have fallen below -3,000cm (Mathias *et al*., 2006).

Plate 2.1 Matrix and fracture effective saturation (S_e) and hydraulic conductivity (K*) curves for different values of air entry pressure (ψ) as indicated on top axis



3 Review of proposed infiltration drainage

3.1 Design basis

3.1.1 The drainage system has been designed to rapidly remove water from the carriageway and accommodate runoff from the highway and from adjacent (external) catchments, with increased rainfall intensities in accordance with predicted climate change effects, to prevent flooding of the carriageway for the design storm return periods within the various constraints of the Project (Cascade, 2019a). Further information is shown in Appendix 14.6: Flood Risk Assessment Part 7 (Application Document 6.3).

3.1.2 The design development has concluded that the disposal of surface water runoff from all the catchments south of the River Thames would be by using infiltration basins (soakaways) and one swale (Swale 2, naming in line with Highways England Water Risk Assessment Tool (HEWRAT) assessment (Cascade, 2020c) (Annex O)). New soakaways and existing ones to be retained would comprise a large open infiltration basin with a series of shallow soakaway trenches across the base of the basin. For the larger catchments, particularly those serving the new sections of the Project running north from the A2, it is proposed to include sedimentation basins at the inlet to remove sediment and to retain accidental spillages.

3.1.3 Depending on water quality assessments, it may be necessary to introduce further water treatment, in which case proprietary products such as vortex separators would be recommended, for example to reduce hydrocarbons and sediment load, and enhance water quality.

3.1.4 Three existing infiltration basins would be retained and upgraded as part of the Project to serve three revised catchments, including both new and existing carriageway surfaces. A further six new infiltration basins would be provided to serve new catchments, and one swale, located along the South Portal access road. It is assumed that all infiltration basins would be constructed wholly within the Chalk to achieve good infiltration rates (Cascade, 2019a). The 10 primary catchments south of the river are as follows:

a. Catchment EXPOS01-001 (existing)

b. Catchment EXPOS02-001 (existing)

c. Catchment EXPOS02-005 (existing)

d. Catchment POS01-001

e. Catchment POS02-001

f. Catchment POS02-002

g. Catchment POS02-003 (three-pond cascading basin)

h. Catchment POS02-004

i. Catchment POS04-001 (two-pond cascading basin)

j. Swale 2 (South Portal access road)

3.1.5 Infiltration basins associated with catchments POS02-003 and POS04-001 have been designed in a cascade formation to allow for overflow.

4 Infiltration rate assessment

4.1 Introduction

4.1.1 An empirical prediction of infiltration rates is outlined (Section 4.2) along with results from the Project Phase 2A *in situ* testing on the Chalk infiltration potential through packer testing and soakaway tests (Section 4.3).

4.2 Prediction of infiltration rate in the unsaturated Chalk

4.2.1 This section considers the vertical component of groundwater flow in the unsaturated zone of the Chalk to provide an empirical estimate for an infiltration rate. As water contained in infiltration basins would quickly develop a positive head at the surface of the Chalk, it is expected that groundwater flow would be dominated by fracture flow (refer to Section 2.3).

4.2.2 Infiltration rates, the mean vertical flow rate (the Darcy velocity, q), are predicted using first principle equations that describe laminar type groundwater flow:

$$q = -K\frac{\delta_i}{\delta_z}$$

Where:

q = Darcy velocity [L^1T^{-1}]

K = hydraulic conductivity in the direction parallel to the fracture [L^1T^{-1}]

$\frac{\delta_i}{\delta_z}$ = hydraulic gradient [L^1L^{-1}]

4.2.3 Region-wide aquifer parameters can be used on this basis to estimate an infiltration rate. However, more usefully, the hydraulic conductivity of a fractured rock (e.g. the Chalk) can be empirically derived from the (Navier-Stokes) cubic law equation:

$$K = \frac{(2b)^3}{2B}\frac{\rho g}{12\mu}$$

Where:

K = hydraulic conductivity in the direction parallel to the fracture [L^1T^{-1}]

b = fracture aperture [L]

B = fracture spacing [L]

ρ = density of water [M^1L^{-3}]

g = acceleration due to gravity [$L^1T^{-1}T^{-1}$]

μ = dynamic viscosity of water [M^1T^{-1}].

4.2.4 Fracture geometry (such as fracture spacing, aperture and connectivity) values have been obtained from the Project borehole logging, downhole geophysics, and scan line surveys carried out on Chalk outcrops near the site (see Cascade (2019c)) and backed up with literature values. Representing non-linear (turbulent) flows is difficult using empirical analytical methods, but the laminar flow method provides an indicative infiltration rate in any case.

4.2.5 Representative geometry values from literature and site-based investigations are as follows:

a. Foster (1975) suggests that typical fracture-apertures within the Chalk might vary between 0.1mm and 1.0mm. Aperture measurements from scan line surveys range from 1mm to 40mm, and downhole apertures range from 0mm to 10mm, with the 50th percentile of 2mm. The limit of measurement for both site-specific techniques is 1mm (fractures <1mm are either missed or measured as 0 or 1mm). Fracture apertures measured by the scan line survey may not be representative of the unsaturated zone due to expansion from weathering and reduced loading. From the information sources, it is assumed that fracture apertures would range between 0.1mm and 10mm, though fractures with apertures >1mm would be infrequent.

b. Mathias (2005) suggests that, while fracture spacing of 5cm is probably common in the upper 3m of the Chalk due to weathering, a fracture spacing of at least 25cm would be expected below 5m depth. Average fracture spacings measured using the Project downhole geophysics range from 0.4cm to 1,770cm, with the 10th, 50th and 90th percentile spacings as 8.2cm, 21cm and 70cm respectively.

c. Ireson *et al*. (2006) found that the vertical hydraulic gradient within the Chalk unsaturated zone ranged between $-0.7 < J < -0.95$ (over the period of November 2003 to August 2004 at a West Ilsley site, Berkshire).

d. Mathias (2005) concludes the fact that such large gradients have been observed, implies that water is being supplied to the fractures in the unsaturated zone.

4.2.6 For the range of likely fracture conditions identified in paragraph 4.2.5, a range of Chalk hydraulic conductivity values derived using the cubic law are presented in Table 4.1. It should be noted that many of the fractures would be infilled to a degree by sediment (such as clays), and that this infill would restrict flow and reduce permeability.

Table 4.1 Estimated hydraulic conductivity values for the Chalk (derived from Navier-Stokes cubic law)

	Hydraulic conductivity (m/s)		
Fracture aperture (2b)	**Fracture spacing (2B) = 5cm**	**Fracture spacing (2B) = 25cm**	**Fracture spacing (2B) = 70cm**
0.1mm	1.6×10^{-5}	3.3×10^{-6}	1.2×10^{-6}
1.0mm	1.6×10^{-2}	3.3×10^{-3}	1.2×10^{-3}

4.2.7 The empirically derived estimates compare relatively well with Adams (2008) (see Table 4.1), except when the fracture spacing is exclusively less than 5cm and where fracture apertures are greater than 1mm (i.e. when hydraulic conductivity would be very high). As inferred by Mathias (2005), however, this condition may only be most probable in the near-surface weathered zone. Considering the geometric mean of all fracture conditions empirically assessed is 20m/d, this compares well with the geometric mean presented by Adams (2008) (14.4m/d).

4.2.8 Using (K) values derived from the cubic law approximation (Table 4.1) and the (more probable) geometric mean taken from Adams (2008), the mean vertical flow rate (potential infiltration rate) has been calculated and is given in Table 4.2.

Table 4.2 Estimation of likely Chalk infiltration rates (Darcy velocity)

Hydraulic conductivity (m/s)	Theoretical Darcy velocity (m/s)	
	Hydraulic gradient, i = -0.7	**Hydraulic gradient, i = -0.95**
3.5×10^{-6}	2.3×10^{-6}	3.5×10^{-6}
1.6×10^{-5}	1.2×10^{-5}	1.6×10^{-5}
$*1.7 \times 10^{-4}$	1.2×10^{-4}	1.6×10^{-4}
3.2×10^{-3}	2.3×10^{-3}	3.1×10^{-3}
1.6×10^{-2}	1.2×10^{-2}	1.6×10^{-2}

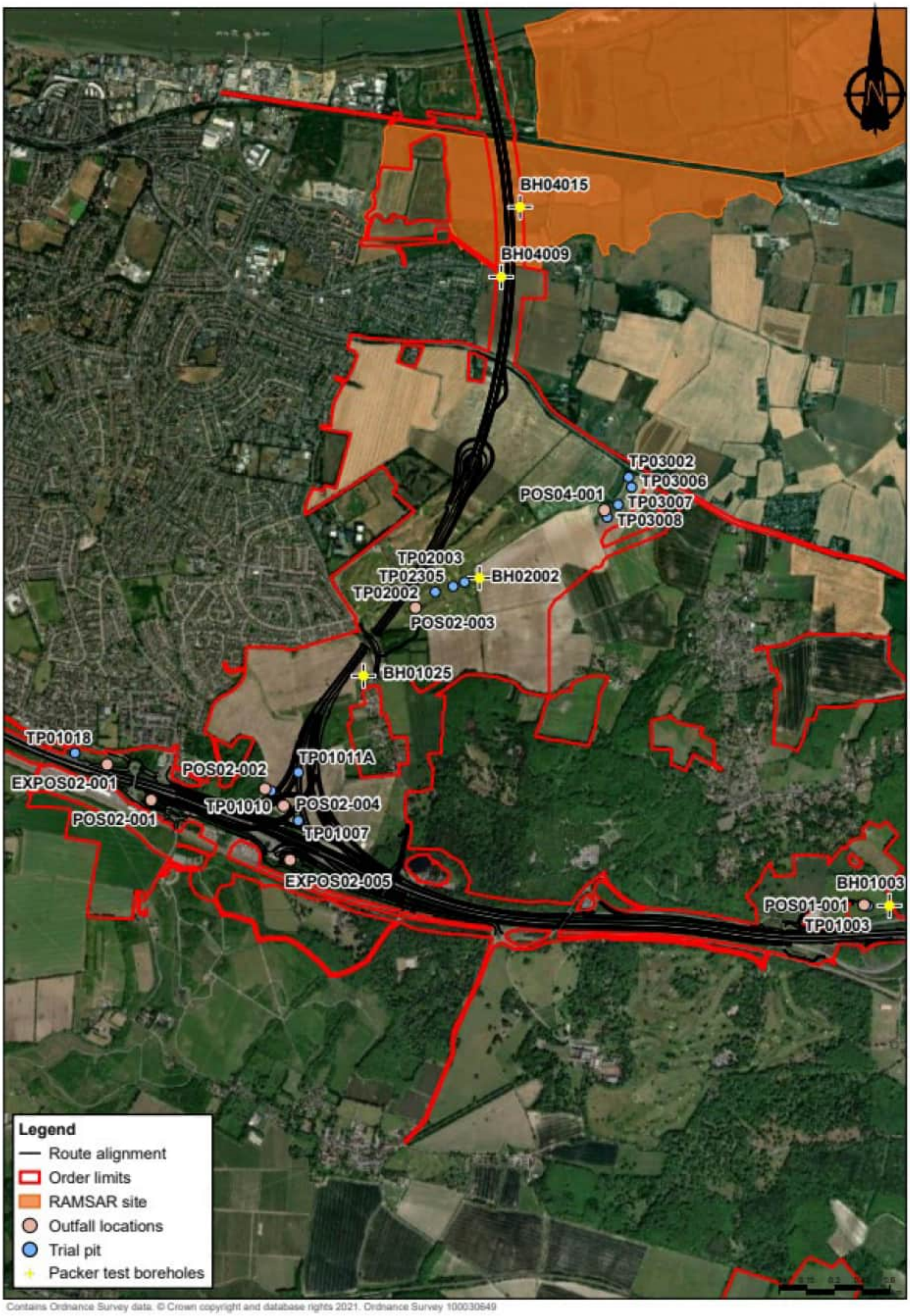
*Taken from Adams (2008)
Geometric mean of empirically derived range (q) = 1.8×10^{-4}m/s (15.6m/d)

4.2.9 Invariably, the rates presented in Table 4.2 would include a minor component of flow from the Chalk matrix. However, the rates associated with the matrix are expected to be too low to have any significant impact at higher flow rates and are only important where actual fracture flows are low. For example, the saturated hydraulic conductivity of the Chalk matrix has been consistently observed by many authors to be around 10mm/d (Mathias, 2005). This would be equivalent to a flow rate (q) of up to 0.001m^3/d under unit gravity hydraulic gradient. The infiltration rates presented are based on a theoretical understanding of the Chalk and its behaviour.

4.3 Phase 2A *in situ* testing

4.3.1 As instructed by Cascade, Perfect Circle Joint Venture conducted packer tests at five borehole localities and soakaway tests in 16 trial pits as part of the Phase 2 Package A ground investigation works. The locations of the boreholes and trial pits are illustrated in relation to the nine proposed infiltration basins in Plate 4.1.

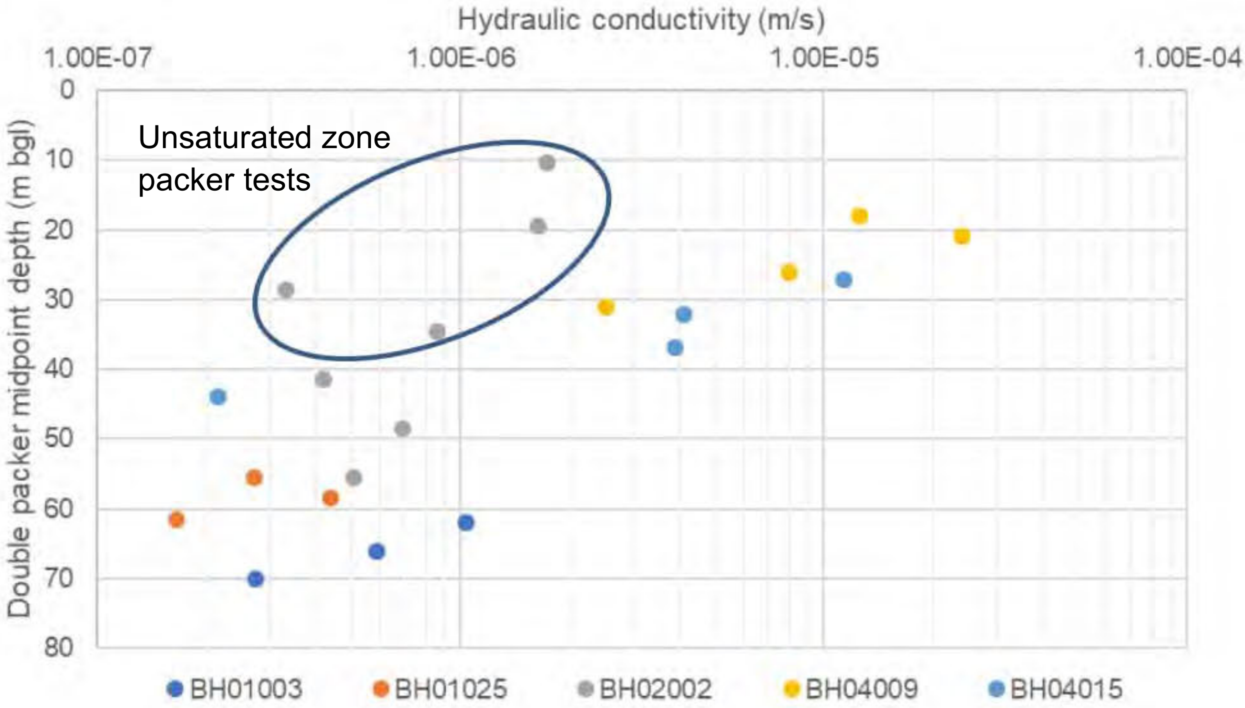
Plate 4.1 Packer test boreholes and soakaway test trial pit locations (south of the River Thames)



4.4 Packer test results

4.4.1 Packer testing was carried out to inform local hydraulic properties of the Chalk at varying depths below ground level. The resulting hydraulic conductivity depth profile is illustrated in Plate 4.2.

Plate 4.2 Phase 2 Package A packer test hydraulic conductivity profile



4.4.2 Results show a trend of reducing hydraulic conductivity with depth, ranging from 2.40×10^{-5}m/s to 1.65×10^{-7}m/s.

4.4.3 Four packer tests were conducted in the Chalk unsaturated zone in BH02002. The midpoint depth of each packer test was 10.25m, 19.50m, 28.5m and 34.5m bgl (rest water level in the borehole approximately 37m bgl). Packer testing above the water table is used as an indicative method for estimating the permeability of the unsaturated zone; BH02002 results range from 1.7×10^{-6}m/s at 10.25m bgl to 3.3×10^{-7}m/s at 28.5m bgl. These results are used with caution; due to the short duration of the packer testing, it is likely that the Chalk is only partially saturated (to a radius of approximately 10m). Hence, results do not represent the saturated hydraulic conductivity that would be achieved below the infiltration basins.

4.4.4 Because of this uncertainty regarding the unsaturated zone packer testing, the indicative hydraulic conductivity values have not been used in the following infiltration basin assessment.

4.5 Soakaway test results

4.5.1 Soakaway tests are an *in situ* method for calculating the potential water infiltration rate of the soil or rock. Infiltration rate is calculated using the following equation (Bettess, 1996):

$$I = \frac{V_{P75-25}}{a_{p50} \times t_{p75-25}}$$

Where:

I = infiltration rate (L^1T^{-1})

V_{p75-25} = effective storage volume of water in trial pit between 75% and 25% effective depth (L^3)

a_{p50} = internal surface area of trial pit up to 50% effective depth and including base area (L^2)

t_{p75-25} = time for water level to fall from 75% to 25% effective depth (T)

4.5.2 Test results are summarised in Table 4.3. Testing in four of the trial pits (TP02305, TP03002, TP03006 and TP03007) failed to drain water from 75% and 25% effective depth, so infiltration rates could not be determined and tests at these sites were unsuccessful. TP03002 and TP03006 failed because the trial pits were not excavated deep enough to reach the Chalk. TP02305 and TP03007 were both excavated into the top of the structureless Chalk, with only one test being carried out in both trial pits with very little infiltration. Two more tests were scheduled for both trial pits but were not completed due to the lack of infiltration and time constraints on site.

Table 4.3 Soakaway test results

Trial pit	Number of successful tests completed	Calculated infiltration rate (m/s)	
		Minimum*	Maximum**
TP01003	3	$1.1x10^{-4}$	$2.0x10^{-4}$
TP01007	3	$5.4x10^{-4}$	$7.5x10^{-4}$
TP01007A	4	$6.4x10^{-5}$	$8.1x10^{-5}$
TP01010	3	$4.7x10^{-5}$	$5.7x10^{-5}$
TP01010A	2	$7.5x10^{-5}$	$8.6x10^{-5}$
TP01011	2	$2.9x10^{-5}$	$3.4x10^{-5}$
TP01011A	3	$4.3x10^{-5}$	$6.7x10^{-5}$
TP01018	2	$2.1x10^{-5}$	$3.0x10^{-5}$
TP02002	2	$9.2x10^{-6}$	$1.1x10^{-5}$
TP02003	3	$3.5x10^{-5}$	$4.3x10^{-5}$
TP02305	Failed	N/A	
TP03002	Failed	N/A	
TP03006	Failed	N/A	
TP03006A	3	$1.76x10^{-4}$	$1.4x10^{-3}$
TP03007	Failed	N/A	
TP03008	2	$1.5x10^{-5}$	$2.4x10^{-5}$

**minimum infiltration rate calculated from the successful tests*

***maximum infiltration rate calculated from the successful tests*

4.5.3 From the successful soakaway tests, calculated infiltration rates are in the order of 10^{-4}m/s to 10^{-5}m/s, with a geometric mean of $7.2x10^{-5}$m/s. The soakaway test with the greatest infiltration rate was conducted in TP03006A. The location of this trial pit is situated on a dry valley (zone of higher permeability).

4.5.4 An infiltration rate of $7.2x10^{-5}$m/s is equivalent to a hydraulic conductivity of 6.6m/d ($7.6x10^{-5}$m/s) (assuming the vertical hydraulic gradient to be -0.95). This result of hydraulic conductivity is comparable to the interpretation of the South Portal pumping test (Cascade, 2020a). The smallest infiltration rate was recorded at TP02002, where the equivalent hydraulic conductivity is 0.8m/d ($9.7x10^{-6}$m/s).

5 Analytical prediction of groundwater mounding

5.1 Introduction

5.1.1 Under the operation of the infiltration basins, a degree of groundwater mounding is expected to occur at the Chalk water table beneath each basin due to the concentration of recharge in a small area (Carleton, 2010).

5.1.2 An assessment of the groundwater mounding response has been carried out with an initial analytical (one-dimensional) assessment and then using high level three-dimensional modelling in Section 6. Swale 2 has not been included in either mounding assessment due to the relatively small catchment area and drainage infiltration rates.

5.2 Analytical method

5.2.1 Analytical equations can be used to estimate the magnitude and radius of groundwater mounding beneath infiltration basins, but are limited by simplified assumptions (Carleton, 2010). The most widely used solution is one by Hantush (1967). This solution uses an equation describing the '*growth and decay of groundwater mounds in response to uniform percolation*'. The following assumptions apply:

a. Water table aquifer of infinite extent and finite thickness.

b. A horizontal impermeable aquifer base.

c. Flow is horizontal.

d. There is negligible change of transmissivity with a change in head.

5.2.2 As part of the study by Carleton (2010), a spreadsheet was developed to use the Hantush solution. This spreadsheet has been used in this assessment. The spreadsheet requires the following input parameters for each infiltration basin assessment:

a. *I*, drainage infiltration rate (L^1T^{-1})

b. *K*, hydraulic conductivity (L^1T^{-1})

c. S_y, specific yield (dimensionless)

d. *x*, half the length of basin (L)

e. *y*, half the width of basin (L)

f. *t*, duration of infiltration period (T)

g. *hi(0)*, initial thickness of saturated zone (L)

5.2.3 Values for drainage infiltration rate and the duration of drainage period(s) have been split into three infiltration scenarios (see Section 5.3). The dimensions of the infiltration basins, x and y, are identified as half the square root of the basin bottom area (see Cascade (2019a)). Using the square root of the basin bottom assumes the infiltration basins to be square and that infiltration occurs across the whole bottom area (infiltration basins are unlined).

5.2.4 The initial thickness of the saturated zone beneath each infiltration basin is set to 30m. This is a conservative (worst-case) assumption based on the statement made by Allen *et al*. (1997) that only the upper 50m of Chalk is transmissive.

5.2.5 Specific yield has been set at 0.02 to be conservative and consistent with the modelling undertaken in Section 6. For hydraulic conductivity, both the minimum and geomean values have been assessed. The minimum value used was 1.5m/d, taken as the vertical hydraulic conductivity of the upper Chalk in the 3D model. The geomean value used was 6.6m/d, which was calculated from the *in situ* soakaway test results and theoretical estimation of infiltration rates from literature values. The assessment assumes the Chalk properties to be homogeneous and isotropic.

5.2.6 For a summary of input parameters, see Annex C.

5.3 Infiltration scenarios

5.3.1 To simulate infiltration to the water table, three scenarios (Table 5.1) have been run for both the analytical assessment and the 3D modelling in Section 6.

5.3.2 For scenarios 1 and 2, the following equation was used to calculate the infiltration rate for each infiltration basin:

$$I = \frac{P\ x\ A\ x\ C}{a}$$

Where:

I, drainage infiltration rate (L^1T^{-1})

P, precipitation rate (L^1T^{-1})

A, impervious drainage catchment area for each basin (L^2)

C, rainfall runoff coefficient (0.9) for asphalt pavement (Garber and Hoel, 2009)

a, basin bottom area (L^2)

5.3.3 Scenario 1: steady state mounding using average drainage infiltration. For this scenario, the average daily precipitation rate (1.78mm/d) (UK Centre for Ecology and Hydrology, 2020) is used to calculate the required infiltration rate for each basin. A runoff coefficient of 0.9 is used for asphalt pavement, hence 10% of precipitation is lost to the likes of interception, evaporation or car carry-off. This is a steady state scenario to assess the potential long-term mounding effects.

5.3.4 Scenario 2: mounding levels after a wet season (180 days). To simulate a wet season, the 90th percentile of daily precipitation (5.8mm/d) is used to calculate the infiltration rate, also assuming a runoff coefficient of 0.9, for a period of 180 consecutive days.

5.3.5 Scenario 3: worst-case drainage infiltration from a 1 in 100-year storm (24 hours infiltration), associated with a 20% increase in peak rainfall intensity due to climate change and a further sensitivity test carried out with a 40% increase in peak rainfall intensity due to climate change. Under the scenario conditions of peak infiltration, mounding is simulated beneath the infiltration basins after 24 hours operation to determine whether the basins would fail and result in groundwater flooding.

5.3.6 The drainage infiltration rates for the nine infiltration basins and three infiltration scenarios are summarised in Table 5.1, along with the total impervious drainage areas.

Table 5.1 Scenario drainage infiltration rates for each basin

Infiltration basin	Total impervious drainage area (m^2)	Scenario 1 – Average drainage infiltration rate (m/d)	Scenario 2 – 90th percentile drainage infiltration rate (m/d)	Scenario 3 – Worst-case drainage infiltration rate (m/d)
EXPOS01-001	60,020	0.078	0.255	1.054
EXPOS02-001	69,240	0.106	0.344	0.823
EXPOS02-005	38,240	0.098	0.319	1.796
POS01-001	133,790	0.033	0.106	0.719
POS02-001	11,060	0.073	0.237	0.902
POS02-002	16,530	0.019	0.063	0.239
POS02-003-1	242,140	0.041	0.132	0.715
POS02-003-2		0.041	0.132	0.683
POS02-003-3		0.041	0.132	0.848
POS02-004	85,250	0.031	0.102	0.632
POS04-001-1	102,390	0.011	0.036	0.304
POS04-001-2		0.012	0.039	0.337

5.3.7 The required drainage infiltration rates in Table 5.1 are significantly smaller than the geomean infiltration rate of 6.6m/d from soakaway testing, and theoretical Chalk (geomean) infiltration rate of 15.6m/d from Section 4.

5.4 Results

5.4.1 Hantush mounding results for the three infiltration scenarios and two hydraulic conductivity values are summarised in Plate 5.1 and Plate 5.2. The approximate thickness of the unsaturated zone is plotted on both graphs to indicate the levels at which the infiltration basin would fail, leading to overtopping and flooding. The thickness of the unsaturated zone (USZ) has been calculated using basin invert levels and contoured high Chalk groundwater levels for February 2014 using Environment Agency boreholes. As the groundwater levels are high, the unsaturated zone thickness is conservative. The pre-operation unsaturated zone for all infiltration basins is extensive at over 25m, formed by the geomorphology of the North Downs. The unsaturated zone is at its greatest in the south, decreasing gradually towards the north as the topography slopes down from the North Downs to the Thames Valley.

Plate 5.1 Analytical model results for groundwater mounding assuming a conservative Chalk hydraulic conductivity of 1.5m/d

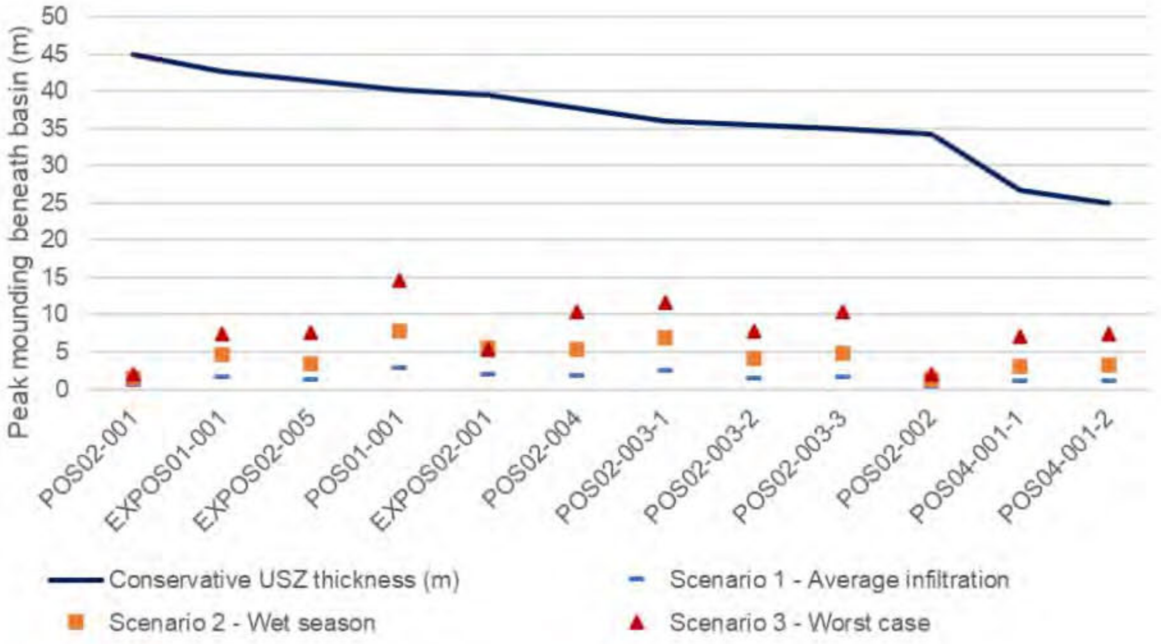
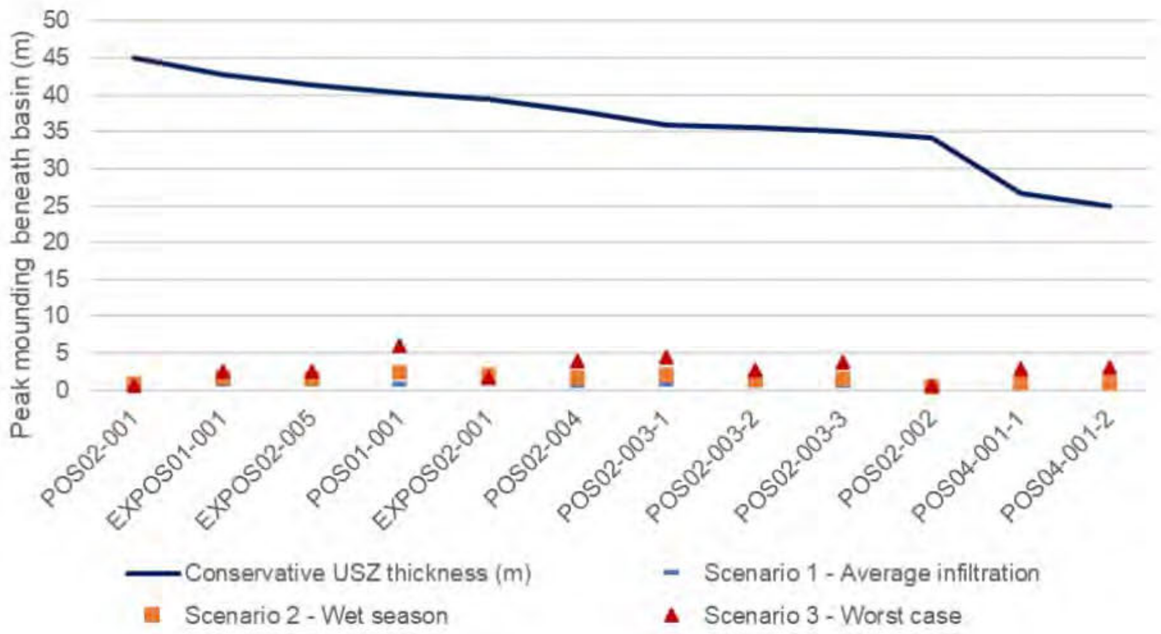


Plate 5.2 Analytical model results for groundwater mounding assuming a geomean Chalk hydraulic conductivity of 6.6m/d



5.4.2 Plate 5.1 shows the mounding results for all scenarios assuming a conservative hydraulic conductivity of 1.5m/d. Across all scenarios, mounding is greatest beneath POS01-001 and smallest beneath POS02-002. Conservative results for each scenario:

a. Scenario 1: mounding levels range from 2.80m to 0.46m. Mounding is very small, the effect on groundwater flows would be negligible and there is no risk of basin failure.

b. Scenario 2: mounding levels increase by approximately three times compared to scenario 1, ranging from 7.78m to 1.31m. Again, the levels of mounding are small compared to the unsaturated zone thickness and there is no risk of basin failure.

c. Scenario 3: worst-case mounding levels range from 14.58m to 1.96m. Levels of mounding do not exceed the unsaturated zone thickness at any of the infiltration basins, hence the analytical solution indicates there is no risk of basin failure when the hydraulic conductivity is 1.5m/d or greater.

5.4.3 Assuming a geomean hydraulic conductivity of 6.6m/d, groundwater mounding predictions are reduced by up to four times compared to the conservative results (see Plate 5.2). Under these conditions, potential impacts on groundwater levels and flow would be negligible.

5.5 Limitations

5.5.1 Predictions of groundwater mounding using the Hantush solution are limited largely to the input parameters, which are often simplified to suit the analytical model.

a. The Chalk hydraulic conductivity is assumed to be homogeneous and isotropic. This could result in the levels of mounding being underestimated, as it is shown by the Project Phase 2 packer testing that the hydraulic conductivity reduces with depth, by up to two orders of magnitude over 50m.

b. For simplification, the model assumes that infiltration occurs across the entire base of the infiltration basin. This scenario exists in the early operational life of the infiltration basin, but with time the base may become clogged with sediment and the infiltration capacity may be reduced. However, the soakaway trenches would be maintained as part of the maintenance regime, and facilities to intercept sediment before runoff reaches the basin could be provided subject to detailed design. In addition, with infiltration only occurring in the trenches, mounding would be convex beneath the trenches and concave between the trenches where no infiltration occurs. Because of this, the maximum height of mounding could be underestimated marginally, as the area of infiltration is smaller.

c. The analytical model does not account for the potential superposition of groundwater mounding from nine infiltration basins all in operation at the same time.

6 3D modelling

6.1 Introduction

6.1.1 3D modelling was carried out using proprietary modelling software Groundwater Vistas 7 and MODFLOW 2005. The model used in this assessment simulates the groundwater regime for the Project in operation. For details on the model geometry, boundary conditions and calibration, refer to Ground Protection Tunnel and Main Tunnels Groundwater Model – Technical note (Cascade, 2020d).

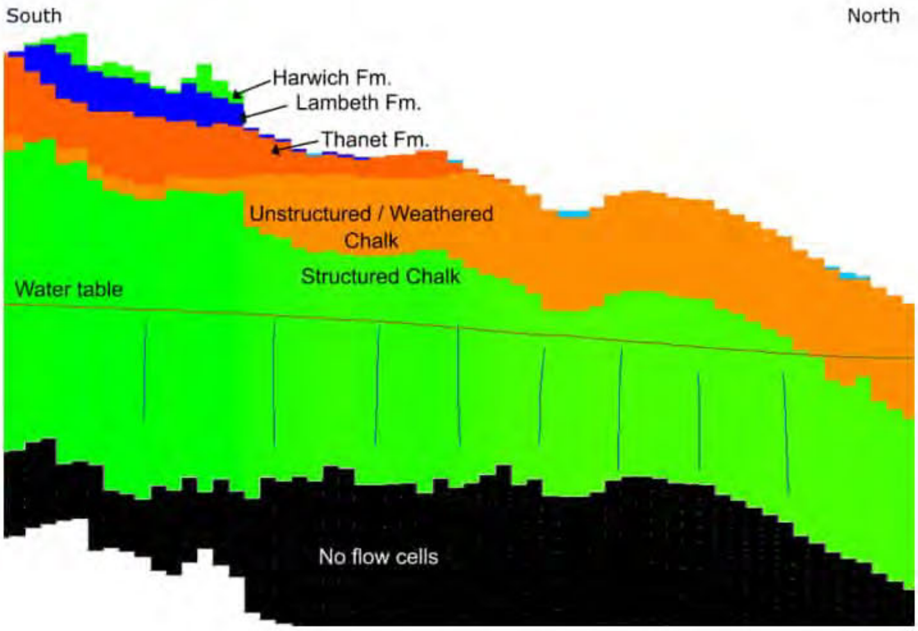
6.2 Model set-up

6.2.1 Hydraulic conductivity distributions were determined by a Monte Carlo analysis. The analysis allows for a range of calibrated models to be simulated with different K values for the hydraulic units; for each simulation the Standardised Root Mean Square Error is calculated. This tolerance for the calibrated simulations was set at 10%. This led to 239 calibrated simulations with different hydraulic properties (Cascade, 2020d). For this assessment, the 50th percentile has been used. See Table 6.1 and Plate 6.1 for hydraulic conductivity properties of the Chalk layers.

Table 6.1 Model Chalk hydraulic conductivity summary

Hydraulic layer	Hydraulic conductivity (m/d)	
	K_x, K_y (horizontal)	K_z (vertical)
Unstructured/weathered Chalk	15.64	1.56
Structured Chalk	1.27	0.13

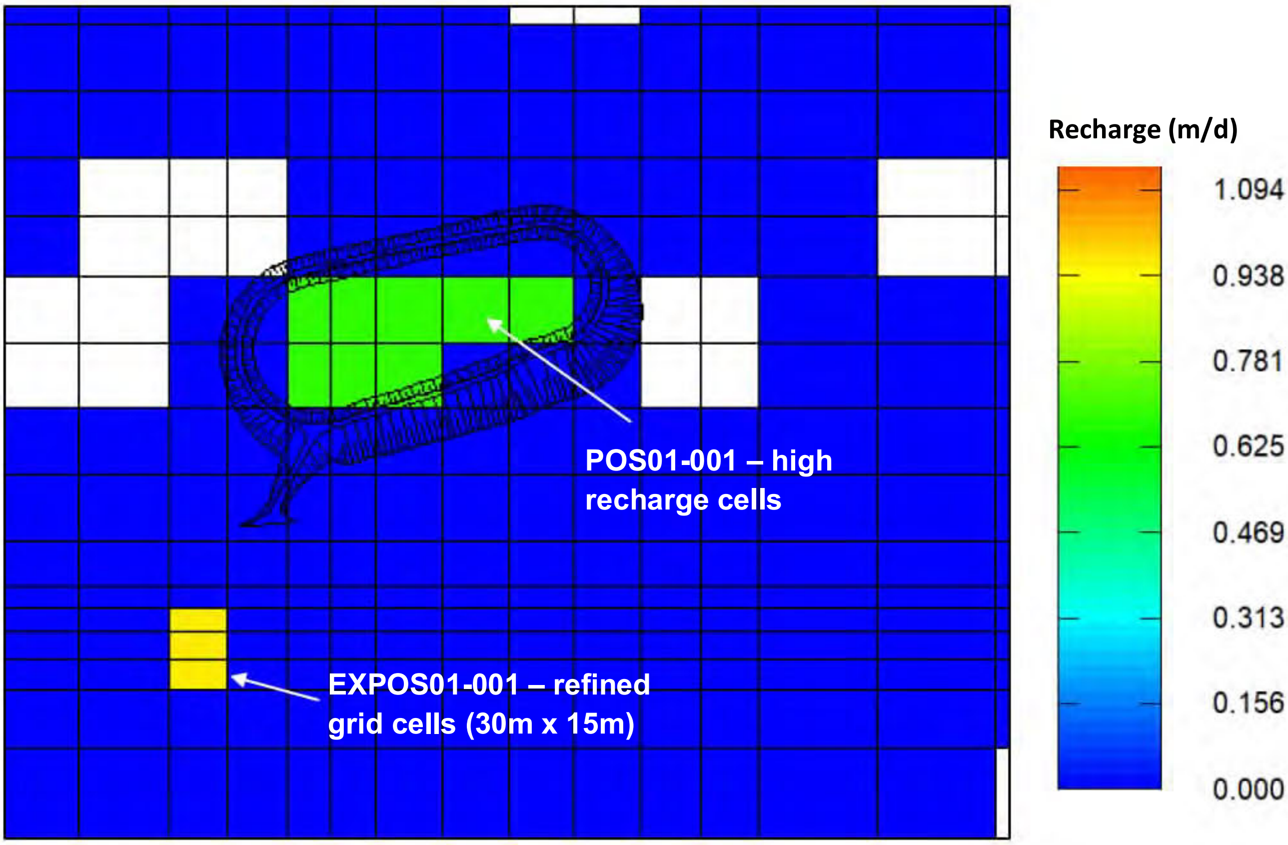
Plate 6.1 MODFLOW hydraulic conductivity zones



6.2.2 The model is a block-centred finite difference model (Cascade, 2020d), with cells that are 60m x 60m (area = 3,600m^2). MODFLOW package is set-up as a saturated zone flow model, thus cells in the unsaturated zone are inactive. To simulate infiltration basins, zones of increased recharge have been applied at the locations of the nine basins. In MODFLOW, recharge is applied to the highest active layer to bypass the inactive cells in the unsaturated zone cells. Re-saturation has been activated to enable unsaturated cells to become wet when mounding occurs at the water table from the zones of increased recharge.

6.2.3 As employed in the analytical assessment, it has been assumed that infiltration would occur through the entire base of each basin, rather than just the trenches. Around the infiltration basin, the model grid was refined to reduce cell size for smaller basins and to fix model convergence issues found when large infiltration rates are applied (see Plate 6.2).

Plate 6.2 Areas of increased recharge at the infiltration basins. White cells indicate areas of no recharge, and blue cells are areas of baseline recharge.



6.3 Infiltration scenarios

6.3.1 Scenarios 1 to 3 have been modelled; see Section 5.3 for descriptions of the scenarios.

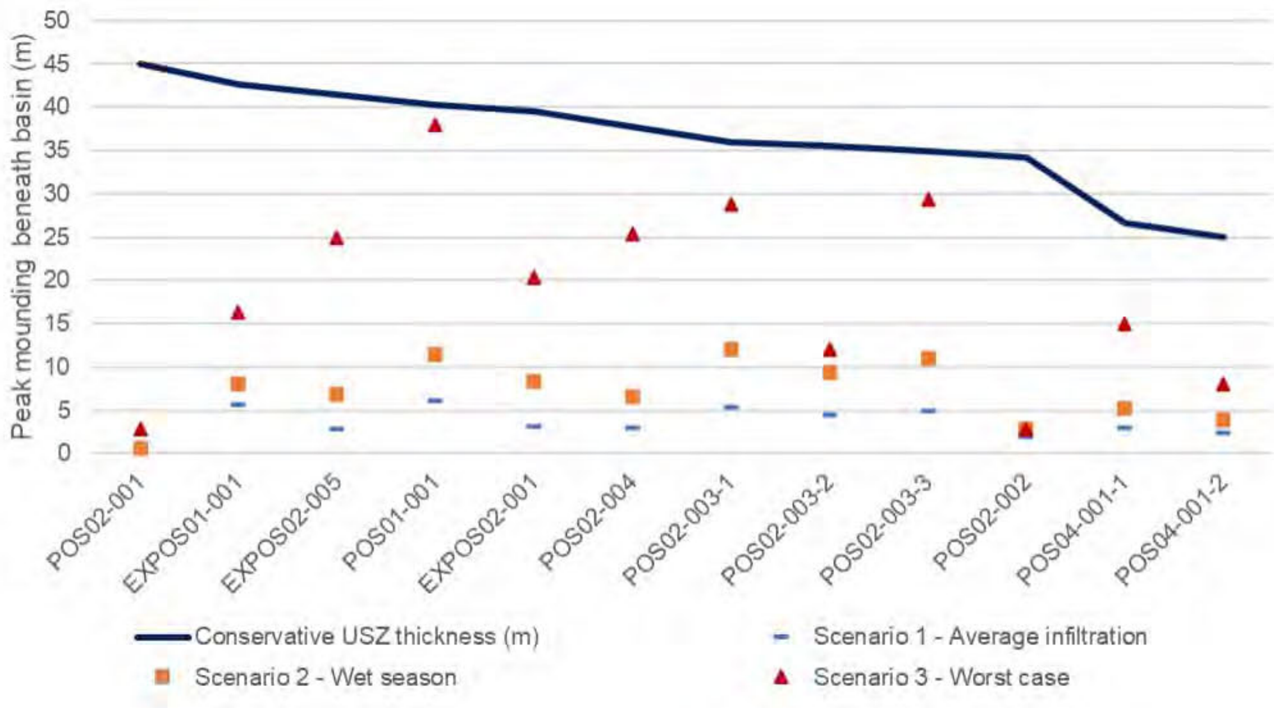
6.3.2 To simulate continuous average infiltration, scenario 1 has been run using a steady state model. Scenarios 2 and 3 require transient stress periods to simulate time-constrained infiltration periods. To run transient simulations, storage values are added into the model. Specific storage (S_s) and specific yield (S_y) for all Chalk layers were set at 0.0008 and 0.02 respectively.

6.4 Results

6.4.1 Head files are simulated for all model timesteps. The timesteps at the end of each scenario are exported from Groundwater Vistas and processed in QGIS to compute peak groundwater mounding contours. 3D modelling has been used to assess the cumulative impact on the water table from the nine infiltration basins to the south of the river.

6.4.2 Peak mounding levels beneath the infiltration basins for both scenarios are plotted in Plate 6.3 (sorted by unsaturated zone thickness).

Plate 6.3 Simulated peak mounding levels for all scenarios



6.4.3 For scenario 1, results suggest that mounding would range from 6.1m to 0.7m. The levels of mounding have been contoured in Plate 6.4. The 0.5m contour extends north of the South Portal, approximately 800m south of the Ramsar site edge. This is attributed to the large infiltration volumes from POS02-003 and less so from POS04-001.

6.4.4 Mounding contours for scenario 2 (wet season) are illustrated in Plate 6.5. The highest level is beneath POS02-003 at 12.0m, and the smallest beneath POS02-001 at 0.7m, the smallest soakaway. With the increase in mounding levels and the reduced time period (180 days), the contours for a wet season are steeper and do not extend laterally to the same extent as the contours for scenario 1 because the mounding does not reach steady state.

6.4.5 Scenario 3 mounding contours after infiltration from a 1 in 100-year storm event (24 hours) are shown in Plate 6.6. Contours are very steep around all infiltration basins, with the lateral spread being very small due to the small time period. Mounding levels peak beneath POS01-001 at 38.0m. The hydraulic gradient is approximately 0.4 from the peak to the base of the mound. Under these conditions, mounding levels do not exceed the unsaturated zone thickness. However, at basin POS01-001, levels are within 2.25m of the basin invert level.

Plate 6.4 Scenario 1, steady state average mounding contours

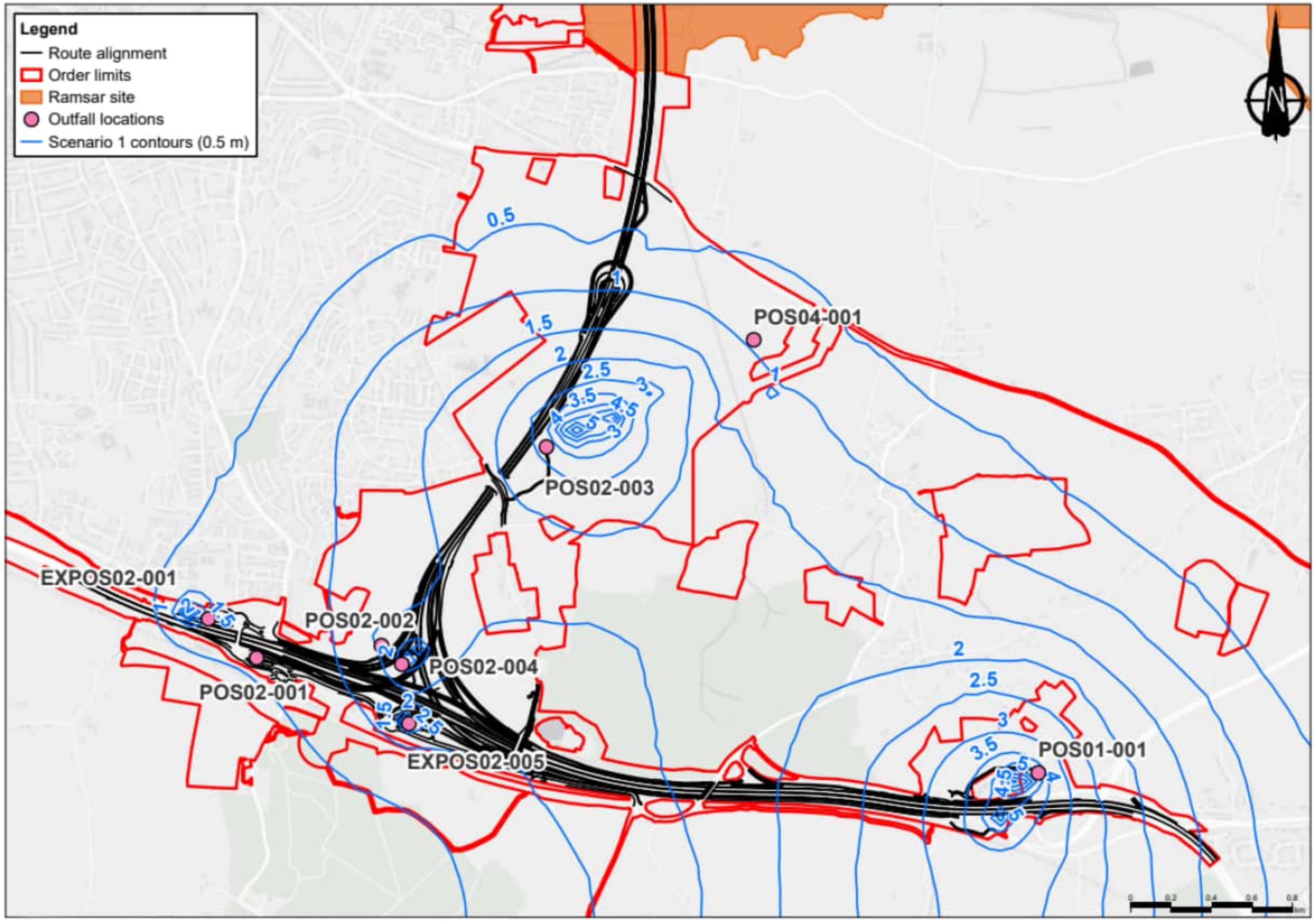


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Plate 6.5 Scenario 2, mounding contours at the end of a wet season

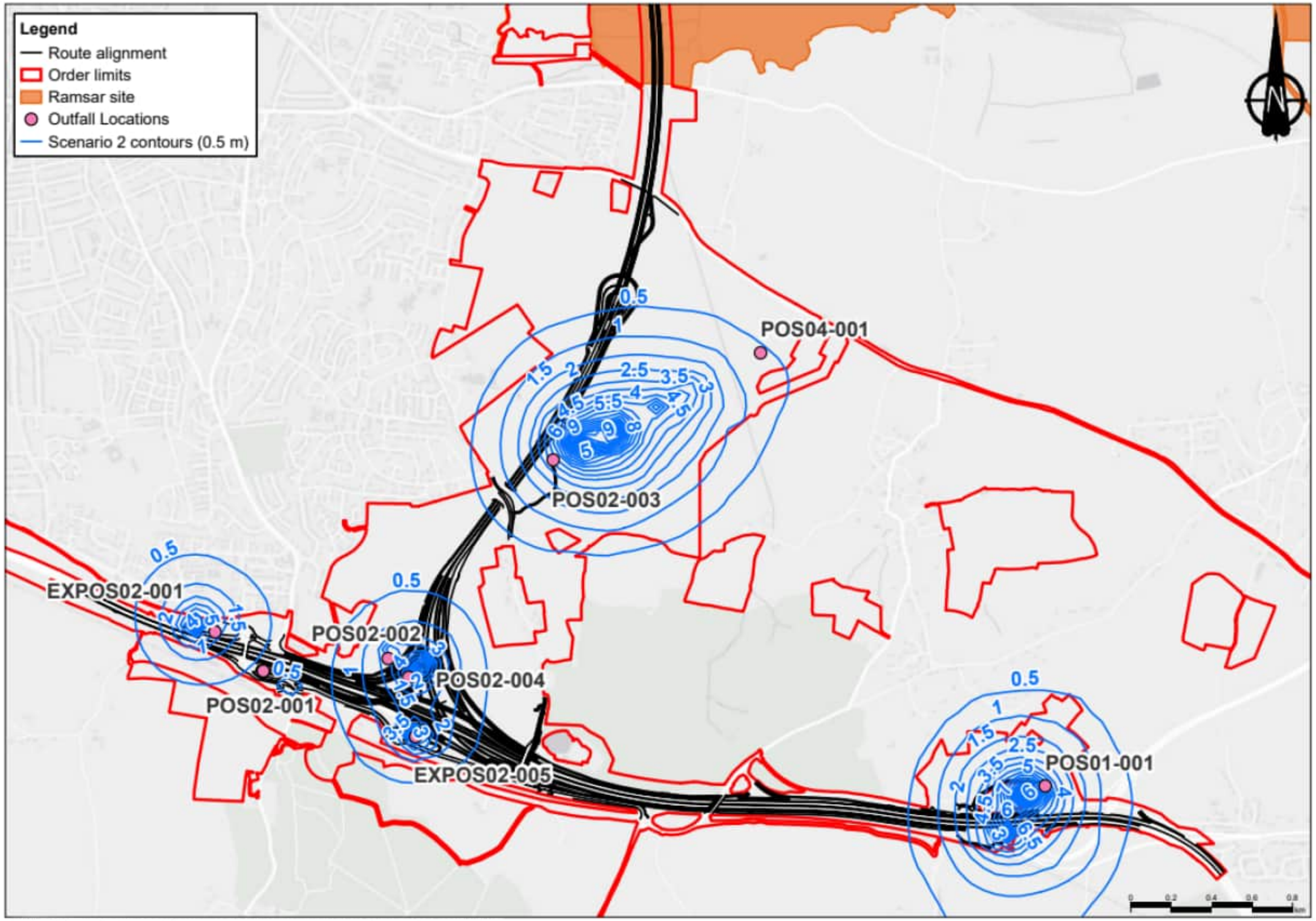
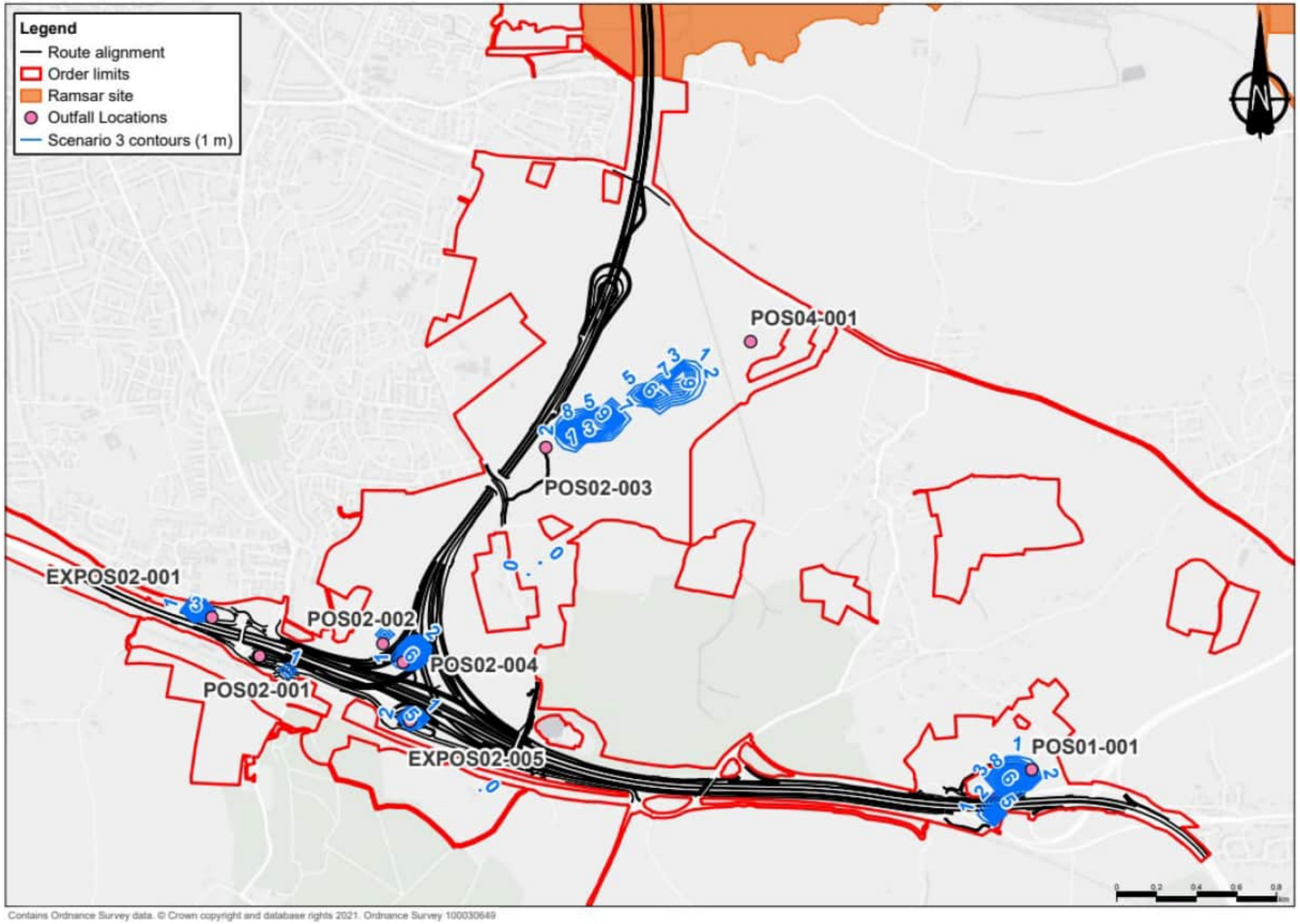


Plate 6.6 Scenario 3, worst-case mounding contours



6.5 Limitations of the 3D model

6.5.1 Mounding predictions using MODFLOW are constrained by the following considerations, but the limitations below mean that the mounding results are consequently more conservative.

d. At the south of the Project, due to the geomorphology of the North Downs, the water table is very deep. Because of the model layering, the water table is located in the lower structured Chalk (see Plate 6.2). This layer has a lower hydraulic conductivity than the above unstructured Chalk (based on assumptions of the 3D model). Since recharge boundary conditions have been used to mimic infiltration basins, the infiltration is applied to the highest active layer (saturated zone model), which for all basins, other than POS04-001, is the structured Chalk, not the unstructured Chalk. This is a misrepresentation of the actual infiltration pathway. As the infiltration continues, the mounding increases, and through ‘rewetting’, cells above become saturated and mounding progresses into the unstructured Chalk. The levels of mounding over a short duration (scenario 3) are likely to be overestimated because of this initial infiltration onto the less conductive structured Chalk.

e. Many of the infiltration basins have been designed to run along the dry valleys to ensure maximum possible infiltration rates are achieved. In the model, they are represented as high permeability zones at the surface and shallow Chalk depths. However, as above, the high permeability zones representing the dry valley are not saturated under steady state pre-operation conditions. This may also mean that the mounding predictions are overestimated.

7 Pollution assessment

7.1 Introduction

7.1.1 Pollution to groundwater from routine highway runoff has been assessed using HEWRAT (Cascade, 2020c) (Annex O).

7.1.2 The results of the HEWRAT simple groundwater quality and routine runoff pollution assessment show that all infiltration basins, and Swale 2, have a risk rating of medium (medium risk of groundwater quality degradation). Therefore, Design Manual for Roads and Bridges LA 113 Road Drainage and the Water Environment (Highways England, 2020b) requires a detailed assessment to be completed.

7.2 Approach

7.2.1 To further assess the potential risk of groundwater contamination from infiltration of routine highway runoff, a detailed assessment has been completed using the groundwater simulation software ConSim, developed on behalf of the Environment Agency (Environment Agency and Golder Associates (UK) Ltd, 2018).

7.2.2 ConSim adopts a tiered approach based on the Remedial Targets Methodology publication (Environment Agency, 2006). The methodology consists of up to four assessment levels which progressively follow the pathway from the contaminant source through to the receptor. The four levels of assessment are detailed in the ConSim 2.5 Manual (Environment Agency and Golder Associates (UK) Ltd, 2018).

7.3 Source, pathway, receptor

7.3.1 The ‘source’ of contamination is the release of routine highway runoff from drainage infiltration features (soakaways and swale). Routine highway runoff contains elevated levels of soluble and particulate pollutants. A study carried out by Crabtree *et al*. (2008) summarised a list of six significant pollutants found in routine runoff:

a. Copper and zinc (total and dissolved)

b. Cadmium, fluoranthene, pyrene and poly aromatic hydrocarbons (total only)

7.3.2 In this assessment, only copper, zinc, lead and chloride have been assessed. High concentrations of chloride are found in highway runoff as a result of de-icing during winter months (de-icing agent being sodium chloride). Cadmium, fluoranthene and pyrene, as well as total polycyclic aromatic hydrocarbons, have been excluded from the assessment because they are only significant pollutants as particulate matter (total), and the dissolved concentrations in runoff are negligible (see Table 4.4 in Crabtree *et al*. (2008)). It is assumed that any particulate matter in runoff would settle out in the sediment forebays and infiltration basins before percolation to the ground.

7.3.3 There are two pathways to contamination: the unsaturated zone and the saturated zone.

7.3.4 There are three potential receptors:

1. The Ramsar site located approximately 1km north of the South Portal
2. Licensed groundwater abstractions to the east of the Project/A2/M2 approach (Southern Water Ltd licensed potable water supply
3. Licensed groundwater abstraction to the north-west of the South Portal (Southern Water Ltd licensed potable water supply)

7.3.5 As explained in Section 2.2, groundwater seepage is likely to occur along the southern edge of the Ramsar site. However, this seepage appears to be very low input compared to the predominance of rainwater to the Ramsar site.

7.4 Methodology

7.4.1 The Ramsar site and licensed groundwater abstractions are all down gradient of the contamination source, hence the pathway of contamination is the unsaturated and saturated zone. To assess contaminant transport along both pathways, a Level 3 assessment is needed. Level 3 considers whether the following mechanisms are sufficient in reducing pollutant concentrations to acceptable levels at the receptors (Environment Agency, 2006):

a. Attenuation of pollutants within the unsaturated zone and dilution of pollutants by groundwater flow at the point of maximum dilution (Level 2 assessment).

b. Attenuation of pollutants down hydraulic gradient of the source (Level 3 assessment). Attenuating effects of degradation, retardation and dispersion are considered in both unsaturated and saturated zones (Environment Agency and Golder Associates (UK) Ltd, 2018).

7.4.2 Regarding ‘acceptable levels’ at the receptors, both Environmental Quality Standards (EQS) and Drinking Water Standards (DWS) values have been used. For the Ramsar site, EQS values for pollutants in a transitional and coastal environment have been used, for waters with high calcium carbonate content (hardness). At the licensed groundwater abstractions, pollutant concentrations have been screened against DWS.

7.4.3 Each receptor requires compliance points at which concentrations of the pollutants have reduced to the required levels (see Plate 7.1). The compliance point for the Ramsar site is the southern site boundary nearest to the northernmost source of contamination, POS04-001. Around licensed groundwater abstractions used for public drinking water supply, source protection zones (SPZ) are defined by the Environment Agency to show the risk of contamination from any activities that might cause pollution (Environment Agency, 2020). The compliance points for the licensed groundwater abstractions in this assessment are the edge of SPZ 1, the inner zone that is defined as the 50-day travel time from any point below the water table to the abstraction borehole (Environment Agency, 2020). Compliance points at the SPZ 2 boundaries have also been added for both licensed groundwater abstractions.

7.4.4 ConSim compliance points:

a. Ramsar site edge – X 568633, Y 173272

b. Ramsar site approach – X 568654, Y 1726525

c. Eastern SPZ 1 – X 570429, Y 170098

d. Eastern SPZ 2 – X 570001, Y 169754

e. North-west SPZ 1 – X 565369, Y 172686

f. North-west SPZ 2 – X 565651, Y 171297

7.4.5 The ConSim model domain is shown in Plate 7.2, where the green lines represent the Project route and the purple lines represent the earthworks. The model is used to compute the cumulative impact on receptors from all infiltration basins as well as the individual risk posed by each source.

Plate 7.1 Locations of licensed groundwater abstractions, SPZs and the Ramsar site

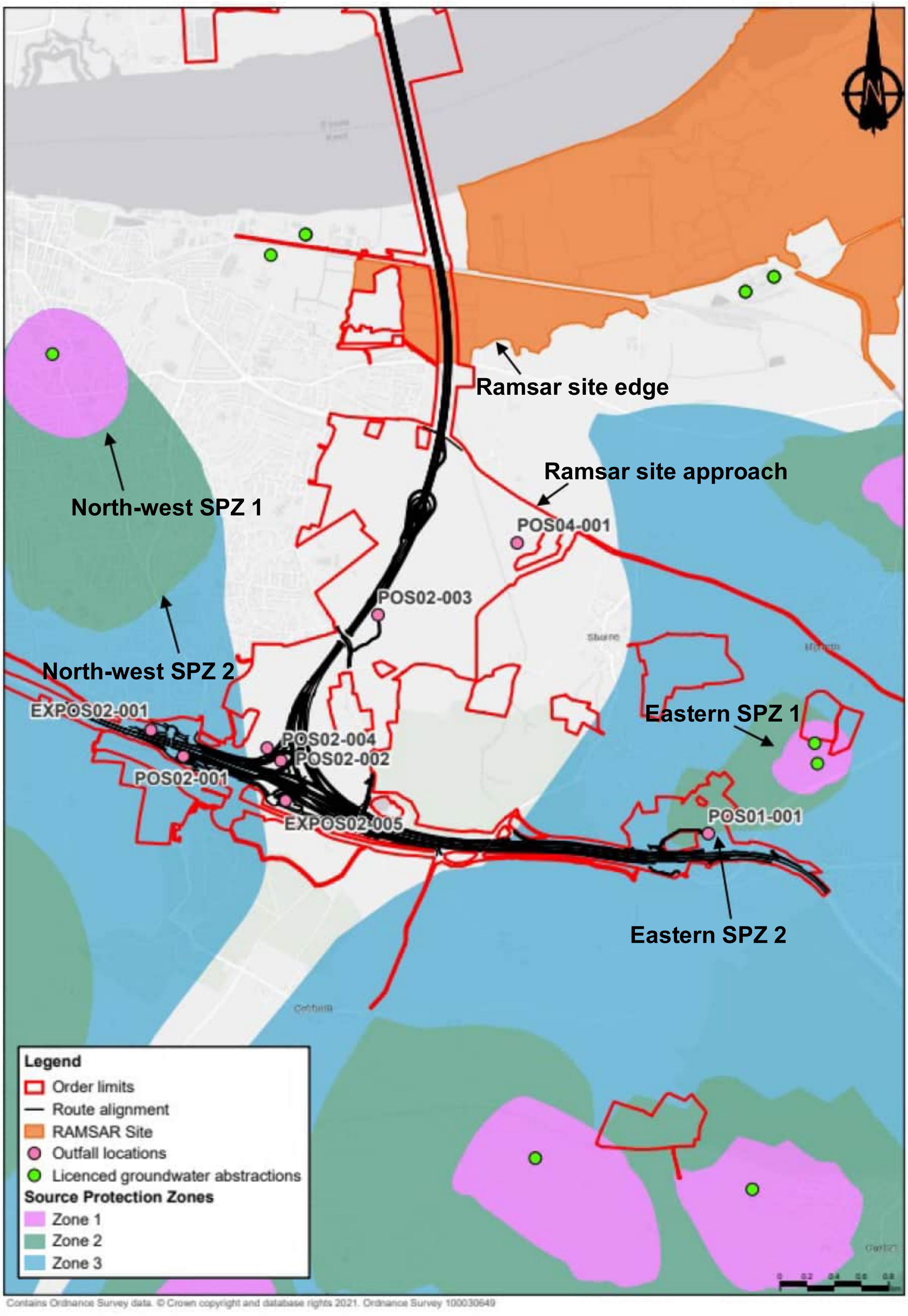
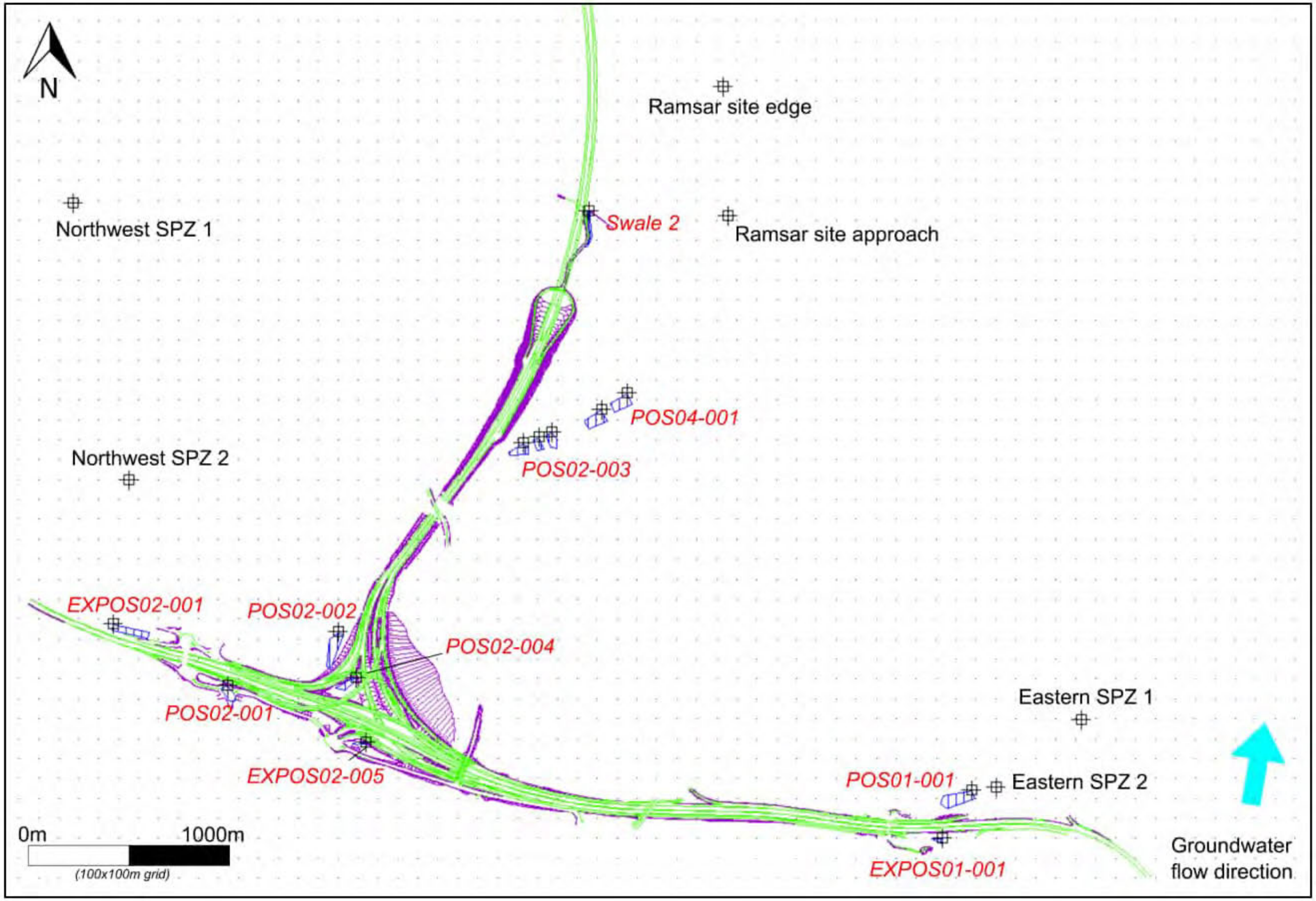


Plate 7.2 ConSim model domain (100m x 100m grid spacing)



7.5 ConSim input data

7.5.1 Table 7.1 provides a summary of sources that have been used to generate the data required as input to the ConSim detailed pollution assessment.

7.5.2 A full list of model input values is included in Annex D.

Table 7.1 Input data sources

Data	Source
Soakaways and swale parameters (source)	
Impermeable drainage catchment area	Information obtained from A2/M2 – LTC A2 Junction – Gravesend Link drainage report (Cascade, 2019a).
Maximum required drainage infiltration rate	Worst-case infiltration rates (scenario 3) – see Section 5.3.
Initial pollutant concentration at source; dissolved copper, dissolved lead, dissolved zinc and chloride.	Event mean concentrations of pollutants in highway runoff have been obtained from Highways Agency report (Crabtree *et al.*, 2008).
Source thickness	Thickness based on infiltration basin trench depth, obtained from the A2/M2 – LTC A2 Junction – Gravesend Link drainage report (Cascade, 2019a).
Source dimensions	X, Y vertices obtained from infiltration basin shapefiles.
Unsaturated zone parameters (pathway)	
Unsaturated zone thickness	Calculated using infiltration basin invert levels and groundwater contouring produced by Cascade and based on Environment Agency 2014 groundwater level data.
Runoff recharge	Precipitation data obtained from the CHESS meteorological database multiplied by runoff coefficient for asphalt pavement (0.9) (Garber and Hoel, 2009).
Vertical hydraulic gradient	ConSim 2.5 manual (Environment Agency and Golder Associates (UK) Ltd, 2018).
Vertical dispersivity	ConSim 2.5 manual – 10% of the USZ thickness.
Dry bulk density of material	Project Phase 1b and Phase 2 Package A ground investigation data.
Partition coefficients for unsaturated zone	Conservative partition coefficient values have been obtained from Environment Agency (2005) science report on Kd test methods.
Contaminant half-life	Conservative values based on professional judgement.
Hydraulic conductivity	Cascade Ramsar numerical modelling technical report (see Section 6). A log-normal distribution has been applied.
Water-filled porosity and effective porosity	Project Phase 1b ground investigation nuclear magnetic resonance logging

Data	Source
Saturated zone input parameters (pathway)	
Background contaminant concentration in groundwater beneath the site	Project Phase 2 Package A groundwater monitoring data
Saturated aquifer thickness	Conservative uniform distribution based on the typical thickness of transmissive Chalk in the UK (Allen *et al*., 1997).
Aquifer hydraulic conductivity	Cascade Ramsar numerical modelling technical report (see Section 6) – a log-normal distribution has been applied.
Hydraulic gradient	Calculated using contoured 2014 Environment Agency groundwater levels
Effective porosity	Project Phase 1b ground investigation NMR logging
Dry bulk density of aquifer material	Project Phase 1b and Phase 2 Package A ground investigation data
Half-life for degradation of contaminant in water	Pollutants in this study are stable
Partition coefficients for saturated zone	Assumed to be the same as unsaturated zone
Dispersivity parameters	ConSim rule of thumb – longitudinal = 10% of pathway length; transverse = 30% of longitudinal dispersivity
Receptor parameters	
Target concentration of contaminants	Environmental Quality Standards Directive and DWS
Distance to compliance point; Ramsar site and licensed groundwater abstractions	Measured using in-house Geographic Information System (GIS) viewer

7.6 Results and interpretation

7.6.1 A Level 3 assessment has been carried out to simulate the cumulative concentration of the four pollutants after 120 years of operation for the nine infiltration basins. A duration of 120 years is in line with the design life of the Project road. ConSim output concentration statistics are based on the probabilistic distributions of the model inputs. The concentrations at the Ramsar site and licensed groundwater abstraction compliance points are summarised in Table 7.2, Table 7.3 and Table 7.4.

Table 7.2 Simulated concentrations at the Ramsar site compliance points after 120 years of operation (SD = Standard deviation)

Pollutant	EQS (mg/l)	Concentration at Ramsar site edge (mg/l)			
		Mean	Min	Max	SD
Chloride	250	144.139	136.505	151.400	2.572
Copper	0.028	0.0189	0.0180	0.0196	0.0002
Lead	0.025	0.0025	0.0021	0.0029	0.0002
Zinc	0.040	0.0354	0.0322	0.0377	0.0008

Pollutant	EQS (mg/l)	Concentration on approach to Ramsar site (mg/l)			
		Mean	Min	Max	SD
Chloride	250	100.125	92.493	109.197	3.194
Copper	0.028	0.0151	0.0159	0.0144	0.0003
Lead	0.025	0.0025	0.0022	0.0026	6.87×10^{-5}
Zinc	0.040	0.0218	0.0193	0.0246	0.001

Table 7.3 Simulated concentrations at the Eastern SPZ 1 and SPZ 2 compliance points after 120 years of operation

Pollutant	DWS (mg/l)	Concentration at Eastern SPZ 1 (mg/l)			
		Mean	Min	Max	SD
Chloride	250	58.9789	56.399	63.435	1.552
Copper	2	0.0114	0.0112	0.0118	0.0001
Lead	0.01	0.0021	0.0021	0.0022	1.70×10^{-5}
Zinc	5	0.0088	0.0080	0.0102	0.0005

Pollutant	DWS (mg/l)	Concentration at Eastern SPZ 2 (mg/l)			
		Mean	Min	Max	SD
Chloride	250	117.290	73.705	206.678	30.216
Copper	2	0.0166	0.0127	0.0247	0.0027
Lead	0.01	0.0027	0.0022	0.0037	0.0003
Zinc	5	0.0270	0.0135	0.0557	0.0096

Table 7.4 Simulated concentrations at the North-west SPZ 1 and SPZ 2 compliance points after 120 years of operation

Pollutant	DWS (mg/l)	Concentration at North-west SPZ 1 (mg/l)			
		Mean	Min	Max	SD
Chloride	250	107.530	99.496	115.195	4.277
Copper	2	0.0157	0.0114	0.0164	0.0005
Lead	0.01	0.0021	0.0021	0.0025	2.94×10^{-5}
Zinc	5	0.0242	0.0210	0.0266	0.0014

Pollutant	DWS (mg/l)	Concentration at North-west SPZ 2 (mg/l)			
		Mean	Min	Max	SD
Chloride	250	162.204	154.423	167.175	2.432
Copper	2	0.0207	0.0200	0.0211	0.0002
Lead	0.01	0.0029	0.0021	0.0033	0.0003
Zinc	5	0.0416	0.0391	0.0432	0.0008

7.6.2 All simulated pollutants are below the screening EQS and DWS values at each compliance point after 120 years of operation. This indicates that the release of highway runoff from the infiltration basins would have no significant impact on the groundwater quality and therefore no impact on the three potential receptors.

7.6.3 It should be noted that the modelling carried out is highly conservative. Due to limitations in the ConSim software, the soakaways are modelled to release highway runoff continuously (steady state), rather than only being active during periods of rainfall (ConSim does not allow transient simulations). The modelling also does not consider any additional attenuation of pollutants that would occur in the sediment forebays, vortex grit separators (in the cascading basins and large infiltration basins), and vegetated infiltration basins. The vegetation in the infiltration basins can reduce pollutant concentrations of metals (e.g. copper and zinc) (Highways England, 2020a). In addition, infiltration of water helps remove dissolved metals and solids (Highways England, 2020a). This attenuation is not included in the assessment, and the predicted concentrations of pollutants at the receptor are likely to be exaggerated.

8 Conclusions

8.1.1 This document presents a feasibility assessment for the proposed drainage infiltration features (nine soakaways and one swale) to the south of the River Thames as part of the Project highway drainage network. The assessment includes a review of potential infiltration rates achievable for the Chalk, a detailed assessment on potential groundwater mounding, and a pollution risk assessment using ConSim 2.5.

8.1.2 The potential infiltration rates achievable for the Chalk have been reviewed on a theoretical basis using literature values and using site-specific soakaway testing carried out as part of the Project Phase 2 ground investigation. On a theoretical basis, Chalk infiltration rates should be in the order of 10^{-6}m/s to 10^{-2}m/s, with a likely geomean value of $1.8x10^{-4}$m/s. Soakaway testing results show that onsite infiltration rates range from $9.2x10^{-6}$m/s to $1.4x10^{-3}$m/s, with a geomean value of $7.2x10^{-5}$m/s.

8.1.3 Groundwater mounding has been predicted using the Hantush (1967) analytical solution and numerical 3D modelling. For both assessment techniques, three infiltration stress periods have been modelled. The worst-case scenario, infiltration from a 1 in 100-year storm, results in the greatest mounding. Assuming a conservative hydraulic conductivity for the Chalk (1.5m/d), the worst-case mounding levels are small relative to the extensive unsaturated zone thickness, so the risk of basin failure is small. When the hydraulic conductivity is increased to the geometric mean (6.6m/d), mounding levels are reduced significantly at all infiltration basins and the impact on groundwater levels and flows would be minimal.

8.1.4 The 3D modelling predicts the maximum height of mounding at each basin but is also used to simulate cumulative impact of the soakaways, with the steady state mounding (scenario 1, average infiltration) extending laterally across the Chalk aquifer with a shallow hydraulic gradient. Results from the 3D model suggest that none of the soakaways would fail for the three scenarios modelled.

8.1.5 Detailed design will confirm the final geometry and storage volumes required, with reference to hydraulic properties of the Chalk.

8.1.6 The detailed pollution risk assessment carried out using ConSim is to determine whether the infiltration of routine highway runoff would degrade the groundwater quality and increase pollutant levels above EQS and DWS screening values. Routine highway runoff typically contains heavy metals (e.g. lead, zinc and copper) from car degradation and, during winter months, high levels of sodium chloride from road salt application (de-icing). Three potential receptors have been identified to be at risk from the infiltration basins: the Ramsar site to the south of the River Thames, and licensed groundwater abstractions to the north-west and east of the Project route south of the Thames. ConSim models the individual and cumulative impact on each receptor from the infiltration basins. Cumulative results indicate that pollutant levels would be below the EQS values at the Ramsar site, and below the DWS at the edge of SPZ 1 and SPZ 2 (both east and north-west abstractions) after 120 years of operation. Therefore, the infiltration basins would have no significant impact on the identified receptors.

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Cascade (2020c). Operational Drainage Pollution Risk Assessment (Doc. Ref. HE540039-CJV-GEN-GEN-TNT-GEO-00126).

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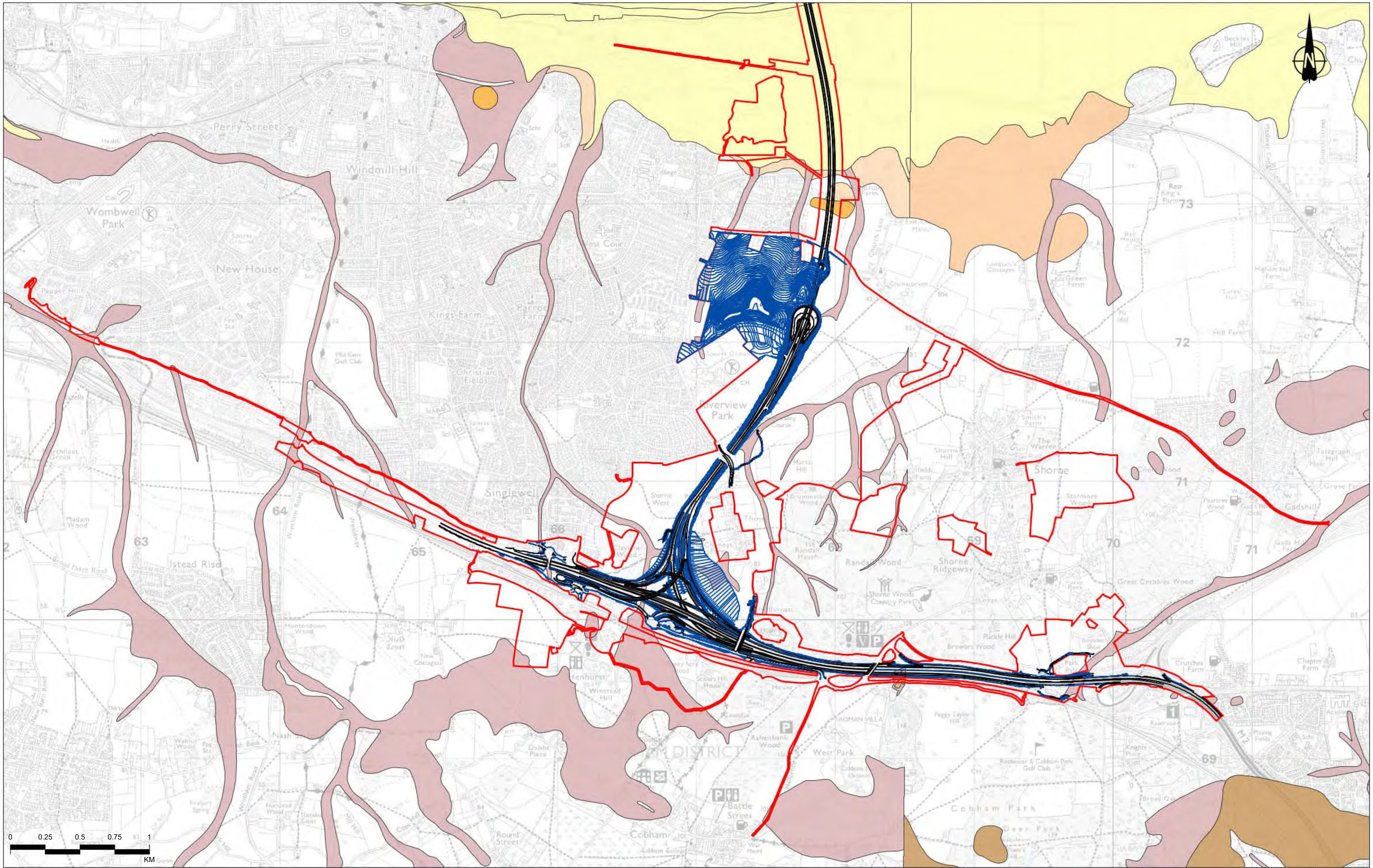
Annexes

Annex A Superficial and bedrock geology maps

Drawing Numbers

HE540039-CJV-GEN-GEN-MAP-GEO-00052-Superficial Geology (South of the River)

HE540039-CJV-GEN-GEN-MAP-GEO-00051-Bedrock Geology (South of the River)



Rev	Status	Rev. Date	Purpose of revision	Drawn	Chck'd	Apprv'd
P01	S8	01/09/2022	For Information	SW	CB	FF

Legend

- Route alignment
- Earthworks
- Order Limits

BGS Geology 50k: Superficial Deposits

- Alluvium
- Tidal River Or Creek Deposits
- Lynch Hill Gravel Member
- Taplow Gravel Formation
- Head
- Peat
- River Terrace Deposits, 1
- River Terrace Deposits, 2
- Clay-With-Flints Formation
- OS 25k: Greyscale
- OS 50k: Greyscale

Client: national highways

Project: LOWER THAMES CROSSING

Status: DCO APPLICATION

Application Document Number: TR010032/APP/6.3

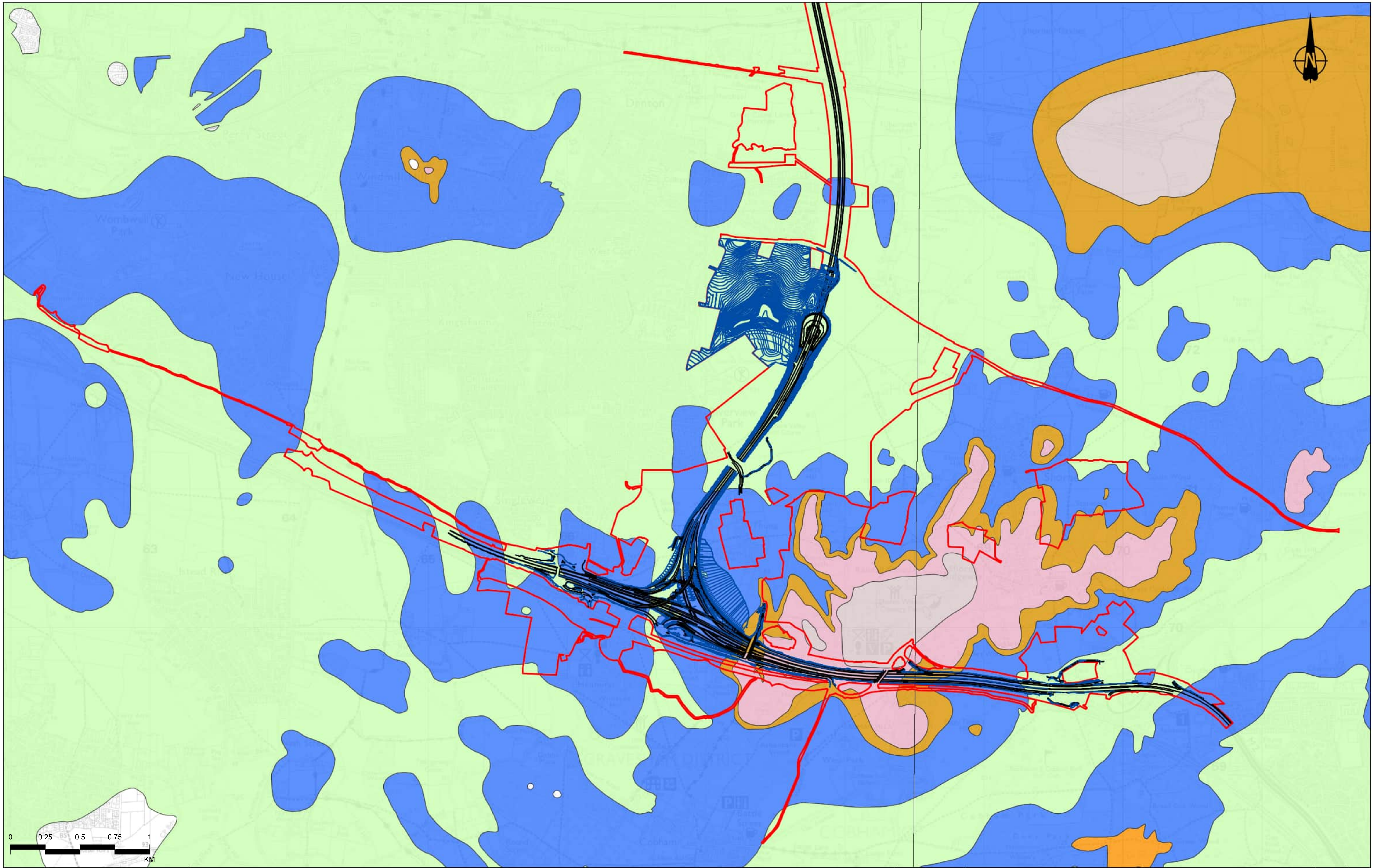
Original Size: A3

Revision: P01

Scale: 1:24,663

Drawing Title: BGS 50K Superficial Geology (South of River)

Drawing Number: HE540039-CJV-GEN-GEN-MAP-GEO-00052



Legend

- Route alignment
- Earthworks
- Order Limits

BGS Geology 50k: Bedrock Geology

- Lenham Formation
- Harwich Formation
- London Clay Formation
- Lambeth Group
- Thanet Formation
- Seaford Chalk Formation
- Lewes Nodular Chalk Formation, Seaford Chalk Formation And Newhaven Chalk Formation (Undifferentiated)
- OS 25k: Greyscale
- OS 50k: Greyscale

Rev	Status	Rev. Date	Purpose of revision	Drawn	Chck'd	Apprv'd
P01	S8	01/09/2022	For Information	SW	CB	FF

Client: national highways

Project: LOWER THAMES CROSSING

Status: DCO APPLICATION

Original Size: A3

Revision: P01

Application Document Number: TR010032/APP/6.3

Scale: 1:24,662

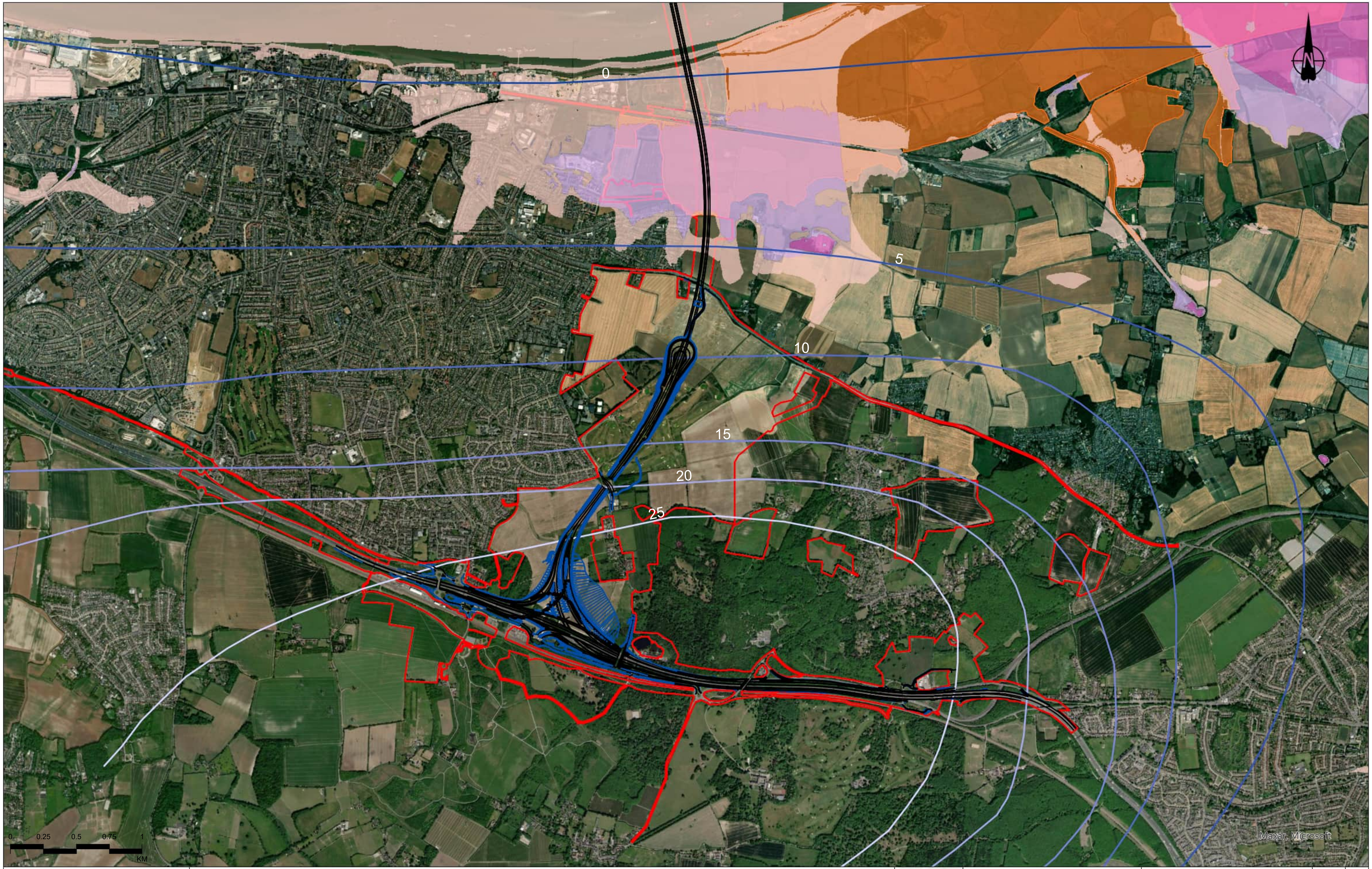
Drawing Title: BGS 50K Bedrock Geology (South of River)

Drawing Number: HE540039-CJV-GEN-GEN-MAP-GEO-00051

Annex B Groundwater flooding potential and Chalk groundwater contours (south of the river)

Drawing Number

HE540039-CJV-GEN-GEN-MAP-GEO-00050



Legend

- Route alignment
- Earthworks
- Order Limits
- Ramsar Site

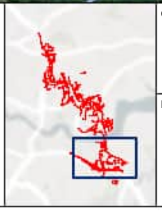
GroundWater Flood Risk - 5m

- High
- Moderate
- Low

Contours of the Groundwater Level in Chalk Aquifer in February 2014

- 25
- 20
- 15
- 10
- 5
- 0
- -5

Rev	Status	Rev. Date	Purpose of revision	Drawn	Chck'd	Apprv'd
P01	S8	23/02/2022	For Information	SW	CB	FF



Client: national highways

Project: LOWER THAMES CROSSING

Status: DCO APPLICATION

Application Document Number: TR010032/APP/XXXX

Original Size: A3

Revision: P01

Scale: 1:26,000

Drawing Title: Groundwater Flooding Potential and Chalk Groundwater contours (South of River)

Drawing Number: HE540039-CJV-GEN-GEN-MAP-GEO-00050

Annex C Analytical assessment input parameters

	CALCULATIONS	DOCUMENT No HE540039-CJV-GEN-GEN-TNT-GEO-00219 - Annex M-C
OFFICE [redacted]	PROJECT TITLE **Lower Thames Crossing**	
SUBJECT **Inifltration basins analytical mounding assessment - South of the River Thames**		SHEET No **1 of 12**

ISSUE	TOTAL SHEETS	AUTHOR	DATE	CHECKED BY	DATE	Revision change	COMMENTS
1	12	[redacted]	02/04/20	[redacted]	02/04/20	NA	
2	12	[redacted]	24/06/20	[redacted]	24/06/20	Updates to infiltration basin catcments, infiltration rates and updates to all mounding calculations	
3	12	[redacted]	09/06/21	[redacted]	02/08/2021	POS04-001 infiltration basin area, change to unsaturated zone thicknesses and updated geomean permeability.	

DESIGN BASIS STATEMENT (Inc. sources of info/data, assumptions made, standards, etc.)

Summary

Analytical assessment of the potential mounding in the Chalk aquifer from the operation of 9 infiltration basins along the LTC route. This detailed assessment has been conducted by the LTC hydrogeology team, part of the tunnels and systems group.

General approach:

The calculations presented here accompany the technical note HE540039-CJV-GEN-GEN-TNT-GEO-00219. The analytical assessment uses the Hantush (1967) solution, as included in Carleton (2010). The solution uses an equaton descirbing the "growth and decay of groundwater mounds in response to uniform percolation".

Carleton, G. B. (2010) Simulation of Groundwater Mounding Beneath Hypothetical Stormwater Infiltration Basins. *US Geological Survey Scientific Investigations Report 2010-5102,* 64.

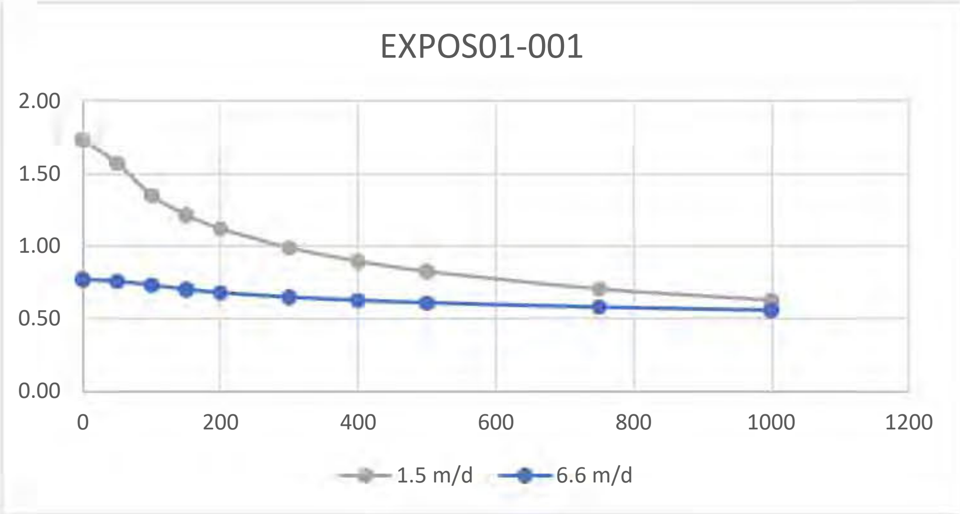
Hantush, M. S. (1967). Growth and decay of groundwater mounds in response to uniform percolation. *Water Resources Research, vol 3,* 227-234.

Infiltration basin input table										Results K = 1.5 m/d			Results K = 6.6 m/d		
Pond	GWL (maOD)	IL (maOD)	Conservative USZ thickness (m)	Basin bottom area (m^2)	x (m)	y (m)	Average infiltration (m/d)	Wet season infiltration (m/d)	Worst case infiltration (m/d)	Scenario 1 - Average (m)	Scenario 2 - Wet season (m)	Scenario 3 - Max (m)	Scenario 1 - Average (m)	Scenario 2 - Wet season (m)	Scenario 3 - Max (m)
EXPOS01-001	25	67.65	42.65	1230	17.54	17.54	0.078	0.255	1.054	1.734	4.624	7.484	0.770	1.704	2.529
EXPOS02-001	24	63.5	39.5	1050	16.20	16.20	0.106	0.344	0.823	2.094	5.448	5.328	0.983	2.108	1.757
EXPOS02-005	26	67.39	41.39	626.408	12.51	12.51	0.098	0.319	1.796	1.407	3.492	7.658	0.784	1.559	2.490
POS01-001	25	65.25	40.25	6559.293	40.49	40.49	0.033	0.106	0.719	2.832	7.780	14.582	0.851	2.323	5.970
POS02-001	26	71	45	243.905	7.81	7.81	0.073	0.237	0.902	0.684	1.476	1.955	0.499	0.887	0.582
POS02-002	26	60.2	34.2	1376.125	18.55	18.55	0.019	0.063	0.239	0.464	1.310	1.963	0.196	0.454	0.644
POS02-003-1	15	51	36	4361.826	33.02	33.02	0.041	0.132	0.715	2.482	6.868	11.611	0.790	2.082	4.479
POS02-003-2	15	50.5	35.5	2389.946	24.44	24.44	0.041	0.132	0.683	1.518	4.214	7.750	0.549	1.340	2.764
POS02-003-3	15	50	35	2800.686	26.46	26.46	0.041	0.132	0.848	1.724	4.797	10.438	0.599	1.497	3.829
POS02-004	26	63.8	37.8	4366.14	33.04	33.04	0.031	0.102	0.632	1.893	5.415	10.379	0.599	1.619	3.985
POS04-001-1	14	40.7	26.7	7450	43.16	43.16	0.011	0.036	0.304	1.081	3.137	7.038	0.315	0.896	2.860
POS04-001-2	13	38	25	6900	41.53	41.53	0.012	0.036	0.337	1.103	3.179	7.452	0.324	0.909	2.998

Aquifer thickness, b	30	m
Conservative K	1.5	m/d
Geomean K	6.6	m/d

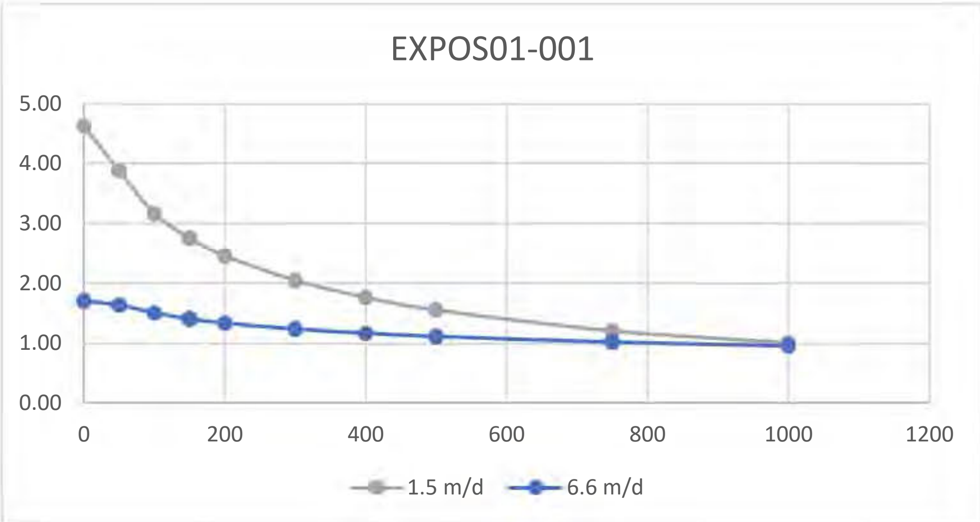
EXPOS01-001	Scenario 1		Q (m^3/d)	a (m^2)	I (m/d)
I	0.07824	m/day	96.23506	1230	0.078
S_y	0.02				
K	Varies	m/day			
x	17.53568	m			
y	17.53568	m			
t	365	days			
hi(0)	30	m			
IL	67.65	m aOD			

		Mounding (m)	
EXPOS01-001	Distance	1.5 m/d	6.6 m/d
	0	1.734	0.770
	50	1.569	0.758
	100	1.349	0.731
	150	1.215	0.703
	200	1.121	0.680
	300	0.989	0.649
	400	0.896	0.627
	500	0.826	0.610
	750	0.705	0.580
	1,000	0.628	0.559



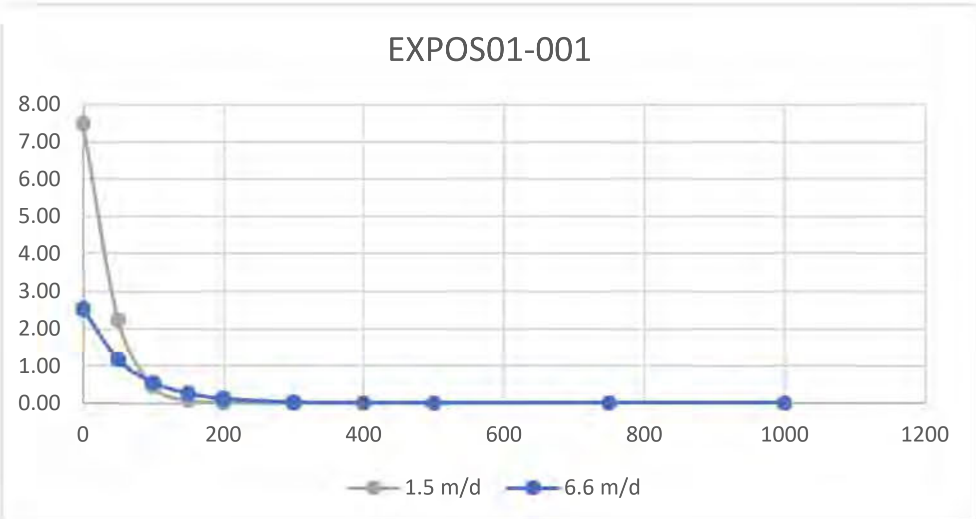
EXPOS01-001	Scenario 2		Q (m^3/d)	a (m^2)	I (m/d)
I	0.255	m/day	313.3044	1230	0.255
S_y	0.02				
K	Varies	m/day			
x	17.53568	m			
y	17.53568	m			
t	180	days			
hi(0)	30	m			
IL	67.5	m aOD			

		Mounding (m)	
EXPOS01-001	Distance	1.5 m/d	6.6 m/d
	0	4.624	1.704
	50	3.877	1.637
	100	3.167	1.509
	150	2.755	1.407
	200	2.461	1.336
	300	2.050	1.238
	400	1.766	1.168
	500	1.554	1.115
	750	1.206	1.020
	1,000	1.008	0.956



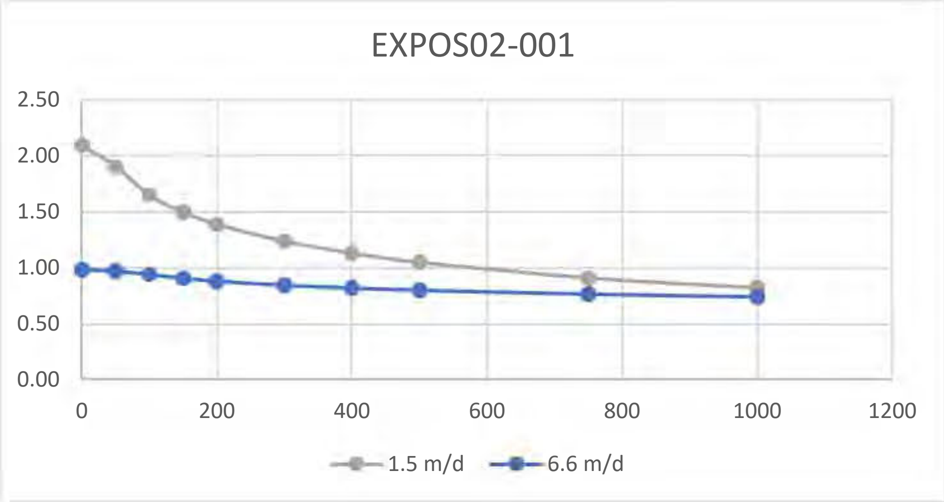
EXPOS01-001	Scenario 3		Q (m^3/d)	a (m^2)	I (m/d)
I	1.054	m/day	1296	1230	1.054
S_y	0.02				
K	Varies	m/day			
x	17.53568	m			
y	17.53568	m			
t	1	days			
hi(0)	30	m			
IL	67.5	m aOD			

		Mounding (m)	
EXPOS01-001	Distance	1.5 m/d	6.6 m/d
	0	7.484	2.529
	50	2.240	1.176
	100	0.456	0.558
	150	0.079	0.272
	200	0.023	0.131
	300	0.018	0.035
	400	0.018	0.019
	500	0.018	0.018
	750	0.018	0.018
	1,000	0.018	0.018



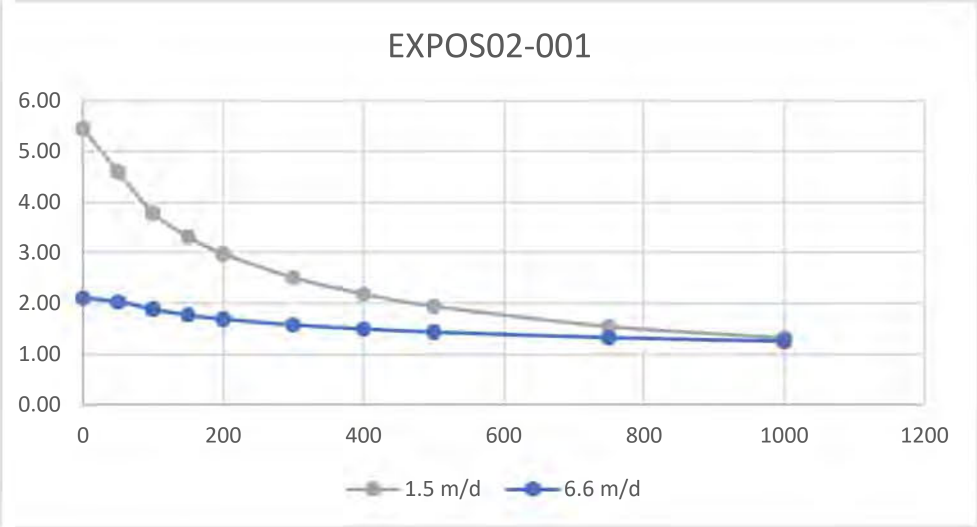
EXPOS01-001	Scenario 1			Q (m^3/d)	a (m^2)	I (m/d)
I	0.106	m/day		111.0182	1050	0.106
S_y	0.02					
K	Varies	m/day				
x	16.202	m				
y	16.202	m				
t	365	days				
hi(0)	30	m				
IL	63.5	m aOD				

EXPOS02-001	Distance	Mounding (m) 1.5 m/d	6.6 m/d
	0	2.094	0.983
	50	1.904	0.970
	100	1.651	0.939
	150	1.497	0.907
	200	1.389	0.880
	300	1.236	0.844
	400	1.130	0.819
	500	1.049	0.800
	750	0.909	0.765
	1,000	0.821	0.741



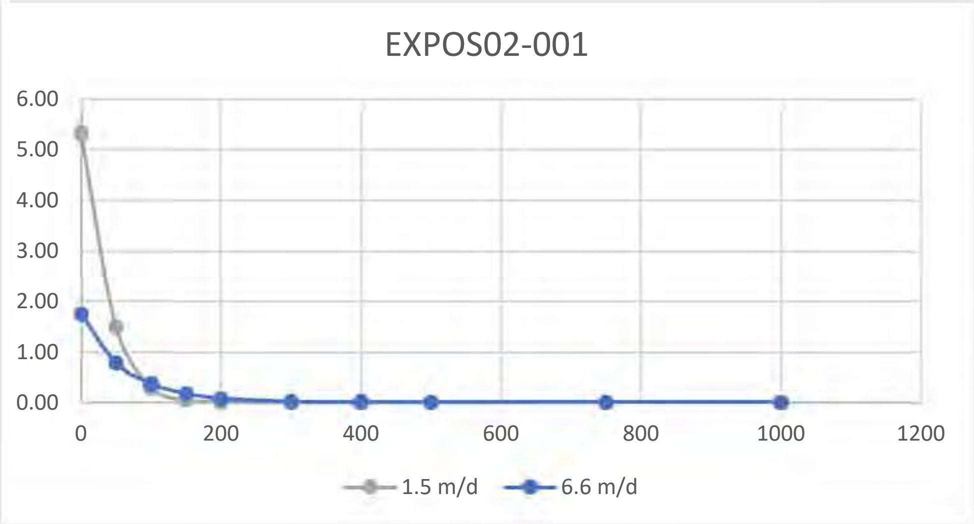
EXPOS01-001	Scenario 2			Q (m^3/d)	a (m^2)	I (m/d)
I	0.344	m/day		361.4238	1050	0.344
S_y	0.02					
K	Varies	m/day				
x	16.202	m				
y	16.202	m				
t	180	days				
hi(0)	30	m				
IL	63.5	m aOD				

EXPOS02-001	Distance	Mounding (m) 1.5 m/d	6.6 m/d
	0	5.448	2.108
	50	4.592	2.031
	100	3.784	1.885
	150	3.314	1.768
	200	2.979	1.687
	300	2.509	1.574
	400	2.184	1.495
	500	1.941	1.433
	750	1.542	1.325
	1,000	1.315	1.251



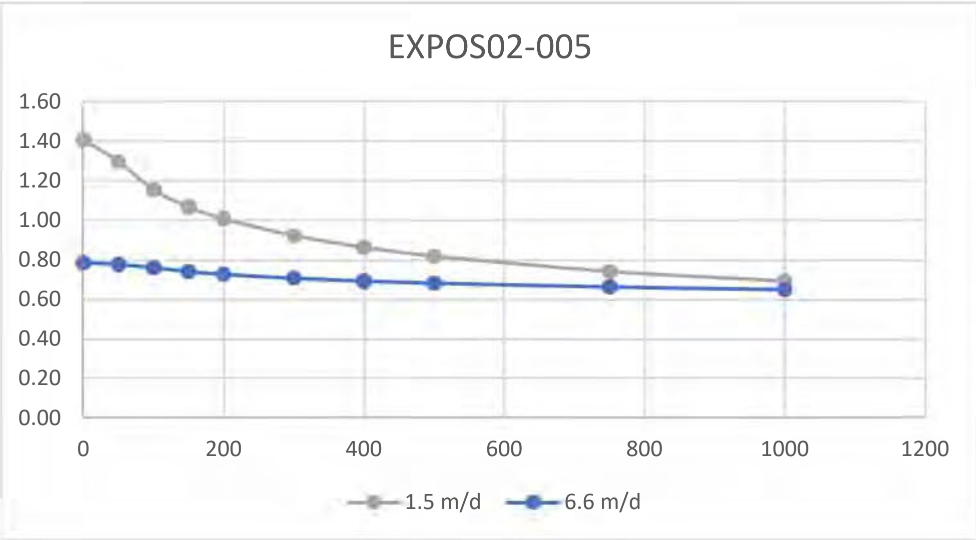
EXPOS01-001	Scenario 3			Q (m^3/d)	a (m^2)	I (m/d)
I	0.823	m/day		864	1050	0.823
S_y	0.02					
K	Varies	m/day				
x	16.202	m				
y	16.202	m				
t	1	days				
hi(0)	30	m				
IL	63.5	m aOD				

EXPOS02-001	Distance	Mounding (m) 1.5 m/d	6.6 m/d
	0	5.328	1.757
	50	1.497	0.789
	100	0.304	0.374
	150	0.054	0.183
	200	0.017	0.089
	300	0.014	0.026
	400	0.014	0.015
	500	0.014	0.014
	750	0.014	0.014
	1,000	0.014	0.014



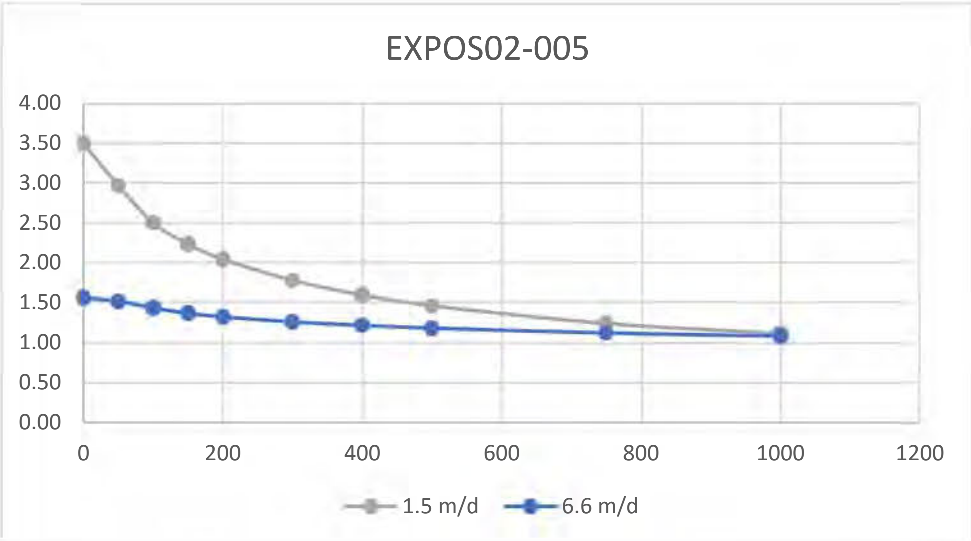
EXPOS02-005	Scenario 1		Q (m^3/d)	a (m^2)	I (m/d)
I	0.098	m/day	61.313	626.41	0.098
S_y	0.02				
K	Varies	m/day			
x	12.514	m			
y	12.514	m			
t	365	days			
hi(0)	30	m			
IL	67.39	m aOD			

EXPOS02-005	Distance	Mounding (m) 1.5 m/d	6.6 m/d
	0	1.407	0.784
	50	1.297	0.776
	100	1.153	0.759
	150	1.067	0.741
	200	1.007	0.726
	300	0.922	0.706
	400	0.863	0.692
	500	0.819	0.682
	750	0.741	0.662
	1,000	0.692	0.649



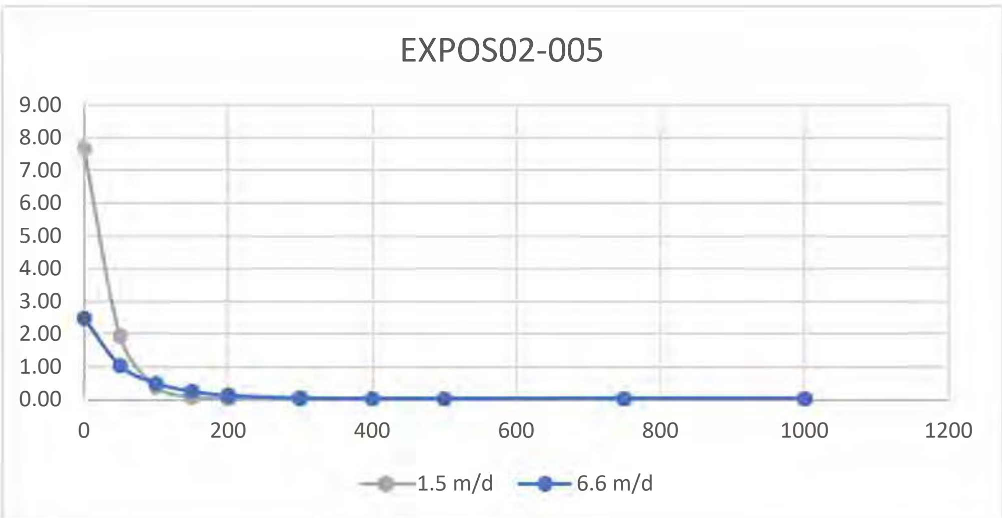
EXPOS02-005	Scenario 2		Q (m^3/d)	a (m^2)	I (m/d)
I	0.319	m/day	199.613	626.41	0.319
S_y	0.02				
K	Varies	m/day			
x	12.514	m			
y	12.514	m			
t	180	days			
hi(0)	30	m			
IL	67.39	m aOD			

EXPOS02-005	Distance	Mounding (m) 1.5 m/d	6.6 m/d
	0	3.492	1.559
	50	2.966	1.515
	100	2.500	1.432
	150	2.232	1.366
	200	2.042	1.321
	300	1.777	1.258
	400	1.595	1.214
	500	1.459	1.180
	750	1.238	1.119
	1,000	1.112	1.078



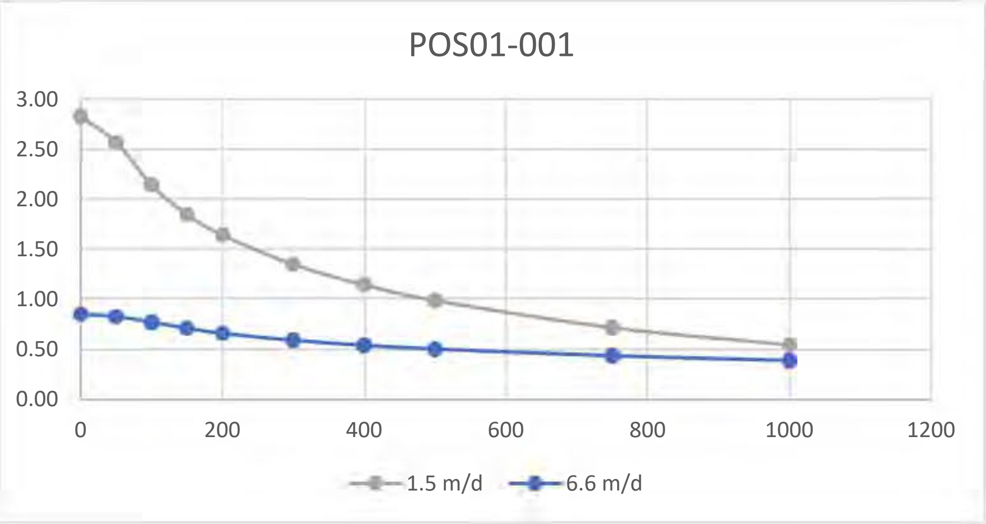
EXPOS02-005	Scenario 3		Q (m^3/d)	a (m^2)	I (m/d)
I	1.796	m/day	1125	626.41	1.796
S	0.02				
K	Varies	m/day			
x	12.514	m			
y	12.514	m			
t	1	days			
hi(0)	30	m			
IL	67.39	m aOD			

EXPOS02-005	Distance	Mounding (m) 1.5 m/d	6.6 m/d
	0	7.658	2.490
	50	1.948	1.037
	100	0.403	0.498
	150	0.082	0.250
	200	0.035	0.128
	300	0.030	0.045
	400	0.030	0.032
	500	0.030	0.030
	750	0.030	0.030
	1,000	0.030	0.030



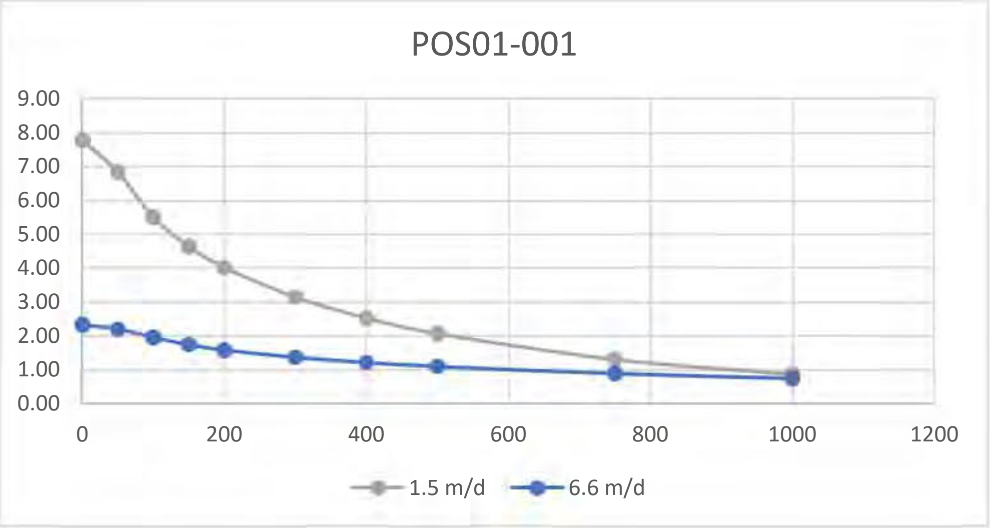
POS01-001	Scenario 1			Q (m^3/d)	a (m^2)	I (m/d)
I	0.033	m/day		214.5166	6559.29	0.033
S_y	0.02					
K	Varies	m/day				
x	40.495	m				
y	40.495	m				
t	365	days				
hi(0)	30	m				
IL	65.25	m aOD				

		Mounding (m)	
POS01-001	Distance	1.5 m/d	6.6 m/d
	0	2.832	0.851
	50	2.572	0.828
	100	2.145	0.772
	150	1.850	0.710
	200	1.643	0.660
	300	1.350	0.590
	400	1.144	0.541
	500	0.987	0.503
	750	0.716	0.435
	1,000	0.543	0.388



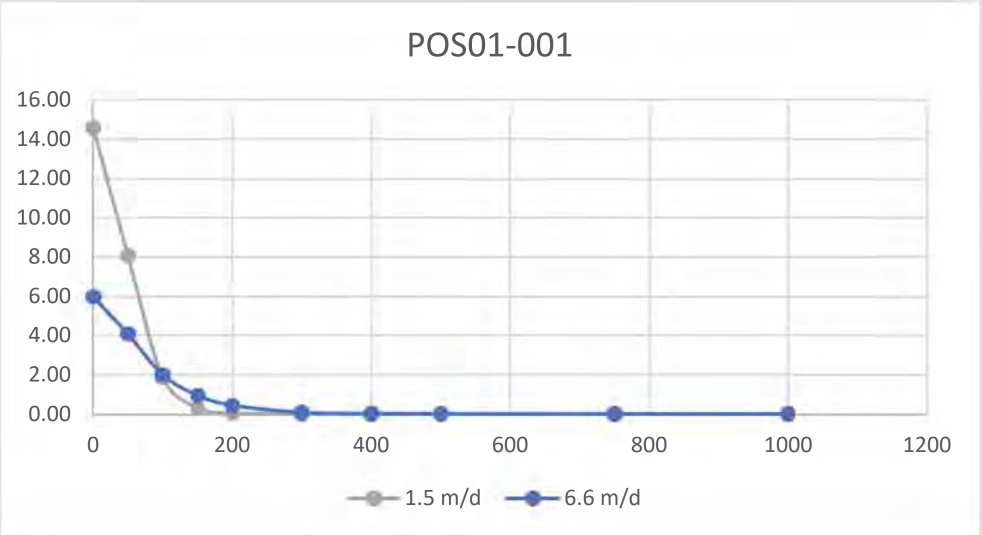
POS01-001	Scenario 2			Q (m^3/d)	a (m^2)	I (m/d)
I	0.106	m/day		698.3838	6559.29	0.106
S_y	0.02					
K	Varies	m/day				
x	40.495	m				
y	40.495	m				
t	180	days				
hi(0)	30	m				
IL	65.25	m aOD				

		Mounding (m)	
POS01-001	Distance	1.5 m/d	6.6 m/d
	0	7.780	2.323
	50	6.842	2.202
	100	5.500	1.952
	150	4.640	1.735
	200	4.020	1.580
	300	3.142	1.364
	400	2.527	1.211
	500	2.065	1.093
	750	1.299	0.883
	1,000	0.860	0.741



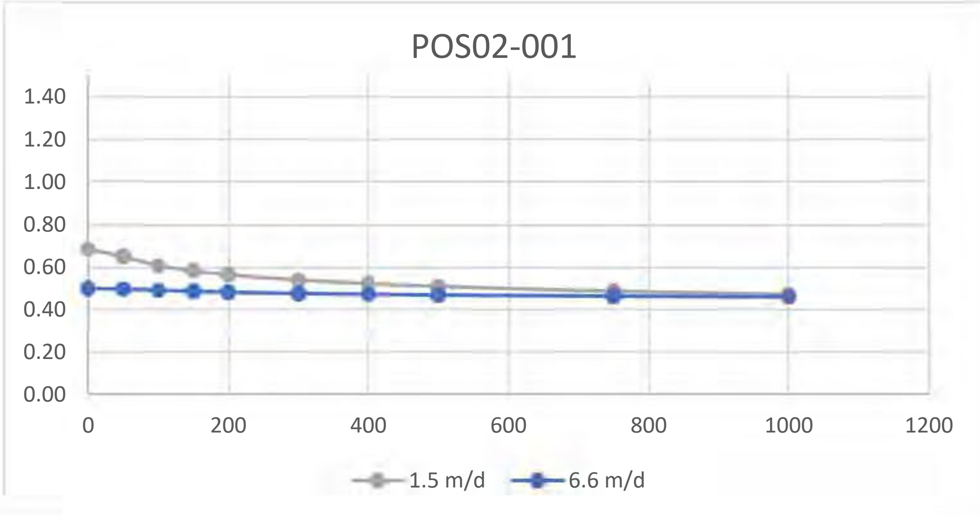
POS01-001	Scenario 3			Q (m^3/d)	a (m^2)	I (m/d)
I	0.719	m/day		4716	6559.29	0.719
S_y	0.02					
K	Varies	m/day				
x	40.495	m				
y	40.495	m				
t	1	days				
hi(0)	30	m				
IL	65.25	m aOD				

		Mounding (m)	
POS01-001	Distance	1.5 m/d	6.6 m/d
	0	14.582	5.970
	50	8.066	4.071
	100	1.870	1.992
	150	0.306	0.961
	200	0.043	0.441
	300	0.012	0.081
	400	0.012	0.020
	500	0.012	0.013
	750	0.012	0.012
	1,000	0.012	0.012



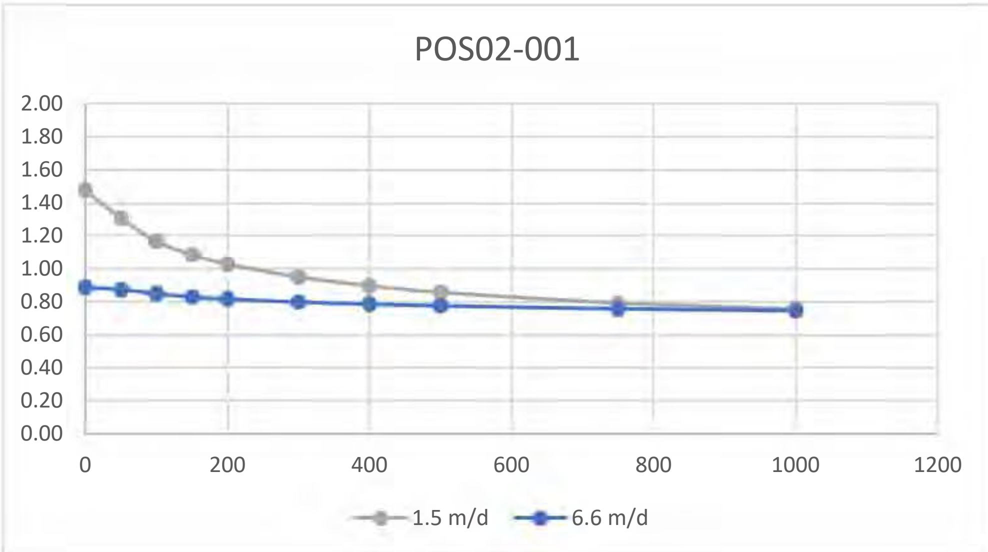
POS02-001	Scenario 1			Q (m^3/d)	a (m^2)	I (m/d)
I	0.073	m/day		17.733	243.905	0.073
S_y	0.02					
K	Varies	m/day				
x	7.809	m				
y	7.809	m				
t	365	days				
hi(0)	30	m				
IL	71	m aOD				

		Mounding (m)	
POS02-001	Distance	1.5 m/d	6.6 m/d
	0	0.684	0.499
	50	0.650	0.497
	100	0.607	0.492
	150	0.582	0.486
	200	0.564	0.482
	300	0.539	0.476
	400	0.522	0.472
	500	0.509	0.469
	750	0.487	0.463
	1,000	0.472	0.459



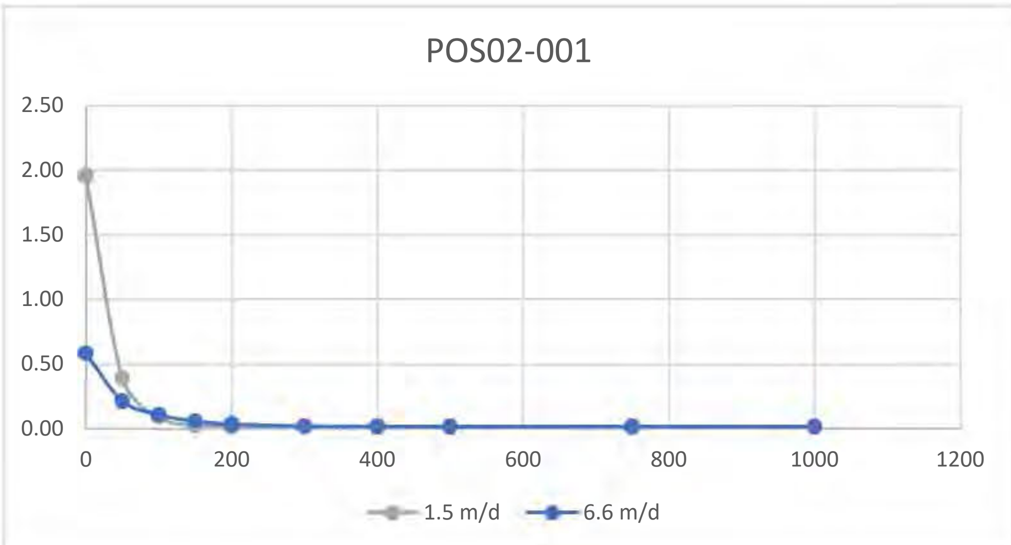
POS02-001	Scenario 2			Q (m^3/d)	a (m^2)	I (m/d)
I	0.237	m/day		57.733	243.905	0.237
S_y	0.02					
K	Varies	m/day				
x	7.809	m				
y	7.809	m				
t	180	days				
hi(0)	30	m				
IL	71	m aOD				

		Mounding (m)	
POS02-001	Distance	1.5 m/d	6.6 m/d
	0	1.476	0.887
	50	1.307	0.874
	100	1.166	0.849
	150	1.086	0.830
	200	1.029	0.817
	300	0.951	0.799
	400	0.897	0.786
	500	0.857	0.776
	750	0.793	0.758
	1,000	0.756	0.746



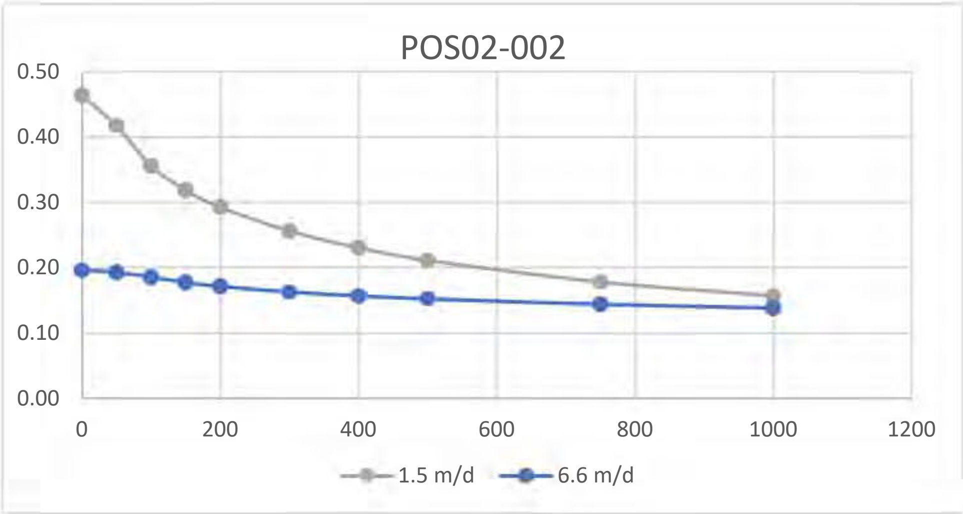
POS02-001	Scenario 3			Q (m^3/d)	a (m^2)	I (m/d)
I	0.902	m/day		220.000	243.905	0.902
S_y	0.02					
K	Varies	m/day				
x	7.809	m				
y	7.809	m				
t	1	days				
hi(0)	30	m				
IL	71	m aOD				

		Mounding (m)	
POS02-001	Distance	1.5 m/d	6.6 m/d
	0	1.955	0.582
	50	0.391	0.213
	100	0.087	0.107
	150	0.025	0.058
	200	0.016	0.034
	300	0.015	0.018
	400	0.015	0.015
	500	0.015	0.015
	750	0.015	0.015
	1,000	0.015	0.015



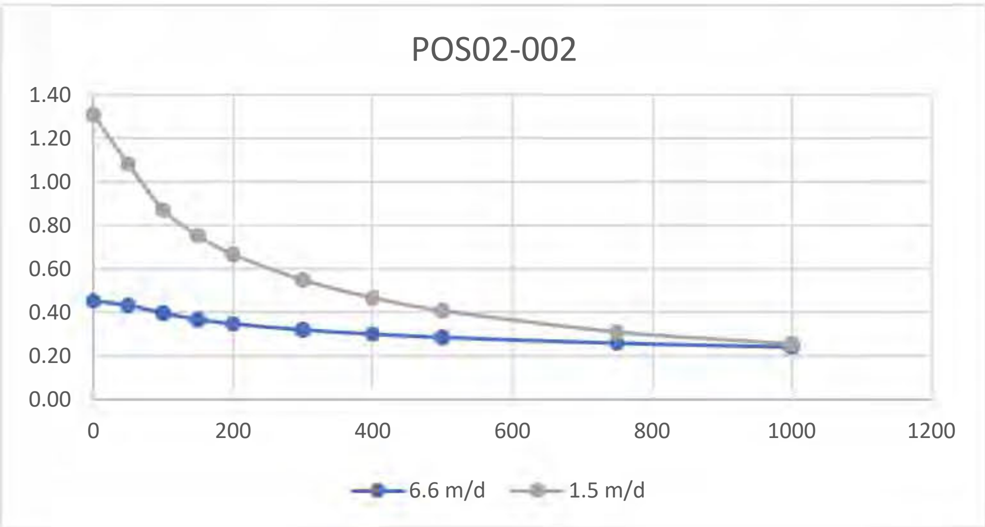
POS02-002	Scenario 1			Q (m^3/d)	a (m^2)	I (m/d)
I	0.019	m/day		26.504	1376.125	0.019
S_y	0.02					
K	Varies	m/day				
x	18.548	m				
y	18.548	m				
t	365	days				
hi(0)	30	m				
IL	60.2	m aOD				

		Mounding (m)	
POS02-002	Distance	1.5 m/d	6.6 m/d
	0	0.464	0.196
	50	0.417	0.193
	100	0.356	0.186
	150	0.319	0.178
	200	0.293	0.171
	300	0.256	0.163
	400	0.231	0.157
	500	0.211	0.152
	750	0.178	0.144
	1,000	0.157	0.138



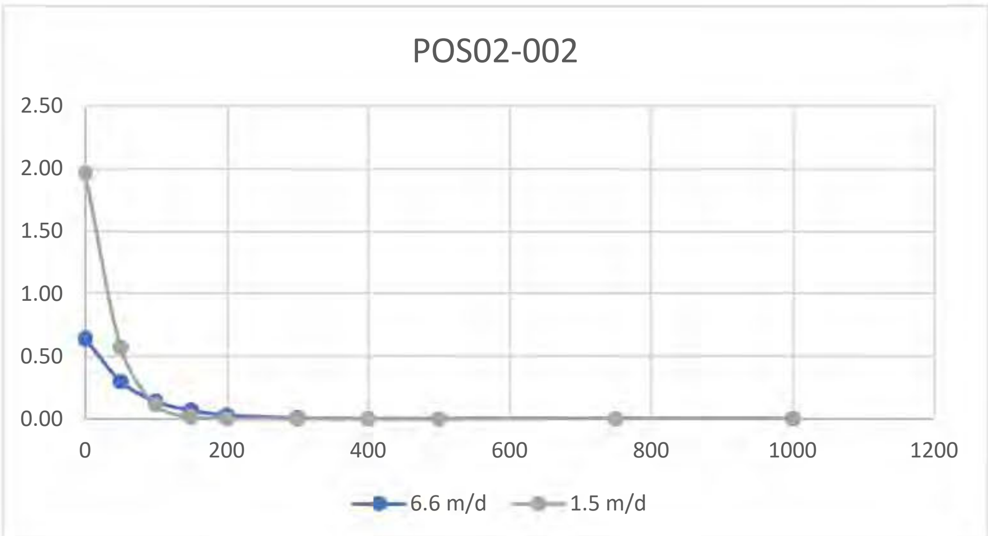
POS02-002	Scenario 2			Q (m^3/d)	a (m^2)	I (m/d)
I	0.063	m/day		86.287	1376.125	0.063
S_y	0.02					
K	Varies	m/day				
x	18.548	m				
y	18.548	m				
t	180	days				
hi(0)	30	m				
IL	60.2	m aOD				

		Mounding (m)	
POS02-002	Distance	1.5 m/d	6.6 m/d
	0	1.310	0.454
	50	1.083	0.434
	100	0.873	0.398
	150	0.753	0.369
	200	0.668	0.349
	300	0.550	0.321
	400	0.469	0.302
	500	0.409	0.287
	750	0.312	0.260
	1,000	0.256	0.242



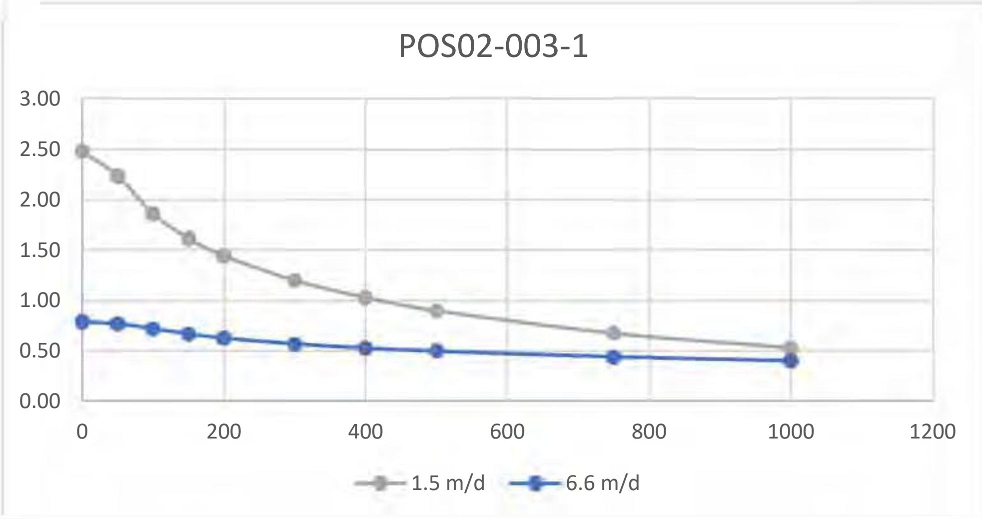
POS02-002	Scenario 3			Q (m^3/d)	a (m^2)	I (m/d)
I	0.239	m/day		329.500	1376.125	0.239
S_y	0.02					
K	Varies	m/day				
x	18.548	m				
y	18.548	m				
t	1	days				
hi(0)	30	m				
IL	60.2	m aOD				

		Mounding (m)	
POS02-002	Distance	1.5 m/d	6.6 m/d
	0	1.963	0.644
	50	0.574	0.301
	100	0.115	0.141
	150	0.020	0.069
	200	0.005	0.033
	300	0.004	0.009
	400	0.004	0.004
	500	0.004	0.004
	750	0.004	0.004
	1,000	0.004	0.004



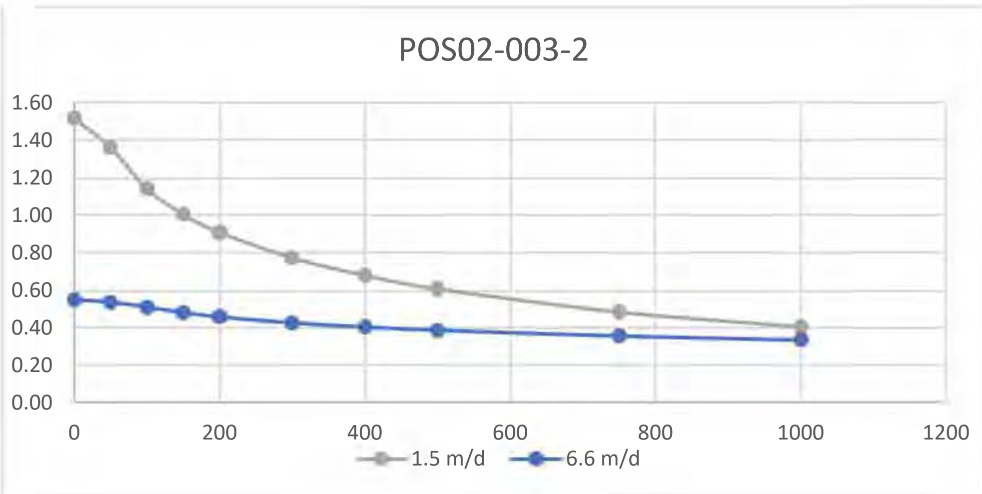
POS02-003	Scenario 1		Pond 1	Q (m^3/d)	a (m^2)	I (m/d)
I	0.041	m/day		177.279	4361.826	0.041
S_y	0.02					
K	Varies	m/day				
x	33.022	m				
y	33.022	m				
t	365	days				
hi(0)	30	m				
IL	51	m aOD				

POS02-003	Distance	Mounding (m) 1.5 m/d	6.6 m/d
	0	2.482	0.790
	50	2.236	0.770
	100	1.862	0.723
	150	1.616	0.671
	200	1.444	0.629
	300	1.200	0.571
	400	1.030	0.531
	500	0.900	0.499
	750	0.675	0.443
	1,000	0.532	0.404



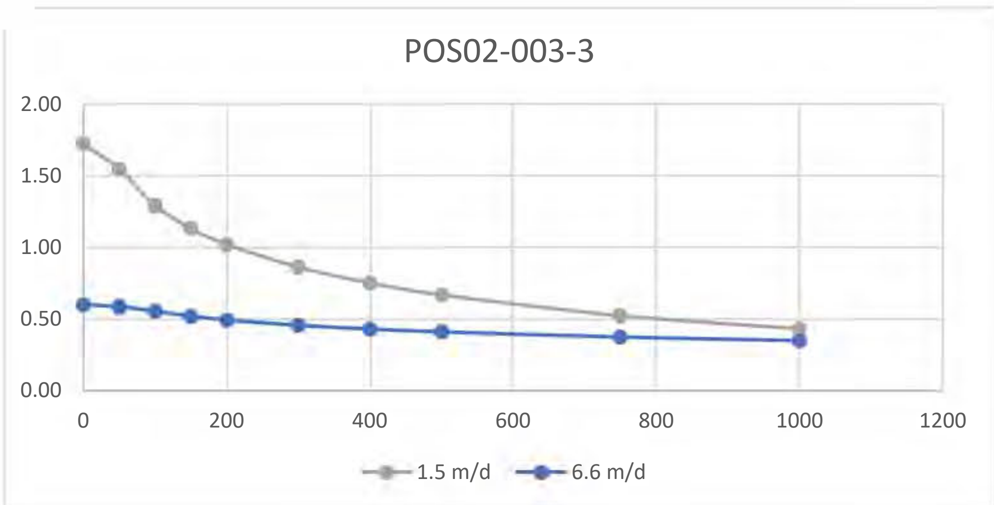
POS02-003	Scenario 1		Pond 2	Q (m^3/d)	a (m^2)	I (m/d)
I	0.041	m/day		97.135	2389.946	0.041
S_y	0.02					
K	Varies	m/day				
x	24.444	m				
y	24.444	m				
t	365	days				
hi(0)	30	m				
IL	50.5	m aOD				

POS02-003	Distance	Mounding (m) 1.5 m/d	6.6 m/d
	0	1.518	0.549
	50	1.361	0.537
	100	1.141	0.510
	150	1.004	0.481
	200	0.908	0.458
	300	0.773	0.426
	400	0.678	0.404
	500	0.607	0.387
	750	0.483	0.356
	1,000	0.404	0.334



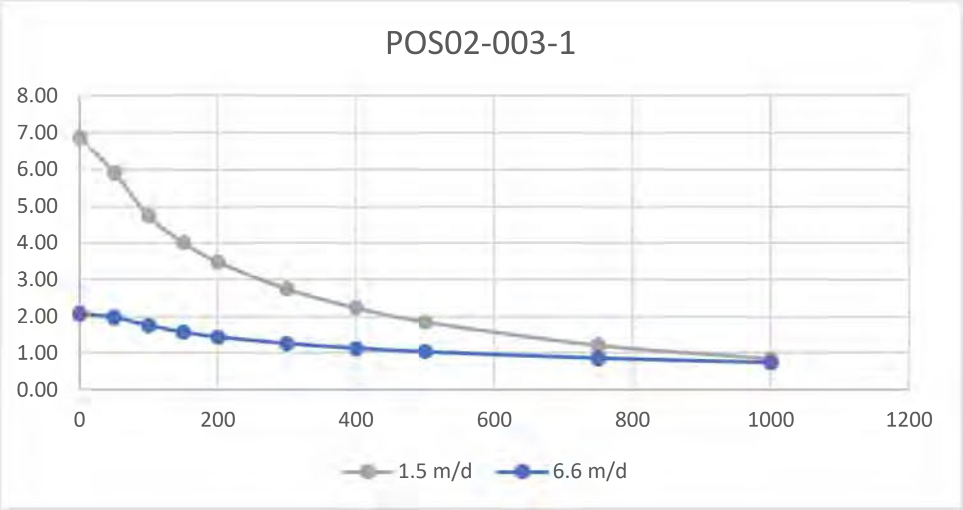
POS02-003	Scenario 1		Pond 3	Q (m^3/d)	a (m^2)	I (m/d)
I	0.041	m/day		113.829	2800.686	0.041
S_y	0.02					
K	Varies	m/day				
x	26.461	m				
y	26.461	m				
t	365	days				
hi(0)	30	m				
IL	50	m aOD				

POS02-003	Distance	Mounding (m) 1.5 m/d	6.6 m/d
	0	1.724	0.599
	50	1.546	0.586
	100	1.293	0.554
	150	1.132	0.521
	200	1.020	0.493
	300	0.862	0.456
	400	0.752	0.430
	500	0.668	0.410
	750	0.523	0.374
	1,000	0.431	0.349



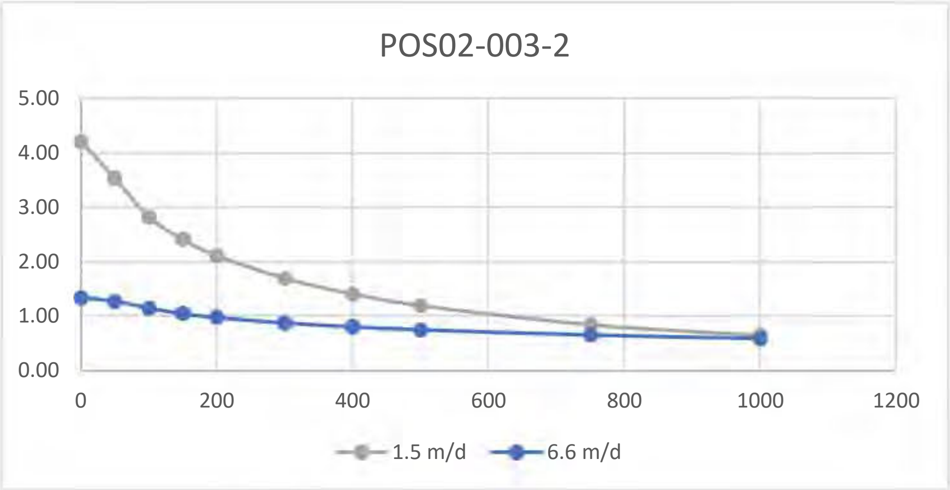
POS02-003	Scenario 2		Pond 1	Q (m^3/d)	a (m^2)	I (m/d)
I	0.132	m/day		577.152	4361.826	0.132
S_y	0.02					
K	Varies	m/day				
x	33.022	m				
y	33.022	m				
t	180	days				
hi(0)	30	m				
IL	51	m aOD				

POS02-003	Distance	Mounding (m) 1.5 m/d	6.6 m/d
	0	6.868	2.082
	50	5.912	1.972
	100	4.728	1.755
	150	4.001	1.572
	200	3.479	1.443
	300	2.743	1.264
	400	2.229	1.136
	500	1.845	1.038
	750	1.209	0.864
	1,000	0.845	0.746



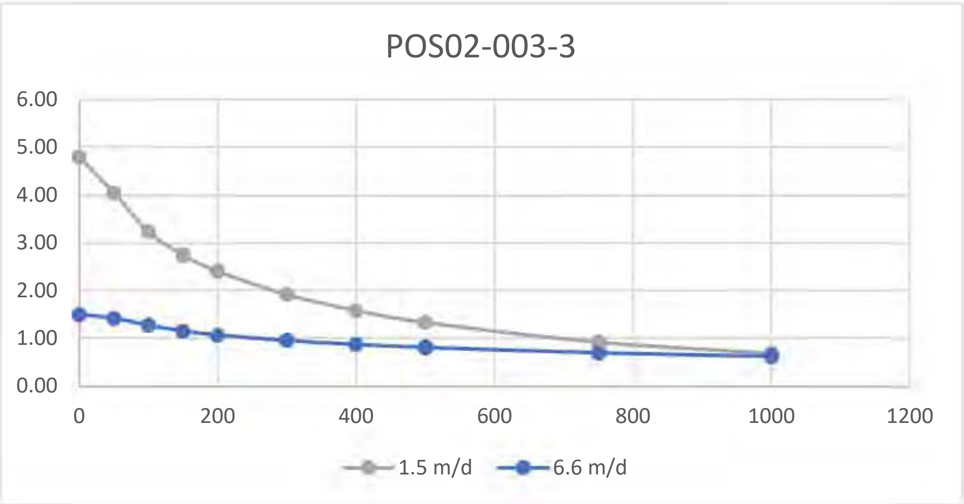
POS02-003	Scenario 2		Pond 2	Q (m^3/d)	a (m^2)	I (m/d)
I	0.132	m/day		316.235	2389.946	0.132
S_y	0.02					
K	Varies	m/day				
x	24.444	m				
y	24.444	m				
t	180	days				
hi(0)	30	m				
IL	50.5	m aOD				

POS02-003	Distance	Mounding (m) 1.5 m/d	6.6 m/d
	0	4.214	1.340
	50	3.534	1.275
	100	2.826	1.148
	150	2.409	1.045
	200	2.111	0.973
	300	1.695	0.874
	400	1.407	0.803
	500	1.193	0.749
	750	0.842	0.653
	1,000	0.642	0.588



POS02-003	Scenario 2		Pond 3	Q (m^3/d)	a (m^2)	I (m/d)
I	0.132	m/day		370.584	2800.686	0.132
S_y	0.02					
K	Varies	m/day				
x	26.461	m				
y	26.461	m				
t	180	days				
hi(0)	30	m				
IL	50	m aOD				

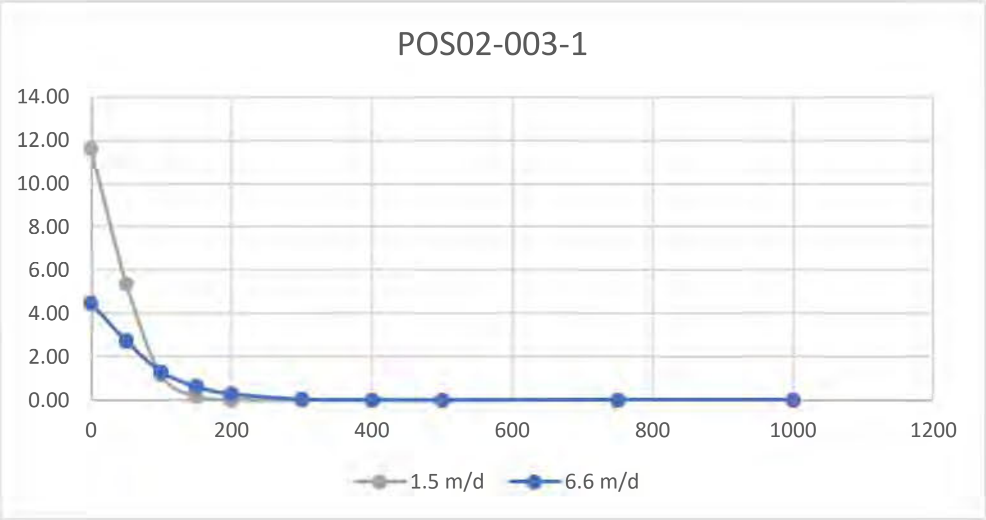
POS02-003	Distance	Mounding (m) 1.5 m/d	6.6 m/d
	0	4.797	1.497
	50	4.044	1.422
	100	3.229	1.275
	150	2.745	1.155
	200	2.400	1.071
	300	1.915	0.955
	400	1.580	0.873
	500	1.329	0.810
	750	0.918	0.697
	1,000	0.684	0.621



POS02-003	Scenario 3		Pond 1
I	0.715	m/day	
S_y	0.02		
K	Varies	m/day	
x	33.022	m	
y	33.022	m	
t	1	days	
hi(0)	30	m	
IL	51	m aOD	

Q (m^3/d)	a (m^2)	I (m/d)
3119.04	4361.826	0.715

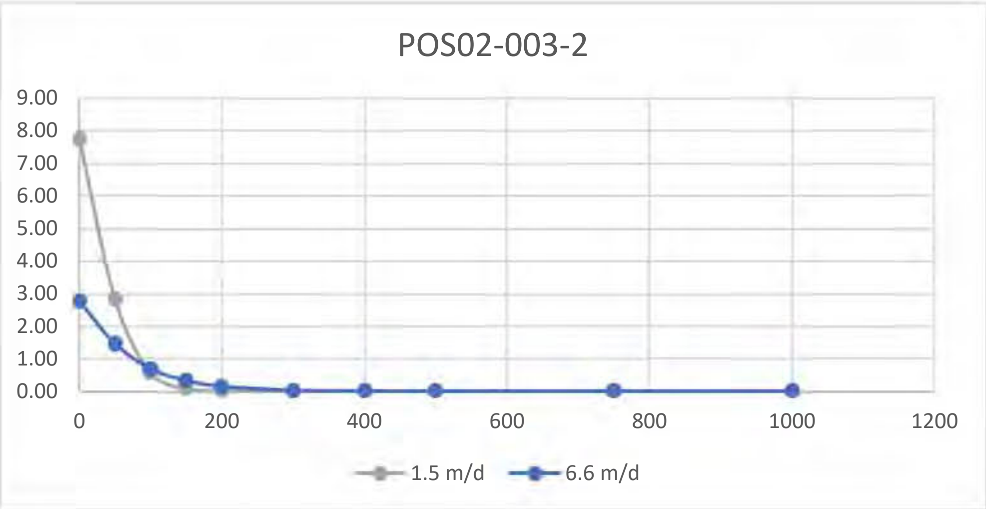
POS02-003	Distance	Mounding (m) 1.5 m/d	6.6 m/d
	0	11.611	4.479
	50	5.391	2.748
	100	1.171	1.319
	150	0.187	0.633
	200	0.030	0.291
	300	0.012	0.057
	400	0.012	0.017
	500	0.012	0.012
	750	0.012	0.012
	1,000	0.012	0.012



POS02-003	Scenario 3		Pond 2
I	0.683	m/day	
S_y	0.02		
K	Varies	m/day	
x	24.444	m	
y	24.444	m	
t	1	days	
hi(0)	30	m	
IL	50.5	m aOD	

Q (m^3/d)	a (m^2)	I (m/d)
1632.50	2389.946	0.683

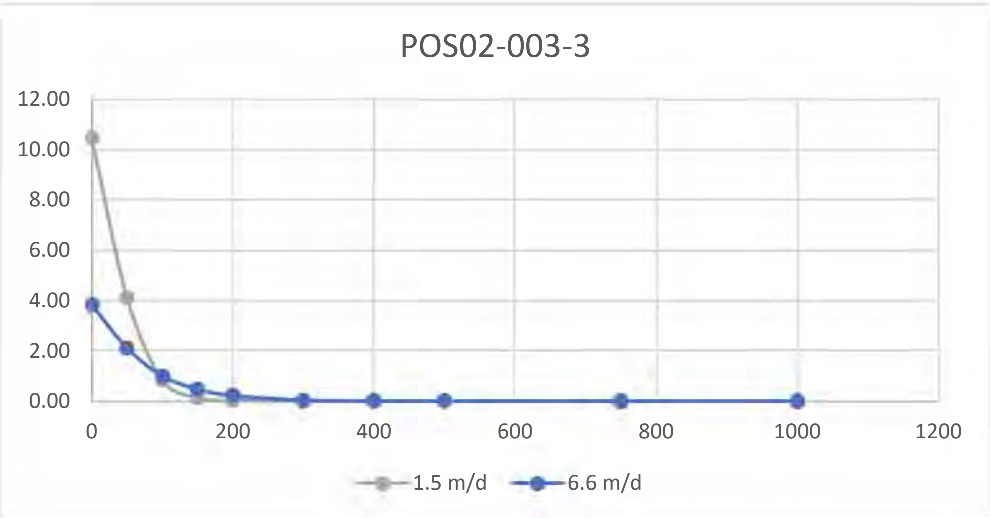
POS02-003	Distance	Mounding (m) 1.5 m/d	6.6 m/d
	0	7.750	2.764
	50	2.832	1.466
	100	0.583	0.694
	150	0.094	0.333
	200	0.019	0.156
	300	0.011	0.034
	400	0.011	0.014
	500	0.011	0.012
	750	0.011	0.011
	1,000	0.011	0.011



POS02-003	Scenario 3		Pond 3
I	0.848	m/day	
S_y	0.02		
K	Varies	m/day	
x	26.461	m	
y	26.461	m	
t	1	days	
hi(0)	30	m	
IL	50	m aOD	

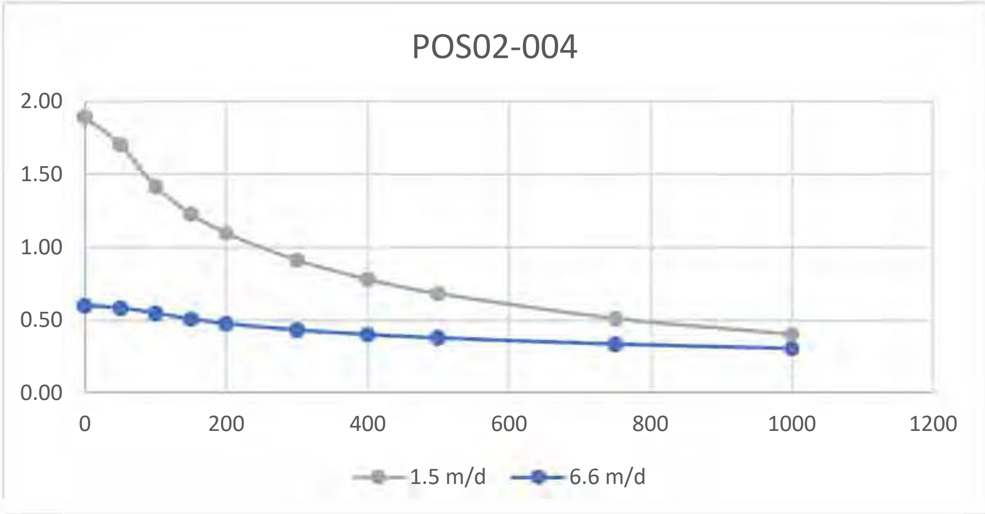
Q (m^3/d)	a (m^2)	I (m/d)
2376.00	2800.686	0.848

POS02-003	Distance	Mounding (m) 1.5 m/d	6.6 m/d
	0	10.438	3.829
	50	4.108	2.117
	100	0.859	1.007
	150	0.137	0.484
	200	0.026	0.225
	300	0.014	0.048
	400	0.014	0.018
	500	0.014	0.014
	750	0.014	0.014
	1,000	0.014	0.014



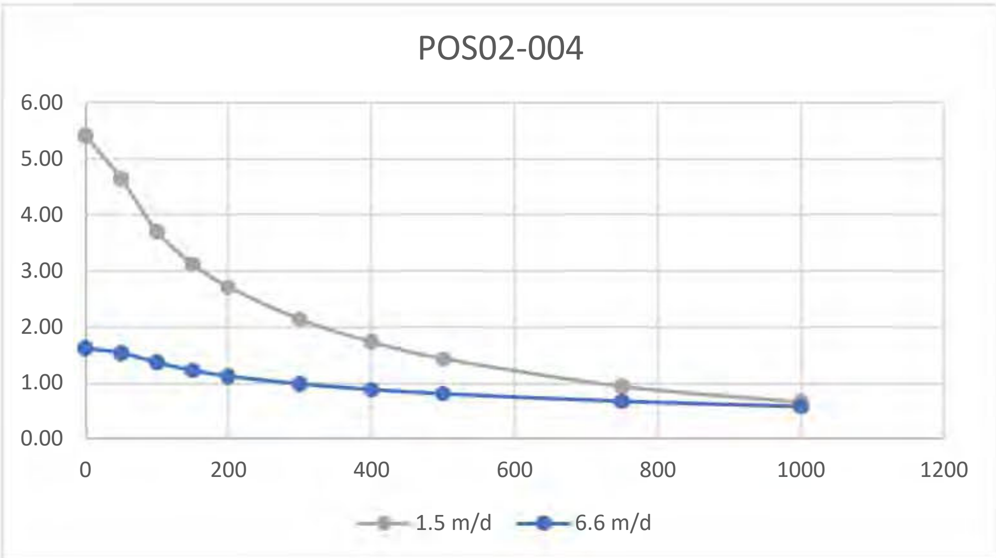
POS02-004	Scenario 1			Q (m^3/d)	a (m^2)	I (m/d)
I	0.031	m/day		136.6884	4366.14	0.0313
S_y	0.02					
K	Varies	m/day				
x	33.038	m				
y	33.038	m				
t	365	days				
hi(0)	30	m				
IL	63.8	m aOD				

		Mounding (m)	
POS02-004	Distance	1.5 m/d	6.6 m/d
	0	1.893	0.599
	50	1.703	0.584
	100	1.416	0.548
	150	1.228	0.508
	200	1.096	0.476
	300	0.911	0.432
	400	0.781	0.402
	500	0.682	0.378
	750	0.511	0.335
	1,000	0.403	0.306



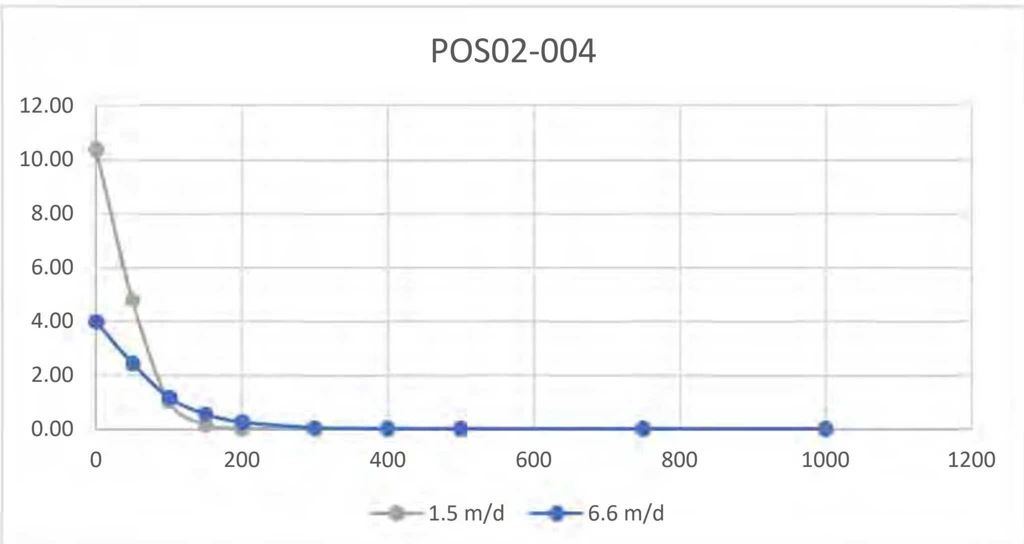
POS02-004	Scenario 2			Q (m^3/d)	a (m^2)	I (m/d)
I	0.102	m/day		445.005	4366.14	0.102
S_y	0.02					
K	Varies	m/day				
x	33.038	m				
y	33.038	m				
t	180	days				
hi(0)	30	m				
IL	63.8	m aOD				

		Mounding (m)	
POS02-004	Distance	1.5 m/d	6.6 m/d
	0	5.415	1.619
	50	4.643	1.533
	100	3.699	1.363
	150	3.123	1.220
	200	2.711	1.119
	300	2.132	0.979
	400	1.730	0.880
	500	1.430	0.804
	750	0.935	0.669
	1,000	0.653	0.577



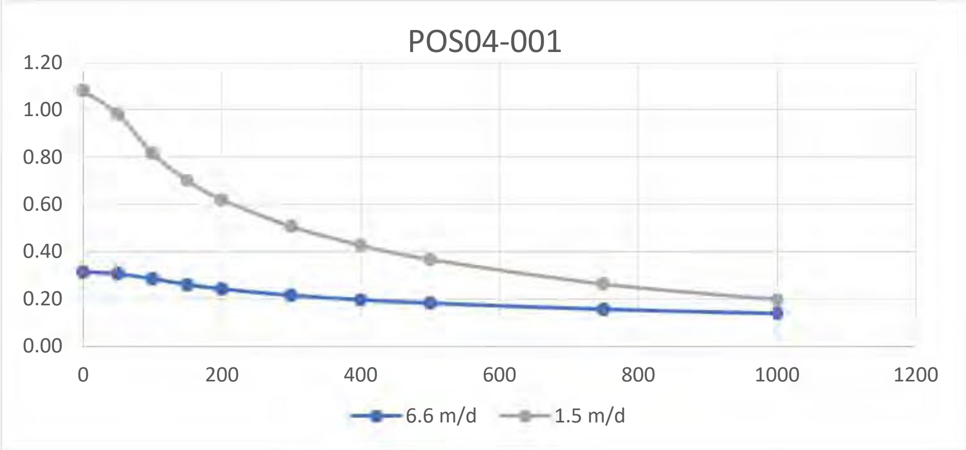
POS02-004	Scenario 3			Q (m^3/d)	a (m^2)	I (m/d)
I	0.632	m/day		2759	4366.14	0.632
S_y	0.02					
K	Varies	m/day				
x	33.038	m				
y	33.038	m				
t	1	days				
hi(0)	30	m				
IL	63.8	m aOD				

		Mounding (m)	
POS02-004	Distance	1.5 m/d	6.6 m/d
	0	10.379	3.985
	50	4.782	2.439
	100	1.035	1.168
	150	0.165	0.560
	200	0.026	0.258
	300	0.011	0.050
	400	0.011	0.015
	500	0.011	0.011
	750	0.011	0.011
	1,000	0.011	0.011



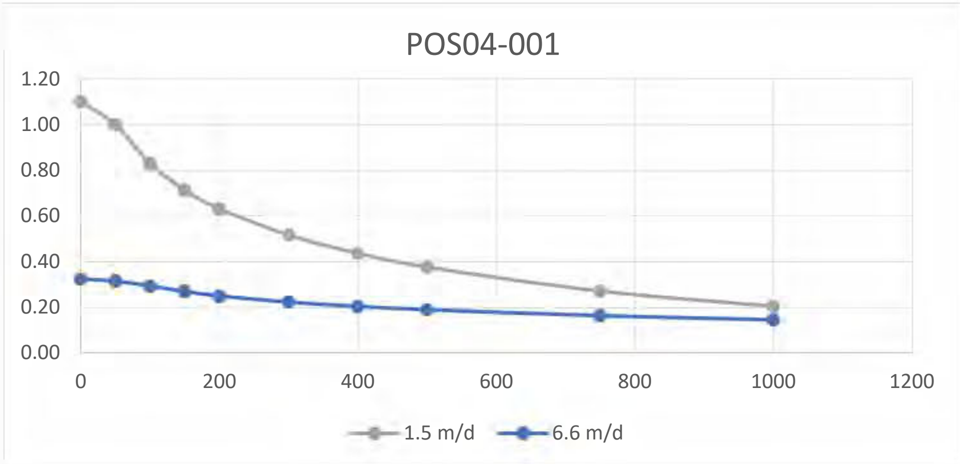
POS04-001	Scenario 1		**Pond 1**		Q (m^3/d)	a (m^2)	I (m/d)
I	0.011	m/day			82.085	7450	0.011
S_y	0.02						
K	Varies	m/day					
x	43.157	m					
y	43.157	m					
t	365	days					
hi(0)	30	m					
IL	40.7	m aOD					

POS04-001	Distance	Mounding (m) 1.5 m/d	6.6 m/d
	0	1.081	0.315
	50	0.982	0.306
	100	0.816	0.284
	150	0.701	0.261
	200	0.620	0.242
	300	0.506	0.215
	400	0.427	0.196
	500	0.366	0.182
	750	0.263	0.156
	1,000	0.197	0.138



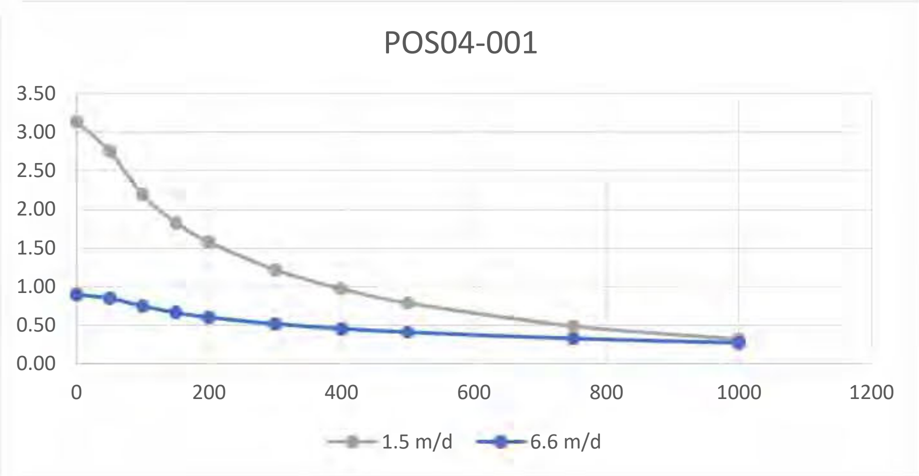
POS04-001	Scenario 1		**Pond 2**		Q (m^3/d)	a (m^2)	I (m/d)
I	0.012	m/day			82.085	6900	0.012
S_y	0.02						
K	Varies	m/day					
x	41.533	m					
y	41.533	m					
t	365	days					
hi(0)	30	m					
IL	38	m aOD					

POS04-001	Distance	Mounding (m) 1.5 m/d	6.6 m/d
	0	1.103	0.324
	50	0.999	0.315
	100	0.830	0.293
	150	0.713	0.269
	200	0.631	0.250
	300	0.517	0.223
	400	0.436	0.204
	500	0.376	0.189
	750	0.271	0.163
	1,000	0.204	0.145



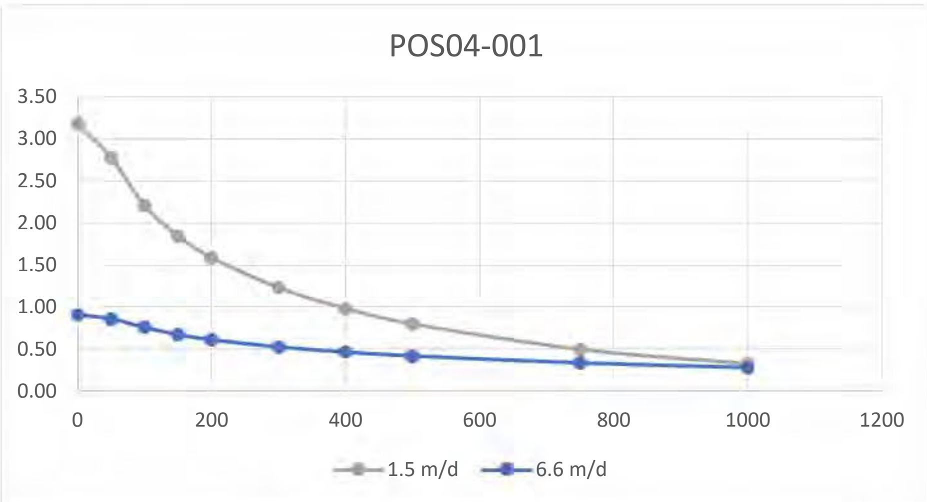
POS04-001	Scenario 2	Pond 1		Q (m^3/d)	a (m^2)	I (m/d)
I	0.036	m/day		267.238	7450	0.036
S_y	0.02					
K	Varies	m/day				
x	43.157	m				
y	43.157	m				
t	180	days				
hi(0)	30	m				
IL	40.7	m aOD				

		Mounding (m)	
POS04-001	Distance	1.5 m/d	6.6 m/d
	0	3.137	0.896
	50	2.752	0.847
	100	2.190	0.748
	150	1.831	0.662
	200	1.575	0.601
	300	1.218	0.516
	400	0.971	0.456
	500	0.788	0.409
	750	0.487	0.327
	1,000	0.317	0.272



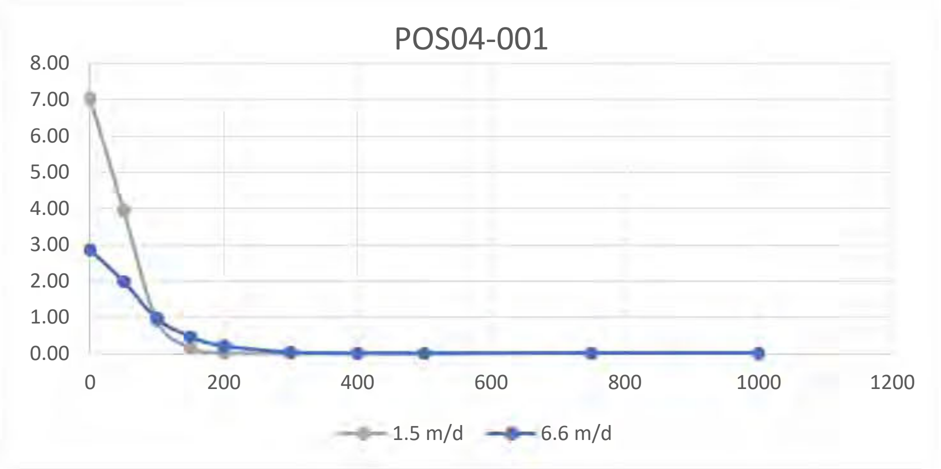
POS04-001	Scenario 2	Pond 2		Q (m^3/d)	a (m^2)	I (m/d)
I	0.039	m/day		267.238	6900	0.039
S_y	0.02					
K	Varies	m/day				
x	41.533	m				
y	41.533	m				
t	180	days				
hi(0)	30	m				
IL	38	m aOD				

		Mounding (m)	
POS04-001	Distance	1.5 m/d	6.6 m/d
	0	3.179	0.909
	50	2.776	0.860
	100	2.205	0.760
	150	1.845	0.673
	200	1.589	0.612
	300	1.230	0.526
	400	0.983	0.466
	500	0.799	0.419
	750	0.497	0.337
	1,000	0.326	0.281



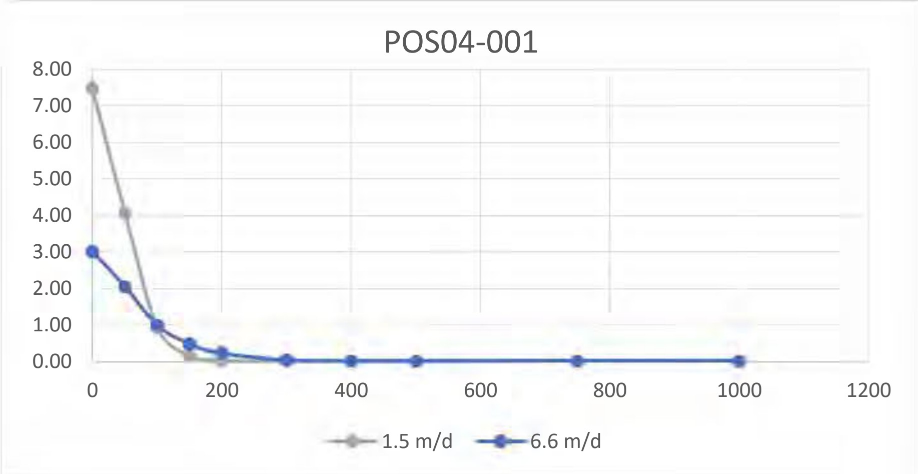
POS04-001	Scenario 3		**Pond 1**	Q (m^3/d)	a (m^2)	I (m/d)
I	0.304	m/day		2267.000	7450	0.304
S_y	0.02					
K	Varies	m/day				
x	43.157	m				
y	43.157	m				
t	1	days				
hi(0)	30	m				
IL	40.7	m aOD				

		Mounding (m)	
POS04-001	Distance	1.5 m/d	6.6 m/d
	0	7.038	2.860
	50	3.956	1.987
	100	0.908	0.962
	150	0.151	0.462
	200	0.021	0.212
	300	0.005	0.039
	400	0.005	0.009
	500	0.005	0.005
	750	0.005	0.005
	1,000	0.005	0.005

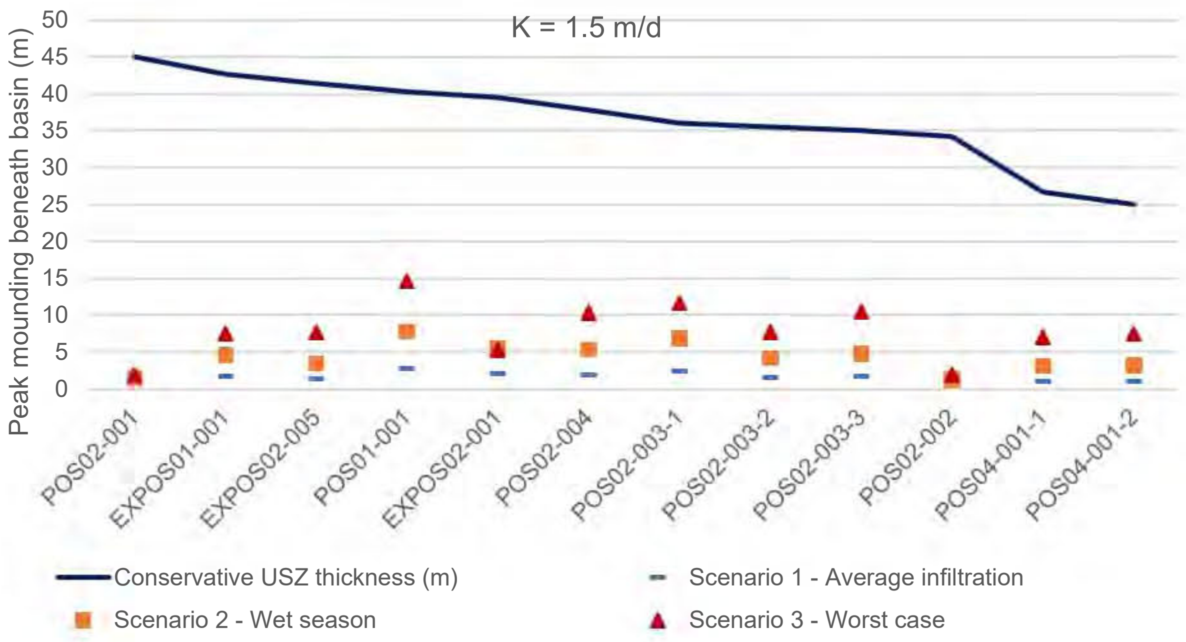


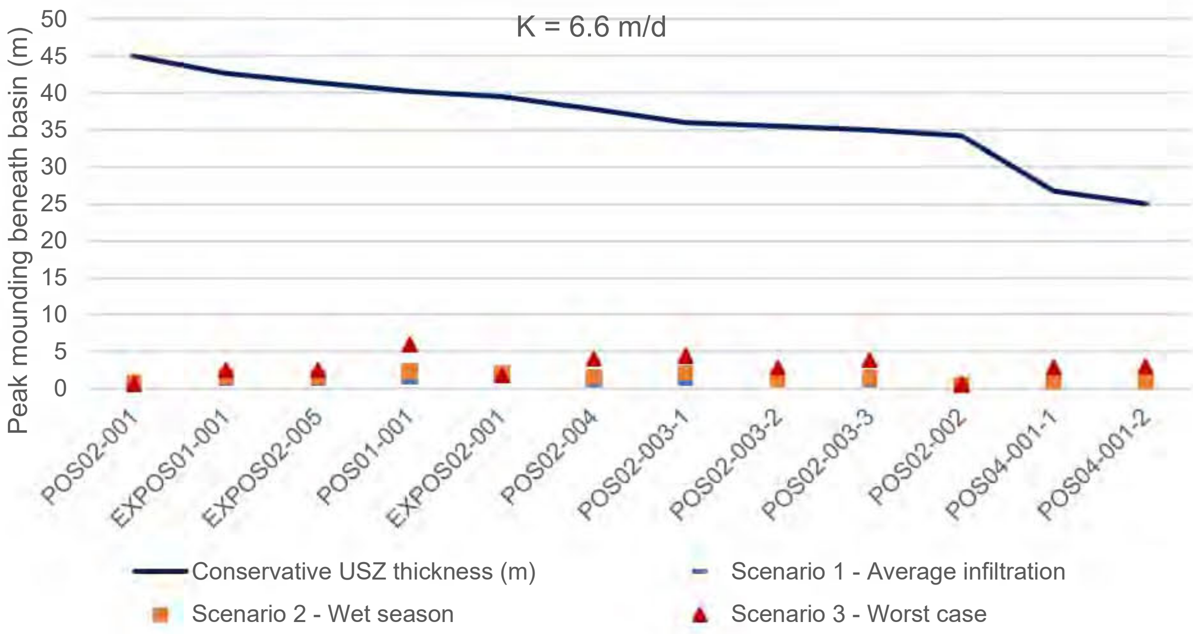
POS04-001	Scenario 3		**Pond 2**	Q (m^3/d)	a (m^2)	I (m/d)
I	0.337	m/day		2323.500	6900	0.337
S_y	0.02					
K	Varies	m/day				
x	41.533	m				
y	41.533	m				
t	1	days				
hi(0)	30	m				
IL	38	m aOD				

		Mounding (m)	
POS04-001	Distance	1.5 m/d	6.6 m/d
	0	7.452	2.998
	50	4.059	2.043
	100	0.922	0.987
	150	0.152	0.474
	200	0.021	0.217
	300	0.006	0.040
	400	0.006	0.009
	500	0.006	0.006
	750	0.006	0.006
	1,000	0.006	0.006



Hantush mounding results (m)		K = 1.5 m/d			K = 6.6 m/d		
	Conservative USZ thickness (m)	Scenario 1 - Average infiltration	Scenario 2 - Wet season	Scenario 3 - Worst case	Scenario 1 - Average infiltration	Scenario 2 - Wet season	Scenario 3 - Worst case
POS02-001	45	0.684	1.476	1.955	0.499	0.887	0.582
EXPOS01-001	42.65	1.734	4.624	7.484	0.770	1.704	2.529
EXPOS02-005	41.39	1.407	3.492	7.658	0.784	1.559	2.490
POS01-001	40.25	2.832	7.780	14.582	0.851	2.323	5.970
EXPOS02-001	39.5	2.094	5.448	5.328	0.983	2.108	1.757
POS02-004	37.8	1.893	5.415	10.379	0.599	1.619	3.985
POS02-003-1	36	2.482	6.868	11.611	0.790	2.082	4.479
POS02-003-2	35.5	1.518	4.214	7.750	0.549	1.340	2.764
POS02-003-3	35	1.724	4.797	10.438	0.599	1.497	3.829
POS02-002	34.2	0.464	1.310	1.963	0.196	0.454	0.644
POS04-001-1	26.7	1.081	3.137	7.038	0.315	0.896	2.860
POS04-001-2	25	1.103	3.179	7.452	0.324	0.909	2.998





Annex D ConSim pollution assessment input values

	CALCULATIONS	DOCUMENT No **HE540039-CJV-GEN-GEN-TNT-GEO-00219 - Annex M-D**

OFFICE	PROJECT TITLE
[redacted]	**Lower Thames Crossing**

SUBJECT	SHEET No
ConSim detailed pollution assessment input parameters - South of the River Thames	**1 of 5**

ISSUE	TOTAL SHEETS	AUTHOR	DATE	CHECKED BY	DATE	Revision change	COMMENTS
1	5	[redacted]	02/04/20	[redacted]	02/04/20	NA	
2	5	[redacted]	24/06/20	[redacted]	24/06/20	Revisions to the infiltration basin catchment areas	
3	[redacted]		10/06/[redacted]		02/08/2021	Revisions to the infiltration basin design and unsaturated zone thickness	

DESIGN BASIS STATEMENT (Inc. sources of info/data, assumptions made, standards, etc.)

Summary

Input paramaters for the ConSim model, south of the River Thames. ConSim has been used to assess the potential risk to groundwater quality from infiltration of routine highway runoff from 9 infiltration basins. The assessment has been conducted by the LTC hydrogeology team, part of the tunnels and systems group.

General approach:

The calculations presented here accompany the technical note HE540039-CJV-GEN-GEN-TNT-GEO-00219 .

Infiltration Basin	Catchment ID	Pond IL (m aOD)	Aproximate Trench length (m)	Basin bottom (m^2)	Worst case drainage infiltration rate (m/d)	Impervious catchment area (m^2)	Run-off recharge (mm/year)	Conservative USZ thickness (m)
EXPOS01-001	1b	67.65	n/a	1230.000	1.054	60020	581	42.65
EXPOS02-001	2a	63.5	n/a	1050.000	0.823	69240	581	39.5
EXPOS02-005	2f	67.39	167.900	626.408	1.796	38240	581	41.39
POS01-001	1a	65.25	556.239	6559.293	0.719	133790	581	40.25
POS02-001	2c	71	77.100	243.905	0.902	11060	581	45
POS02-002	2d	60.2	214.930	1376.125	0.239	16530	581	34.2
		51	320.640	4361.826	0.715	110566	581	36
POS02-003	2e	50.5	249.140	2389.946	0.683	60581	581	35.5
		50	282.560	2800.686	0.848	70993	581	35
POS02-004	2b	63.8	254.530	4366.140	0.632	85250	581	37.8
POS04-001	4a	27.5	500.000	7450.000	0.304	51195	581	26.7
		27.5	450.000	6900.000	0.337	51195	581	25
Swale 2	n/a	31.3	190.000	2660.000	1.230	4560	581	23.8

Parameter	Unit	Value: Max or mean	Value: Min or Stdev	Distribution type	Source
Source					
Lead concentration at source	mg/l	0.00381		Single	Average EMC (WRc, 2008. Improved determination of pollutants in highway runoff phase 2)
Copper concentration at source	mg/l	0.03131		Single	Average EMC (WRc, 2008. Improved determination of pollutants in highway runoff phase 2)
Zinc concentration at source	mg/l	0.111		Single	Average EMC (WRc, 2008. Improved determination of pollutants in highway runoff phase 2)
Chloride concentration at source	mg/l	349.53		Single	Average EMC (WRc, 2008. Improved determination of pollutants in highway runoff phase 2)
Source thickness	m	1		Single	Trench depth - Drainage report HE540039-CJV-GEN-GEN-REP-HWY-0147-A2 Junction-Gravesend Link
Source dimensions	m, coordinates	x, y vertices		Single	Inhouse GIS shapefiles for DR3.0 drainage release
Infiltration to the unsaturated zone	mm/yr	581		Single	CHESS database https://eip.ceh.ac.uk/apps/chess/
Maximum infiltration rate	m/d	See Soakaway tab		Single	Covered in Infiltration features sheet - taken from drainage drawings
Catchment area	m^3	See Soakaway tab		Single	Covered in Infiltration features sheet - provided by LTC- ASCADE drainage team in a drainage summary spreadsheet
Unsaturated zone pathway					
USZ dry bulk density	g/cm^3	1.69	1.43	Triangular - Likely = 1.47	Phase 1b & 2 lab testing results - Phase 1B and 2 Package A factual report (summarised in draft calcs tab)
Lead half life in USZ	years	1.00E+30		Single	Conservative - inert metal based on professional judgement
Copper half life in USZ	years	1.00E+30		Single	Conservative - inert metal based on professional judgement
Zinc half life in USZ	years	1.00E+30		Single	Conservative - inert metal based on professional judgement
Chloride half life in USZ	years	1.00E+30		Single	Conservative - inert metal based on professional judgement
Partition coefficient for chloride	ml/g	0		Single	Conservative - Professional judgment as chloride is used as a trace contaminant
Partition coefficient of copper	ml/g	67		Single	Allison and Allison. 2005. Kd for metals in surface water, soil and waste. pp15.
Partition coefficient for lead	ml/g	320		Single	EA. 2005. Development of the partition coefficent test method. pp15.
Partition coefficient for zinc	ml/g	45		Single	EA. 2005. Development of the partition coefficent test method. pp15.
USZ effective porosity	fraction	0.11	0.01	Triangle - Likely = 0.05	Phase 2 ground investigation data - NMR/BMR logging summarised in draft calcs tab
USZ conductivity	m/s	1.9E-04	5.0E-05	Log normal	Numerical model - Monte Carlo analysis results for upper Chalk
Vertical hydraulic gradient	m/m	1		Single	ConSim 2.5 Manual suggestion for Soakaways
Saturated zone pathway					
Background concentration of lead	mg/l	0.00207		Single	Phase 2 GI data - ESdat Package A export, summarised in Backgrond conc. tab
Background concentration of copper	mg/l	0.011		Single	Phase 2 GI data - ESdat Package A export, summarised in Backgrond conc. tab
Background concentration of zinc	mg/l	0.00729		Single	Phase 2 GI data - ESdat Package A export, summarised in Backgrond conc. tab
Background concentration of chloride	mg/l	54.2		Single	Phase 2 GI data - ESdat Package A export, summarised in Backgrond conc. tab
Hydraulic conductivity of Chalk	m/s	0.000194	0.00005	Log normal	Numerical model - Monte Carlo analysis results for upper Chalk
Hydraulic gradient	-	0.01		Single	2014 EA February high groundwater contours
Aquifer thickness	m	50	30	Uniform	Conservative values based on literature - Major aquifer properties manual (Allen et al. 2007)
Mixing zone thickness	m	n/a		Single	Calculated by ConSim
Groundwater flow direction	degrees	10	0	Single	LTC inhouse GIS viewer - groundwater contours for February 2014
Chalk aquifer effective porosity	fraction	0.2	0	Triangle = 0.05	Phase 2 ground investigation data - NMR/BMR logging summarised in draft calcs tab
Aquifer bulk density	g/cm^3	1.69	1.43	Triangle - Likely = 1.47	Phase 1b lab testing results - Phase 1B factual report (summarised in draft calcs tab)
Aquifer longitudinal dispersivity	m	10% of compliance distance		Single	ConSim 2.5 Manual suggests we use rule of thumb. pp34
Aquifer transverse dispersivity	m	30% of longitudinal dispersivity		Single	ConSim 2.5 Manual suggests we use rule of thumb. pp34
Lead half life in unsaturated zone	years	1E+30		Single	Conservative - inert metal based on professional judgement
Copper half life in unsaturated zone	years	1E+30		Single	Conservative - inert metal based on professional judgement
Zinc half life in unsaturated zone	years	1E+30		Single	Conservative - inert metal based on professional judgement
Chloride half life in unsaturated zone	years	1E+30		Single	Conservative - inert metal based on professional judgement
Partition coefficient of chloride in aquifer	ml/g	0		Single	Conservative - professional judgment as chloride is used as a trace contaminant
Partition coeffieient of copper in aquifer	ml/g	67		Single	Allison and Allison. 2005. Kd for metals in surface water, soil and waste. pp15.
Partition coefficient of lead in aquifer	ml/g	320		Single	EA. 2005. Development of the partition coefficent test method. pp15.
Partition coefficient of zinc in aquifer	ml/g	45		Single	EA. 2005. Development of the partition coefficent test method. pp15.
Receptor compliance points					
Ramsar site	m (coordinate)	568633, 173272		Single	LTC inhouse GIS Viewer
Eastern SPZ1	m (coordinate)	570429, 170098		Single	LTC inhouse GIS Viewer
Eastern SPZ 2	m (coordinate)	570001, 169755		Single	LTC inhouse GIS Viewer
Northwest SPZ1	m (coordinate)	565369, 172686		Single	LTC inhouse GIS Viewer
Northwest SPZ 2	m (coordinate)	565651, 171297		Single	LTC inhouse GIS Viewer
EQS values					
Chloride	mg/l	250		Single	
Copper	mg/l	0.028		Single	
Lead	mg/l	0.025		Single	
Zinc	mg/l	0.04		Single	
WQS values					
Chloride	mg/l	250		Single	
Copper	mg/l	2		Single	
Lead	mg/l	0.01		Single	
Zinc	mg/l	5		Single	

Draft Calculations

effective porosity %

BMR			USZ			Saturated zone		
BH ID	Fluid level	Total range %	Min	Max	Likely	Min	Max	Likely
BH03001	39 m bgl	0-15	1	10	5	0	15	8
BH03003	50 mbgl	0-20	1	11	5	0	20	9

Total water filled porosity %

BMR			USZ			Saturated zone		
BH ID	Fluid level	Total range %	Min	Max	Likely	Min	Max	Likely
BH03001	39 m bgl	0-15	36	59	45	30	51	40
BH03003	50 mbgl	0-20	36	61	45	30	50	40

q=Q/A
q=Ki
Q=-Aki

Dry density (g/cm3)	
Average	1.48464286
Mode	1.47
Min	1.43
max	1.69

BH/TP ID	Phase	Depth (m)	Dry density (Mg/m3)	Dry density (kg/m3)	Dry density (g/cm3)
TP01010	2A	1.2	1.69	1690	1.69
WS01016	2A	1	1.45	1450	1.45
BH2034	1b	9.69	1.47	1470	1.47
BH2034	1b	10.73	1.48	1480	1.48
BH2034	1b	12.69	1.47	1470	1.47
BH2034	1b	14.71	1.54	1540	1.54
BH2034	1b	17.36	1.46	1460	1.46
BH2034	1b	19.33	1.49	1490	1.49
BH2034	1b	21.95	1.44	1440	1.44
BH2034	1b	23.72	1.46	1460	1.46
BH2034	1b	24.7	1.46	1460	1.46
BH2034	1b	27.81	1.47	1470	1.47
BH2034	1b	29.31	1.53	1530	1.53
BH2312A	1b	23.52	1.46	1460	1.46
BH2312A	1b	27.1	1.47	1470	1.47
BH2312A	1b	28	1.47	1470	1.47
BH2312A	1b	28.82	1.47	1470	1.47
BH2312A	1b	33.39	1.46	1460	1.46
BH2312A	1b	40.4	1.44	1440	1.44
BH2312A	1b	41.81	1.43	1430	1.43
BH2312A	1b	42.8	1.49	1490	1.49
BH2312A	1b	43.9	1.43	1430	1.43
BH2312A	1b	45.82	1.46	1460	1.46
OH03001	1b	10.04	1.52	1520	1.52
OH03001	1b	15.13	1.5	1500	1.5
OH03001	1b	18.68	1.48	1480	1.48
OH03001	1b	20.44	1.47	1470	1.47
OH03001	1b	23.58	1.61	1610	1.61

Background concentrations | Maximum concentrations

BH ID	X	Y	Phase	Chloride - mg/l	Copper - ug/l	Zinc - ug/l	Cadmium - ug/l	Lead - ug/l
BH01003	570033	169729.1	2	54.2	0.687	7.29		<0.2
BH01020	566742.9	170283.2	2	18.6	0.593	4.19		0.315
BH01033	566684.7	170436.9	2	17.9	2.59	7.6		<0.2
BH01025	567177.8	170977.2	2	33.8	4.73	1.71		<0.2
BH03002	568603.1	172015.2	2	31.3	11	46.9		31.9
BH03006	567686.9	172208.3	2	26.2	0.883	3.59		<0.2
BH03003	567768.4	172362.3	2	37.2	1.34	6.79		0.324
OH03003	567902.9	172583.2	1	30			<LOD	<LOD
OH03001	568079	172615.2	1	30			<LOD	<LOD
PW03001	568046	172651.7	1	54			<LOD	<LOD
OH03002	568056.3	172652.1	1	31			<LOD	<LOD
BH2034	567986.5	172698.4	1				<LOD	<LOD
BH2036	567969.3	172857.8	1	35			<LOD	<LOD
BH04001	568176.1	172956.2	2	44.1	1.48	47.8		1.19
BH2301	568028	173026.3	1	10			<LOD	<LOD
BH04004	568158.3	173161.2	2	52.6	0.434	7.68		<0.2
OH04001A	567741.9	173314.4	1	49	<5	18	<LOD	<LOD
BH04012	567939.3	173317.7	2	44.7	1.05	4.19		<0.2
BH04010	567671.7	173337.3	2	56.7	1.61	9.45		2.07
OH04007	568061.7	173396.2	1	100	11	12	<LOD	<LOD
OH04006	567695.8	173497.8	1	5510	<5	36	<LOD	<LOD
OH04002	568566.4	173522.5	1	73	12	7	<LOD	<LOD
OH04005A	568564.7	173530.4	1	7770			<LOD	<LOD
OH04005	568566.4	173532.1	1	7770	15	7	<LOD	<LOD
BH2316-2	568038.2	173653.4	1	646	6	27	<LOD	<LOD
BH2316-1	568038.2	173653.4	1	1090	9	13	<LOD	<LOD
OH04003	568133	173695.8	1	470	12	6	<LOD	<LOD
OH04008	568097.2	173701	1	572	14	9	<LOD	<LOD
OH04004	568079	173818.2	1	202	<5	12	<LOD	<LOD
OH05002	568038.5	173825.3	1	65	10	25	<LOD	<LOD
BH2322	567883.4	173842.1	1	614	10	5	<LOD	<LOD

LOD		
Lead	1	ug/l
Cadmium	0.2	ug/l
Copper	5	ug/l

EQS		
Copper	0.028	mg/l
Zinc	0.04	mg/l
Lead	0.025	mg/l
Chloride	250	mg/l

Annex N Infiltration drainage hydrogeological assessment North Portal to A13/A1089/A122 Lower Thames Crossing junction – technical note

Lower Thames Crossing

Annex N Infiltration Drainage Hydrogeological Assessment North Portal to A13/A1089/A122 Lower Thames Crossing Junction – Technical Note

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1 Introduction

1.1 Background

1.1.1 This report presents a hydrogeological assessment of infiltration drainage of part of the proposed A1222 Lower Thames Crossing (the Project).

1.1.2 The A122 Lower Thames Crossing (the Project) would provide a connection between the A2 and M2 in Kent, east of Gravesend, crossing under the River Thames through a tunnel, before joining the M25 south of junction 29. The A122 road would be approximately 23km long, 4.25km of which would be in tunnel. On the south side of the River Thames, the Project route would link the tunnel to the A2 and M2. On the north side, it would link to the A13 and junction 29 of the M25. The tunnel entrances would be located to the east of the village of Chalk on the south of the River Thames and to the west of East Tilbury on the north side.

1.1.3 Highway drainage systems are designed to rapidly remove water from the carriageway and accommodate runoff from the highway, to prevent flooding of the carriageway.

1.1.4 The drainage design along the Project route north of the River Thames includes one soakaway at the A13/A1089/A122 Lower Thames Crossing junction and several swales. Soakaways and swales allow highway runoff to drain into a basin and the water to seep into the ground beneath. It is considered that the infiltration basin would work well at the A13/A1089/A122 Lower Thames Crossing junction, where the geology consists of sands and gravels overlying Chalk.

1.1.5 A simple pollution risk assessment from routine highway runoff was completed following the Design Manual for Roads and Bridges LA113 methodology (Highways England, 2020b), using Highways England Water Risk Assessment Tool (HEWRAT). The outcome of this assessment showed that a detailed assessment was required for twelve infiltration features along the section from the North Portal to the M25/Lower Thames Crossing junction. More details on the HEWRAT assessment can be found in Appendix 14.5: Hydrogeological Risk Assessment (Application Document 6.3).

1.2 Brief and scope

1.2.1 The purpose of this technical note is to present a groundwater appraisal for the proposed highway drainage by infiltration to ground, north of the River Thames, from the North Portal to the M25/Lower Thames Crossing junction.

1.2.2 The objectives of this technical note are to analyse the feasibility of the proposed infiltration structures in terms of hydrogeological model, potential groundwater mounding and risk of pollution from infiltration of routine highway runoff. Infiltration volumes for the swales are generally low and does not constitute an infiltration capacity problem and so are not further assessed in the mounding assessment. However, swales near to infiltration basins (as in the A13/A1089/A122 Lower Thames Crossing junction) are also assessed for cumulative mounding risks. Swales are included in this assessment where a simple assessment (Annex O) has shown there to be a potential risk to groundwater quality from highway runoff.

1.3 Limitations

1.3.1 Pollution prevention control measures, such as to intercept oils, are discussed in the drainage design basis statement (Cascade, 2019a) and are not part of the scope of this technical note.

1.3.2 This assessment is based on published and Project ground investigation data.

1.4 Legislation and guidance

1.4.1 For a list of all relevant legislation and guidance see Chapter 14: Road Drainage and the Water Environment (Application Document 6.1).

2 Conceptual site model

2.1 Geology

2.1.1 The geology at the A13/A1089/A122 Lower Thames Crossing junction is summarised in Table 2.1. See Annex A for superficial and bedrock geology maps.

2.1.2 The bedrock geology consists of a sequence of Palaeogene strata overlying the White Chalk Group. Palaeogene strata, comprising the London Clay Formation, Lambeth Group (Upnor Formation) and Thanet Formation have a thickness of up to 30m above the Chalk in the area surrounding the A13/A1089/A122 Lower Thames Crossing junction.

2.1.3 Superficial geology is made up of Head and River Terrace Deposits (RTD). Both deposits are found at outcrop, with the RTD extending south towards the River Thames floodplain.

Table 2.1 Summary of the geology surrounding the A13/A1089/A122 Lower Thames Crossing junction

Strata	General description
Head Deposits	Gravel, sand and clay depending on upslope source.
RTD: Boyn Hill Gravel Member	Terrace deposits: gravel, sandy and clayey in part.
London Clay Formation	Dark bluish to brownish grey clay, containing variable amounts of fine-grained sand and silt.
Lambeth Group: Upnor Formation	Glauconitic fine to coarse sands with variable clay and silt content, and with beds, lenses and stringers of well-rounded, black flint gravel, and minor thin clays (British Geological Survey, 2020b). Difficult to distinguish Upnor Formation from the underlying Thanet Formation (Jones *et al*., 2000).
Thanet Formation Pegwell Member	Greenish to brownish grey silty, fine to coarse sand, clayey and siltier in the lower part, with a conglomerate of flint pebbles and nodular flints at the base. Clayey silty basal member. This layer is not laterally continuous beneath the sands.
White Chalk Group comprising: Seaford Chalk Formation Newhaven Chalk Formation	White fossiliferous, nodular chalk with bands of nodular and tabular flints, hardgrounds and marl seams. Smooth white chalk with marl seams and flint bands.

2.2 Hydrogeology

2.2.1 Annex B presents a plan of groundwater flooding potential for north of the River Thames to the A13/A1089/A122 Lower Thames Crossing junction. Groundwater flooding potential is based on rock type, topography and predicted groundwater level after extended rainfall from numerical and statistical modelling (British Geological Survey, 2020a).

2.2.2 The Environment Agency classifies the Chalk as a Principal aquifer (Natural England, 2019) – an aquifer that may support water supply and/or river base flow on a strategic scale. The RTD, Lambeth Group and Thanet Formation are classified as Secondary A aquifers – aquifers considered to provide important baseflow to rivers and potential resources for small-scale water supplies (e.g. domestic, agricultural).

2.2.3 The Thanet Formation and the lower part of the Lambeth Group (Upnor Formation) are together known as the 'Basal Sands' unit/aquifer (Allen *et al*., 1997). It is considered from a hydrogeological point of view that this unit is in hydraulic continuity with the underlying Chalk strata across the Thames Basin and wider South Essex catchment area (Environment Agency, 2016). At a local scale, the degree of hydraulic connection between the Chalk and the overlying Basal Sands unit can vary according to lithological heterogeneity (cohesive lenses/layers) (Environment Agency, 2016).

2.2.4 Typically, Chalk is a low storage, high transmissivity aquifer. Most flow occurs in the fractures, with storage in the matrix released to the fractures as groundwater levels fall (Cascade, 2018). The overlying Basal Sands unit has moderate hydraulic conductivity and storativity properties and could provide additional storage capacity for the Chalk aquifer (Environment Agency, 2016).

2.2.5 Potential groundwater flooding is generally a risk in low-lying areas where groundwater levels are high (Annex B). Areas south of Muckingford Road, on the approach to the North Portal, are shown as having low to moderate groundwater flooding risk. The risk is likely a mix of pluvial and groundwater flooding, a result of low permeability Alluvium deposits found at the surface confining the Chalk aquifer beneath.

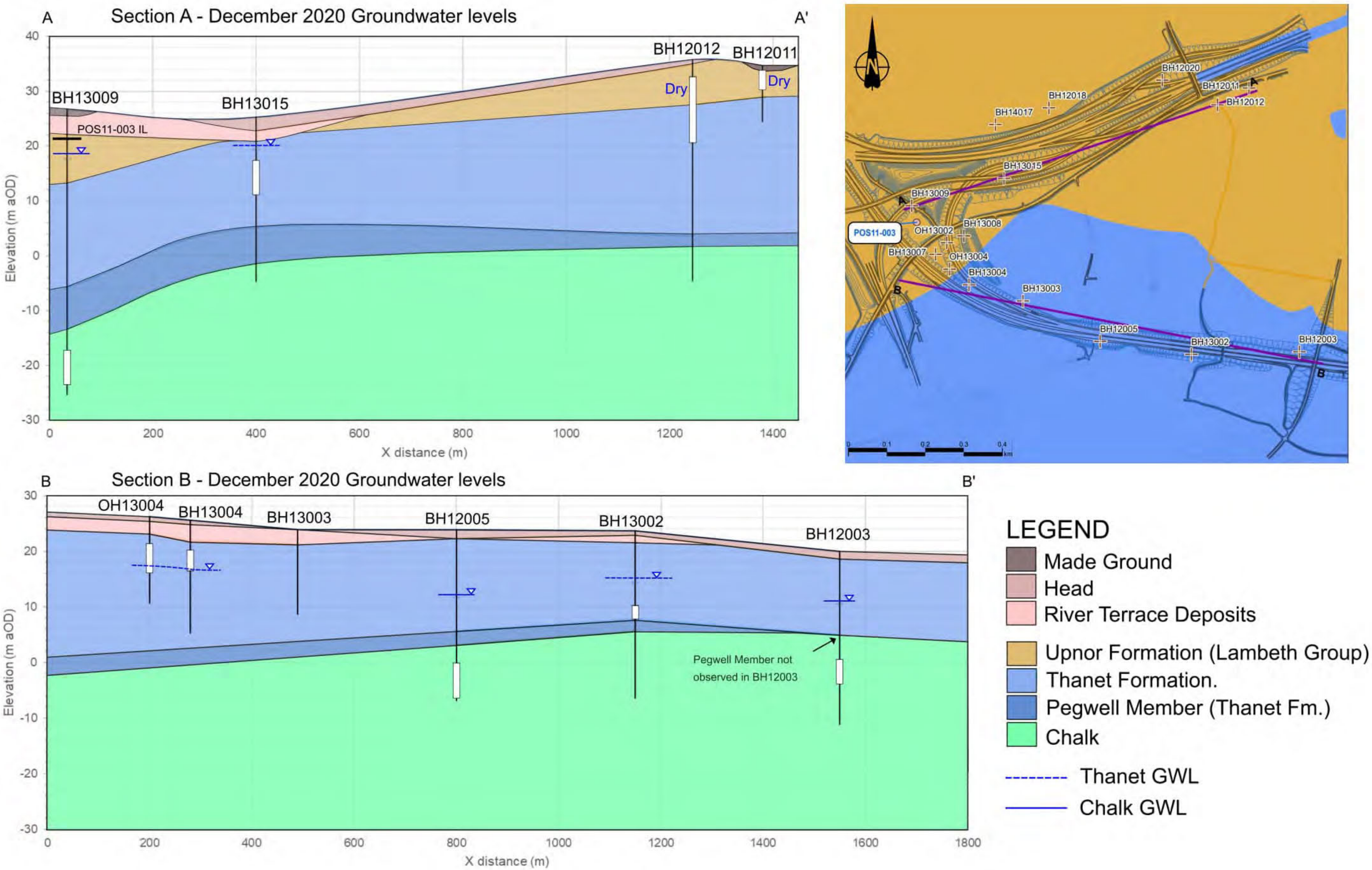
2.3 Ground model

2.3.1 A ground model for the A13/A1089/A122 Lower Thames Crossing junction is illustrated by section lines A and B in Plate 2.1:

a. The sections have been constructed using Project Phase 2 ground investigation and December 2020 groundwater levels (high groundwater level).

b. The map illustrating the section lines includes the proposed Project route, the location of the proposed infiltration basin (POS11-003) and British Geological Survey 50K bedrock geology mapping.

Plate 2.1 Ground model, section lines A and B (vertical exaggeration x10)



2.3.2 Section A runs from west to east along the existing A13. Here, the Chalk is overlain by the Thanet Formation, Lambeth Group, and superficial RTD outcropping to the west, but pinching out beneath deposits of Head to the east.

2.3.3 Section B is aligned along the proposed Project route approaching the A13/A1089/A122 Lower Thames Crossing junction. Based on available ground investigation data, the Lambeth Group is not found above the Thanet Formation along this section, but like section A, superficial Head and RTD are found at outcrop.

2.3.4 The site-specific geology for the A13 and its hydrogeological significance are described below:

a. Field descriptions for the Upnor Formation (Lambeth Group) show the matrix material to vary between largely glauconitic sands (BH13007) to being solely made up of cohesive clays and silts (BH13009). The heterogeneous makeup of this formation results in the hydraulic properties being anisotropic, as the granular material allows water to pass easily, but the cohesive parts act as barriers to groundwater flow.

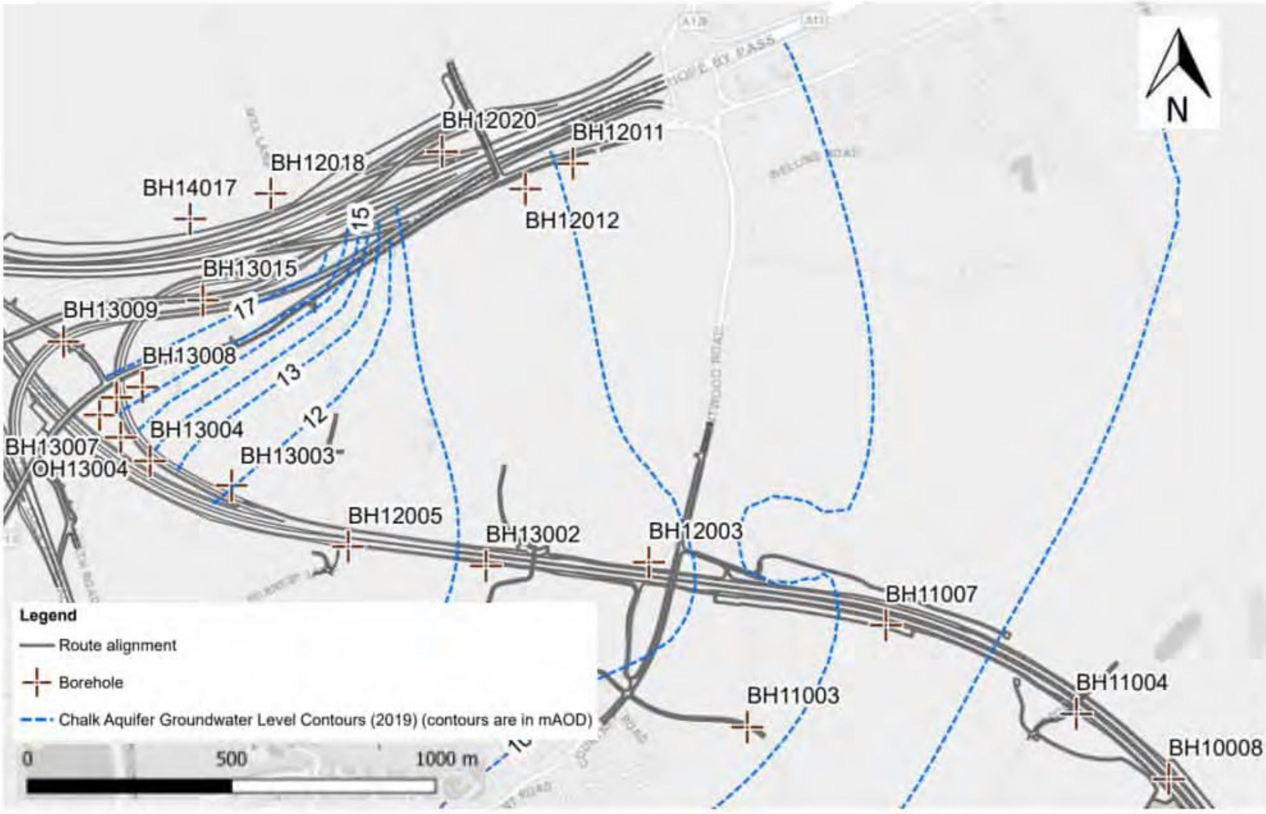
b. At the base of the Thanet Formation, the primarily cohesive Pegwell Member (basal unit) was observed across most boreholes (all boreholes but BH12003), separating the largely sandy upper Thanet Formation from the top of the Chalk. Where the basal member is found, vertical groundwater flow between the Thanet Formation and the Chalk would likely be restricted, enhancing horizontal flows along the top of the Pegwell Member, and in parts reducing the hydraulic connection.

2.4 Groundwater levels and contouring

2.4.1 Across the Package C ground investigation, there are 17 Phase 2 groundwater monitoring boreholes. The boreholes are screened across the three hydrogeological units: RTD, Basal Sands aquifer (Lambeth Group and Thanet Formation) and the Chalk.

2.4.2 Four boreholes are installed to target the Chalk. Monitored groundwater levels for December 2020 have been contoured using Surfer 15 (see Plate 2.2). Contouring was achieved using the interpolation method of Ordinary Kriging.

Plate 2.2 Chalk groundwater contours using Package C boreholes (groundwater levels metres above ordnance datum (AOD))



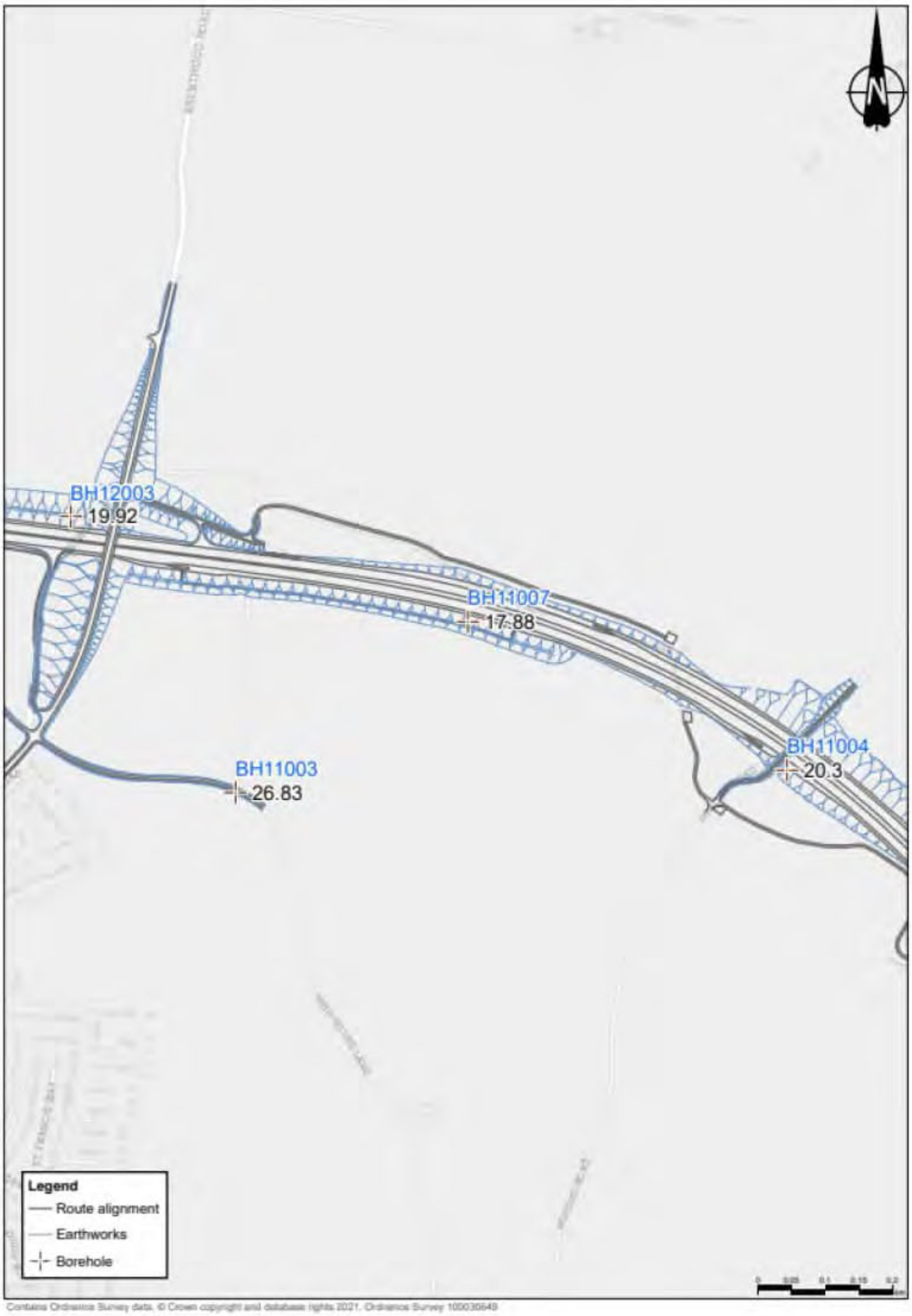
2.4.3 Contouring indicates that groundwater in the Chalk flows in a south-easterly direction, with higher groundwater levels at the A13/A1089/A122 Lower Thames Crossing junction to lower groundwater levels towards the River Thames.

2.4.4 Monitoring data from the boreholes screened in the RTD, Lambeth Group and Thanet Formation indicate, in parts, some separation in the groundwater in the Basal Sands from the Chalk aquifer.

a. In BH13002 (see section B in Plate 2.1), the groundwater level in the Thanet Formation was observed at 15.39m AOD, 3m to 4m higher than the two boreholes either side (BH12005 and BH12003) screened in the Chalk.

b. In BH11003 (not included in either section, see Plate 2.3), the groundwater level was monitored to fluctuate between 21.12m and 20.6m AOD (water drops below base of the response zone). The groundwater level here in the Thanet Formation is up to 10m higher than the levels recorded in the Chalk.

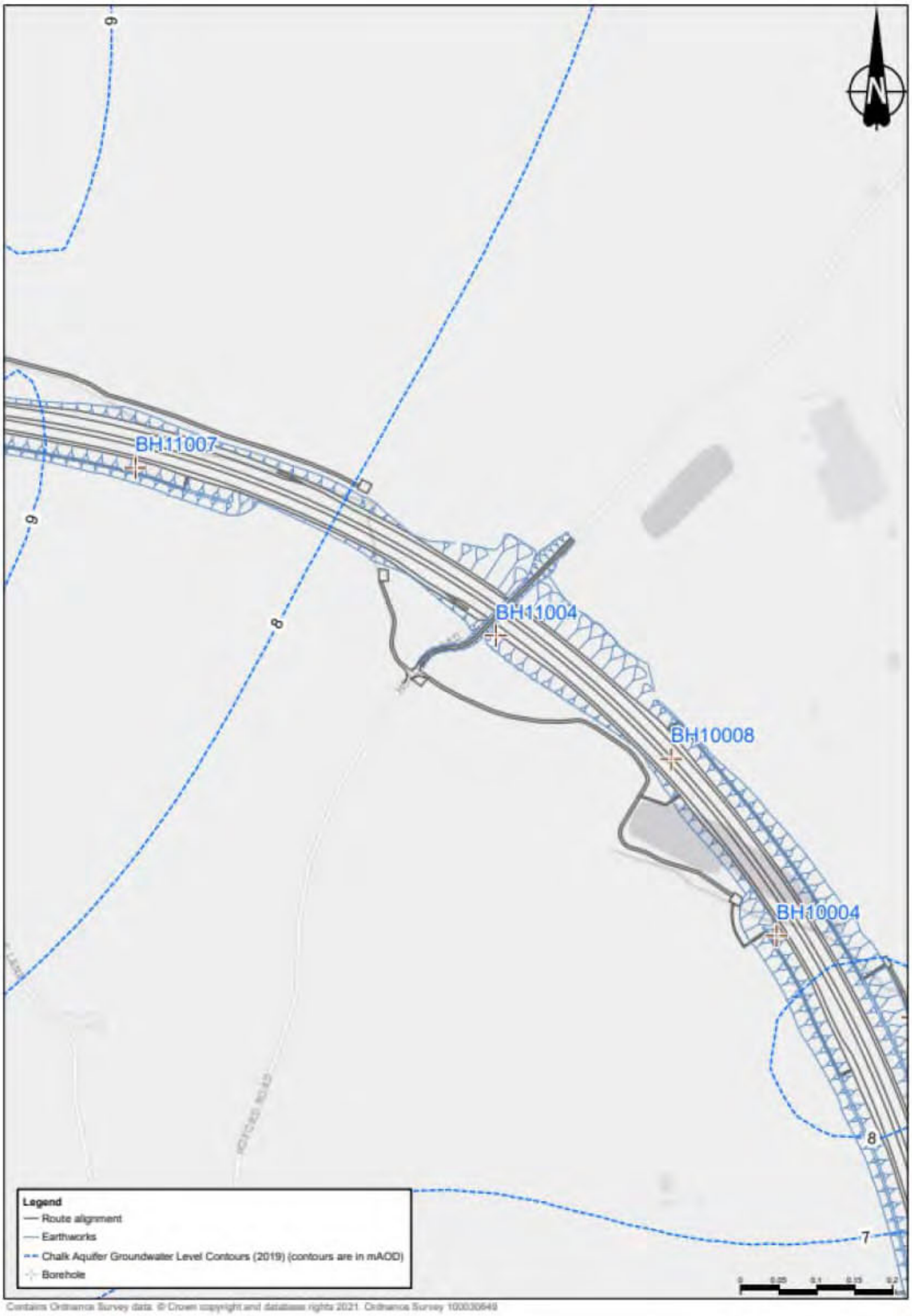
Plate 2.3 Groundwater separation observed in BH11003



2.4.5 The separation in groundwater levels in the Basal Sands is caused by perching of groundwater above the cohesive Pegwell Member, due to flow restrictions to the Chalk below.

2.4.6 Further to the south-east, around Hoford Road, the Pegwell Member thickness decreases at the base of the Thanet Formation. Here, the Basal Sands and Chalk are in hydraulic continuity, as illustrated by the contouring in Plate 2.4

Plate 2.4 Hoford Road contours using December 2020 groundwater levels (m AOD)



2.5 Hydraulic properties

2.5.1 Hydraulic conductivity of the main hydrogeological units around the A13/A1089/A122 Lower Thames Crossing junction have been summarised in Table 2.2 using various literature sources for the Thames Basin.

Table 2.2 Summary of literature hydraulic conductivity properties

Strata		Hydraulic conductivity		Source
		m/d	m/s	
River Terrace Deposits (RTD)		5.56	6.4×10^{-5}	Mean hydraulic conductivity of the RTD (Bricker and Bloomfield, 2014).
River Terrace Deposits (RTD)		86.4 to 1.73	1.0×10^{-3} to 2.0×10^{-5}	Range of values depending on clay content (Cascade, 2020b).
Basal Sands aquifer	Upnor Formation (Lambeth Group)	20	2.3×10^{-4}	Jones *et al*. (2000) states that at any one locality the hydraulic conductivity is likely to be between 2m/d and 60m/d, with a tendency to increase towards the top of the deposit. A representative average is 20m/d.
Basal Sands aquifer	Upnor Formation (Lambeth Group)	8.6 to 0.86	10^{-4} to 10^{-5}	Values measured in the Upnor Formation on the Channel Tunnel Rail Link Project (Hight *et al*., 2004).
Basal Sands aquifer	Thanet Formation	2.5	3×10^{-5}	Jones *et al*. (2000) states hydraulic conductivity is between 1.39m/d and 3.89m/d.
Basal Sands aquifer	Thanet Formation	0.86 to 0.09	10^{-5} to 10^{-6}	Results from pumping test conducted in the Thanet Formation as part of the Crossrail Project (Menkiti *et al*., 2015).
Chalk		14.4	1.7×10^{-4}	Geometric mean of the unconfined Chalk aquifer (Adams, 2008). Can be highly variable depending on grade and site-specific ground conditions.

2.5.2 It is understood that heterogeneity in the Upnor and Thanet Formations results in a significant range in hydraulic conductivity values for the Basal Sands aquifer. In parts, the Upnor Formation can have a hydraulic conductivity of up to 60m/d (Jones *et al*., 2000), but values measured as part of the Channel Tunnel Rail Link Project were as low as 0.86m/d (Hight *et al*., 2004). The conductivity range for the Thanet Formation is significantly smaller, between 3.89m/d to 0.09m/d.

2.5.3 The storage coefficient of unconfined Chalk is typically 0.02, with the overlying Basal Sands having a larger storage coefficient of typically 0.10 (Allen *et al*., 1997). As both the Chalk and Basal Sands are generally unconfined in the area surrounding the A13, the storage coefficient is approximately equal to the specific yield (S_y).

In situ hydraulic conductivity testing

2.5.4 Variable and constant head tests, along with packer testing, were carried out as part of the Project ground investigation works. Results from the 30 tests carried out across the RTD, Upnor Formation, Thanet Formation and Chalk are summarised in Table 2.3. Testing results for the Thanet Formation have been split in two, separating tests in the bulk Thanet material from tests conducted in the basal Pegwell Member.

Table 2.3 Project Phase 2 and 3 Package C *in situ* permeability testing results

Strata	Method	No. of tests	Hydraulic conductivity, K					
			Minimum		Maximum		Geomean	
			m/s	m/d	m/s	m/d	m/s	m/d
RTD	RHT	5	2.13×10^{-6}	0.18	2.74×10^{-4}	23.66	1.24×10^{-5}	1.07
Upnor Formation (Lambeth Group)	RHT	2	2.02×10^{-6}	0.18	1.91×10^{-4}	16.50	1.09×10^{-5}	0.96
	CHT	2	2.55×10^{-7}	0.33	1.19×10^{-5}	1.03		
Thanet Formation – Bulk material	RHT	8	1.77×10^{-7}	0.02	6.52×10^{-5}	5.63	4.61×10^{-6}	0.31
	FHT	4	4.54×10^{-7}	0.04	6.32×10^{-5}	5.46		
Thanet Formation – Pegwell Member	RHT	2	1.41×10^{-7}	0.01	3.99×10^{-7}	0.03	2.69×10^{-7}	0.02
	FHT	2	3.79×10^{-7}	0.03	4.63×10^{-7}	0.04		
Chalk	RHT	3	2.42×10^{-7}	0.02	1.37×10^{-4}	11.84	6.30×10^{-6}	0.54
	FHT	2	4.19×10^{-6}	0.19	1.25×10^{-4}	10.80		
	PK	6*	1.61×10^{-6}	0.14	1.91×10^{-5}	1.65		

RHT = rising head test; FHT = falling head test; CHT = constant head test; PK = double packer test; 6* = six tests in one borehole (BH10003)

2.5.5 A comparison between literature-sourced hydraulic conductivity values and the Project *in situ* ground investigation results is described below:

c. RTD hydraulic conductivity ranged from 0.18m/d to 23.66m/d (geomean of 1.07m/d) – a significant range in values, likely due to heterogeneity in the deposits. The range is within the values presented in Table 2.2 from literature sources.

d. Variable head and constant head testing in the Upnor Formation found the hydraulic conductivity to range from 0.18m/d to 16.5m/d (geomean of 0.96m/d), a similar range to those presented in Table 2.2.

e. Testing results in the Thanet Formation (excluding the Pegwell Member) range from 0.02m/d to 5.63m/d, with a geomean of 0.31m/d. The range in results is in the same order of magnitude as the results obtained from pumping tests conducted as part of the Crossrail Project (Menkiti *et al.*, 2015). The significant range in values is due to heterogeneity in the granular deposits, and varying clay and silt contents.

f. Hydraulic conductivity of the Pegwell Member (base of Thanet Formation) was measured consistently in the order of 10^{-7}m/s (0.02m/d), typical values for an aquitard layer.

g. For the Chalk, the hydraulic conductivity was assessed to range from 0.02m/d to 11.84m/d (10^{-7}m/s to 10^{-4}m/s). Packer testing was conducted in one borehole (BH10003); the midpoint depth of the six tests ranged from 46.5m to 17.5m below ground level (bgl). The maximum hydraulic conductivity was recorded at shallow midpoint depth of 17.5m bgl. As depth increases, the Chalk fractures become increasingly tight and sparsely distributed, resulting in reduced hydraulic conductivity with depth.

Soakaway testing

2.5.6 Soakaway tests are an *in situ* method for calculating the potential water infiltration rate of the soil or rock. Infiltration rate is calculated using the following equation (Bettess, 1996):

$$I = \frac{V_{P75-25}}{a_{p50} \times t_{p75-25}}$$

Where:

I = infiltration rate (L^1T^{-1})

V_{p75-25} = effective storage volume of water in trial pit between 75% and 25% effective depth (L^3)

a_{p50} = internal surface area of trial pit up to 50% effective depth and including base area (L^2)

t_{p75-25} = time for water level to fall from 75% to 25% effective depth (T)

2.5.7 Three soakaway tests were also carried out as part of the Package C ground investigation works. Two tests were successfully completed in trials pits dug into material that was described as slightly silty, fine to medium sand with flint gravels, likely to be the RTD or the top of Thanet Formation (see Table 2.4), and one test conducted in the Upnor Formation.

Table 2.4 Package C soakaway test results

Trial pit	GI Phase	Strata	Calculated infiltration rate (m/s)
TP10004	2	RTD/Thanet Formation	2.87×10^{-5}
TP10004A	2	RTD/Thanet Formation	2.86×10^{-6}

TP13308	3	Upnor Formation	1.21×10^{-5}

2.5.8 The infiltration rates calculated vary by an order of magnitude, from 10^{-5} to 10^{-6}m/s. These rates are equivalent to a hydraulic conductivity of 1.0m/d to 0.23m/d (assuming the vertical hydraulic gradient to be -0.95), values that are comparable to those found from the rising and falling head testing.

2.5.9 TP13308 is located on the proposed site of POS11-003, so the infiltration rate (and equivalent hydraulic conductivity = 1m/d) is directly comparable to the drainage area at the A13/A1089/A122 Lower Thames Crossing junction. The other two soakaway tests were conducted in trial pits located approximately 3km south-east of the proposed drainage at the A13 and are not directly comparable.

3 Review of proposed drainage design

3.1 Design basis

3.1.1 The drainage system has been designed to rapidly remove water from the carriageway and accommodate runoff from the highway and from adjacent (external) catchments, with increased rainfall intensities in accordance with predicted climate change effects, to prevent flooding of the carriageway for the design storm return periods within the various constraints of the Project. Further information is shown in Appendix 14.6: Flood Risk Assessment Part 7 (Application Document 6.3) and the Drainage Plans (Application Document 2.16).

3.1.2 The design development concluded that the disposal of surface water runoff for the section between the North Portal and A13/A1089/A122 Lower Thames Crossing junction would primarily be by positive piped drainage networks draining to attenuation basins before discharge to surface watercourses (Cascade, 2019b). The watercourses crossing the Project north of the Thames include Tilbury Main; unnamed tributary of Tilbury Main; ordinary watercourse west of Linford; Orsett Fen Sewer; and the Mardyke river. Drainage by infiltration to the ground is also proposed using an infiltration basin (soakaway) at the A13/A1089/A122 Lower Thames Crossing junction, and numerous swales along the route where the Project road is on embankment or at small catchments on side roads (Cascade, 2019b; 2020a).

3.2 POS11-003

3.2.1 The soakaway at A13/A1089/A122 Lower Thames Crossing junction, POS11-003, would comprise a large open infiltration basin with a series of shallow soakaway trenches across the base.

3.2.2 Table 3.1 provides a summary of the infiltration basin details.

Table 3.1 POS11-003 design details

Basin invert level (m AOD)	Impervious catchment area (m^2)	Storage volume (m^3)	Basin bottom area (m^2)	Total design infiltration flow rate (L/s)
21.59	8,520	1,263.5	1,051.97	13.1

3.3 Unsaturated zone

3.3.1 The unsaturated zone beneath POS011-003 is made up of Upnor Formation. The thickness of unsaturated material has been estimated using groundwater levels recorded in BH13007, BH13353 and BH13354 (response zone across the Upnor Formation and Thanet Formation), the boreholes nearest to the proposed basin location. Groundwater levels are summarised in Table 3.2.

3.3.2 Maximum water level was recorded at 18.28m AOD in September 2019. Based on the available data, the unsaturated zone thickness is estimated to range from 3.31m to more than 6.30m.

Table 3.2 Groundwater levels beneath POS11-003

Borehole	Response zone	Monitoring data		
		Period	Maximum water level (m AOD)	Minimum water level (m AOD)
BH13007	Upnor/Thanet	October 2019 – December 2020	18.28	Dry <15.30
BH13353	Upnor	December 2020	17.83	17.74
BH13354	Upnor	November 2020-December 2020	17.87	17.63

Upnor = Upnor Formation; Thanet = Thanet Formation.

4 Groundwater mounding assessment

4.1 Introduction

4.1.1 When infiltration basins are used, there is expected to be a degree of groundwater mounding at the water table, due to the concentration of recharge in a small area (Carleton, 2010). POS11-003 is the one and only infiltration basin to the north of the River Thames. The groundwater mounding response has been assessed using an analytical (one-dimensional) method. Swales have not been included in the assessment because they have generally small drainage catchment areas and small volumes of infiltration. The exception is swales SWS11-002A and SWS11-008 which are located in the vicinity of infiltration basin POS11-003.

4.2 Analytical method

4.2.1 Analytical equations can be used to estimate the magnitude and radius of groundwater mounding beneath infiltration basins, but are limited by simplified assumptions (Carleton, 2010). The most widely used solution is one by Hantush (1967). This solution uses an equation describing the '*growth and decay of groundwater mounds in response to uniform percolation*'. The following assumptions apply:

a. Water table aquifer of infinite extent and finite thickness.

b. A horizontal impermeable aquifer base.

c. Flow is horizontal.

d. There is negligible change of transmissivity with a change in head.

4.2.2 As part of the study by Carleton (2010), a spreadsheet was developed to use the Hantush solution (Hantush, 1967). This spreadsheet has been used in this assessment. The spreadsheet requires the following input parameters for each infiltration basin and swales assessments:

a. *I*, infiltration rate (L^1T^{-1})

b. *K*, hydraulic conductivity (L^1T^{-1})

c. S_y, specific yield (dimensionless)

d. *x*, half the length of basin (L)

e. *y*, half the width of basin (L)

f. *t*, duration of infiltration period (T)

g. *hi(0)*, initial thickness of saturated zone (L).

4.2.3 Values of drainage infiltration rate and the duration of drainage period(s) have been split into three infiltration scenarios (see Section 4.2), and other parameter inputs are summarised in Section 4.3.

4.3 Infiltration scenarios

4.3.1 To simulate infiltration to the water table, three scenarios have been assessed using the Hantush solution, the same methodology used for infiltration basins south of the River Thames in Annex M.

4.3.2 For scenarios 1 and 2, the following equation was used to calculate the infiltration rate for each infiltration basin.

$$I = \frac{P\ x\ A\ x\ C}{a}$$

Where:

I, drainage infiltration rate (L^1T^{-1})

P, precipitation rate (L^1T^{-1})

A, impervious drainage catchment area for each basin (L^2)

C, rainfall runoff coefficient (0.9) for asphalt pavement (Garber and Hoel, 2009)

a, basin bottom area (L^2).

4.3.3 Scenario 1: steady state mounding using average drainage infiltration. For this scenario, the average daily precipitation rate (1.4mm/d at the A13/A1089/A122 Lower Thames Crossing junction) (UK Centre for Ecology and Hydrology, 2020) is used to calculate the required infiltration rate for POS11-003, SWS11-002A and SWS11-008. A runoff coefficient of 0.9 is used for asphalt pavement, hence 10% of precipitation is lost to the likes of interception, evaporation or car carry-off. This is a steady-state scenario to assess the potential long-term mounding effects.

4.3.4 Scenario 2: mounding levels after a wet season (180 days). To simulate a wet season, the 90^{th} percentile of daily precipitation (4.6mm/d at the A13/A1089/A122 Lower Thames Crossing junction) is used to calculate the infiltration rate, also assuming a runoff coefficient of 0.9, for a period of 180 consecutive days.

4.3.5 Scenario 3: required drainage infiltration from a 1 in 100-year storm. The drainage requirements include a 20% increase in peak rainfall intensity due to climate change and a further sensitivity test carried out with a 40% increase in peak rainfall intensity due to climate change (Cascade, 2019a). This scenario simulates mounding beneath the infiltration basins after operation at the peak infiltration for 24 hours.

4.4 Input data

4.4.1 Table 4.1 provides a summary of the input parameters and sources used for the analytical mounding assessment on POS11-003, SWS11-002A and SWS11-008.

4.4.2 During seasonal high groundwater levels, the ground beneath POS11-003 and SWS11-008 is made up of layers of unsaturated and saturated Upnor Formation, above the saturated Thanet Formation. Ground Investigation has shown the top of Thanet Formation that underlays SWS11-002A, has a significant unsaturated zone thickness even during high groundwater levels.

Table 4.1 Mounding assessment input parameters for POS11-003, SWS11-002A and SWS11-008

Parameter	Value	Source and justification
I, infiltration rate (m/d)	POS11-003 Scenario 1 = 0.011 Scenario 2 = 0.037 Scenario 3 = 0.266 SWS11-002A Scenario 1 = 0.047 Scenario 2 = 0.155 Scenario 3 = 1.875 SWS11-008 Scenario 1 = 0.101 Scenario 2 = 0.331 Scenario 3 = 4.014	See Section 4.3 for justification and Annex C for calculation.
K, hydraulic conductivity (m/d)	$K_{Upnor\ Fm.}$ = 1.00 $K_{Thanet\ Fm.}$ = 0.30	Two values used to represent the heterogeneity in the Basal Sands. Hydraulic conductivity values from Variable Head Test (VHT) testing results and soakaway testing; geomean values for Upnor Formation and Thanet Formation (Section 2.5).
S_y	0.10	See Section 2.5.
x, y (m)	POS11-003 16.21 SWS11-002A 71.35, 0.75 SWS11-008 73.7, 0.50	Half the square root of the basin bottom area, assuming the infiltration basin to be square (basin bottom area = 1,051m^2). The swales are under 1m wide trenches.
t, duration of infiltration (days)	Scenario 1 = 365 Scenario 2 = 180 Scenario 3 = 1	In line with scenarios used in infiltration basin assessment for south of the River Thames.
hi(0), initial saturated thickness (m)	24.0	Assuming no flow through the cohesive Pegwell Member and separation in groundwater in the Chalk aquifer from the Basal Sands aquifer, hence the saturated thickness is equal to the head of water above the Pegwell Member (using BH13007 water level).

4.5 Results

4.5.1 Hantush mounding assessment results for the three infiltration scenarios and two hydraulic conductivity values are shown in Plate 4.1 (graph A to C). If the levels of mounding exceed the unsaturated zone thickness (minimum of 3.31m for POS11-003, 6.5m for SWS11-002A and 11m for SWS11-008 based on available groundwater data), the infiltration basin and swales would result in localised flooding due to overtopping of water from the basin. In case of mounding interaction between the water features, the mounding levels are cumulative.

4.5.2 Scenario 1 for POS11-003 (Graph A’): using the geomean Thanet Formation hydraulic conductivity (0.30m/d), the mounding beneath the basin peaks at 0.80m. Using the less conservative Upnor Formation hydraulic conductivity (1.00m/d), the mounding peaks at 0.30m. Under both conditions, no flooding would occur as the unsaturated zone thickness is not exceeded, only reduced to a minimum of 2.5m beneath the basin invert level.

4.5.3 Scenario 2 for POS11-003 (Graphs B’): mounding predictions peak at 2.27m for the lower Thanet Formation hydraulic conductivity, reducing to 0.85m using the Upnor Formation hydraulic conductivity. Predictions show that the unsaturated zone would be reduced to a minimum of 1.0m thick beneath the basin invert level, with no risk of localised flooding.

4.5.4 Scenario 3 for POS11-003 (Graphs C’): the largest mounding is predicted. Mounding peaks at 2.30m beneath the basin assuming the Thanet Formation hydraulic conductivity. Applying the Upnor Formation hydraulic conductivity, the mounding reduces to 1.5m. Similarly, to scenario 2, the unsaturated zone thickness would be reduced to 1.0m beneath the basin invert level.

4.5.5 Scenario 1 for SWS11-002A (Graph A’’): using the geomean Thanet Formation hydraulic conductivity (0.30m/d), the mounding beneath the basin peaks at 0.54m. Using the less conservative Upnor Formation hydraulic conductivity (1.00m/d), the mounding peaks at 0.24m. Under both conditions, no flooding would occur as the unsaturated zone thickness is not exceeded.

4.5.6 Scenario 2 for SWS11-002A (Graphs B’’): mounding predictions peak at 1.42m for the lower Thanet Formation hydraulic conductivity, reducing to 0.62m using the Upnor Formation hydraulic conductivity. Under both conditions, no flooding would occur as the unsaturated zone thickness is not exceeded.

4.5.7 Scenario 3 for SWS11-002A (Graphs C’’): the largest mounding is predicted. Mounding peaks at 1.78m beneath the basin assuming the Thanet Formation hydraulic conductivity. Applying the Upnor Formation hydraulic conductivity, the mounding reduces to 0.99m. Under both conditions, no flooding would occur as the unsaturated zone thickness is not exceeded.

4.5.8 Scenario 1 for SWS11-008 (Graph A’’’): using the geomean Thanet Formation hydraulic conductivity (0.30m/d), the mounding beneath the basin peaks at 0.82m. Using the less conservative Upnor Formation hydraulic conductivity (1.00m/d), the mounding peaks at 0.38m. Under both conditions, no flooding would occur as the unsaturated zone thickness is not exceeded.

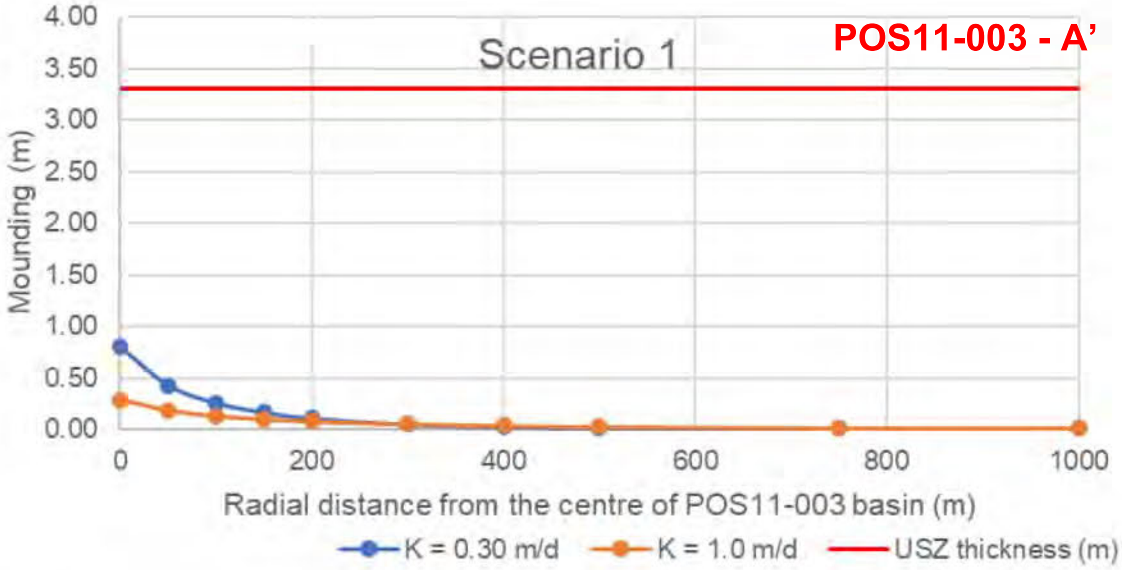
4.5.9 Scenario 2 for SWS11-008 (Graphs B’’’): mounding predictions peak at 2.10m for the lower Thanet Formation hydraulic conductivity, reducing to 0.96m using the Upnor Formation hydraulic conductivity. Under both conditions, no flooding would occur as the unsaturated zone thickness is not exceeded.

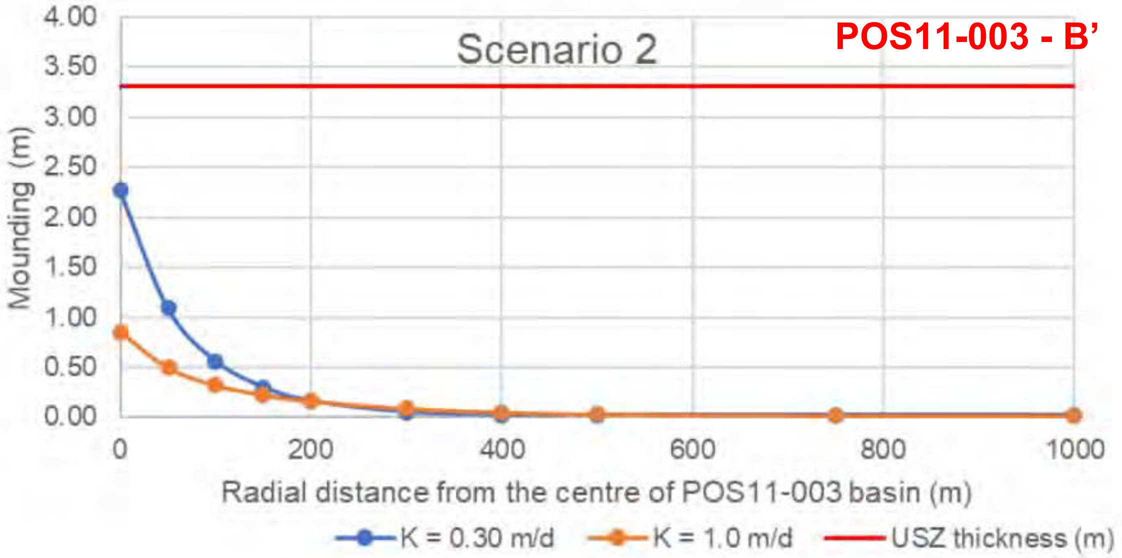
4.5.10 Scenario 3 for SWS11-008 (Graphs C’’’): mounding predictions peak at 2.55m for the lower Thanet Formation hydraulic conductivity. Applying the Upnor

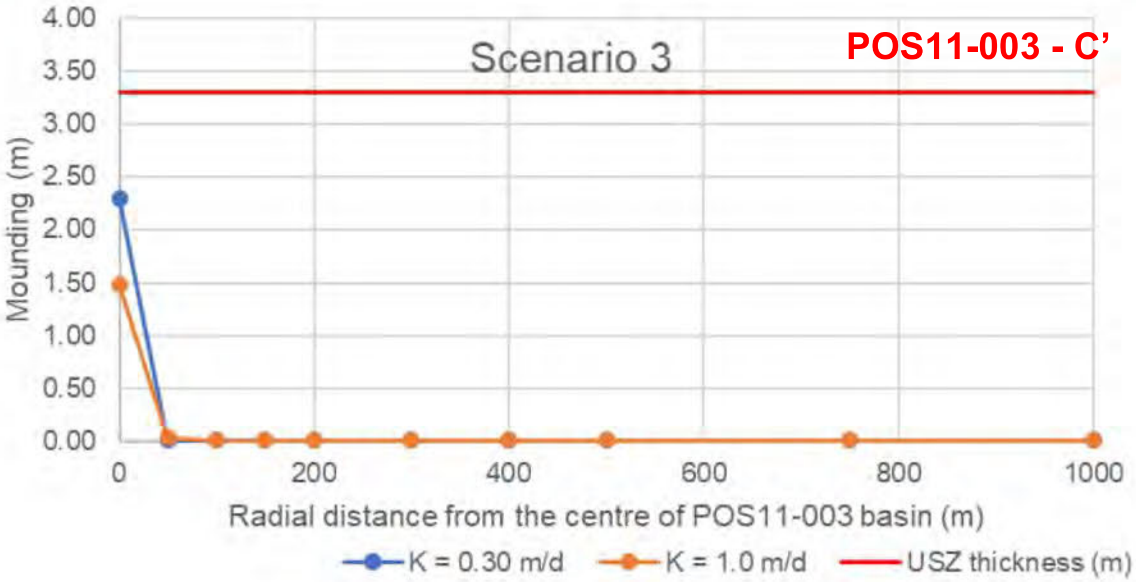
Formation hydraulic conductivity, the mounding reduces to 1.43m. Under both conditions, no flooding would occur as the unsaturated zone thickness is not exceeded.

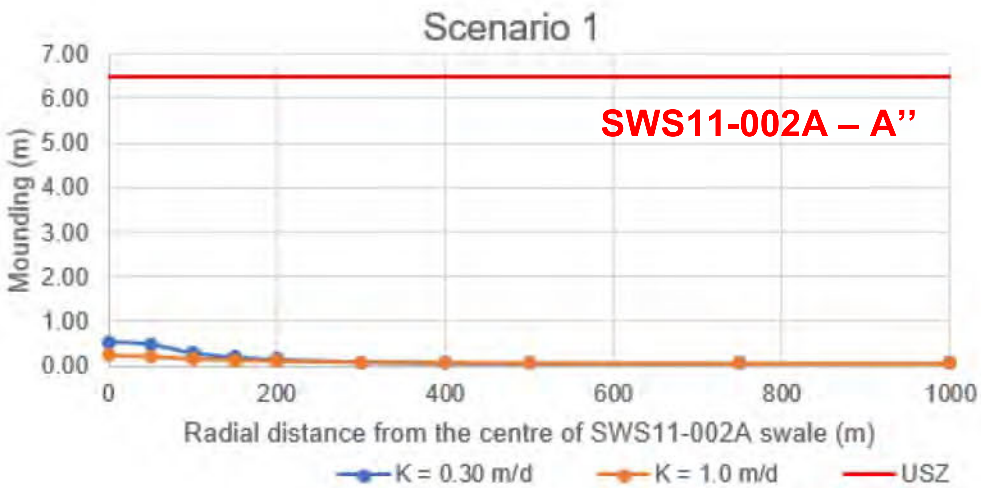
4.5.11 From the results summarised above, there is no risk of localised flooding around the infiltration basin and the swales local to the soakaway. This is based on the available *in situ* hydraulic conductivity testing and soakaway tests for the Basal Sands aquifer (Upnor Formation and Thanet Formation). There is no risk of cumulative mounding either.

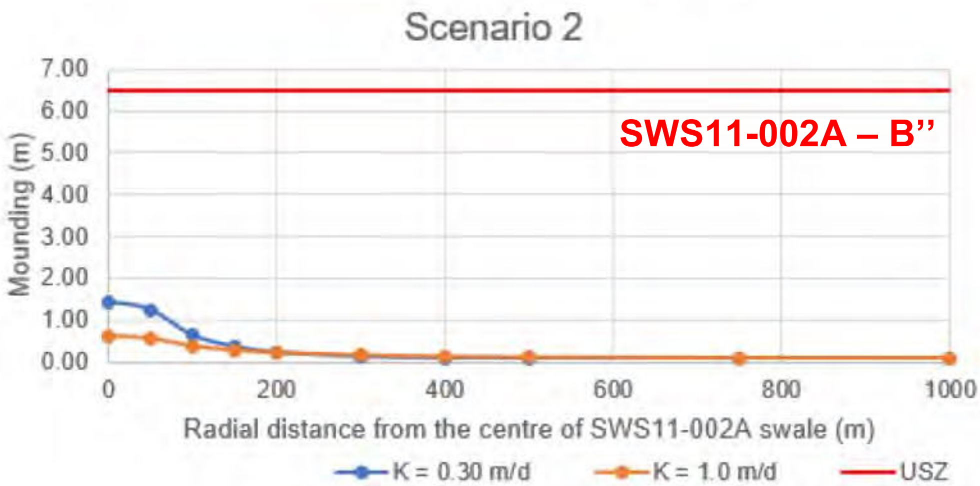
Plate 4.1 Analytical mounding results for all scenarios (USZ = unsaturated zone)

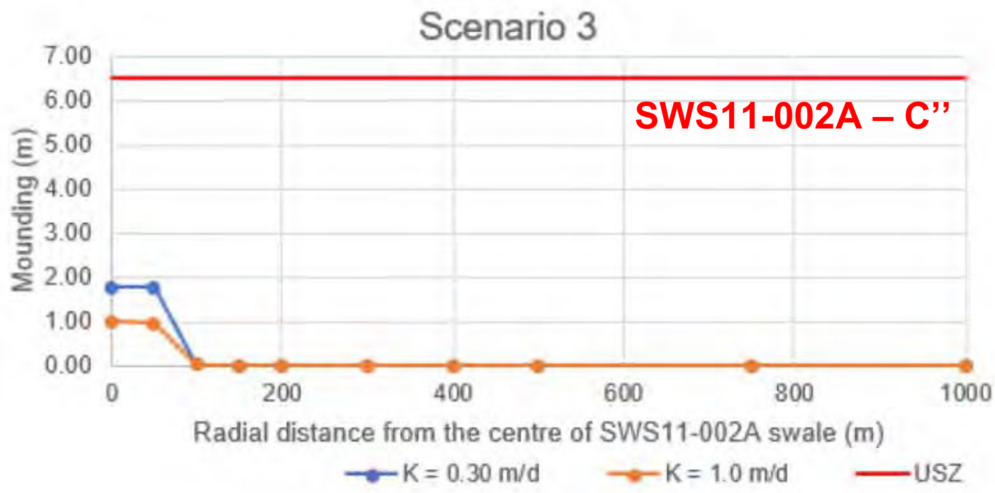


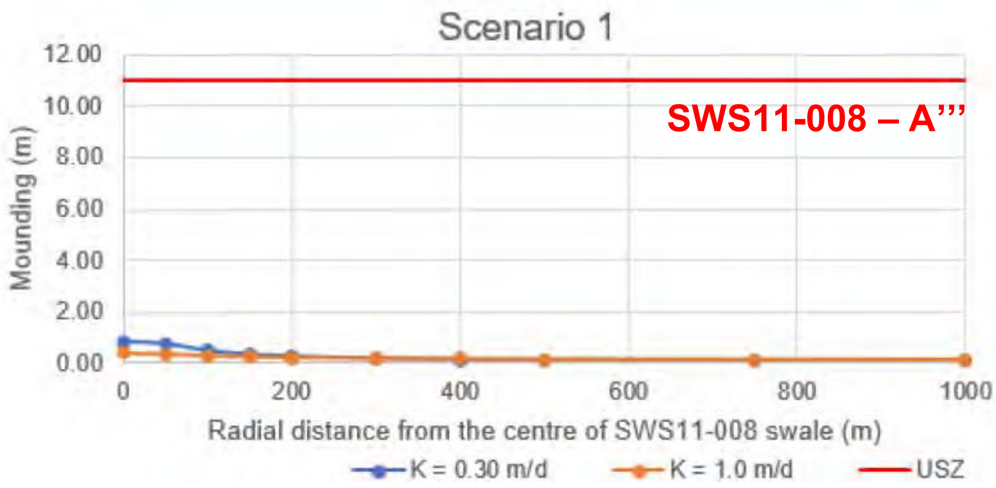


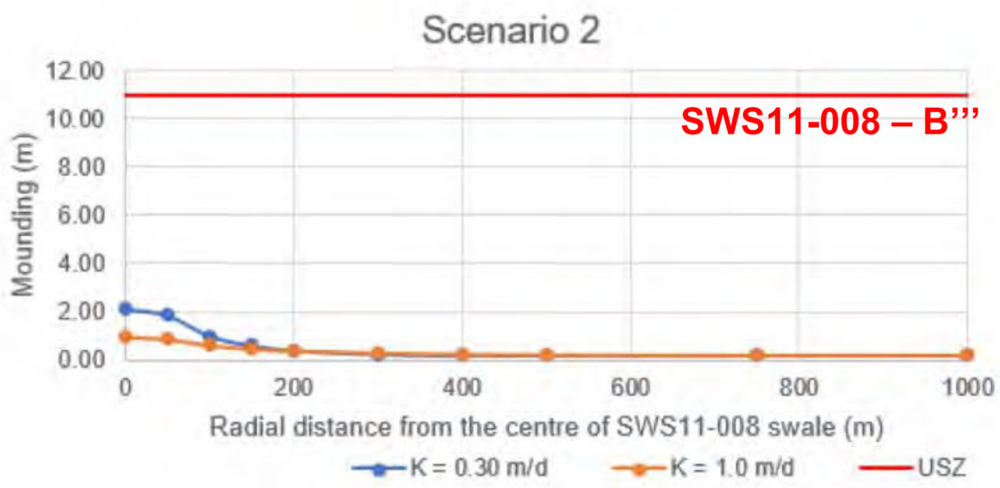

Scenario 3
POS11-003 - C'
Mounding (m)
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
0
200
400
600
800
1000
Radial distance from the centre of POS11-003 basin (m)
K = 0.30 m/d
K = 1.0 m/d
USZ thickness (m)

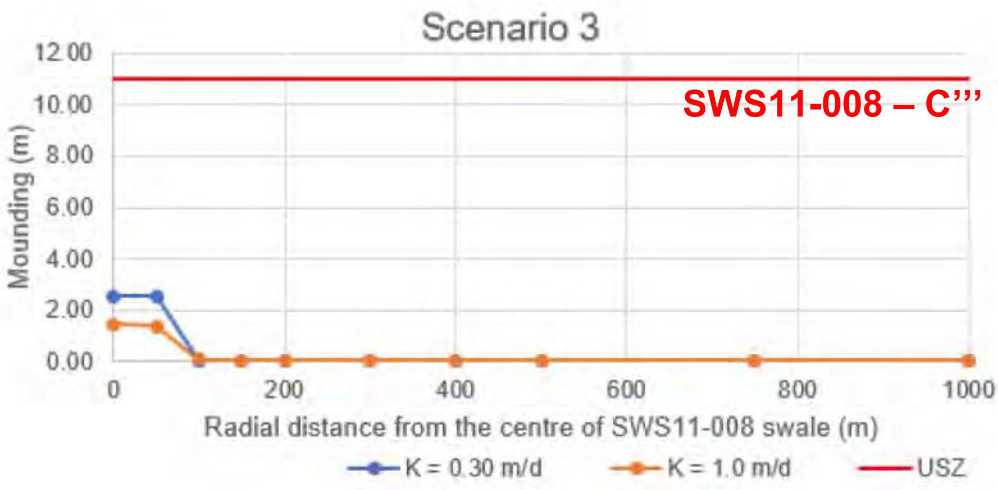

Scenario 1
SWS11-002A – A''
Mounding (m)
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
0
200
400
600
800
1000
Radial distance from the centre of SWS11-002A swale (m)
K = 0.30 m/d
K = 1.0 m/d
USZ


Scenario 2
SWS11-002A – B''
Mounding (m)
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
0
200
400
600
800
1000
Radial distance from the centre of SWS11-002A swale (m)
K = 0.30 m/d
K = 1.0 m/d
USZ


Scenario 3
SWS11-002A – C''
Mounding (m)
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
0
200
400
600
800
1000
Radial distance from the centre of SWS11-002A swale (m)
K = 0.30 m/d
K = 1.0 m/d
USZ


Scenario 1
SWS11-008 – A'''
Mounding (m)
12.00
10.00
8.00
6.00
4.00
2.00
0.00
0
200
400
600
800
1000
Radial distance from the centre of SWS11-008 swale (m)
K = 0.30 m/d
K = 1.0 m/d
USZ


Scenario 2
SWS11-008 – B'''
Mounding (m)
12.00
10.00
8.00
6.00
4.00
2.00
0.00
0
200
400
600
800
1000
Radial distance from the centre of SWS11-008 swale (m)
K = 0.30 m/d
K = 1.0 m/d
USZ



4.6 Limitations

4.6.1 Predictions of groundwater mounding using the Hantush solution are limited largely due to the input parameters, which are often simplified to suit the analytical model.

a. The hydraulic conductivity of the Basal Sands aquifer is assumed to be homogeneous and isotropic. However, *in situ* testing results indicate the permeability can be variable, depending on the clay and silt content. Mounding predictions do not account for changes in hydraulic conductivity, but the predictions are conservative in using the geomean 0.30m/d hydraulic conductivity.

b. Basal Sands aquifer and Chalk are assumed not to be in hydraulic continuity at the location of the infiltration basin, based on observed separation in parts of the ground investigation. However, this may not be the case as ground investigation data is sparse and only runs along the Project route. If the two aquifers are in fact in continuity, the levels of mounding would likely be overestimated as the saturated thickness would be greater than assumed in this assessment, reducing the mounding.

c. For simplification, the model assumes that infiltration occurs across the entire base of the infiltration basin. This scenario exists in the early operational life of the infiltration basin, but with time the base may become clogged with sediment and the infiltration capacity may be reduced. However, the soakaway trenches would be maintained as part of the maintenance regime, and facilities to intercept sediment before runoff reaches the basin could be provided subject to detailed design.

5 Pollution assessment

5.1 Introduction

5.1.1 Pollution to groundwater from routine highway runoff has been assessed using HEWRAT (Annex O).

5.1.2 The results of the HEWRAT simple groundwater quality and routine runoff pollution assessment show that POS11-033 and thirteen swales (referred to as SWS10-009, SWS10-011, SWS11-002A, SWS11-002, SWS11-003, SWS11-004, SWS11-005, SWS11-006, SWS11-008, SWS11-013, SWS11-014, SWS11-015 and SWS11-016) have a risk rating of medium (medium risk of groundwater quality degradation).

5.1.3 However, four of these swales (SWS11-013, SWS11-014, SWS11-015 and SWS11-016) are scoped out of the detailed assessment based on hydrogeological considerations (Annex O – Application Document 6.3).

5.1.4 Swales SWS10-001, SWS10-002 and SWS10-004 have been added to the detailed assessment because of their vicinity with Linford Abstraction SPZ1.

5.1.5 Therefore, Design Manual for Roads and Bridges LA 113 Road Drainage and the Water Environment (Highways England, 2020b) requires that a detailed assessment be completed on the thirteen drainage structures.

5.2 Approach

5.2.1 To further assess the potential risk of groundwater contamination from infiltration of routine highway runoff, a detailed assessment has been completed using the groundwater simulation software ConSim, developed on behalf of the Environment Agency (Environment Agency and Golder Associates (UK) Ltd, 2018).

5.2.2 ConSim adopts a tiered approach based on the Remedial Targets Methodology publication (Environment Agency, 2006). The methodology consists of up to four assessment levels which progressively follow the pathway from the contaminant source through to the receptor. The four levels of assessment are detailed in the ConSim 2.5 Manual (Environment Agency and Golder Associates (UK) Ltd, 2018).

5.3 Source, pathway, receptor

5.3.1 The ‘source’ of contamination is the release of routine highway runoff from infiltration drainage structures (POS11-003 and twelve swales). Routine highway runoff contains elevated levels of soluble and particulate pollutants. A study carried out by Crabtree *et al*. (2008) summarised a list of six significant pollutants found in routine runoff:

a. Copper and zinc (total and dissolved)

b. Cadmium, fluoranthene, pyrene and polycyclic aromatic hydrocarbons (total only)

5.3.2 In this assessment, only copper, zinc, lead, and chloride have been assessed. High concentrations of chloride are found in highway runoff as a result of de-icing during winter months (de-icing agent being sodium chloride). Cadmium, fluoranthene and pyrene, as well as total polycyclic aromatic hydrocarbons, have been excluded from the assessment because they are only significant pollutants as particulate matter (total), and the dissolved concentrations in runoff are negligible (see Table 4.4 in Crabtree *et al*. (2008)). It is assumed that any particulate matter in runoff would settle out in the sediment forebays and infiltration basins before percolation to the ground.

5.3.3 There are two pathways of contamination: the unsaturated zone and the saturated zone.

5.3.4 Two potential receptors have been identified:

1. Linford – licensed groundwater abstraction 350m to the north-east of three swales located along Muckingford Road (Northumbrian Water Ltd. – potable water supply from the Chalk aquifer)
2. Licensed groundwater abstraction approximately 2km to the east of A13/A1089/A122 Lower Thames Crossing junction (Orsett Golf Club – Abstraction for direct spray irrigation from the Chalk aquifer).

5.4 Methodology

5.4.1 The two licensed groundwater abstractions are down gradient of the majority of the potential contamination sources, hence the pathway of contamination is the unsaturated and saturated zone. However, during the Linford pumping, the groundwater flow direction is expected to be reverse between swale SWS10-004 and the Linford abstraction. In this case, SWS10-004 becomes up gradient of the Linford abstraction. To assess contaminant transport along both pathways, a Level 3 assessment is needed. Level 3 considers whether the following mechanisms are sufficient in reducing pollutant concentrations to acceptable levels at the receptors (Environment Agency, 2006):

a. Attenuation of pollutants within the unsaturated zone and dilution of pollutants by groundwater flow at the point of maximum dilution (Level 2 assessment).
b. Attenuation of pollutants down hydraulic gradient of the source (Level 3 assessment). Attenuating effects of degradation, retardation and dispersion are considered in both unsaturated and saturated zones (Environment Agency and Golder Associates (UK) Ltd, 2018).

5.4.2 Regarding ‘acceptable levels’ at the receptors, Drinking Water Standards (DWS) values have been used as both receptors are licensed groundwater abstractions.

5.4.3 Each receptor requires compliance points at which concentrations of the pollutants have reduced to the required levels (see Plate 5.1). Around licensed groundwater abstractions used for potable water supply, source protection zones (SPZs) are defined by the Environment Agency to show the risk of contamination from any activities that might cause pollution (Environment Agency, 2020). Three compliance points have been designated for the licensed groundwater abstraction at Linford: the north-western edge of SPZ 1 and SPZ 2 and the southeastern edge of the SPZ 1 (in relation to SWS10-004 only which lies within the SPZ 2. Hence groundwater flow direction is considered toward the abstraction and in the opposite direction to the rest of the model domain).

5.4.4 At Orsett Golf Club, the licensed groundwater abstraction is for direct irrigation, so no SPZ is designated by the Environment Agency. For this receptor, compliance points have been specified at the point of abstraction, and at a midpoint between the POS11-003 infiltration basin and the Orsett Golf Club abstraction.

5.4.5 ConSim compliance points:

a. Linford SPZ 1 [(northwest boundary)– X 566874, Y 179396

b. Linford SPZ 2 (northwest boundary) – X 566343, Y 179692

c. Linford SPZ 1 (southeast boundary) – X 567271, Y 178977

d. Orsett Golf Club abstraction – X 565985, Y 180732

e. Orsett Golf Club mid-point – X 564932, Y 180611

5.4.6 ConSim can only model a single layered aquifer system. Therefore, it cannot model the complexities of the multi-layered aquifer system found along the Project route leading to the A13/A1089/A122 Lower Thames Crossing junction (Basal Sands aquifer overlying the Chalk aquifer). To solve this issue, two ConSim models have been used:

f. The first model predicts the concentration of pollutants after infiltration and attenuation in the unsaturated and saturated Basal Sands aquifer.

g. The second model uses predicted concentrations from the Basal Sands aquifer to then simulate attenuation of pollutants in the saturated Chalk aquifer.

5.4.7 ConSim can also not model changing flow directions or changing aquifer conditions. Therefore, for swale SWS10-004 located southeast of the Linford abstraction and within the SPZ 2, a separate model has been created. In this model, the flow direction has been set towards the abstraction (opposite direction to the model considering all swales combined). Due to the likely drawdown effects of the abstraction when active, only the chalk aquifer has been modelled. While some dilution may still occur in the Basal Sand aquifer prior to it reaching the Chalk aquifer, this is likely less significant than for the swales located outside the SPZ 2 and has therefore conservatively not been modelled. Site specific data has been used to assign unsaturated zone and aquifer parameters for this model.

5.4.8 In the model 2 domain (Plate 5.2), SWS10-004 is the closest swale to Linford abstraction. A sensitivity test was performed by including all the swales and the output was the same indicating all the other swales did not have any effect on the model outputs.

5.4.9 The ConSim model domains are shown in Plate 5.2 and Plate 5.3, where the blue lines represent the Project route and the yellow lines represent the earthworks. The model is used to compute the cumulative impact on receptors from all infiltration features as well as the individual risk posed by each source.

Plate 5.1 Locations of licensed groundwater abstractions, SPZs and compliance points

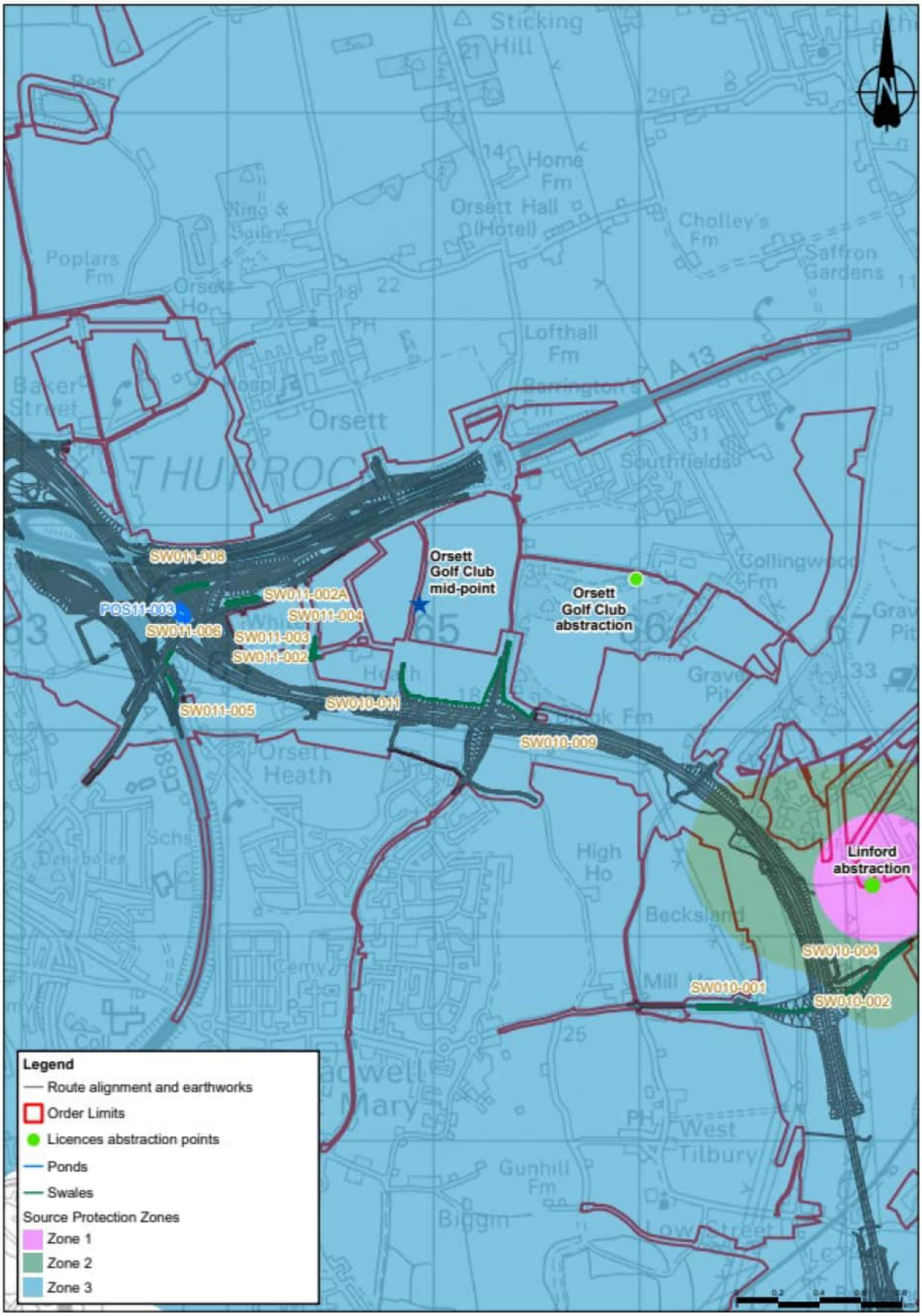


Plate 5.2 ConSim model 1 domain (100m x 100m grid spacing)

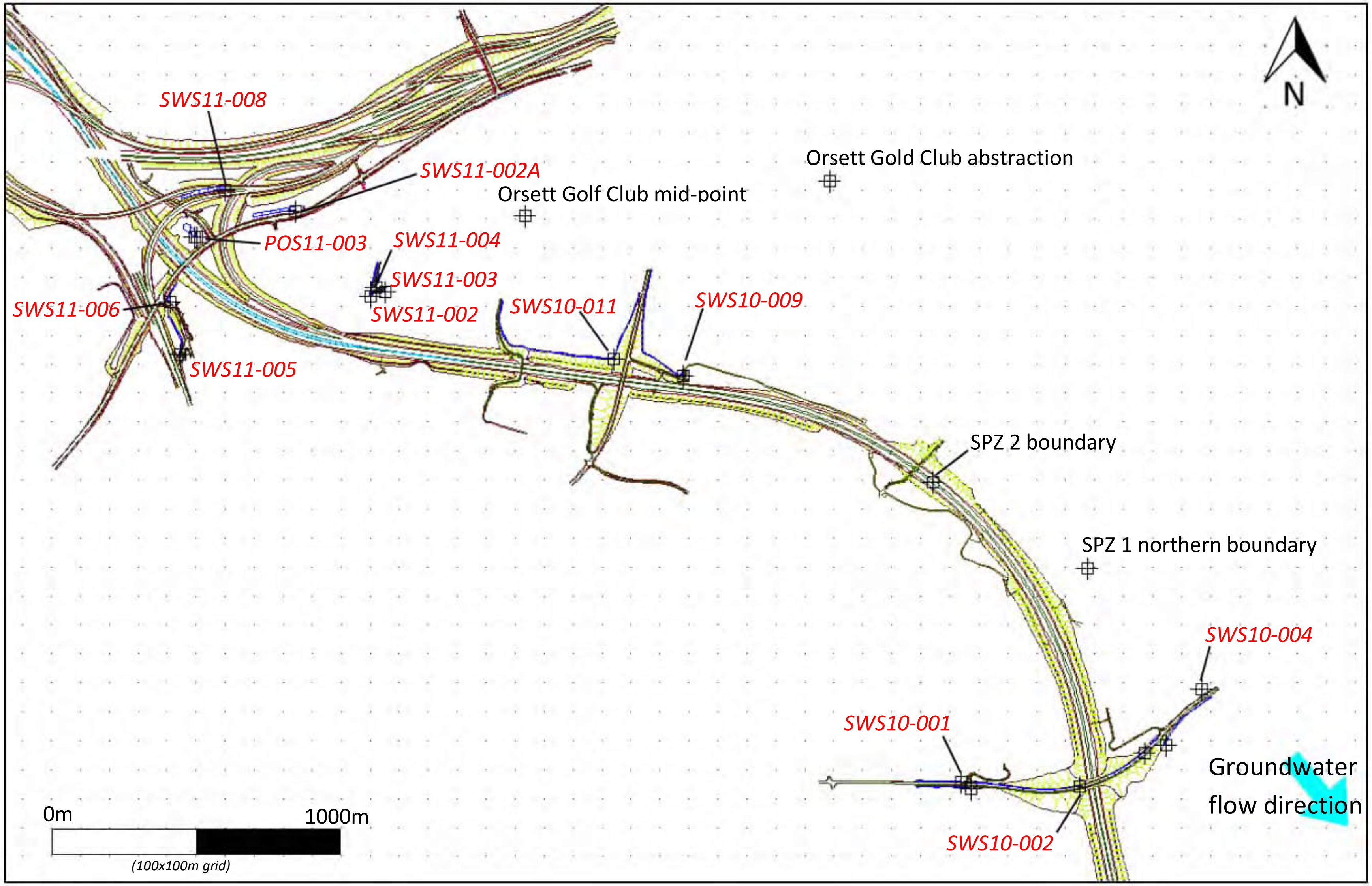
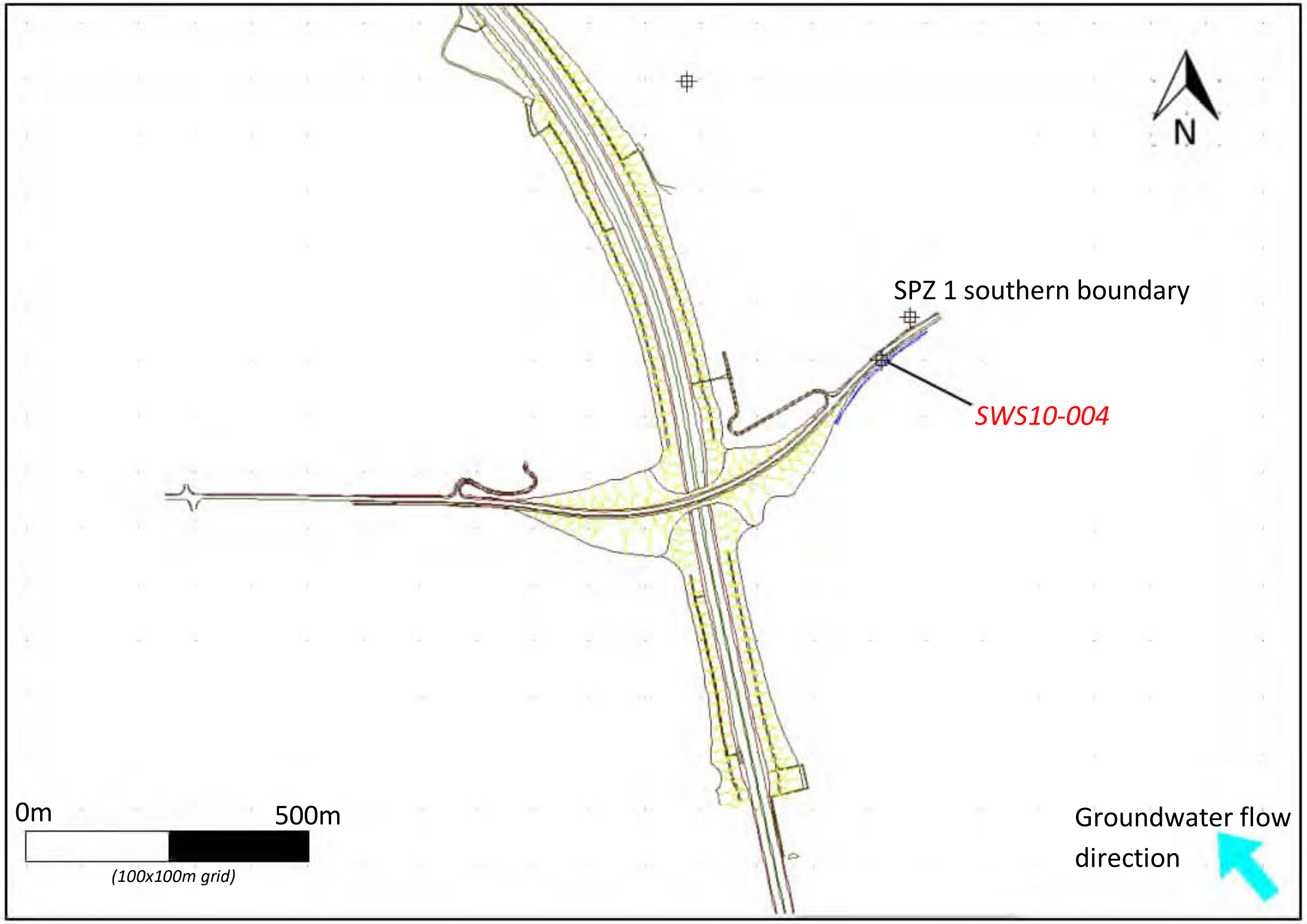


Plate 5.3 ConSim model 2 domain (100m x 100m grid spacing)



5.5 ConSim input data

5.5.1 Table 5.1 provides a summary of sources that have been used to generate the data required as input to the ConSim detailed pollution assessment.

5.5.2 A full list of model input values is included in Annex D.

Table 5.1 Input data sources

Data	Source
Soakaways parameters (source)	
Impermeable drainage catchment area	Information obtained from calculation sheets supplied by the Project drainage design team.
Maximum required drainage infiltration rate	Scenario 3 infiltration rates for POS11-003 (see Section 4.3) and maximum daily rainfall rates from CHESS database for the twelve swales.
Initial pollutant concentration at source; dissolved copper, dissolved lead, dissolved zinc and chloride.	Event mean concentrations of pollutants in highway runoff have been obtained from Highways Agency report (Crabtree *et al*., 2008).
Source thickness	Thickness based on infiltration trench depth (obtained from drainage drawings).
Source dimensions	X, Y vertices obtained from infiltration basin shapefiles.
Unsaturated zone parameters (pathway)	
Unsaturated zone thickness	Calculated using basin and swales invert levels, and groundwater contouring produced by Cascade based on the Project's January 2020 groundwater level monitoring data.
Runoff recharge	Precipitation data obtained from the CHESS meteorological database multiplied by runoff coefficient for asphalt pavement (0.9) (Garber and Hoel, 2009).
Vertical hydraulic gradient	ConSim 2.5 manual (Environment Agency and Golder Associates (UK) Ltd, 2018).
Vertical dispersivity	ConSim 2.5 manual – 10% of the unsaturated zone thickness.
Dry bulk density of material	Triangular distribution based on Project Phase 2 Package C ground investigation data.
Partition coefficients for unsaturated zone	Conservative partition coefficient values have been obtained from Environment Agency (2005) science report on Kd test methods.
Contaminant half-life	Conservative values based on professional judgement.
Hydraulic conductivity	Log-normal distribution of the Lambeth Group (unsaturated zone made up of Upnor Formation above Thanet Formation) from literature sources (see Table 2.2). For the SWS10-004 model, site data for the Thanet formation has been used to provide maximum, minimum and mean values.

Data	Source
Water filled porosity and effective porosity	Probabilistic triangular distribution based on specific yield values for sand (Morris and Johnson, 1967) and the storage coefficient (specific yield) of the Basal Sands aquifer (Jones *et al.*, 2000).
Saturated zone input parameters (pathway)	
Background contaminant concentration in groundwater beneath the site	Project Phase 2 Package C groundwater monitoring data.
Saturated aquifer thickness	Uniform distributions for both the Thanet Formation and Chalk using thicknesses from Project ground investigation boreholes.
Aquifer hydraulic conductivity	Log-normal distribution of the Thanet Formation hydraulic conductivity from Package C *in situ* testing, and for the Chalk, a log-normal distribution in line with the 3D modelling.
Hydraulic gradient	Calculated using groundwater contouring produced by Cascade based on Project January 2020 groundwater level monitoring data.
Effective porosity	Probabilistic triangular distribution based on specific yield values for sand (Morris and Johnson, 1967) and the storage coefficient (specific yield) of the Basal Sands aquifer (Jones *et al.*, 2000).
Dry bulk density of aquifer material	Probabilistic distribution based on Project Phase 2 Package C ground investigation data.
Half-life for degradation of contaminant in water	Pollutants in this study are stable.
Partition coefficients for saturated zone	Assumed to be the same as unsaturated zone.
Dispersivity parameters	ConSim rule of thumb – longitudinal = 10% of pathway length; transverse = 30% of longitudinal dispersivity.
Receptor parameters	
Target concentration of contaminants	DWS
Distance to compliance points: Linford and Orsett Golf Club	Measured using in-house Geographic Information Systems viewer.

5.6 Background concentrations

5.6.1 Background concentrations of the four pollutants in groundwater have been monitored in 13 boreholes as part of the Project long-term groundwater monitoring schedule. The maximum and minimum concentrations for each borehole are summarised in Annex D.

5.6.2 High concentrations of zinc have been observed in three boreholes along Package C: BH13009, BH11007 and BH12005.

5.6.3 In ConSim, background concentrations at receptors were modelled based on BH1004, which was the borehole nearest to the compliance point..

5.7 Results and interpretation

5.7.1 A Level 3 assessment has been carried out to simulate the cumulative concentration of the four pollutants after 120 years of operation for one infiltration basin and twelve swales. A duration of 120 years is in line with the design life of the Project road. ConSim output concentration statistics are based on the probabilistic distributions of the model inputs. The concentrations at the Linford and Orsett Gold Club licensed groundwater abstraction compliance points are summarised in Table 5.2, Table 5.3 and Table 5.4. All concentrations are predictions for groundwater in the Chalk aquifer. ConSim produces a range of statistical outputs. This assessment uses the 95th percentile output to represent likely worst case conditions, where 95% of model runs calculate concentrations below this value.

5.7.2 Descriptive statistics produced in the ConSim statistical output are also presented below for information including; maximum, minimum , mean and standard deviation. It is noted that the maximum value presented can be higher than that which could theoretical be calculated by worst case parameters (e.g. may exceed source input concentration). As such, the 95th percentile output provides a more accurate statistic for the purpose of assessment and decision making.

Table 5.2 Simulated concentration at Linford SPZ 1 and SPZ 2 north-western compliance points after 120 years of operation (SD = Standard deviation)

Pollutant	DWS (mg/l)	Concentration at SPZ 1 (mg/l)				
		Mean	Min	Max	SD	95th %ile
Chloride	250	94.040	90.520	100.243	1.9110	97.7677
Copper	2	0.01001	0.01	0.01082	7.39E-05	1.00E-02
Lead	0.01	0.001	0.001	0.001	-	1.00E-03
Zinc	5	0.01208	0.012	0.01425	0.0003363	0.0129052

Pollutant	DWS (mg/l)	Concentration at SPZ 2 (mg/l)				
		Mean	Min	Max	SD	95th %ile
Chloride	250	173.178	119.069	265.805	26.998	227.51
Copper	2	0.0160833	0.0121201	0.0229235	0.00199094	0.0200776
Lead	0.01	0.00143071	1.13E-03	0.00197764	1.54E-04	0.00173917
Zinc	5	0.028317	0.0177802	0.0463984	0.00527474	0.0388658

Table 5.3 Simulated concentration at the Orsett Golf Club compliance points after 120 years of operation

Pollutant		Concentration at abstraction well (mg/l)

	DWS (mg/l)	Mean	Min	Max	SD	95th %ile
Chloride	250	88.8315	88.4669	89.6138	0.138548	89.1063
Copper	2	0.0100316	0.01	0.0100921	1.96E-05	1.01E-02
Lead	0.01	0.00100063	0.001	0.00100583	1.05E-06	1.00E-03
Zinc	5	0.0121495	0.0120004	0.0123611	6.94E-05	1.23E-02

Pollutant	DWS (mg/l)	Concentration at mid-point (mg/l)				
		Mean	Min	Max	SD	95th %ile
Chloride	250	107.687	99.5894	113.909	2.18851	111.345
Copper	2	0.0112946	0.0101334	0.0121398	0.000350314	0.0118081
Lead	0.01	0.00105534	0.00100057	0.00119331	4.28E-05	0.0011349
Zinc	5	0.0171641	0.0124933	0.0198348	0.00107832	0.0187476

Table 5.4 Simulated concentrations at Linford SPZ 1 south-eastern compliance point after 120 years of operation (SD = Standard deviation)

Pollutant	DWS (mg/l)	Concentration at SPZ 1 (mg/l)				
		Mean	Min	Max	SD	95th %ile
Chloride	250	142.215	88	281.288	47.3406	226.445
Copper	2	0.0147076	0.01	0.0263322	0.00413004	0.0221646
Lead	0.01	0.00100127	0.001	0.00153411	2.42E-05	1.00E-03
Zinc	5	0.0291613	0.012	0.0729644	0.0149984	0.0559603

5.7.3 Summary of model predictions:

a. At the SPZ 1 and SPZ 2 compliance points for Linford (licensed groundwater abstraction), all pollutant concentrations are significantly below the screening DWS values at a 95% confidence level.

b. The same trend is predicted for the Orsett Golf Club compliance points, with all concentrations below the DWS values.

5.7.4 From these predictions, there would be no significant impact on either receptor, as groundwater concentrations at the compliance points are predicted to be the same as, or very similar to, the background concentrations inputted to the model.

5.7.5 It should be noted that the modelling carried out is highly conservative, due to limitations in the ConSim software. The soakaways and swales are modelled to release highway runoff continuously (steady state), rather than only being active during periods of rainfall (ConSim does not allow transient simulations). The modelling also does not consider the additional attenuation of pollutants that would occur in the sediment forebays and vegetated infiltration basins and swales. The vegetation in the swales can reduce pollutant concentrations of metals (e.g. copper and zinc) by up to 50% (Highways England, 2020a). In addition, infiltration of water helps remove dissolved metals and solids (Highways England, 2020a). This attenuation process is not included in the assessment, and the predicted concentrations of pollutants at the receptors are likely to be exaggerated and very conservative.

6 Conclusions

6.1.1 This document presents a hydrogeological assessment for the proposed infiltration drainage structures located between the North Portal and the A13/A1089/A122 Lower Thames Crossing junction. The assessment includes a hydrogeology conceptual site model from Project Phase 2 Package C data and literature sources, a detailed assessment on potential groundwater mounding, and a pollution risk assessment using ConSim 2.5.

6.1.2 As part of the conceptual model, Project Phase 2 Package C ground investigation data was reviewed. The conceptual model concluded that groundwater conditions are variable over the study area. Near the A13/A1089/A122 Lower Thames Crossing junction, the groundwater in the Chalk and overlying Basal Sands (RTD, Lambeth Group and Thanet Formation) is separated by the cohesive Pegwell Member, resulting in semi-confinement of the Chalk and perching of groundwater in the Thanet Formation. However, to the south-eastern end of the study area, the groundwater in the Chalk and overlying strata are in hydraulic continuity.

6.1.3 Groundwater mounding beneath infiltration basin POS11-003 and swales SWS11-002A and SWS11-008 has been predicted using the Hantush analytical solution (Hantush, 1967). Three drainage infiltration scenarios have been modelled, ranging from average infiltration to 1 in 100-year storm infiltration conditions. Because of heterogeneity in the Basal Sands aquifer, two hydraulic conductivity values were used in the prediction: geomean values for the Upnor Formation and the underlying Thanet Formation (both values obtained from Project *in situ* testing).

a. Mounding predictions peak at 2.30m for infiltration basin POS11-003, and 1.78m and 2.55 m, respectively for swales SWS11-002A and SWS11-008, in scenarios 3 using the lower Thanet Formation conductivity (0.3m/d). Under these conditions, the unsaturated zone is reduced to a thickness of under 1m beneath the infiltration basin POS11-003. However, for swales SWS11-002A and SWS11-008, the unsaturated zone stays, respectively above 4.5m and 8 m.

b. Using the less conservative Upnor Formation hydraulic conductivity (1.0m/d) to represent the top of the Basal Sands aquifer and unsaturated zone, the levels of mounding are reduced significantly, to a maximum mounding of 1.48m for POS11-003 in Scenario 3.

c. The infiltration rate conditions used in Scenario 3 are conservative. The results show that there is no risk of localised flooding, based on the three infiltration scenarios and the available ground investigation *in situ* testing data.

a. No risk of cumulative mounding between the three drainage features has been observed.

6.1.4 The soakaway testing at TP13308 show infiltration rates at the site of POS11-003 are in the order 10^{-5}m/s, giving an equivalent hydraulic conductivity of 1.0m/d. Therefore, predictions using the less conservative Upnor Formation hydraulic conductivity are likely accurate.

6.1.5 The detailed pollution risk assessment carried out using ConSim is used to determine whether infiltration from routine highway runoff would degrade the groundwater quality and increase pollutant levels above DWS. Routine highway runoff typically contains heavy metals (e.g. copper, lead and zinc) from car degradation and, during winter months, high levels of sodium chloride from road salt application (de-icing). Two potential receptors have been identified to be at risk from the infiltration basin and swales along the study area: Linford licensed groundwater abstraction (potable water supply) and Orsett Golf Club licensed groundwater abstraction (direct irrigation). ConSim models the individual and cumulative impact on each receptor from the sources. Cumulative results show that pollutant levels after 120 years of operation are lower than the DWS values at all compliance points. Therefore, the infiltration of routine highway runoff would have no significant impact on any of the identified receptors.

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Annex M, Cascade (2020d). Infiltration Basins Detailed Assessment – South of the River Thames (Doc. Ref. HE540039-CJV-GEN-GEN-TNT-GEO-00219).

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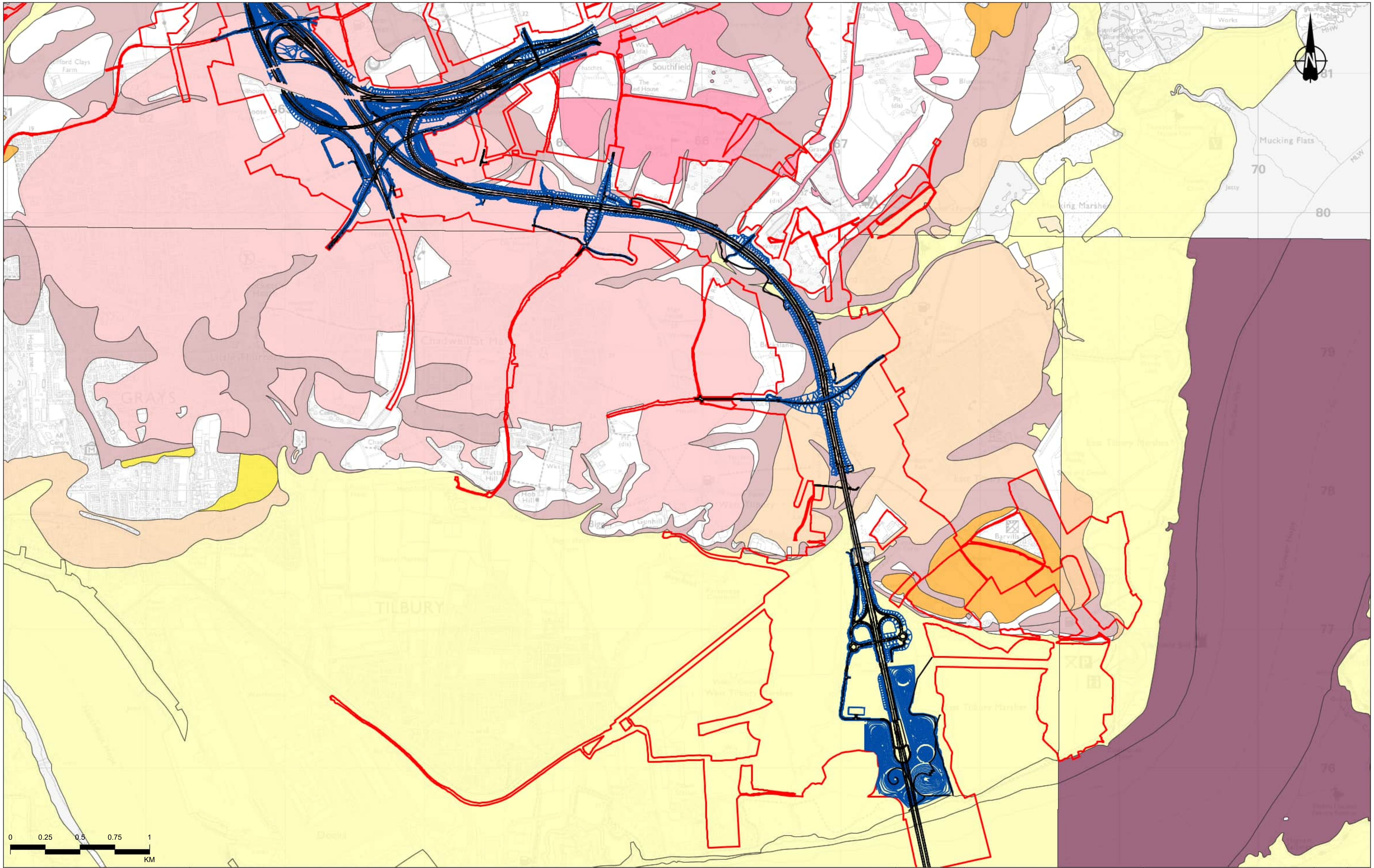
Annexes

Annex A Superficial and bedrock geology maps

Drawing Numbers

HE540039-CJV-GEN-GEN-DRA-GEO-00106-Superfical Geology (North Portal to A13)

HE540039-CJV-GEN-GEN-DRA-GEO-00107-Bedrock Geology (North Portal to A13)



Rev	Status	Rev. Date	Purpose of revision	Drawn	Chck'd	Apprv'd
P01	S8	01/09/2022	For Information	SW	CB	FF

Legend

- Route alignment
- Earthworks
- Order Limits

BGS Geology 50k: Superficial Deposits

- Alluvium
- Tidal River Or Creek Deposits
- Kempton Park Gravel Formation
- Ilford Silt Member
- Lynch Hill Gravel Member
- Taplow Gravel Formation
- Boyn Hill Gravel Member
- Black Park Gravel Member
- Beach And Tidal Flat Deposits (Undifferentiated)
- Head
- River Terrace Deposits, 2
- River Terrace Deposits (Undifferentiated)
- OS 25k: Greyscale
- OS 50k: Greyscale

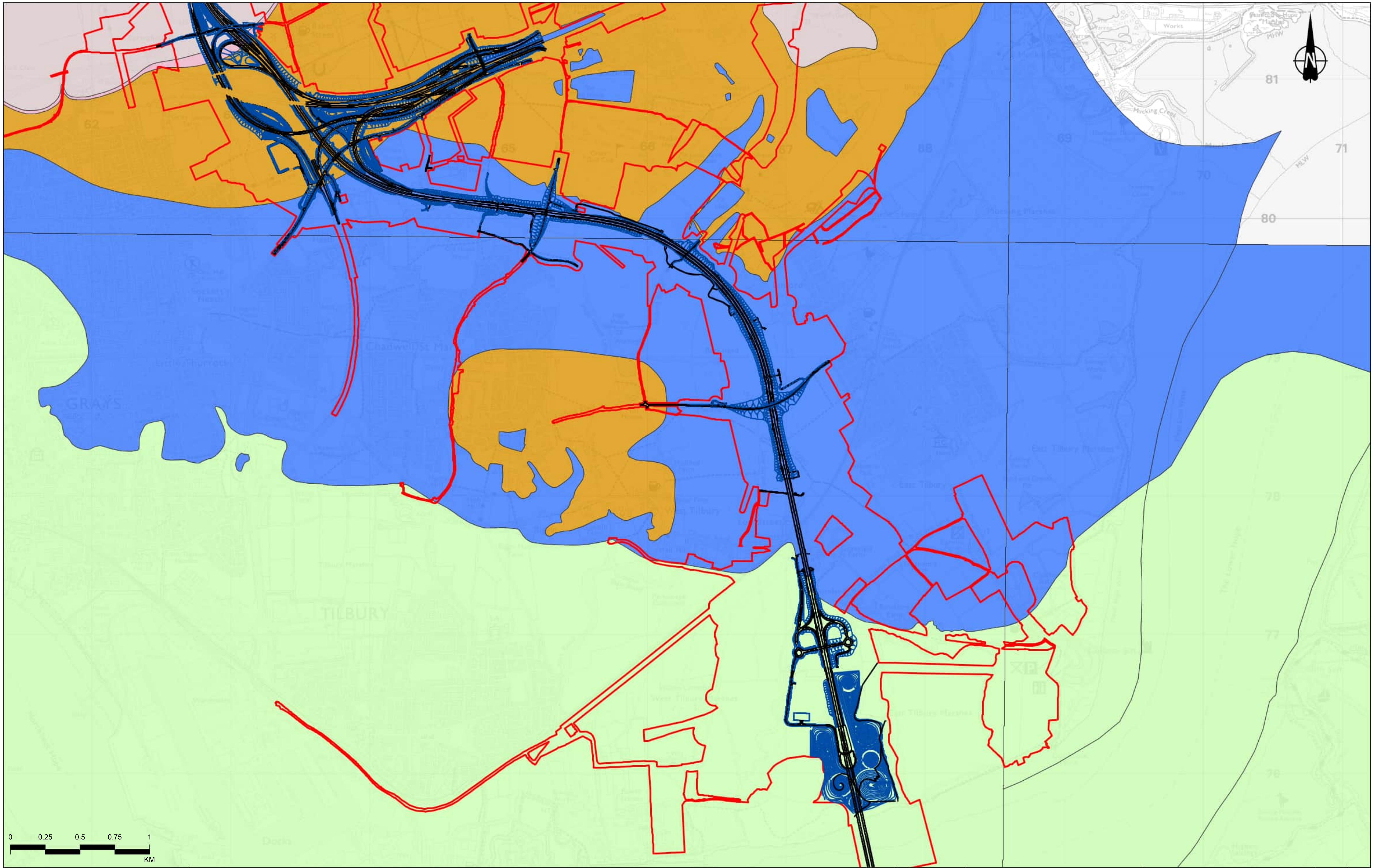
Client: national highways

Project: LOWER THAMES CROSSING

Status	DCO APPLICATION	Original Size A3	Revision P01
Application Document Number	TR010032/APP/6.3	Scale 1:24,663	

Drawing Title: BGS 50K Superficial Geology (North of River)

Drawing Number: HE540039-CJV-GEN-GEN-DRA-GEO-00106



Rev	Status	Rev. Date	Purpose of revision	Drawn	Chck'd	Apprv'd
P01	S8	01/09/2022	For Information	SW	CB	FF

Legend

- Route alignment
- Earthworks
- Order Limits
- Harwich Formation
- London Clay Formation
- Lambeth Group
- Thanet Formation
- Seaford Chalk Formation
- Lewes Nodular Chalk Formation, Seaford Chalk Formation And Newhaven Chalk Formation (Undifferentiated)
- OS 25k: Greyscale
- OS 50k: Greyscale

Client: national highways

Project: LOWER THAMES CROSSING

Status: DCO APPLICATION

Original Size: A3

Revision: P01

Application Document Number: TR010032/APP/6.3

Scale: 1:24,662

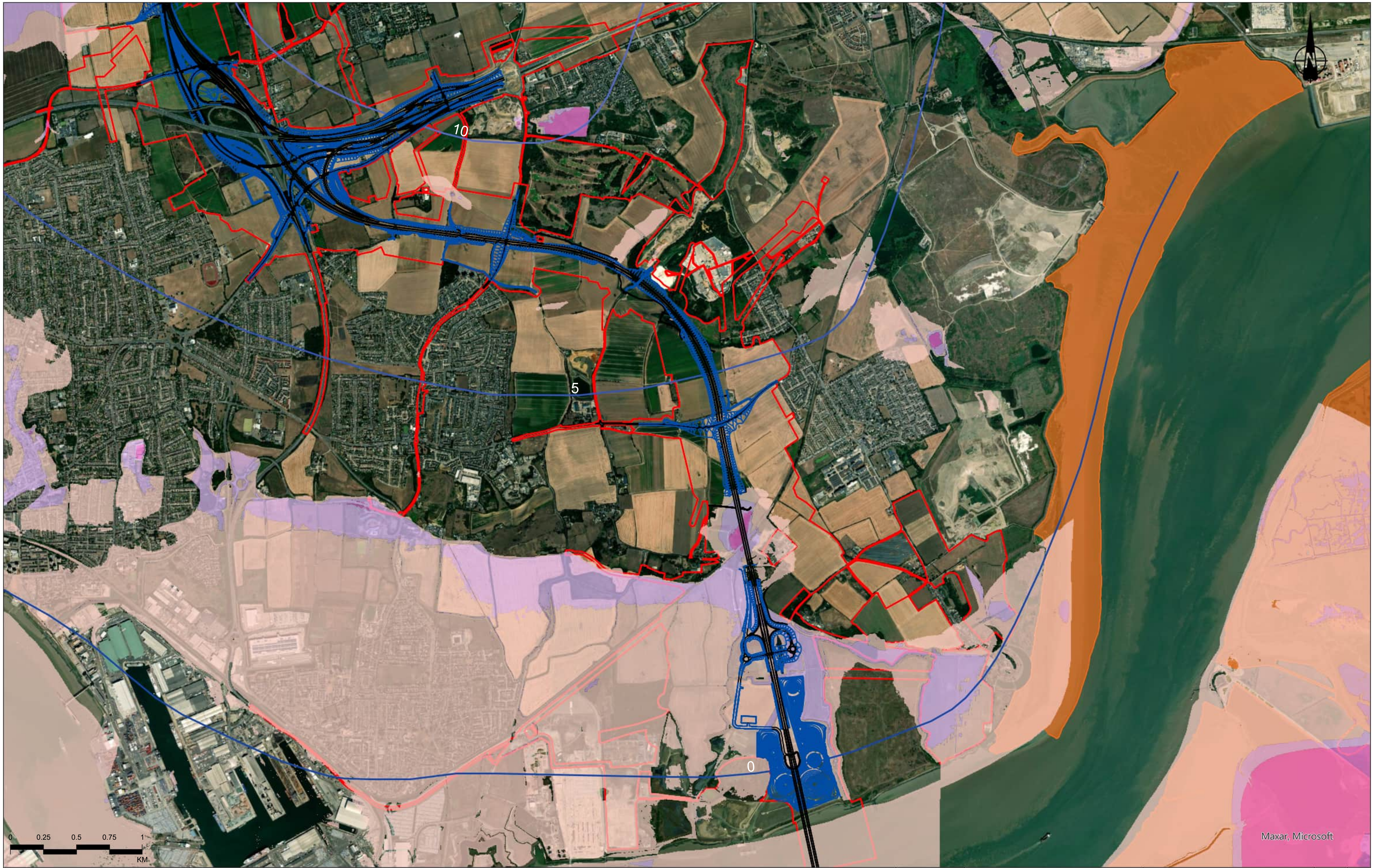
Drawing Title: Bedrock Geology Map (North Portal to A13)

Drawing Number: HE540039-CJV-GEN-GEN-DRA-GEO-00107

Annex B Groundwater flooding potential

Drawing Number

HE540039-CJV-GEN-GEN-DRA-GEO-00108 Groundwater flooding potential (North Portal to A13)



Legend

- Route alignment
- Earthworks
- Order Limits
- Ramsar Site

GroundWater Flood Risk - 5m
- High
- Moderate
- Low

Contours of the Groundwater Level in Chalk Aquifer in February 2014
- 25
- 20
- 15
- 10
- 5
- 0
- -5

Rev	Status	Rev. Date	Purpose of revision	Drawn	Chck'd	Apprv'd
P01	S8	23/02/2022	For Information	SW	CB	FF

Client: national highways

Project: LOWER THAMES CROSSING

Status: DCO APPLICATION

Application Document Number: TR010032/APP/XXXX

Original Size: A3

Revision: P01

Scale: 1:26,000

Drawing Title: Groundwater Flooding Potential (North Portal to A13)

Drawing Number: HE540039-CJV-GEN-GEN-DRA-GEO-00108

Annex C Analytical assessment input parameters

CALCULATIONS

DOCUMENT No	HE540039-CJV-GEN-GEN-TNT-GEO-00222 - Annex N-C
OFFICE	[redacted]
PROJECT TITLE	**Lower Thames Crossing**
SUBJECT	**POS11-003 infiltration basin analytical mounding assessment**
SHEET No	1 of 4

ISSUE	TOTAL SHEETS	AUTHOR	DATE	CHECKED BY	DATE	Revision change	COMMENTS
1	2	[redacted]	22/05/20	[redacted]	22/05/20	NA	
2	2	[redacted]	09/04/21	[redacted]	09/05/21	Minor changes to hydraulic conductivity inputs based on Phase 3 GI data	
3	4	[redacted]	23/06/22	[redacted]	27/06/22	Added assesments for swales SWS11-002A and SWS11-008	

DESIGN BASIS STATEMENT (Inc. sources of info/data, assumptions made, standards, etc.)

Summary

Analytical assessment of the potential mounding in the Thanet Fomation from the operation of POS11-003 infiltration basin at the LTC A13 Junction. This detailed assessment has been conducted by the LTC hydrogeology team, part of the tunnels and systems group.

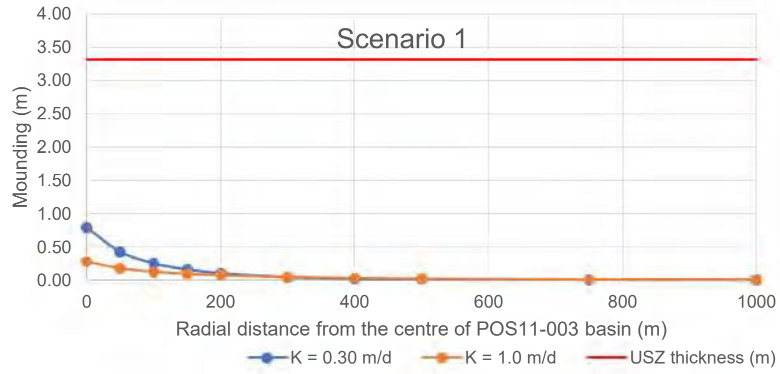
General approach:

The calculations presented here accompany the technical note HE540039-CJV-GEN-GEN-TNT-GEO-00222
The analytical assessment uses the Hantush (1967) solution, as included in Carleton (2010). The solution uses an equaton descirbing the "growth and decay of groundwater mounds in response to uniform percolation".

Carleton, G. B. (2010) Simulation of Groundwater Mounding Beneath Hypothetical Stormwater Infiltration Basins. *US Geological Survey Scientific Investigations Report 2010-5102,* 64.
Hantush, M. S. (1967). Growth and decay of groundwater mounds in response to uniform percolation. *Water Resources Research, vol 3,* 227-234.

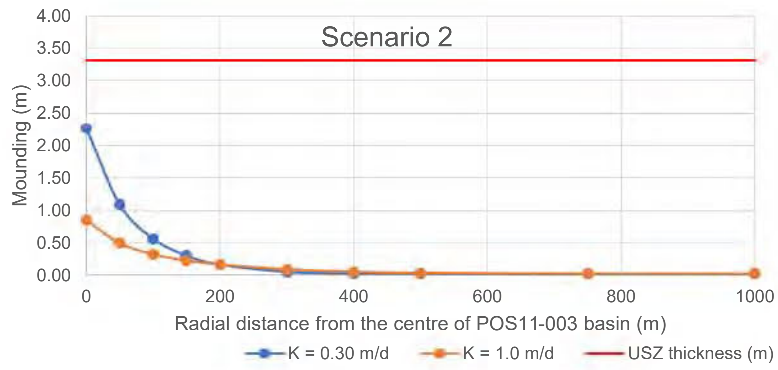
POS11-003		**Scenario 1**		Q (m^3/d)	a (m^2)	I (m/d)
I	0.011323	m/day		11.9	1051	0.011323
S_y	0.1					
K	Varies	m/day				
x	16.20957	m				
y	16.20957	m				
t	365	days				
hi(0)	23.5	m				
IL	21.6	m aOD				
USZ	3.88					

		Mounding (m)	
POS11-003	Distance	K = 0.30 m/d	K = 1.0 m/d
	0	0.798	0.287
	50	0.430	0.186
	100	0.259	0.132
	150	0.167	0.102
	200	0.111	0.081
	300	0.051	0.054
	400	0.027	0.038
	500	0.018	0.028
	750	0.014	0.017
	1,000	0.014	0.014



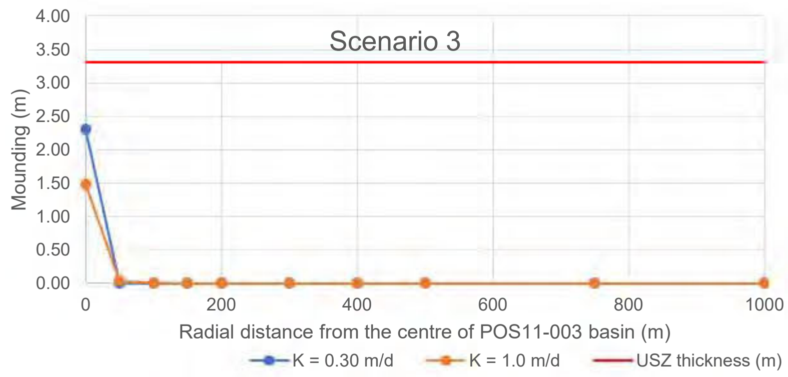
POS11-003		**Scenario 2**		Q (m^3/d)	a (m^2)	I (m/d)
I	0.037209	m/day		39.1068	1051	0.037209
S_y	0.1					
K	Varies	m/day				
x	16.20957	m				
y	16.20957	m				
t	180	days				
hi(0)	23.5	m				
IL	21.6	m aOD				

		Mounding (m)	
POS11-003	Distance	K = 0.30 m/d	K = 1.0 m/d
	0	2.267	0.849
	50	1.090	0.495
	100	0.563	0.323
	150	0.304	0.228
	200	0.165	0.166
	300	0.053	0.092
	400	0.027	0.055
	500	0.023	0.036
	750	0.022	0.024
	1,000	0.022	0.022



POS11-003		**Scenario 3**		Q (m^3/d)	a (m^2)	I (m/d)
I	0.265937	m/day		279.5	1051	0.265937
S_y	0.1			Q = 50% of the requred infiltration basin storage for 1 in 100 year storm		
K	Varies	m/day				
x	16.20957	m				
y	16.20957	m				
t	1	days				
hi(0)	23.5	m				
IL	21.6	m aOD				

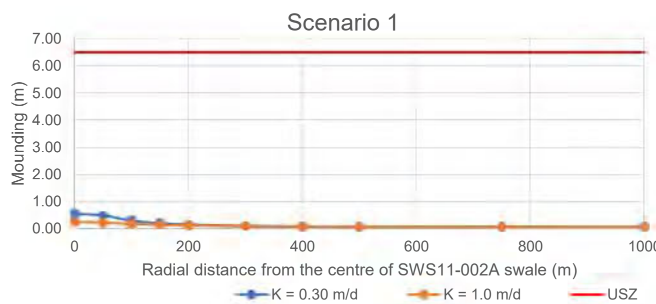
		Mounding (m)	
POS11-003	Distance	K = 0.30 m/d	K = 1.0 m/d
	0	2.302	1.485
	50	0.002	0.034
	100	0.001	0.001
	150	0.001	0.001
	200	0.001	0.001
	300	0.001	0.001
	400	0.001	0.001
	500	0.001	0.001
	750	0.001	0.001
	1,000	0.001	0.001



SWS11-002A		**Scenario 1**
I	0.047245	m/day
Sy	0.1	
K	Varies	m/day
x	71.35	m
y	0.748294	m
t	365	days
hi(0)	23.5	m
IL	23.7624	m aOD
USZ	6.5	m

Q (m^3/d)	a (m^2)	I (m/d)
10.08982	213.563	0.047245

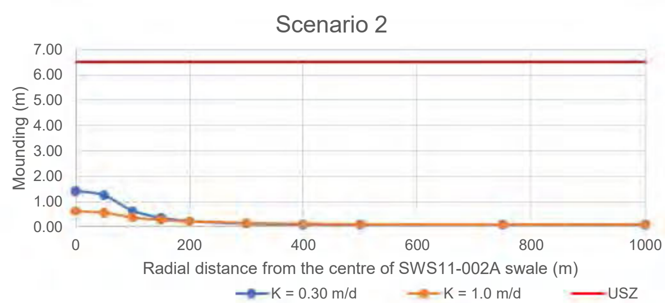
		Mounding (m)	
SWS11-002A	Distance	K = 0.30 m/d	K = 1.0 m/d
	0	0.54128082366	0.2394400840
	50	0.48326454959	0.2212579686
	100	0.29217059711	0.1664310889
	150	0.19886926929	0.1358436623
	200	0.14567464706	0.1166372870
	300	0.09100162558	0.0926388824
	400	0.06907754862	0.0785201295
	500	0.06101686550	0.0698638412
	750	0.05757648397	0.0603566867
	1,000	0.05748254858	0.0580014430



SWS11-002A		**Scenario 2**
I	0.154861	m/day
Sy	0.1	
K	Varies	m/day
x	71.35	m
y	0.748294	m
t	180	days
hi(0)	23.5	m
IL	23.7624	m aOD
USZ	6.5	m

Q (m^3/d)	a (m^2)	I (m/d)
33.07254	213.563	0.154861

		Mounding (m)	
SWS11-002A	Distance	K = 0.30 m/d	K = 1.0 m/d
	0	1.42282042603	0.6173400643
	50	1.24574808592	0.5594462632
	100	0.63615848287	0.3740988588
	150	0.36593273878	0.2781176267
	200	0.23084143095	0.2203080514
	300	0.12376091825	0.1540824081
	400	0.09827434609	0.1212413797
	500	0.09360898403	0.1052233056
	750	0.09291748627	0.0939886285
	1,000	0.09291649394	0.0929684981

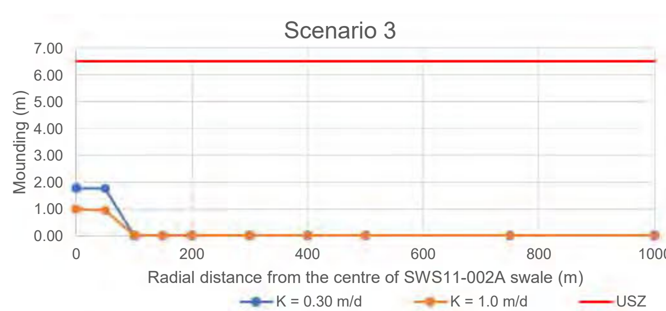


SWS11-002A		**Scenario 3**
I	1.875199	m/day
Sy	0.1	
K	Varies	m/day
x	71.35	m
y	0.748294	m
t	1	days
hi(0)	23.5	m
IL	23.7624	m aOD
USZ	6.5	m

Q (m^3/d)	a (m^2)	I (m/d)
400.4732	213.563	1.875199

Q = 50% of the requred infiltration basin storage for 1 in 100 year storm

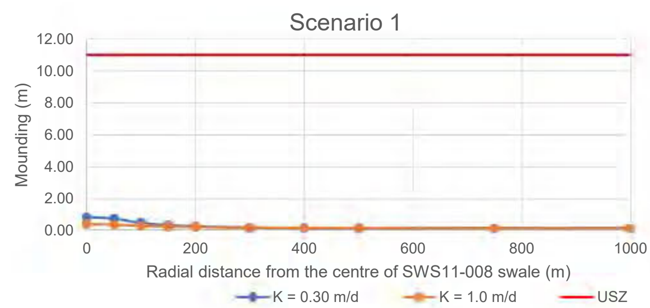
		Mounding (m)	
SWS11-002A	Distance	K = 0.30 m/d	K = 1.0 m/d
	0	1.780431047	0.9998591031
	50	1.76871746	0.9494826051
	100	0.007907312	0.0282542492
	150	0.006250664	0.0062595247
	200	0.006250664	0.0062506643
	300	0.006250664	0.0062506643
	400	0.006250664	0.0062506643
	500	0.006250664	0.0062506643
	750	0.006250664	0.0062506643
	1,000	0.006250664	0.0062506643



SWS11-008		Scenario 1
I	0.101135	m/day
Sy	0.1	
K	Varies	m/day
x	73.7	m
y	0.497269	m
t	365	days
hi(0)	23.5	m
IL	31	m aOD
USZ	11	m

Q (m^3/d)	a (m^2)	I (m/d)
14.82588	146.595	0.101135

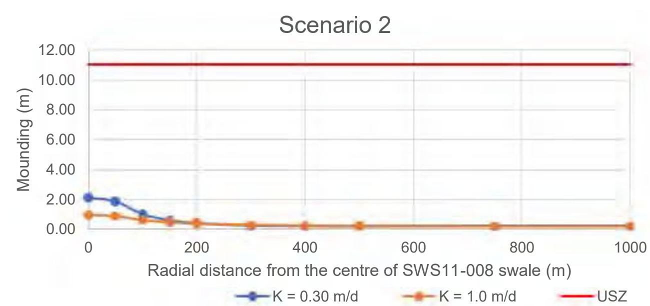
		Mounding (m)	
SWS11-008	Distance	K = 0.30 m/d	K = 1.0 m/d
	0	0.821063334	0.386974877
	50	0.742698959	0.362281309
	100	0.470182013	0.283752483
	150	0.331700582	0.238353276
	200	0.253210042	0.210054296
	300	0.172588876	0.174760631
	400	0.140222925	0.154005965
	500	0.128298471	0.141278348
	750	0.123189797	0.127288649
	1,000	0.123050941	0.123817308



SWS11-008		Scenario 2
I	0.331501	m/day
Sy	0.1	
K	Varies	m/day
x	73.7	m
y	0.497269	m
t	180	days
hi(0)	23.5	m
IL	31	m aOD
USZ	11	m

Q (m^3/d)	a (m^2)	I (m/d)
48.59646	146.595	0.331501

		Mounding (m)	
SWS11-008	Distance	K = 0.30 m/d	K = 1.0 m/d
	0	2.101923670	0.955811091
	50	1.866193477	0.877657118
	100	1.004499256	0.613657343
	150	0.603580735	0.471553949
	200	0.403711955	0.386462440
	300	0.244943753	0.289054561
	400	0.206957260	0.240712533
	500	0.199951834	0.217101262
	750	0.198902424	0.200496491
	1,000	0.198900871	0.198979102

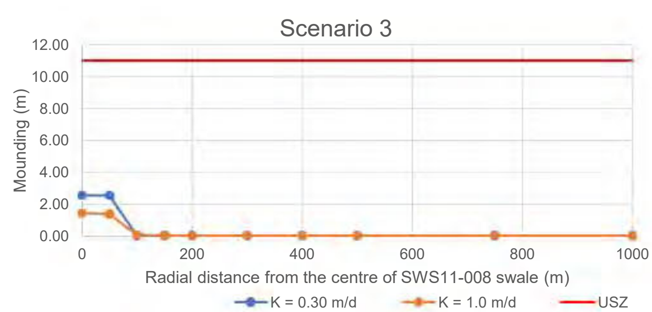


SWS11-008		Scenario 3
I	4.014129	m/day
Sy	0.1	
K	Varies	m/day
x	73.7	m
y	0.497269	m
t	1	days
hi(0)	23.5	m
IL	31	m aOD
USZ	11	m

Q (m^3/d)	a (m^2)	I (m/d)
588.4512	146.595	4.014129

Q = 50% of the requred infiltration basin storage for 1 in 100 year storm

		Mounding (m)	
SWS11-008	Distance	K = 0.30 m/d	K = 1.0 m/d
	0	2.545918525	1.426735557
	50	2.536157894	1.371110741
	100	0.01786261	0.054546562
	150	0.013380435	0.013400482
	200	0.013380429	0.013380429
	300	0.013380429	0.013380429
	400	0.013380429	0.013380429
	500	0.013380429	0.013380429
	750	0.013380429	0.013380429
	1,000	0.013380429	0.013380429



Annex D ConSim pollution assessment input values

CALCULATIONS

DOCUMENT No

HE540039-CJV-GEN-GEN-TNT-GEO-00222 - Annex D

OFFICE

[redacted]

PROJECT TITLE

Lower Thames Crossing

SUBJECT

ConSim detailed pollution assessment input parameters - Infiltration Drainage North Portal to A13 Junction

SHEET No

1 of 5

ISSUE	TOTAL SHEETS	AUTHOR	DATE	CHECKED BY	DATE	Revision change	COMMENTS
1	5	[redacted]	22/05/20	[redacted]	22/05/20	NA	
2	5	[redacted]	24/06/[redacted]		24/06/20	Minor revisions to Source, pathway, receptor inputs sheet	
3	5	[redacted]	24/06/20	[redacted]	01/08/21	Minor revisions to Source, pathway, receptor inputs sheet - including hydraulic conductivity values for the unsaturated and saturated zones	
4	5	[redacted]	23/06/22	[redacted]	23/06/22	Added assessment, new swales north of the River	

DESIGN BASIS STATEMENT (Inc. sources of info/data, assumptions made, standards, etc.)

Summary

Input paramaters for the ConSim model, infiltration drainage North Portal to A13 Junction. ConSim has been used to assess the potential risk to groundwater quality from infiltration of routine highway runoff from one infiltration basin and twelve swales. The assessment has been conducted by the LTC hydrogeology team, part of the tunnels and systems group.

General approach:

The calculations presented here accompany the technical note HE540039-CJV-GEN-GEN-TNT-GEO-00222.

Drainage ID	Catchment	X	Y	Trench length (m)	Basin bottom (m^2)	IL (m aOD)	Worst case infiltration rate (m/d)	Impervious catchment area (m^2)	Run-off recharge (mm/year)	Conservative USZ thickness (m)
SWS10-001	n/a	566472.6	178636.6	186.9	92.8	20.092	0.648	1082.00472	511.118	5
SWS10-002	n/a	566435.8	178661.8	151.9	73.6	20.821	0.582	770.81565	511.118	5
SWS10-004	n/a	567304.3	178952.9	235.7	233.6	24.368	0.627	2635.6818	511.118	5
SWS10-009	n/a	565371.3	180427.1	463.3	232.2	23.769	0.750	3132.40274	511.118	6
SWS10-011	n/a	565327.6	180347.9	764.3	763.2	21.485	0.398	5470.02754	511.118	6
SWS11-002	n/a	564450.7	180354.0	55.3	53.1	23.146	0.220	210	511.118	9
SWS11-002A	n/a	564150.5	180641.3	142.7	213.6	23.762	1.875	7205.3468	511.118	3
SWS11-003	n/a	564430.8	180411.3	47.6	44.3	23.350	0.163	130	511.118	9
SWS11-004	n/a	564424.8	180454.1	118.8	118.2	23.402	0.150	320	511.118	9
SWS11-005	n/a	563701.8	180265.7	144.2	68.9	24.729	0.427	530	511.118	10
SWS11-006	n/a	563708.8	180317.1	70.3	35.1	31.050	0.791	500	511.118	10
SWS11-008	n/a	563900.1	180709.4	147.4	146.6	31.529	4.014	10587.463	511.118	3
POS11-003	11c	563797.9	180545.6	54.5	1052.0	21.592	0.266	9926	511.118	3.88

Rainfall (mm/d)	
1.555915792	Average
39.7000008	Max
5.100000019	90th Percentile
Average over a year	**Average with 10% loss**
mm/year	mm/year
567.9092642	511.1183378

Parameter	Unit	Value: Max or mean	Value: Min or Stdev	Distribution type	Source
Source					
Lead concentration at source	mg/l	0.00381		Single	Average EMC (WRc, 2008. Improved determination of pollutants in highway runoff phase 2)
Copper concentration at source	mg/l	0.03131		Single	Average EMC (WRc, 2008. Improved determination of pollutants in highway runoff phase 2)
Zinc concentration at source	mg/l	0.11109		Single	Average EMC (WRc, 2008. Improved determination of pollutants in highway runoff phase 2)
Chloride concentration at source	mg/l	349.53		Single	Average EMC (WRc, 2008. Improved determination of pollutants in highway runoff phase 2)
Source thickness	m	1		Single	Trench depth - Drainage report HE540039-CJV-GEN-GEN-REP-HWY-0147-A2 Junction-Gravesend Link
Source dimensions	m, coordinates	x, y vertices		Single	Inhouse GIS shapefiles for DR3.0 drainage release
Infiltration to the unsaturated zone	mm/yr	511		Single	CHESS database https://eip.ceh.ac.uk/apps/chess/ - Stifford cannot be trusted due to missing or not checked data
Maximum infiltration rate	m/d	See Soakaway tab		Single	Covered in Infiltration features sheet - for infiltration basin, taken from drainage drawings for swale, calculated with max rainfall (CHESS)
Catchment area	m^3	See Soakaway tab		Single	Covered in Infiltration features sheet - provided by drainage team in catchment summary spreadsheet
Unsaturated zone pathway					
USZ dry bulk density	g/cm^3	2.05	1.79	Triangle = 1.9	Phase 2 Package C lab testing results - RTD and Lambeth Group tests results (summarised in draft calcs tab)
Lead half life in USZ	years	1.00E+30		Single	Conservative - inert metal based on professional judgement
Copper half life in USZ	years	1.00E+30		Single	Conservative - inert metal based on professional judgement
Zinc half life in USZ	years	1.00E+30		Single	Conservative - inert metal based on professional judgement
Chloride half life in USZ	years	1.00E+30		Single	Conservative - inert metal based on professional judgement
Partition coefficient for chloride	ml/g	0		Single	Conservative - Professional judgment as chloride is used as a trace contaminant
Partition coefficient of copper	ml/g	67		Single	Allison and Allison. 2005. Kd for metals in surface water, soil and waste. pp15.
Partition coefficient for lead	ml/g	320		Single	EA. 2005. Development of the partition coefficent test method. pp15.
Partition coefficient for zinc	ml/g	45		Single	EA. 2005. Development of the partition coefficent test method. pp15.
USZ effective porosity	fraction	0.3	0.01	Triangular, likely = 0.1	Allen et al. 1997. Major aquifer manual inidicates storage coefficeint for Basal Sands aquifer. No BMR logging available for the Thanet or Lambeth
USZ hydraulic conductivity (Model 1 Domain)	m/s	1.0E-04	1.1E-04	Log normal	USZ is made up by the Upnor Formation, hence hydraulic conductivity values for this formation have been used.
USZ hydraulic conductivity (Model 2 Domain)	m/s	2.7E-07	2.0E-05	Triangular, likely = 5.68e-6	Defined based on permeability data from Thanet Sand in area of SWS10-004
Vertical hydraulic gradient	m/m	1		Single	ConSim 2.5 Manual suggestion for Soakaways
Saturated zone pathway (Thanet Formation)					
Background concentration of lead	mg/l	0.001		Single	Phase 2 GI data - ESdat Package C export, summarised in Backgrond conc. tab
Background concentration of copper	mg/l	0.01		Single	Phase 2 GI data - ESdat Package C export, summarised in Backgrond conc. tab
Background concentration of zinc	mg/l	0.012		Single	Phase 2 GI data - ESdat Package C export, summarised in Backgrond conc. tab
Background concentration of chloride	mg/l	88		Single	Phase 2 GI data - ESdat Package C export, summarised in Backgrond conc. tab
Hydraulic conductivity of aquifer	m/s	9.35E-07	1.18E-06	Log normal	Average and standard deviation of hydraulic conductivity values for Thanet Formation from Package C in-situ testing
Hydraulic gradient	-	0.03		Single	Approximate head gradient using January 2020 contours from source to receptor
Aquifer thickness	m	50	15	Uniform	Head measured from January 2020 levels to top of the Pegwell Member (cohesive Thanet formation)
Mixing zone thickness	m	n/a		Single	Calculated by ConSim
Groundwater flow direction (Model 1 Domain)	degrees	140		Single	LTC inhouse GIS viewer - groundwater contours for February 2014
Groundwater flow direction (Model 12 Domain)	degrees	320		Single	Assume worst-case flow direction during pumping from Lindford is directly toward SPZ 1 from SWS10-004
Aquifer effective porosity	fraction	0.3	0.01	Triangular, likely = 0.1	Allen et al. 1997. Major aquifer manual inidicates storage coefficeint for Basal Sands aquifer and Chalk aquifer.
Aquifer dry bulk density	g/cm^3	1.56	0.08228	Log normal	Phase 2 Package C lab testing results - Thanet Formation (see draft calcs tab)
Aquifer longitudinal dispersivity	m	10% of compliance distance		Single	ConSim 2.5 Manual suggests we use rule of thumb. pp34
Aquifer transverse dispersivity	m	30% of longitudinal dispersivity		Single	ConSim 2.5 Manual suggests we use rule of thumb. pp34
Lead half life in unsaturated zone	years	1E+30		Single	Conservative - inert metal based on professional judgement
Copper half life in unsaturated zone	years	1E+30		Single	Conservative - inert metal based on professional judgement
Zinc half life in unsaturated zone	years	1E+30		Single	Conservative - inert metal based on professional judgement
Chloride half life in unsaturated zone	years	1E+30		Single	Conservative - inert metal based on professional judgement
Partition coefficient of chloride in aquifer	ml/g	0		Single	Conservative - professional judgment as chloride is used as a trace contaminant
Partition coeffieient of copper in aquifer	ml/g	67		Single	Allison and Allison. 2005. Kd for metals in surface water, soil and waste. pp15.
Partition coefficient of lead in aquifer	ml/g	320		Single	EA. 2005. Development of the partition coefficent test method. pp15.
Partition coefficient of zinc in aquifer	ml/g	45		Single	EA. 2005. Development of the partition coefficent test method. pp15.
Saturated zone pathway (Chalk aquifer)					
Background concentration of lead	mg/l	0.001		Single	Phase 2 GI data - ESdat Package C export, summarised in Backgrond conc. tab
Background concentration of copper	mg/l	0.01		Single	Phase 2 GI data - ESdat Package C export, summarised in Backgrond conc. tab
Background concentration of zinc	mg/l	0.012		Single	Phase 2 GI data - ESdat Package C export, summarised in Backgrond conc. tab
Background concentration of chloride	mg/l	88		Single	Phase 2 GI data - ESdat Package C export, summarised in Backgrond conc. tab
Hydraulic conductivity of Chalk	m/s	0.000194	0.00005	Log normal	Numerical model - Monte Carlo analysis results for upper Chalk
Hydraulic gradient	-	0.01		Single	2014 EA February high groundwater contours
Aquifer thickness	m	50	30	Uniform	Conservative values based on literature - Major aquifer properties manual (Allen et al. 2007)
Mixing zone thickness	m	n/a		Single	Calculated by ConSim
Groundwater flow direction	degrees	140		Single	LTC inhouse GIS viewer - groundwater contours for February 2014
Chalk aquifer effective porosity	fraction	0.2	0	Triangle = 0.05	Phase 2 ground investigation data - NMR/BMR logging summarised in draft calcs tab
Aquifer bulk density	g/cm^3	1.69	1.43	Triangle - Likely = 1.47	Phase 1b lab testing results - Phase 1B factual report (summarised in draft calcs tab)
Aquifer longitudinal dispersivity	m	10% of compliance distance		Single	ConSim 2.5 Manual suggests we use rule of thumb. pp34
Aquifer transverse dispersivity	m	30% of longitudinal dispersivity		Single	ConSim 2.5 Manual suggests we use rule of thumb. pp34
Lead half life in unsaturated zone	years	1E+30		Single	Conservative - inert metal based on professional judgement
Copper half life in unsaturated zone	years	1E+30		Single	Conservative - inert metal based on professional judgement
Zinc half life in unsaturated zone	years	1E+30		Single	Conservative - inert metal based on professional judgement
Chloride half life in unsaturated zone	years	1E+30		Single	Conservative - inert metal based on professional judgement
Partition coefficient of chloride in aquifer	ml/g	0		Single	Conservative - professional judgment as chloride is used as a trace contaminant
Partition coeffieient of copper in aquifer	ml/g	67		Single	Allison and Allison. 2005. Kd for metals in surface water, soil and waste. pp15.
Partition coefficient of lead in aquifer	ml/g	320		Single	EA. 2005. Development of the partition coefficent test method. pp15.
Partition coefficient of zinc in aquifer	ml/g	45		Single	EA. 2005. Development of the partition coefficent test method. pp15.
Receptor compliance points					
Linford SPZ 1 (Model Domain 1 - northern boundary)	m (coordinate)	566874, 179396		Single	LTC inhouse GIS Viewer (Linford, Northumbrian Water Ltd, general use - Chalk)
Linford SPZ 1 (Model Domain 2 - southern boundary)	m (coordinate)	567271, 178977		Single	LTC inhouse GIS Viewer (Linford, Northumbrian Water Ltd, general use - Chalk)
Linford SPZ 2	m (coordinate)	566343, 179692		Single	LTC inhouse GIS Viewer (Linford, Northumbrian Water Ltd, general use - Chalk)
Orsett Golf Club abstraction well	m (coordinate)	565985, 180732		Single	LTC inhouse GIS Viewer (Orsett Golf club Ltd, spray irrigation - Chalk)
Orsett Golf Club mid-point	m (coordinate)	564934, 180611		Single	LTC inhouse GIS Viewer (Linford, Northumbrian Water Ltd, general use - Chalk)
DWS values					
Chloride	mg/l	250		Single	
Copper	mg/l	2		Single	

Lead	mg/l	0.01	Single
Zinc	mg/l	5	Single

Draft Calculations

BH/TP ID	Phase	Depth (m)	Strata	Dry density (Mg/m3)	Dry density (g/cm3)
BH12005	2	1.5	Head/Thanet	1.5	1.5
BH12005	2	23.14	Chalk	1.41	1.41
BH12005	2	29.12	Chalk	1.45	1.45
BH12012	2	6.5	Lambeth	1.9	1.9
BH12012	2	36	Chalk	1.48	1.48
BH12012	2	2.2	Chalk	1.42	1.42
BH13004	2	2	RTD	1.87	1.87
BH13004	2	5.2	Thanet	1.59	1.59
BH13009	2	42.17	Chalk	1.44	1.44
BH13009	2	50.27	Chalk	1.4	1.4
BH12003	2	17.24	Chalk	1.43	1.43
BH12003	2	22.22	Chalk	1.45	1.45
BH12003	2	27.46	Chalk	1.49	1.49
BH12003	2	6.5	Thanet	1.47	1.47
BH13007	2	4.7	RTD	2.05	2.05
BH13007	2	21.5	Thanet	1.57	1.57
OH13002	2	2.5	RTD	1.79	1.79
OH13004	2	6	Thanet	1.68	1.68

Bulk dry density per strata:

	Chalk	Thanet	Lambeth	RTD
Average	1.441	1.562	n.a	1.903
Mode	1.450	#N/A	n.a	#N/A
Min	1.400	1.470	1.900	1.790
Max	1.490	1.680	1.900	2.050
Stdev	0.030184617	0.08228001		0.133166562

BH ID	X	Y	Strata	Phase	Chloride - mg/l		Copper - ug/l		Zinc - ug/l		Lead - ug/l	
					Max	Min	Max	Min	Max	Min	Max	Min
BH09002	567046.2	177958.1	Chalk	2	81	71	5	0.611	16	1.28	<1	<1
BH09006	566928	178336.7	Thanet	2	97	88.4	5	1	24	13.1	<1	<1
BH09010	566834.4	178691.1	Chalk	2	45	44	9	0.843	77	35	<1	<1
BH10003	566824.3	179204.7	Chalk	2	61	48.8	10	0.3	38	1	<1	<1
BH10004	566645.5	179312.1	Thanet	2	88	81	4	1	12.1	6.86	<1	<1
BH10008	566506.5	179544.7	Chalk	2	78	77	3.62	0.3	10	3.63	<1	<1
BH11004	566276	179707	Thanet	2	183	177	5	1	19	15	<1	<1
BH11007	565801.6	179927.6	Thanet	2	72	68	20	1	802	23	26	0.477
BH12003	565211.2	180084.2	Chalk	2	63	58	<1	<1	20	9.69	<1	<1
BH12005	564462.1	180123.4	Chalk	2	18	11.4	8.68	1	41	3	2.97	<1
BH13002	564805.2	180074.9	Thanet	2	50	50	2	2	19	19	<1	<1
BH13009	563752.8	180633.3	Chalk	2	40	33	25.7	0.3	491	30.9	<1	<1
BH13015	564100	180736.3	Thanet	2	88	56	5	1	10	3.86	<1	<1

BH10004 is used for background concentration, as this borehole is nearest to the Linford compliance point, therefore best represents the groundwater quality

LOD

Lead	1	ug/l
Cadmium	0.2	ug/l
Copper	5	ug/l

	EQS	DWS	
Copper	0.028	2	mg/l
Zinc	0.040	5	mg/l
Lead	0.025	0.01	mg/l
Chloride	250	250	mg/l

Exceed the EQS

Close to EQS

5

Annex O Operational drainage pollution risk assessment

Lower Thames Crossing

Annex O Operational Drainage Pollution Risk Assessment

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1 Introduction

1.1.1 This document presents the assessment of pollution risks to groundwater bodies that would receive discharges of operational drainage from the proposed A1222 Lower Thames Crossing (the Project).

1.1.2 The purpose of this assessment is to carry out a simple evaluation of the groundwater pollution risk by assessing the:

a. groundwater quality and runoff risk

b. the risk of pollution being caused by accidental spillage

1.1.3 The assessment has been carried out in line with the methodologies set out in the Design Manual for Roads and Bridges (DMRB) LA 113 Road Drainage and the Water Environment (Highways England, 2020a). These methods have been implemented using the Highways England Water Risk Assessment Tool (HEWRAT).

1.1.4 The data from this assessment has been used to inform Environmental Statement Chapter 14: Road Drainage and the Water Environment (Application Document 6.1).

1.1.5 This assessment forms Annex O of the Hydrogeological Risk Assessment. The assessment of drainage-related pollution risks to surface water bodies is presented separately in Appendix 14.3: Operational Surface Water Drainage Pollution Risk Assessment (Application Document 6.3).

2 Drainage design

2.1 Infiltration basin catchments and basin design assumptions

2.1.1 The information regarding the drainage design is presented in Appendix 14.6: Flood Risk Assessment (Part 7) (Application Document 6.3) and the Drainage Plans in the Book of Plans (Application Document 2.16).

2.1.2 The information shows that ten infiltration basin catchments and corresponding basins are to be assessed.

2.1.3 The infiltration basin catchments and corresponding basin designations are summarised in Table 2.1 and displayed in Plate 2.1 and Plate 2.2.

Table 2.1 Summary of infiltration basin catchments and infiltration basin locations with coordinates

Basin name	Infiltration basin catchments	Easting*	Northing*	South or North of River Thames
EXPOS01-01	1b	569708	169488	South
POS01-001	1a	569896	169734	South
EXPOS02-001	2a	565786	170496	South
POS02-001	2c	566025	170303	South
POS02-002	2d	566643	170264	South
POS02-003 (cascade)	2e	567460	171347	South
POS02-004	2b	566744	170272	South
EXPOS02-005	2f	566779	169977	South
POS04-001 (cascade)	4a	568051	171641	South
POS11-003	11c	563798	180546	North

*Coordinates from the centre point of each basin or first basin if a cascade

Plate 2.1 Infiltration basin and swale locations south of the River Thames

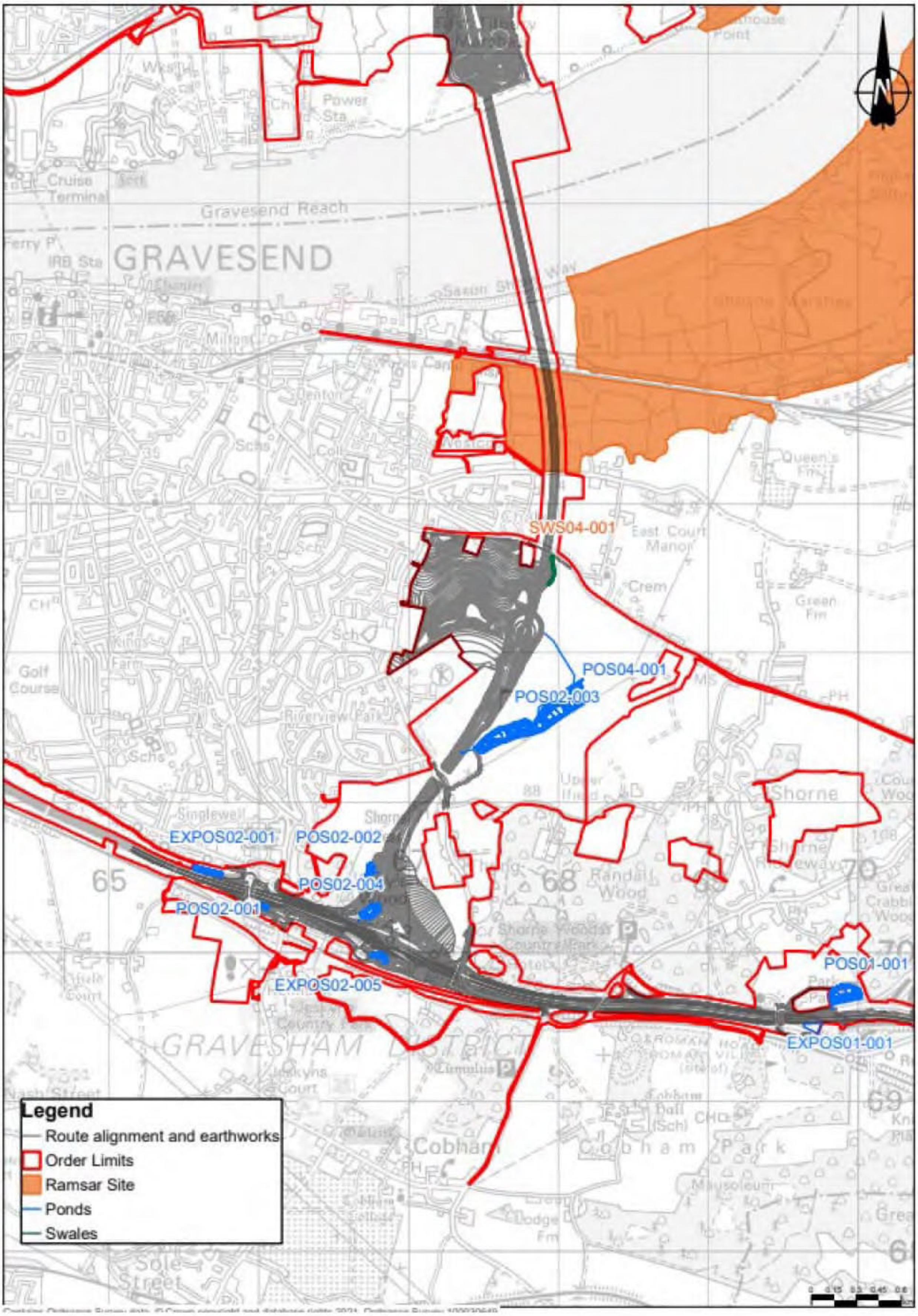
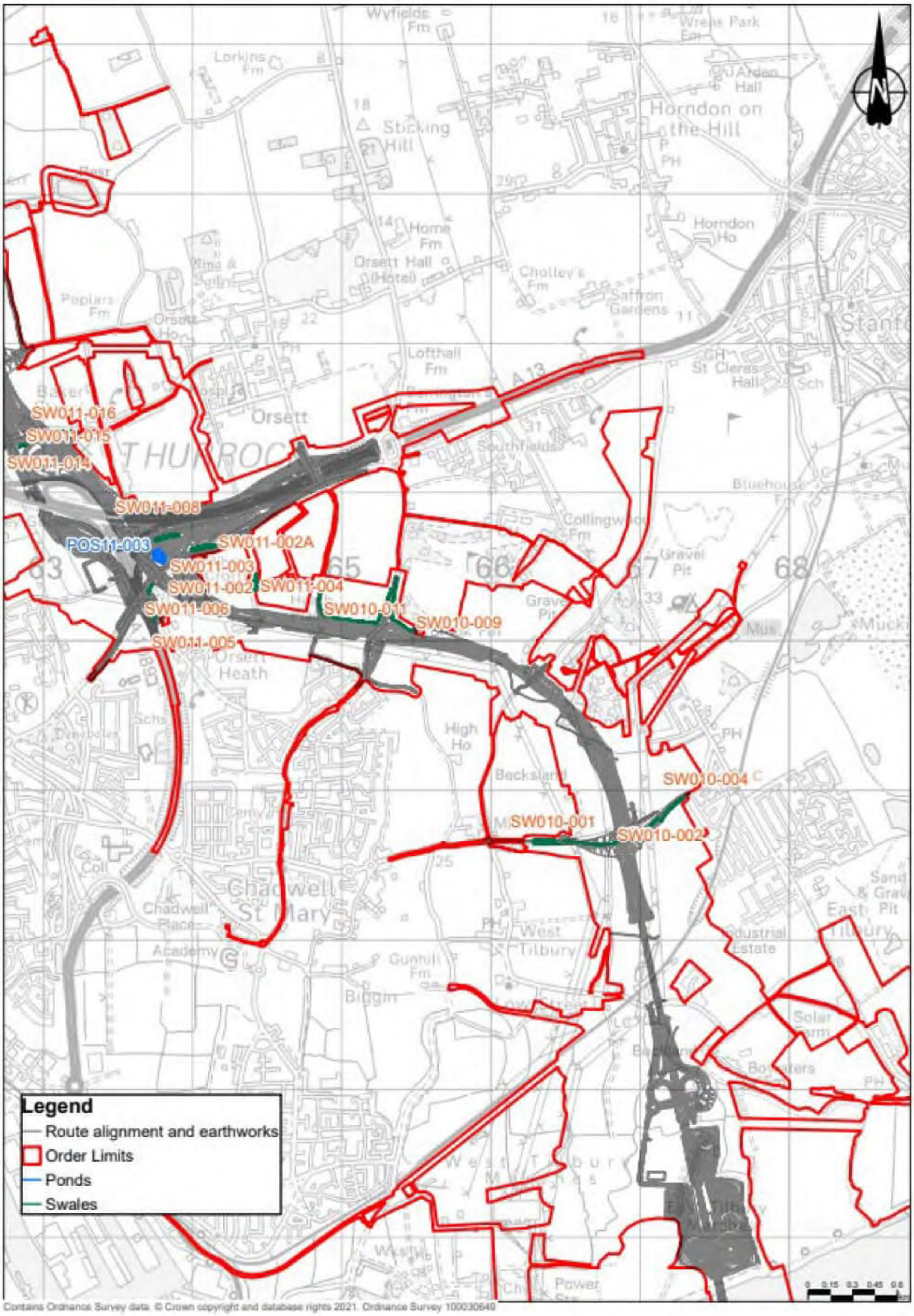
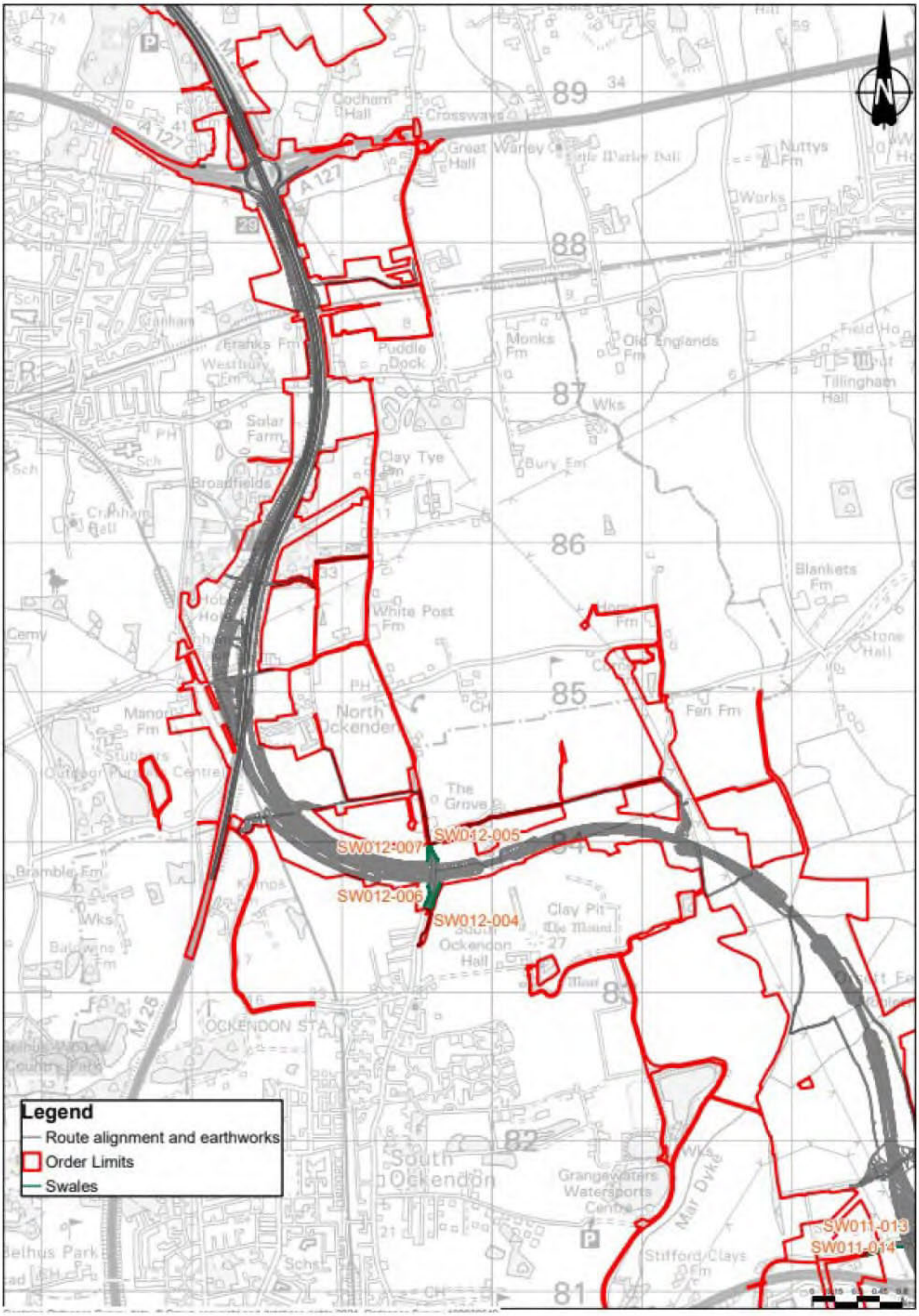


Plate 2.2 Infiltration basin and swale location north of the River Thames




Legend
Route alignment and earthworks
Order Limits
Swales
SW012-007
SW012-005
SW012-006
SW012-004
SW011-013
SW011-014

2.1.4 The infiltration basins associated with infiltration basin catchments 2e (POS02-003) and 4a (POS04-001) have been designed in a cascade formation to allow for overflow.

2.1.5 For the purpose of this simple assessment, assumed soakage would only occur from the trenches around the base of the infiltration basins. Each proposed trench has a uniform dimension of 1m x 1m, so the surface area will be $1m^2$ per metre length of trench.

2.2 Swales

2.2.1 In addition to the infiltration basins above, swales are proposed as part of the operational pollution drainage system.

2.2.2 The below swales have been selected for this assessment because they are considered at possible risk of receiving road drainage runoff. The swales which are isolated from road drainage runoff have been scoped out of this assessment.

2.2.3 The swales are shown in Plate 2.1 and Plate 2.2 and the coordinates listed in Table 2.2.

Table 2.2 Summary of swale locations with coordinates

Swale name	Easting	Northing
SWS04-001	567959	172646
SWS10-001	566472	178636
SWS10-002	566435	178661
SWS10-004	567304	178952
SWS10-009	565371	180427
SWS10-011	565327	180347
SWS11-002A	564150	180641
SWS11-002	564450	180353
SWS11-003	564430	180411
SWS11-004	564424	180454
SWS11-005	563701	180265
SWS11-006	563708	180317
SWS11-008	563900	180709
SWS11-013	562665	181288
SWS11-014	562739	181293
SWS11-015	562884	181317
SWS11-016	563185	181404
SWS12-004	559654	183714
SWS12-005	559641	183872
SWS12-006	559552	183570

Swale name	Easting	Northing
SWS12-007	559569	183869

3 Methodology

3.1 Groundwater quality and runoff risk assessment

3.1.1 Appendix C of DMRB LA 113 (Highways England, 2020a) establishes the methodology to carry out the groundwater quality routine runoff risk assessment. This is determined by the guidance to be a simple assessment. HEWRAT has been used to produce the outputs (see Annex A). The method focuses on the potential impacts on groundwater quality from highway drainage.

3.1.2 Each of the locations are scored based on several parameters to produce an overall risk score. The parameters in the matrix are attributed a weighted scoring system multiplied by the conceptualised risk score. If the final risk score is below a cumulative value of 150 (low risk), no further action is needed. If the cumulative score is between 150 to 250 (medium risk) or above 250 (high risk), a detailed assessment is recommended.

3.1.3 There are three ‘source’ parameters and six ‘pathway’ parameters which are used to build up the cumulative score. The three ‘source’ parameters comprise traffic flow, rainfall depth annual averages and drainage area ratio.

3.1.4 The six ‘pathway’ parameters comprise infiltration method, unsaturated zone, flow type, unsaturated zone clay content, organic carbon and unsaturated zone pH.

3.1.5 The receptor at each of the locations is the top of the water table.

3.1.6 Plate 3.1 is an excerpt of the guidance from Appendix C of DMRB LA 113 showing the risk matrix for this assessment.

Plate 3.1 Groundwater quality and risk assessment matrix extracted from Appendix C of DMRB LA 113

Table C.1 Groundwater quality and runoff risk assessment matrix

	Parameter	Weighting factor	Low risk (Score 1)	Medium risk (Score 2)	High risk (Score 3)
Source	Traffic flow	10	≤50,000 AADT	>50,000 AADT to <100,000 AADT	≥100,000 AADT
	Rainfall depth (annual averages)	10	≤740 mm	>740 mm to <1060 mm	≥1060 mm
	Drainage area ratio	10	≤50	>50 to <150	≥150
Pathway	Infiltration method	15	"Continuous" shallow linear (e.g. unlined ditch, swale, grassed channel)	"Region", shallow infiltration systems, (e.g. infiltration basin).	"Point" systems (e.g. chamber soakaways, deep shafts) 2
	Unsaturated zone	20	Depth to water table ≥15 m or unproductive strata	Depth to water table <15 m and >5 m	Depth to water table ≤5 m
	Flow type	20	Dominantly intergranular flow	Mixed fracture and intergranular flow	Flow dominated by fractures/ fissures
	Unsaturated zone clay content	5	≥15 % clay minerals	<15 % to >1 % clay minerals	≤1 % clay minerals
	Organic carbon	5	≥15 % Soil organic matter	<15% to >1% soil organic matter	≤1 % Soil organic matter
	Unsaturated zone soil pH	5	pH ≥8	pH <8 to >5	pH ≤5

3.2 Groundwater quality and spillage assessment

3.2.1 Appendix D of DMRB LA 113 (Highways England, 2020a) establishes the methodology to carry out the spillage assessment. The method initially estimates the risk that there will be an incident causing the spillage of a potentially polluting substance somewhere on the length of road being assessed. It then calculates the risk, assuming a spillage has occurred, that the pollutant will reach and impact on the receiving groundwater body. The risks are expressed as annual probabilities of such an event occurring.

3.2.2 The risk of a serious pollution incident is deemed acceptable if the annual probability is less than 1%. Where the spillage could affect sensitive areas or activities, for example a designated nature conservation site or potable water supply abstraction, the risk of a serious pollutant incident is deemed acceptable if the annual probability is less than 0.5%.

3.2.3 Mitigation systems which reduce the likelihood of a spillage leading to a pollution incident, defined in DMRB CG 501 Design of Highway Drainage Systems (Highways England, 2020b), can be factored into the assessment to establish the mitigated annual probability.

3.2.4 Each basin has a designated catchment within which road nodes are present. Each road node has been modelled to provide values for expected traffic flows. Another key parameter used from the modelled traffic flows include the percentage of Heavy Goods Vehicles (HGVs) that are likely to use the road.

3.3 HEWRAT input data sources

3.3.1 Table 3.1 and Table 3.2 provide a summary of sources that have been used to generate the data required as input to the HEWRAT pollution risk calculations. See Annex A and Annex B for all input values.

3.3.2 A further update to the traffic modelling has been completed since conducting the HEWRAT assessment on all soakaways (infiltration basins). The new traffic model, simulation reference ID: LR_CS67 2045, dated May 2022, which is representative of the 2045 operational year, has been reviewed and assessed for percentage change of total Annual Average Daily Traffic (AADT) and percentage HGVs. Details of the traffic model are provided in the Combined Traffic Modelling and Appraisal report (Application Document 7.7).

3.3.3 The swales have been newly assessed against the most updated traffic model (CS67 2045, 2022).

3.3.4 For most soakaway locations, the AADT change is equal to or less than 5%. Excepting catchments 2d (south of River) and 11c (north of River), which AADT change is respectively 7% and 15%. In all cases, this resulted in no change to the HEWRAT scoring for traffic flow in the routine runoff risk assessment. Therefore, there was no change to the input of the HEWRAT groundwater quality and runoff simple risk assessment. For the spillage assessment, this resulted in small changes to the traffic flow and %HGV input values, the largest changes of which were for catchments 2a, 2c, 2d, 2f and 11c.

Table 3.1 Summary of HEWRAT input data sources – groundwater quality and runoff risk assessment

Data	Source
Traffic flow	For soakaways: Simulation and Assignment of Traffic to Urban Road Networks (SATURN) Traffic Flow Models using the Annual Average

Data	Source
	Daily Traffic 24 (AADT24) value (Do Something Design Year – DCO Model - CS12 2042). The traffic model has been since updated by DCO Model - CS67 2045 but resulting in no change of traffic flow score and therefore no change to results. For swales: Simulation and Assignment of Traffic to Urban Road Networks (SATURN) Traffic Flow Models using the Annual Average Daily Traffic 24 (AADT24) value (Do Something Design Year – DCO Model - CS67 2045).
Rainfall depth annual averages	Flood Estimation Handbook Web Service (UK Centre for Ecology and Hydrology, 2020)
Drainage area ratio	Drainage area of road discharging to the soakaway (or total catchment area) divided by active surface area of infiltration device. For infiltration basins, the trench surface area has been used to calculate the active surface area. Information has been obtained from the proposed basin drainage design drawings associated with the reports listed in Section 2.1.
Infiltration method	Design description and professional judgement
Unsaturated zone	Project ground investigation data British Geological Survey (2020) GeonIndex Onshore viewer Land Information System (LandIS) Soilscapes viewer (Cranfield Soil and AgriFood Institute, 2020) In-house Geographic Information Systems (GIS) viewer – Chalk aquifer contours from February 2014 Environment Agency data
Flow type	Professional judgement based on geology
Unsaturated zone clay content	Project ground investigation data British Geological Survey (2020) GeoIndex Onshore viewer LandIS Soilscapes viewer
Organic carbon	Professional judgement based on geology and clay content
Unsaturated zone pH	LandIS Soilscapes viewer

Table 3.2 Summary of HEWRAT input data sources – spillage assessment – groundwater risk

Data	Source
Water body type	Modelling infiltration basin to groundwater
Length of road draining to outfall *(m)*	For soakaways: From ‘Link Length’ Do Something (DS) CS08 131119_Table For swales: GIS
Road type *(A-road or motorway)*	From ‘Road Class’ Project Saturn Traffic Model
If A-road, is site urban or rural?	From ‘UrbanRural’ DS CS08 131119_Table
Junction type	From ‘NatureCarr’ DS CS08 131119_Table or GIS

Data	Source
Location (response time for emergency services)	Site-specific estimation using Google Maps (Google, 2022) direction tool to closest emergency service location
Traffic flow (AADT two way)	From 'AADT24, All vehicles (veh/day)' Project Saturn Traffic Model after identifying the road node
%HGV	From 'AADT24, %HDV' Project Saturn Traffic Model after identifying the road node
Spillage factor *(no/10^9HGVkm/year - or* serious spillage rates in billion HGV km/year)	Selection from HEWRAT spillage factor table based on conceptualisation
Risk of accidental spillage	HEWRAT inbuilt calculation
Probability factor	Based on location response time (HEWRAT inbuilt calculation)
Risk of pollution incident	HEWRAT inbuilt calculation
Is risk greater than 0.01?	Greater than 0.01 (1%) in 'Risk of accidental spillage'
Return period without pollution reduction measures	HEWRAT inbuilt calculation
Existing measures factor	Selection from HEWRAT pollution risk reduction factor based on conceptualisation. A default value of 1 is used if no measures are considered or no value is entered.
Return period with existing pollution reduction measures	HEWRAT inbuilt calculation
Proposed measures factor	Selection from HEWRAT pollution risk reduction factor based on conceptualisation.
Residual with proposed pollution reduction measures	HEWRAT inbuilt calculation

3.3.5 The routine runoff assessment also requires traffic flow data, in the form of AADT for the design year of the proposed development. This information has been extracted from the operational traffic model.

3.3.6 The information required to define the infiltration basin catchment locations, permeable and impermeable areas (hectares) draining to each basin and the proposed runoff treatment train was provided by the Drainage Team.

3.4 Assumptions and limitations

3.4.1 The HEWRAT calculations are fixed and do not account for other hydrogeological parameters such as evaporation and attenuation.

3.4.2 The highest six traffic flows within each catchment have been selected to give worst-case scenario values for input into the spillage assessment model.

3.4.3 The new traffic model, DCO Model - CS67 2045, has been compared against DCO Model - CS12 and assessed for percentage change of total AADT and percentage HGVs. For the routine runoff assessment, this has resulted in no change to the HEWRAT scoring for traffic flow and therefore no change to the input of the HEWRAT groundwater quality and runoff simple risk assessment. For the spillage assessment, this resulted in small changes to the traffic flow and %HGV input values, the largest changes of which were for catchments 2a, 2c, 2d, 2f and 11c. These locations were therefore checked for any changes to the results, which are discussed in Section 4.2.

3.4.4 The design parameters and values are correct at the time of the assessment.

4 Assessment results

4.1 Groundwater quality and runoff results

4.1.1 The process described in the above report sections produces an overall score from which the risk is assessed as low, medium or high as follows:

c. <150 low risk

d. 150 – 250 medium risk

e. >250 high risk

Infiltration basins

4.1.2 The results in Table 4.1 show that all the proposed infiltration basins and infiltration basin catchments have a risk rating of medium because they have a score of between 150 and 250, which is the range of scores that are defined as medium risk by HEWRAT.

Table 4.1 Summary of HEWRAT – groundwater quality and runoff simple risk assessment

Basin name	Infiltration basin catchment number	Score	Risk
EXPOS01-001	1b	205	Medium
POS01-001	1a	215	Medium
EXPOS02-001	2a	205	Medium
POS02-001	2c	195	Medium
POS02-002	2d	195	Medium
POS02-003	2e	215	Medium
POS02-004	2b	215	Medium
EXPOS02-005	2f	215	Medium
POS04-001	4a	215	Medium
POS11-003	11c	175	Medium

4.1.3 These results mean that a detailed assessment is required for the infiltration basins.

Swales

4.1.4 An analysis of the swales was also undertaken. The results are shown in Table 4.2.

Table 4.2 Summary of HEWRAT – groundwater quality and runoff simple risk assessment

Swale name	Score	Risk
SWS04-001	160	Medium
SWS10-001	140	Low
SWS10-002	140	Low
SWS10-004	140	Low
SWS10-009	155	Medium
SWS10-011	155	Medium
SWS11-002A	150	Medium
SWS11-002	160	Medium
SWS11-003	160	Medium
SWS11-004	160	Medium
SWS11-005	155	Medium
SWS11-006	155	Medium
SWS11-008	150	Medium
SWS11-013	150	Medium
SWS11-014	150	Medium
SWS11-015	150	Medium
SWS11-016	150	Medium
SWS12-004	145	Low
SWS12-005	125	Low
SWS12-006	145	Low
SWS12-007	125	Low

4.1.5 The swale groundwater quality runoff results, where shown as of medium risk, mean that a detailed assessment is also required, although it is noted that all medium scores were close to the lower end of medium risk.

4.1.6 Ground investigation data shows that swales SWS11-013, SWS11-014, SWS11-015 and SWS11-016 are laying over less than 5 m of superficial deposits (Secondary A aquifer RTD) which is on top of the bedrock formation (non-aquifer London Clay). Phase 3 boreholes BH14343, BH15304 and BH15035, which have been installed in the RTD, recorded perched water during the year 2020 wet season (October, November and December 2020). However, the superficial deposits are thin, on the edge of the outcrop and known to be generally dry in the A13 junction area, with the RTD being replaced by Head deposits to the north of these swales. The perched water recorded during the wet season is considered localised and discontinuous. Therefore, the above swales are proposed to be constructed above generally dry RTD and Unproductive strata belonging to London Clay. Additionally, both the superficial deposits and the bedrock formation are sloping towards the north, where no known environmental receptor is present. With this information, swales SWS11-013, SWS11-014, SWS11-015 and SWS11-016 are scoped out of the detailed assessment.

4.1.7 Swales SWS10-001, SWS10-002 and SWS10-004 have scored a low risk, however they are in the vicinity of Linford Abstraction SPZ1. Therefore, they are included in the detailed assessment (Annex N of Appendix 14.5 - Application Document 6.3).

4.2 Spillage assessment – groundwater risk

Infiltration basins

4.2.1 Some of the infiltration basins are located close to source protection zones (SPZ3) and one is close to an outer source protection zone (SPZ2) as listed in Appendix 14.5: Hydrogeological Risk Assessment (Application Document 6.3). Therefore, the risk of a serious pollution incident to be deemed acceptable should be below 0.5%.

4.2.2 A check on the change of input values of traffic flow and %HGV, using the updated traffic model DCO – CS67 2045 has found no changes to results for the locations that show greatest change of traffic flow. Catchments 2a, 2c, 2d, 2f and 11c all calculated the same results of 0.02%, 0.00%, 0.00%, 0.01%, and 0.01% risk of pollution incident respectively.

4.2.3 Table 4.3 shows that all of the basins and catchments are below 0.5%, with the highest risk of a pollution incident (without existing measures) of 0.18% at infiltration basin catchment 1a or basin POS01-001. The cumulative risk to the Chalk aquifer (south of the River Thames) without any protection measures is 0.62%, above the 0.5% action value. However, with the proposed mitigation measures (Annex A of Appendix 14.5 – Application Document 6.3) the risk decreases to 0.35%.

4.2.4 Based on these results, in accordance with DMRB LA 113 (Highways England 2020a), no further action is required.

Table 4.3 Summary of HEWRAT – groundwater quality and runoff simple risk assessment – infiltration basins

Basin name	Infiltration basin catchment number	Risk of pollution incident	Risk with proposed pollution reduction measures
M2/A2/Lower Thames Crossing junction (south of River Thames)			
EXPOS01-001	1b	0.07%	0.03%
POS01-001	1a	0.18%	0.11%
EXPOS02-001	2a	0.03%	0.02%
POS02-001	2c	0.01%	0.00%
POS02-002	2d	0.00%	0.00%
POS02-003	2e	0.14%	0.08%
POS02-004	2b	0.04%	0.02%
EXPOS02-005	2f	0.02%	0.01%
POS04-001	4a	0.13%	0.08%

Basin name	Infiltration basin catchment number	Risk of pollution incident	Risk with proposed pollution reduction measures
Cumulative risk (South of River Thames)		0.62%	0.35%
A13/A1089/A122 Lower Thames Crossing junction (north of River Thames)			
POS11-003	11c	0.02%	0.01%

4.2.5 Pollution reduction measures are included in Annex A of Appendix 14.5 (Application Document 6.3).

Swales

4.2.6 Table 4.4 shows that all swales are assessed as having a below 0.5% risk of pollution incident. Therefore, no further assessment is required.

Table 4.4 Summary of HEWRAT – groundwater quality and spillage risk assessment – swales

Swale Name	Risk of pollution incident	Risk with proposed pollution reduction measures
M2/A2/Lower Thames Crossing junction (south of River Thames)		
SWS04-001	<0.01%	<0.01%
A13/A1089/A122 Lower Thames Crossing junction (north of River Thames)		
SWS10-001	<0.01%	<0.01%
SWS10-002	<0.01%	<0.01%
SWS10-004	<0.01%	<0.01%
SWS10-009	<0.01%	<0.01%
SWS10-011	<0.01%	<0.01%
SWS11-002A	0.00%	0.00%
SWS11-002	0.00%	0.00%
SWS11-003	0.00%	0.00%
SWS11-004	0.00%	0.00%
SWS11-005	<0.01%	<0.01%
SWS11-006	<0.01%	<0.01%
SWS11-008	<0.01%	<0.01%
SWS11-013	<0.01%	<0.01%
SWS11-014	<0.01%	<0.01%
SWS11-015	<0.01%	<0.01%

Swale Name	Risk of pollution incident	Risk with proposed pollution reduction measures
SWS11-016	<0.01%	<0.01%
SWS12-004	<0.01%	<0.01%
SWS12-005	<0.01%	<0.01%
SWS12-006	<0.01%	<0.01%
SWS12-007	<0.01%	<0.01%
Cumulative risk (north of River Thames)	<0.5%	<0.5%

4.2.7 Table 4.3 and Table 4.4 show that the cumulative risk with proposed pollution reduction measures, from all of the infiltration basin catchments and swales is below 0.5% isouth of the Thames and below 0.5% north of the Thames..

5 Conclusions

5.1.1 The results of the simple groundwater quality and routine runoff pollution assessment show that each of the infiltration basin catchments and each of the swales have a medium risk rating (between scores of 150 and 250) using HEWRAT. Therefore, DMRB LA 113 (Highways England, 2020a) requires that a detailed assessment be completed.

5.1.2 The results of the simple groundwater quality and routine runoff pollution assessment show that fourteen swales have a medium risk rating using the HEWRAT tool. However, four of these swales (SWS11-013, SWS11-014, SWS11-015 and SWS11-016) are proposed to be constructed above generally dry RTD and the non-aquifer London Clay Formation, therefore they are scoped out of the detailed assessment. Additionally, swales SWS10-001, SWS10-002 and SWS10-004, which have scored a low risk, but are in the vicinity of Linford Abstraction SPZ1 are further assessed. A detailed assessment has therefore been completed on thirteen swales: SWS04-001, SWS10-001, SWS10-002, SWS10-004, SWS10-009, SWS10-011, SWS11-002A, SWS11-002, SWS11-003, SWS11-004, SWS11-005, SWS11-006 and SWS11-008. For the remaining four swales which have a low risk using the HEWRAT tool (Section 4.1 - Table 4.2), DMRB LA 113 requires no further action with respect to the simple groundwater quality and routine runoff pollution assessment.

5.1.3 The results of the simple spillage assessment relating to groundwater show that none of the infiltration basin catchments returned a score greater than 0.11%, with pollution reduction measures. This is below the trigger value of 0.5% for sensitive locations. Therefore, DMRB LA 113 requires no further action with respect to the spillage assessment.

5.1.4 The results of the simple spillage assessment relating to groundwater show that the swales all score below 0.01%. Therefore, DMRB LA 113 requires no further action with respect to the spillage assessment.

5.1.5 Additionally, the results of the simple spillage assessment shows that the cumulative risk with proposed pollution reduction measures from all of the infiltration basin catchments and swales are below 0.5% south of the Thames and below 0.5% north of the Thames.

5.1.6 The detailed assessment of potential groundwater impact from routine highway drainage runoff is presented in Annex N of Appendix 14.5 (Application Document 6.3). Project commitments relating to highway drainage are detailed in Chapter 14: Road drainage and the water environment.

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Annexes

Annex A Groundwater routine runoff input values

Catchment	Total Catchment Area (m3)	Bottom (m2)	Bottom (ha)	Swale Location		Traffic Flow (Source)		Rainfall Depth Annual Averages (Source)		Drainage area Ratio (Source)		Infiltration method (Pathway)		Unsaturated Zone (Pathway)		Flow Type (Pathway)		Unsaturated Zone Clay Content (Pathway)		Organic Carbon (Pathway)		Unsaturated Zone pH (Pathway)	
(...)	(m3)			Easting	Northing	Score	Rationale	Score	Rationale	Score	Rationale	Score	Rationale	Score	Rationale	Score	Rationale	Score	Rationale	Score	Rationale	Score	Rationale
SWS04-001		190	0.190	567960	172647	≤50,000 AADT	based on nearest road node from traffic model data	≤ 740mm	≤ 740mm	≤ 50	we don't have catchment area information for new swales. But comparing swales size with the previous	"Continuous" shallow linear (e.g. unlined ditch, swale, grassed channel)	Swale	Depth to water table ≥15 m or unproductive strata	Between 5 to 10 mAOD Ground elevation: 42.51mAOD Estimated gw level based on the above: 37 to 32 mbgl	Flow dominated by fractures/fissures	Flow dominated by fractures/fissures	≤1 % clay minerals	Chalk bedrock <1% clay minerals	≤1 % Soil organic matter	Likely <1% carbon within the chalk	pH ≥8	"Freely draining lime-rich loamy soils" - alkaline?
SWS10-001		93	0.093	566473	178637	≤50,000 AADT	based on nearest road node from traffic model data	≤ 740mm	≤ 740mm	≤ 50	we don't have catchment area information for new swales. But comparing swales size with the previous	"Continuous" shallow linear (e.g. unlined ditch, swale, grassed channel)	Swale	Depth to water table 5-15 m	Approx 6mbgl BH09010	Dominantly intergranular flow	RTD (gravel) over Thanets	<15 % to >1 % clay minerals	RTD (gravel) over Thanets (sand)	≤1 % Soil organic matter	Likely <1% carbon	pH <8 to >5	"Freely draining slightly acidic loamy soils"
SWS10-002		74	0.074	566436	178662	≤50,000 AADT	based on nearest road node from traffic model data	≤ 740mm	≤ 740mm	≤ 50	we don't have catchment area information for new swales. But comparing swales size with the previous	"Continuous" shallow linear (e.g. unlined ditch, swale, grassed channel)	Swale	Depth to water table 5-15 m	Approx 6mbgl BH09010	Dominantly intergranular flow	RTD (gravel) over Thanets	<15 % to >1 % clay minerals	RTD (gravel) over Thanets (sand)	≤1 % Soil organic matter	Likely <1% carbon	pH <8 to >5	"Freely draining slightly acidic loamy soils"
SWS10-004		234	0.234	567304	178953	≤50,000 AADT	based on nearest road node from traffic model data	≤ 740mm	≤ 740mm	≤ 50	we don't have catchment area information for new swales. But comparing swales size with the previous	"Continuous" shallow linear (e.g. unlined ditch, swale, grassed channel)	Swale	Depth to water table 5-15 m	Approx 6mbgl BH09010	Dominantly intergranular flow	RTD (gravel) over Thanets	<15 % to >1 % clay minerals	RTD (gravel) over Thanets (sand)	≤1 % Soil organic matter	Likely <1% carbon	pH <8 to >5	"Freely draining slightly acidic loamy soils"
SWS10-009		232	0.232	565371	180427	≤50,000 AADT	based on nearest road node from traffic model data	≤ 740mm	≤ 740mm	≤ 50	we don't have catchment area information for new swales. But comparing swales size with the previous	"Continuous" shallow linear (e.g. unlined ditch, swale, grassed channel)	Swale	Depth to water table 5-15 m	Approx 8-9mbgl BH12003	Mixed fracture and intergranular flow	Head (clay) over Thanet (sand)	≥15 % clay minerals	Head (clay) over Thanet (sand)	<15% to >1% soil organic matter	Likely <15% to >1% carbon within the Head deposits	pH <8 to >5	"Freely draining slightly acidic loamy soils"
SWS10-011		763	0.763	565328	180348	≤50,000 AADT	based on nearest road node from traffic model data	≤ 740mm	≤ 740mm	≤ 50	we don't have catchment area information for new swales. But comparing swales size with the previous	"Continuous" shallow linear (e.g. unlined ditch, swale, grassed channel)	Swale	Depth to water table 5-15 m	Approx 8-9mbgl BH12003	Mixed fracture and intergranular flow	RTD, or Head (clay) over Thanet (sand)	≥15 % clay minerals	Head (clay) over Thanet (sand)	<15% to >1% soil organic matter	Likely <15% to >1% carbon within the Head deposits	pH <8 to >5	"Freely draining slightly acidic loamy soils"
SWS11-002A		214	0.214	564150	180641	≤50,000 AADT	based on nearest road node from traffic model data	≤ 740mm	≤ 740mm	≤ 50	we don't have catchment area information for new swales. But comparing swales size with the previous	"Continuous" shallow linear (e.g. unlined ditch, swale, grassed channel)	Swale	Depth to water table 5-15 m	Approx 8-9mbgl BH13007	Mixed fracture and intergranular flow	MG over Boyn Hill (sands and gravels) over Lambeth Group (clays and silts as well as some sand content - BH13008) >15% clay minerals	≥15 % clay minerals	MG over Boyn Hill (sands and gravels) over Lambeth Group (clays and silts as well as some sand content - BH13008) >15% clay minerals	<15% to >1% soil organic matter	Likely <15% to >1% carbon within the Lambeth	pH <8 to >5	"Freely draining slightly acidic loamy soils"
SWS11-002		53	0.053	564451	180354	≤50,000 AADT	based on nearest road node from traffic model data	≤ 740mm	≤ 740mm	≤ 50	we don't have catchment area information for new swales. But comparing swales size with the previous	"Continuous" shallow linear (e.g. unlined ditch, swale, grassed channel)	Swale	Depth to water table 5-15 m	Approx 11-12mbgl BH12005	Mixed fracture and intergranular flow	Boyn Hill (sands and gravels) over Thanet (sand)	<15 % to >1 % clay minerals	Boyn Hill (sands and gravels) over Thanet (sand)	≤1 % Soil organic matter	Likely <1% carbon	pH <8 to >5	"Freely draining slightly acidic loamy soils"
SWS11-003		44	0.044	564431	180411	≤50,000 AADT	based on nearest road node from traffic model data	≤ 740mm	≤ 740mm	≤ 50	we don't have catchment area information for new swales. But comparing swales size with the previous	"Continuous" shallow linear (e.g. unlined ditch, swale, grassed channel)	Swale	Depth to water table 5-15 m	Approx 11-12mbgl BH12005	Mixed fracture and intergranular flow	Boyn Hill (sands and gravels) over Thanet (sand)	<15 % to >1 % clay minerals	Boyn Hill (sands and gravels) over Thanet (sand)	≤1 % Soil organic matter	Likely <1% carbon	pH <8 to >5	"Freely draining slightly acidic loamy soils"
SWS11-004		118	0.118	564425	180454	≤50,000 AADT	based on nearest road node from traffic model data	≤ 740mm	≤ 740mm	≤ 50	we don't have catchment area information for new swales. But comparing swales size with the previous	"Continuous" shallow linear (e.g. unlined ditch, swale, grassed channel)	Swale	Depth to water table 5-15 m	Approx 11-12mbgl BH12005	Mixed fracture and intergranular flow	Boyn Hill (sands and gravels) over Thanet (sand)	<15 % to >1 % clay minerals	Boyn Hill (sands and gravels) over Thanet (sand)	≤1 % Soil organic matter	Likely <1% carbon	pH <8 to >5	"Freely draining slightly acidic loamy soils"
SWS11-005		69	0.069	563702	180266	≤50,000 AADT	based on nearest road node from traffic model data	≤ 740mm	≤ 740mm	≤ 50	we don't have catchment area information for new swales. But comparing swales size with the previous	"Continuous" shallow linear (e.g. unlined ditch, swale, grassed channel)	Swale	Depth to water table 5-15 m	Perched water likely to be present in the Thanets at a shllower depth than the chalk therefore using professional judgement can say water level likely to be <15 mbgl and >5mbgl	Mixed fracture and intergranular flow	MG over Boyn Hill (sands and gravels) over Lambeth Group (clays and silts as well as some sand content - BH13008) >15% clay minerals	≥15 % clay minerals	MG over Boyn Hill (sands and gravels) over Lambeth Group (clays and silts as well as some sand content - BH13008) >15% clay minerals	<15% to >1% soil organic matter	Likely <15% to >1% carbon within the Lambeth	pH <8 to >5	"Freely draining slightly acidic loamy soils"
SWS11-006		35	0.035	563709	180317	≤50,000 AADT	based on nearest road node from traffic model data	≤ 740mm	≤ 740mm	≤ 50	we don't have catchment area information for new swales. But comparing swales size with the previous	"Continuous" shallow linear (e.g. unlined ditch, swale, grassed channel)	Swale	Depth to water table 5-15 m	Perched water likely to be present in the Thanets at a shllower depth than the chalk therefore using professional judgement can say water level likely to be <15 mbgl and >5mbgl	Mixed fracture and intergranular flow	MG over Boyn Hill (sands and gravels) over Lambeth Group (clays and silts as well as some sand content - BH13008) >15% clay minerals	≥15 % clay minerals	MG over Boyn Hill (sands and gravels) over Lambeth Group (clays and silts as well as some sand content - BH13008) >15% clay minerals	<15% to >1% soil organic matter	Likely <15% to >1% carbon within the Lambeth	pH <8 to >5	"Freely draining slightly acidic loamy soils"
SWS11-008		147	0.147	563900	180709	≤50,000 AADT	based on nearest road node from traffic model data	≤ 740mm	≤ 740mm	≤ 50	we don't have catchment area information for new swales. But comparing swales size with the previous	"Continuous" shallow linear (e.g. unlined ditch, swale, grassed channel)	Swale	Depth to water table 5-15 m	Approx 7-8mbgl BH13327, BH13332, BH13331	Mixed fracture and intergranular flow	MG over Boyn Hill (sands and gravels) over Lambeth Group (clays and silts as well as some sand content - BH13008) >15% clay minerals	≥15 % clay minerals	MG over Boyn Hill (sands and gravels) over Lambeth Group (clays and silts as well as some sand content - BH13008) >15% clay minerals	<15% to >1% soil organic matter	Likely <15% to >1% carbon within the Lambeth	pH <8 to >5	"Freely draining slightly acidic loamy soils"
SWS11-013		162	0.162	562666	181289	≤50,000 AADT	based on nearest road node from traffic model data	≤ 740mm	≤ 740mm	≤ 50	we don't have catchment area information for new swales. But comparing swales size with the previous	"Continuous" shallow linear (e.g. unlined ditch, swale, grassed channel)	Swale	Depth to water table 5-15 m	Approx 10-11mbgl BH14012	Mixed fracture and intergranular flow	RTD (sand and gravel) over Lambeth (clay, gravels and sands) BH14012 mixture of lithologies including stiff clays. Stiff clays could fracture.	≥15 % clay minerals	RTD (sand and gravel) over Lambeth (clay) (BH14012)	<15% to >1% soil organic matter	Likely <15% to >1% carbon within the Lambeth - professional judgement given absense of local SOM data	pH <8 to >5	"Freely draining slightly acidic loamy soils"
SWS11-014		49	0.049	562740	181293	≤50,000 AADT	based on nearest road node from traffic model data	≤ 740mm	≤ 740mm	≤ 50	we don't have catchment area information for new swales. But comparing swales size with the previous	"Continuous" shallow linear (e.g. unlined ditch, swale, grassed channel)	Swale	Depth to water table 5-15 m	Approx 10-11mbgl BH14012	Mixed fracture and intergranular flow	RTD (sand and gravel) over Lambeth (clay, gravels and sands) BH14012 mixture of lithologies including stiff clays. Stiff clays could fracture.	≥15 % clay minerals	RTD (sand and gravel) over Lambeth (clay) (BH14012)	<15% to >1% soil organic matter	Likely <15% to >1% carbon within the Lambeth - professional judgement given absense of local SOM data	pH <8 to >5	"Freely draining slightly acidic loamy soils"
SWS11-015		40	0.040	562885	181318	≤50,000 AADT	based on nearest road node from traffic model data	≤ 740mm	≤ 740mm	≤ 50	we don't have catchment area information for new swales. But comparing swales size with the previous	"Continuous" shallow linear (e.g. unlined ditch, swale, grassed channel)	Swale	Depth to water table 5-15 m	Approx 10-11mbgl BH14012	Mixed fracture and intergranular flow	RTD (sand and gravel) over Lambeth (clay, gravels and sands) BH14012 mixture of lithologies including stiff clays. Stiff clays could fracture.	≥15 % clay minerals	RTD (sand and gravel) over Lambeth (clay) (BH14012)	<15% to >1% soil organic matter	Likely <15% to >1% carbon within the Lambeth - professional judgement given absense of local SOM data	pH <8 to >5	"Freely draining slightly acidic loamy soils"

SWS11-016		98	0.098	563185	181404	≤50,000 AADT	based on nearest road node from traffic model data	≤ 740mm	≤ 740mm	≤ 50	we don't have catchment area information for new swales. But comparing swales size with the previous ones. Drainage	"Continuous" shallow linear (e.g. unlined ditch, swale, grassed channel)	Swale	Depth to water table 5-15 m	Approx 10-11mbgl BH14012	Mixed fracture and intergranular flow	RTD (sand and gravel) over Lambeth (clay, gravels and sands) BH14012 mixture of lithologies including stiff clays. Stiff clays could fracture.	≥15 % clay minerals	RTD (sand and gravel) over Lambeth (clay) (BH14012)	<15% to >1% soil organic matter	Likely <15% to >1% carbon within the Lambeth - professional judgement given absense of local SOM data	pH <8 to >5	"Freely draining slightly acidic loamy soils"
SWS12-004		170	0.170	559654	183714	≤50,000 AADT	based on nearest road node from traffic model data	≤ 740mm	≤ 740mm	≤ 50	we don't have catchment area information for new swales. But comparing swales size with the previous ones. Drainage	"Continuous" shallow linear (e.g. unlined ditch, swale, grassed channel)	Swale	Depth to water table ≥15 m or unproductive strata	Perched water within the gravel (1m) above London Clay	Flow dominated by fractures/fissures	Boyn Hill Gravel over London Clay	≥15 % clay minerals	Thin layer of gravel over London Clay	>15% soil organic matter	London Clay	pH <8 to >5	"Freely draining slightly acidic loamy soils"
SWS12-005		102	0.102	559642	183872	≤50,000 AADT	based on nearest road node from traffic model data	≤ 740mm	≤ 740mm	≤ 50	we don't have catchment area information for new swales. But comparing swales size with the previous ones. Drainage	"Continuous" shallow linear (e.g. unlined ditch, swale, grassed channel)	Swale	Depth to water table ≥15 m or unproductive strata	Perched water within the Head (1m) above London Clay	Mixed fracture and intergranular flow	Head (clay) over London Clay	≥15 % clay minerals	Thin layer of clayey Head over London Clay	>15% soil organic matter	London Clay	pH <8 to >5	"Freely draining slightly acidic loamy soils"
SWS12-006		139	0.139	559552	183571	≤50,000 AADT	based on nearest road node from traffic model data	≤ 740mm	≤ 740mm	≤ 50	we don't have catchment area information for new swales. But comparing swales size with the previous ones. Drainage	"Continuous" shallow linear (e.g. unlined ditch, swale, grassed channel)	Swale	Depth to water table ≥15 m or unproductive strata	Perched water within the gravel (1m) above London Clay	Flow dominated by fractures/fissures	Boyn Hill Gravel over London Clay	≥15 % clay minerals	Thin layer of gravel over London Clay	>15% soil organic matter	London Clay	pH <8 to >5	"Freely draining slightly acidic loamy soils"
SWS12-007		88	0.088	559569	183869	≤50,000 AADT	based on nearest road node from traffic model data	≤ 740mm	≤ 740mm	≤ 50	we don't have catchment area information for new swales. But comparing swales size with the previous ones. Drainage	"Continuous" shallow linear (e.g. unlined ditch, swale, grassed channel)	Swale	Depth to water table ≥15 m or unproductive strata	Perched water within the Head (1m) above London Clay	Mixed fracture and intergranular flow	Head (clay) over London Clay	≥15 % clay minerals	Thin layer of clayey Head over London Clay	>15% soil organic matter	London Clay	pH <8 to >5	"Freely draining slightly acidic loamy soils"

Data from Drainage Design Team
Data converted or calculated for groundwater routine runoff assessment
Information added to original data from Drainage Design Team

Annex B Spillage assessment input values

											Dec 19 CS12 V1			
Link ID	Road Class	Speed limit (kph)	Dual or single Carriageway or oneway	Speed (kph)	Link Length (km)	Link Length (m)	Speed-band	NatureCarr	Classification	UrbanRural	AADT All Vehicles (veh/day)	HGV (veh/day)	HGV %	Difference
81941_82501	Motorway	112	1	89.31	0.21567	215.67155	Free flow	Dual Carria	M2	Rural hamlets and isolated dwellings	85639	7291	9	2052
81962_87538	A Road	112	1	100.45	1.98085	1980.85234	High Spee	0.00000	0.00000	Rural hamlets and isolated dwellings	69329	6978	10	-523
87531_81941	A Road	112	1	98.57	0.86846	868.46217	High Spee	0.00000	0.00000	Rural hamlets and isolated dwellings	67406	6949	10	-166
87551_87531	A Road	112	1	100.83	1.82722	1827.21935	High Spee	0.00000	0.00000	Rural village	67406	6949	10	-166
87918_83347	Motorway	96	1	85.63	0.65742	657.41914	Free flow	0.00000	0.00000	Rural village	38036	1698	4	431
87574_82968	A Road	96	1	85.63	0.81090	810.90461	High Spee	0.00000	0.00000	Rural village	36838	1836	5	201
83348_87574	A Road	96	1	85.58	0.52656	526.55942	High Spee	0.00000	0.00000	Rural village	36838	1836	5	201
83347_83348	A Road	112	1	94.08	0.36056	360.56212	High Spee	Dual Carria	A2	Rural village	34631	1596	5	270
81942_81941	Motorway	96	1	62.96	0.18815	188.15418	Light Cong	Slip Road	M2	Rural village	18206	363	2	2254
81962_71906	Motorway	112	1	68.89	0.45716	457.15956	Light Cong	Dual Carria	M2	Rural hamlets and isolated dwellings	15408	353	2	-378
83341_71823	A Road	80	1	71.22	0.23001	230.00538	Free Flow	Slip Road	A2	Rural hamlets and isolated dwellings	13948	311	2	-305
83347_83346	A Road	80	1	51.06	0.20804	208.04046	Free Flow	Slip Road	A2	Rural village	3405	101	3	161
83346_83348	A Road	80	1	80.42	0.26434	264.34181	High Spee	Slip Road	A2	Rural village	2204	241	11	-70

TOTAL TRAFFIC FLOW FOR 1a	489294
Average %HDV for all nodes in catchment 1a	6.05%
Sum value of HDV traffic in catchment 1a	36500
% of HDV for catchment 1a	7.46%

Traffic Data values summary for Catchment 1a, Basin POS01-001

Link ID	Node A	Node B	Road Class	Direction	Speed limit (kph)	New/ Removed Link	ARN	All Vehicles Flow (veh/day)	% HDV	HDV as values	Speed (kph)	Comments	Speed-band	Link Length (km)	Link Length (m)	Speed-band	NatureCarr	Classification	UrbanRural
81962_87538	81962	87538	A Road		112	DS		69329.06	10%	6977.55	100.51		High Speed	1.98085	1980.85234	Free flow	0.00000	0.00000	Rural hamlets and isolated dwellings
83184_87545	83184	87545	A Road		96	DS		38998.99	6%	2314.75	87.89		High Speed	0.36246	362.46415	Free flow	0.00000	0.00000	Rural hamlets and isolated dwellings
82967_83184	82967	83184	A Road		80	BASE&DM& DS		38998.99	6%	2314.75	80.00	As the piv	Free Flow	0.26660	266.60049	Free flow	Dual Carri	A2	Rural hamlets and isolated dwellings

TOTAL TRAFFIC FLOW FOR 1b	147327
Average %HDV for all nodes in catchment 1b	7.31%
Sum value of HDV traffic in catchment 1b	11607
% of HDV for catchment 1b	7.88%

Traffic Data values summary for Catchment 1b, Basin EXPOS01-001

				AADT24						Dec 19 CS12 V1			
Link ID	Road Class	Speed limit (kph)	Dual or single Carriageway or oneway	Link Length (km)	Link Length (m)	Speed-band	NatureCarr	Classification	UrbanRural	AADT All Vehicles (veh/day)	HGV (veh/day)	HGV %	Difference
82355_83660	A Road	112	1	0.51075	510.75	High Speed	0.00000	0.00000	Rural hamlets and isolated dwellings	70110	3716	5	-69
87589_82356	A Road	112	1	0.29798	297.98	High Speed	0.00000	0.00000	Rural hamlets and isolated dwellings	63443	3372	5	799
87615_87589	A Road	112	1	0.28779	287.79	High Speed	0.00000	0.00000	Rural hamlets and isolated dwellings	63443	3372	5	799
87548_87615	A Road	112	1	0.20446	204.46	High Speed	0.00000	0.00000	Rural hamlets and isolated dwellings	60558	3292	5	880
83660_87537	A Road	112	1	0.68889	688.89	High Speed	0.00000	0.00000	Rural village	36360	2474	7	-420
20177_87457	Minor Road	48	2	0.09620	96.20	Light Congestion	0.00000	0.00000	Urban major conurbation	33937	701	2	-7
83660_83663	A Road	112	1	0.39323	393.23	High Speed	0.00000	0.00000	Rural village	33750	1242	4	351
82381_87673	Minor Road	48	2	0.11001	110.01	Light Congestion	0.00000	0.00000	Rural hamlets and isolated dwellings	27887	630	2	-80
87671_87672	Minor Road	48	1	0.03177	31.77	Light Congestion	0.00000	0.00000	Rural hamlets and isolated dwellings	25129	588	2	149
87672_87673	Minor Road	48	1	0.05066	50.66	Light Congestion	0.00000	0.00000	Urban major conurbation	23058	575	2	53
82381_87457	Minor Road	48	1	0.05098	50.98	Free Flow	0.00000	0.00000	Urban major conurbation	15811	279	2	40
87674_87675	Minor Road	48	1	0.07500	75.00	Free Flow	0.00000	0.00000	Rural hamlets and isolated dwellings	15713	336	2	-74
87667_82356	Minor Road	96	1	0.43659	436.59	Free Flow	0.00000	A2	Rural hamlets and isolated dwellings	15037	324	2	27
82355_87671	Minor Road	112	1	0.32743	327.43	Free Flow	0.00000	A2	Rural hamlets and isolated dwellings	14427	209	1	163
20178_87672	Minor Road	48	2	0.11559	115.59	Light Congestion	0.00000	0.00000	Urban major conurbation	13869	380	3	-31
87667_87668	Minor Road	48	1	0.05320	53.20	Free Flow	0.00000	0.00000	Rural hamlets and isolated dwellings	10699	380	4	-14
87668_87670	Minor Road	48	1	0.07671	76.71	Free Flow	0.00000	0.00000	Rural hamlets and isolated dwellings	10699	380	4	-14
87670_87671	Minor Road	48	1	0.02120	21.20	Heavy Congestion	0.00000	0.00000	Rural hamlets and isolated dwellings	10699	380	4	-14
87457_82381	Minor Road	48	1	0.05098	50.98	Heavy Congestion	0.00000	0.00000	Urban major conurbation	10271	195	2	-104
88169_87666	Minor Road	64	1	0.15098	150.98	Heavy Congestion	0.00000	0.00000	Rural hamlets and isolated dwellings	9216	162	2	97
88170_88169	Minor Road	48	1	0.06833	68.33	Light Congestion	0.00000	0.00000	Rural hamlets and isolated dwellings	9216	162	2	97
87457_87458	Minor Road	48	1	0.08326	83.26	Light Congestion	0.00000	0.00000	Rural hamlets and isolated dwellings	7854	227	3	56
83658_88172	Minor Road	64	1	0.52877	528.77	Free Flow	0.00000	0.00000	Rural hamlets and isolated dwellings	7296	42	1	352
87608_87669	Minor Road	112	1	0.36540	365.40	Free Flow	0.00000	0.00000	Rural hamlets and isolated dwellings	5850	419	7	-7
87666_88169	Minor Road	64	1	0.13712	137.12	Light Congestion	0.00000	0.00000	Rural hamlets and isolated dwellings	5032	220	4	3
88169_88172	Minor Road	48	1	0.07854	78.54	Light Congestion	0.00000	0.00000	Rural hamlets and isolated dwellings	5032	220	4	3
88170_26023	Minor Road	64	1	0.21335	213.35	Free Flow	0.00000	0.00000	Rural hamlets and isolated dwellings	3096	166	5	-94
87608_87615	Motorway	112	1	0.29254	292.54	Light Congestion	0.00000	0.00000	Rural hamlets and isolated dwellings	2886	79	3	-82
88172_83658	Minor Road	64	1	0.54440	544.40	Free Flow	0.00000	0.00000	Rural hamlets and isolated dwellings	2536	52	2	77
26023_88170	Minor Road	64	1	0.21114	211.14	Light Congestion	0.00000	0.00000	Rural hamlets and isolated dwellings	2517	121	5	-273
82381_87458	Minor Road	48	1	0.07251	72.51	Light Congestion	0.00000	0.00000	Rural hamlets and isolated dwellings	1805	156	9	-16

TOTAL TRAFFIC FLOW FOR 2a	617237
Average %HDV for all nodes in catchment 2a	3.56%
Sum value of HDV traffic in catchment 2a	24853
% of HDV for catchment 2a	4.03%

Traffic Data values summary for Catchment 2a, Basin EXPOS02-001

										Dec 19 CS12 V1			
Link ID	Road Class	Speed limit (kph)	Dual or single Carriageway or oneway	Link Length (km)	Link Length (m)	Speed-band	NatureCarr	Classification	UrbanRural	AADT All Vehicles (veh/day)	HGV (veh/day)	HGV %	Difference
87548_87615	A Road	112	1	0.20446	204.45824	High Speed	0.00000	0.00000	Rural hamlets and isolated dwellings	60558	3292	5	880
87664_87548	A Road	112	1	0.31548	315.48447	High Speed	0.00000	0.00000	Rural village	44234	1722	4	635
87576_87613	Motorway	112	1	0.36117	361.16583	High Speed	0.00000	0.00000	Rural village	41658	5978	14	661
83660_87537	A Road	112	1	0.68889	688.88914	High Speed	0.00000	0.00000	Rural village	36360	2474	7	-420
87537_87533	A Road	112	1	0.81983	819.82525	High Speed	0.00000	0.00000	Rural village	36360	2474	7	-420
87663_87664	A Road	112	1	0.54075	540.74790	High Speed	0.00000	0.00000	Rural village	34296	1718	5	-539
87390_87450	Motorway	112	1	0.38785	387.85477	Free flow	0.00000	0.00000	Rural village	28211	4459	16	197
83663_87575	A Road	96	1	1.04925	1049.24858	High Speed	0.00000	0.00000	Rural village	28073	1166	4	344
87547_87549	A Road	96	1	0.42651	426.51042	High Speed	0.00000	0.00000	Rural village	26258	1576	6	1416
87549_87548	A Road	96	1	0.17071	170.70592	High Speed	0.00000	0.00000	Rural village	16314	1576	10	231
87549_87664	A Road	96	1	0.11813	118.12639	Free Flow	0.00000	0.00000	Rural village	9944	0	0	1185
87609_87608	Motorway	112	1	0.54776	547.76490	High Speed	0.00000	0.00000	Rural village	8736	498	6	-89
83658_88172	Minor Road	64	1	0.52877	528.76637	Free Flow	0.00000	0.00000	Rural hamlets and isolated dwellings	7296	42	1	352
87454_87450	Motorway	112	1	0.23069	230.69436	Light Congestion	0.00000	0.00000	Rural village	2840	12	0	57
88172_83658	Minor Road	64	1	0.54440	544.39790	Free Flow	0.00000	0.00000	Rural hamlets and isolated dwellings	2536	52	2	77

TOTAL TRAFFIC FLOW FOR 2b	383673
Average %HDV for all nodes in catchment 2b	5.78%
Sum value of HDV traffic in catchment 2b	27041
% of HDV for catchment 2b	7.05%

Traffic Data values summary for Catchment 2b, Basin POS02-004

											Dec 19 CS12 V1			
Link ID	Road Class	Speed limit (kph)	Dual or single Carriageway or oneway	Speed (kph)	Road Length (km)	Road Length (m)	Speed-band	NatureCarr	Classification	UrbanRural	AADT All Vehicles (veh/day)	HGV (veh/day)	HGV %	Difference
87669_87666	Minor Road	48	1	18.93	0.02703	27.03327	Heavy Congestion	0.00000	0.00000	Rural hamlets and isolated dwellings	21551	763	4	-81
87675_87669	Minor Road	48	1	20.48	0.08197	81.97262	Light Congestion	0.00000	0.00000	Rural hamlets and isolated dwellings	15713	336	2	-74
87667_82356	Minor Road	96	1	72.18	0.43659	436.59253	Free Flow	0.00000	A2	Rural hamlets and isolated dwellings	15037	324	2	27
87667_87668	Minor Road	48	1	48.06	0.05320	53.19689	Free Flow	0.00000	0.00000	Rural hamlets and isolated dwellings	10699	380	4	-14
88169_87666	Minor Road	64	1	18.46	0.15098	150.97964	Heavy Congestion	0.00000	0.00000	Rural hamlets and isolated dwellings	9216	162	2	97
87608_87669	Minor Road	112	1	47.20	0.36540	365.40392	Free Flow	0.00000	0.00000	Rural hamlets and isolated dwellings	5850	419	7	-7
87666_88169	Minor Road	64	1	42.24	0.13712	137.11511	Light Congestion	0.00000	0.00000	Rural hamlets and isolated dwellings	5032	220	4	3

TOTAL TRAFFIC FLOW FOR 2c	83099
Average %HDV for all nodes in catchment 2c	3.53%
Sum value of HDV traffic in catchment 2c	2604
% of HDV for catchment 2c	3.13%

Traffic Data values summary for Catchment 2c, Basin POS02-001

												Dec 19 CS12 V1			
Link ID	Road Class	Speed limit (kph)	New/ Removed Link	Dual or single Carriageway or oneway	Speed (kph)	Link Length (km)	Link Length (m)	Speed-band	NatureCarr	Classification	UrbanRural	AADT All Vehicles (veh/day)	HGV (veh/day)	HGV %	Difference
87451_87452	Motorway	48	DS	1	35.82	0.23	234.20	Heavy Congestion	0.00000	0.00000	Rural village	9658	384	4	40
87458_87451	Minor Road	48	DS	1	39.41	0.27	267.17	Light Congestion	0.00000	0.00000	Rural village	9658	384	4	40
87452_87677	Motorway	112	DS	1	92.05	0.71	710.51	Free flow	0.00000	0.00000	Rural village	6818	372	5	-17
87452_87454	Motorway	48	DS	1	48.01	0.44	440.63	Light Congestion	0.00000	0.00000	Rural village	2840	12	0	57

TOTAL TRAFFIC FLOW FOR 2d	28974
Average %HDV for all nodes in catchment 2d	3.46%
Sum value of HDV traffic in catchment 2d	1152
% of HDV for catchment 11c	3.98%

Traffic Data values summary for Catchment 2d, Basin POS02-002

											Dec 19 CS12 V1			
Link ID	Road Class	Speed limit (kph)	Dual or single Carriageway or oneway	Speed (kph)	Link Length (km)	Link Length (m)	Speed-band	NatureCarr	Classification	UrbanRural	AADT All Vehicles (veh/day)	HGV (veh/day)	HGV %	Difference
87538_87540	A Road	112	1	97.61	0.66610	666.09810	High Speed	0.00000	0.00000	Rural hamlets and isolated dwellings	69329	6978	10	-523
87532_87551	A Road	112	1	100.83	0.27999	279.99279	High Speed	0.00000	0.00000	Rural village	67406	6949	10	-166
87551_87531	A Road	112	1	100.83	1.82722	1827.21935	High Speed	0.00000	0.00000	Rural village	67406	6949	10	-166
87678_87386	Motorway	112	1	98.71	0.91573	915.72704	High Speed	0.00000	0.00000	Rural village	54118	6451	12	661
87677_87678	Motorway	112	1	102.50	0.27089	270.89257	High Speed	0.00000	0.00000	Rural village	54118	6451	12	661
87533_87532	A Road	112	1	95.69	0.08335	83.34815	High Speed	0.00000	0.00000	Rural hamlets and isolated dwellings	52682	3771	7	-271
87352_87677	Motorway	112	1	96.98	0.39583	395.82787	High Speed	0.00000	0.00000	Rural village	47321	6065	13	674
87385_87456	Motorway	112	1	99.81	1.07563	1075.63173	High Speed	0.00000	0.00000	Rural village	46911	5490	12	195
87576_87613	Motorway	112	1	100.84	0.36117	361.16583	High Speed	0.00000	0.00000	Rural village	41658	5978	14	661
87613_87352	Motorway	112	1	97.97	0.29668	296.68136	High Speed	0.00000	0.00000	Rural village	41658	5978	14	661
83184_87545	A Road	96	1	88.64	0.36246	362.46415	High Speed	0.00000	0.00000	Rural hamlets and isolated dwellings	38999	2315	6	2345
87918_83347	Motorway	96	1	85.63	0.65742	657.41914	Free flow	0.00000	0.00000	Rural village	38036	1698	4	431
87575_87918	A Road	96	1	84.11	0.25624	256.23686	High Speed	0.00000	0.00000	Rural village	38036	1698	4	431
87540_87663	A Road	112	1	104.15	0.45508	455.08272	High Speed	0.00000	0.00000	Rural village	37988	1738	5	-359
87537_87533	A Road	112	1	96.85	0.81983	819.82525	High Speed	0.00000	0.00000	Rural village	36360	2474	7	-420
87663_87664	A Road	112	1	104.98	0.54075	540.74790	High Speed	0.00000	0.00000	Rural village	34296	1718	5	-539
83660_83663	A Road	112	1	96.73	0.39323	393.22650	High Speed	0.00000	0.00000	Rural village	33750	1242	4	351
87540_87576	A Road	112	1	99.89	0.44539	445.38834	High Speed	0.00000	0.00000	Rural hamlets and isolated dwellings	31341	5239	17	-164
87450_87534	Motorway	112	1	89.85	0.16126	161.26274	Free flow	0.00000	0.00000	Rural village	31035	4482	14	254
87545_87547	A Road	96	1	91.84	0.27154	271.53625	High Speed	0.00000	0.00000	Rural hamlets and isolated dwellings	28676	1578	6	1504
87390_87450	Motorway	112	1	95.24	0.38785	387.85477	Free flow	0.00000	0.00000	Rural village	28211	4459	16	197
87456_87390	Motorway	112	1	98.96	0.58697	586.97438	High Speed	0.00000	0.00000	Rural village	28211	4459	16	197
83663_87575	A Road	96	1	90.25	1.04925	1049.24858	High Speed	0.00000	0.00000	Rural village	28073	1166	4	344
87456_87455	Motorway	112	1	103.97	0.43744	437.44465	High Speed	0.00000	0.00000	Rural village	18699	1030	6	-2
87534_87533	Motorway	112	1	86.44	0.26802	268.02323	Free flow	0.00000	0.00000	Rural village	16318	1301	8	150
87534_87532	Motorway	112	1	89.74	0.35048	350.48413	Free flow	0.00000	0.00000	Rural village	14717	3181	22	103
87545_87576	A Road	112	1	99.88	0.42900	428.99704	High Speed	0.00000	0.00000	Rural hamlets and isolated dwellings	10323	736	7	841
87455_87575	Motorway	112	1	94.69	0.85294	852.94491	Free flow	0.00000	0.00000	Rural village	9963	532	5	87
87455_87609	Motorway	112	1	108.94	0.20692	206.92400	High Speed	0.00000	0.00000	Rural village	8736	498	6	-89
87609_87608	Motorway	112	1	104.35	0.54776	547.76490	High Speed	0.00000	0.00000	Rural village	8736	498	6	-89
87452_87677	Motorway	112	1	92.05	0.71051	710.51339	Free flow	0.00000	0.00000	Rural village	6818	372	5	-17
76725_83352	Minor Road	64	2	56.26	0.03044	30.44498	Free Flow	Traffic Isla	0.00000	Rural hamlets and isolated dwellings	5996	99	2	160
83663_87352	Motorway	112	1	89.76	0.51219	512.18879	Free flow	0.00000	0.00000	Rural village	5677	77	1	8
20153_71335	Minor Road	48	2	49.87	0.12251	122.51169	Free Flow	Single Car	0.00000	Rural village	5524	42	1	4
87663_88179	A Road	112	1	87.99	0.41066	410.66436	High Speed	0.00000	0.00000	Rural village	3691	20	1	179
87454_87450	Motorway	112	1	68.59	0.23069	230.69436	Light Congestion	0.00000	0.00000	Rural village	2840	12	0	57
87452_87454	Motorway	48	1	48.01	0.44063	440.62983	Light Congestion	0.00000	0.00000	Rural village	2840	12	0	57

TOTAL TRAFFIC FLOW FOR 2e	1096497
Average %HDV for all nodes in catchment 2e	7.89%
Sum value of HDV traffic in catchment 2e	103736
% of HDV for catchment 2e	9.46%

Traffic Data values summary for Catchment 2e, Basin POS02-003

											Dec 19 CS12 V1			
Link ID	Road Class	Speed limit (kph)	Dual or single Carriageway or oneway	Speed (kph)	Link Length (km)	Link Length (m)	Speed-band	NatureCarr	Classification	UrbanRural	AADT All Vehicles (veh/day)	HGV (veh/day)	HGV %	Difference
87545_87547	A Road	96	1	91.84	0.271536	271.536250	High Speed	0.00000	0.00000	Rural hamlets and isolated dwellings	28676	1578	6	1504
87547_87549	A Road	96	1	82.78	0.426510	426.510415	High Speed	0.00000	0.00000	Rural village	26258	1576	6	1416
87549_87548	A Road	96	1	84.56	0.170706	170.705918	High Speed	0.00000	0.00000	Rural village	16314	1576	10	231
88180_88181	Minor Road	48	1	29.73	0.023174	23.173608	Light Congestion	0.00000	0.00000	Rural hamlets and isolated dwellings	8647	72	1	344
83658_88172	Minor Road	64	1	55.50	0.528766	528.766366	Free Flow	0.00000	0.00000	Rural hamlets and isolated dwellings	7296	42	1	352
88181_83658	Minor Road	48	1	40.94	0.102605	102.605247	Light Congestion	0.00000	0.00000	Rural hamlets and isolated dwellings	7296	42	1	352
88179_88180	Minor Road	48	1	33.31	0.037383	37.382685	Light Congestion	0.00000	0.00000	Rural hamlets and isolated dwellings	6228	70	1	256
76725_83352	Minor Road	64	2	56.26	0.030445	30.444979	Free Flow	Traffic Island Link At Junctio	0.00000	Rural hamlets and isolated dwellings	5996	99	2	160
76725_88181	Minor Road	64	2	59.53	0.609073	609.072847	Free Flow	0.00000	0.00000	Rural hamlets and isolated dwellings	5585	71	1	311
71718_76725	Minor Road	48	2	46.88	0.014731	14.730914	Free Flow	Single Carriageway	0.00000	Rural hamlets and isolated dwellings	5519	42	1	4
87663_88179	A Road	112	1	87.99	0.410664	410.664364	High Speed	0.00000	0.00000	Rural village	3691	20	1	179
83658_88179	Minor Road	48	1	29.60	0.026602	26.602056	Light Congestion	0.00000	0.00000	Rural hamlets and isolated dwellings	2536	52	2	77
87547_88180	A Road	96	1	70.78	0.273506	273.505666	Free Flow	0.00000	0.00000	Rural hamlets and isolated dwellings	2419	2	0	88

TOTAL TRAFFIC FLOW FOR 2f	126462
Average %HDV for all nodes in catchment 2f	2.36%
Sum value of HDV traffic in catchment 2f	5242
% of HDV for catchment 2f	4.15%

Traffic Data values summary for Catchment 2f, Basin EXPOS02-005

											Dec 19 CS12 V1			
Link ID	Road Class	Speed limit (kph)	Dual or single Carriageway or oneway	Speed (kph)	Road Length (m)	Link Length (m)	Speed-band	NatureCarr	Classification	UrbanRural	AADT All Vehicles (veh/day)	HGV (veh/day)	HGV %	Difference
87678_87386	Motorway	112	1	98.71	0.92	915.73	High Speed	0.00000	0.00000	Rural village	54118	6451	12	661
87386_87684	Motorway	112	1	98.71	0.83	826.51	High Speed	0.00000	0.00000	Urban major conurbation	54118	6451	12	661
87385_87456	Motorway	112	1	99.81	1.08	1075.63	High Speed	0.00000	0.00000	Rural village	46911	5490	12	195
87683_87385	Motorway	112	1	98.81	0.92	918.22	High Speed	0.00000	0.00000	Urban major conurbation	46911	5490	12	195

TOTAL TRAFFIC FLOW FOR 4a	202056
Average %HDV for all nodes in catchment 4a	11.81%
Sum value of HDV traffic in catchment 4a	23881
% of HDV for catchment 4a	11.82%

Traffic Data values summary for Catchment 4a, Basin POS04-001

				AADT24							Dec 19 CS12 V1			
Link ID	Road Class	Speed limit (kph)	Dual or single Carriageway or oneway	Speed (kph)	Link Length (km)	Link Length (m)	Speed-band	NatureCarr	Classification	UrbanRural	AADT All Vehicles (veh/day)	HGV (veh/day)	HGV %	Difference
75211_76343	A Road	64	2	60.19	0.28	277.58	Free Flow	Single Car	A1013	Urban major conurbation	18683	744	4	8
71907_76343	A Road	64	2	62.63	0.22	220.11	Free Flow	Single Car	A1013	Urban city and town	17156	736	4	-10
83753_83754	A Road	112	1	107.03	0.78	780.92	High Spee	0.00000	0.00000	Urban city and town	4607	321	7	-2
83753_76267	A Road	96	1	79.93	0.68	677.55	Free Flow	0.00000	0.00000	Urban major conurbation	3441	158	5	48
75373_76343	B Road	64	2	48.31	0.11	114.32	Free Flow	Single Car	B188	Urban city and town	1527	8	1	18

TOTAL TRAFFIC FLOW FOR 11c	45414
Average %HDV for all nodes in catchment 11c	4.08%
Sum value of HDV traffic in catchment 11c	1968
% of HDV for catchment 11c	4.33%

Traffic Data values summary for Catchment 11c, Basin POS11-003

					AADT24										
Link ID	Node A	Node B	Road Class	Speed limit (kph)	All Vehicles - Flow (veh/day)	% HDV	HDV value	Speed (kph)	Comments	Speed-band	Link Length (km)	Link Length (m)	NatureCarr	Classification	UrbanRural
76364_88344	76364	88344			2068	2%	44				0.188	188			
88344_76364	88344	76364			2332	2%	51				0.188	188			
76355_88344	76355	88344			2332	2%	51				0.188	188			
88344_76355	88344	76355			2068	2%	44				0.188	188			

TOTAL TRAFFIC FLOW FOR 7	8800.21
Average %HDV for all nodes in catchment	2%
Sum value of HDV traffic in catchment	190.64
% of HDV for catchment	2.17

Spillage Traffic Input SWALE SWS10-001

					AADT24										
Link ID	Node A	Node B	Road Class	Speed limit (kph)	All Vehicles - Flow (veh/day)	% HDV	HDV value	Speed (kph)	Comments	Speed-band	Link Length (km)	Link Length (m)	NatureCarr	Classification	UrbanRural
76364_88344	76364	88344			2068	2%	44				0.15	150			
88344_76364	88344	76364			2332	2%	51				0.15	150			
76355_88344	76355	88344			2332	2%	51				0.15	150			
88344_76355	88344	76355			2068	2%	44				0.15	150			

TOTAL TRAFFIC FLOW FOR 7	8800.21
Average %HDV for all nodes in catchment	2%
Sum value of HDV traffic in catchment	190.64
% of HDV for catchment	2.17

Spillage Traffic Input SWALE SWS10-002

					AADT24										
Link ID	Node A	Node B	Road Class	Speed limit (kph)	All Vehicles - Flow (veh/day)	% HDV	HDV value	Speed (kph)	Comments	Speed-band	Link Length (km)	Link Length (m)	NatureCarr	Classification	UrbanRural
76364_88344	76364	88344			2068	2%	44				0.238	238			
88344_76364	88344	76364			2332	2%	51				0.238	238			
76355_88344	76355	88344			2332	2%	51				0.238	238			
88344_76355	88344	76355			2068	2%	44				0.238	238			

TOTAL TRAFFIC FLOW FOR 7	8800.21
Average %HDV for all nodes in catchment	2%
Sum value of HDV traffic in catchment	190.64
% of HDV for catchment	2.17

Spillage Traffic Input SWALE SWS10-004

					AADT24										
Link ID	Node A	Node B	Road Class	Speed limit (kph)	All Vehicles - Flow (veh/day)	% HDV	HDV value	Speed (kph)	Comments	Speed-band	Link Length (km)	Link Length (m)	NatureCarr	Classification	UrbanRural
89560_76236	89560	76236			6292	2%	135				0.288	288			
76236_89560	76236	89560			9641	2%	207				0.288	288			

TOTAL TRAFFIC FLOW FOR 7	15932.80
Average %HDV for all nodes in catchment	2%
Sum value of HDV traffic in catchment	341.61
% of HDV for catchment	2.14

Spillage Traffic Input SWALE SWS10-009

					AADT24										
Link ID	Node A	Node B	Road Class	Speed limit (kph)	All Vehicles - Flow (veh/day)	% HDV	HDV value	Speed (kph)	Comments	Speed-band	Link Length (km)	Link Length (m)	NatureCarr	Classification	UrbanRural
89560_76236	89560	76236			6292	2%	135				0.245	245			
76236_89560	76236	89560			9641	2%	207				0.245	245			

TOTAL TRAFFIC FLOW FOR 7	**15932.80**
Average %HDV for all nodes in catchment	**2%**
Sum value of HDV traffic in catchment	**341.61**
% of HDV for catchment	**2.14**

Spillage Traffic Input SWALE SWS10-011

Spillage Traffic Input SWALE SWS11-003

					AADT24										
Link ID	Node A	Node B	Road Class	Speed limit (kph)	All Vehicles - Flow (veh/day)	% HDV	HDV value	Speed (kph)	Comments	Speed-band	Link Length (km)	Link Length (m)	NatureCarr	Classification	UrbanRural
71902_75210	71902	75210			0	0%	0				0.046	46			
75210_71902	75210	71902			0	0%	0				0.046	46			

TOTAL TRAFFIC FLOW FOR 7	0.17
Average %HDV for all nodes in catchment	0%
Sum value of HDV traffic in catchment	0.00
% of HDV for catchment	0.00

					AADT24										
Link ID	Node A	Node B	Road Class	Speed limit (kph)	All Vehicles - Flow (veh/day)	% HDV	HDV value	Speed (kph)	Comments	Speed-band	Link Length (km)	Link Length (m)	NatureCarr	Classification	UrbanRural
71902_75210	71902	75210			0	0%	0				0.12	120			
75210_71902	75210	71902			0	0%	0				0.12	120			

TOTAL TRAFFIC FLOW FOR 7	0.17
Average %HDV for all nodes in catchment	0%
Sum value of HDV traffic in catchment	0.00
% of HDV for catchment	0.00

Spillage Traffic Input SWALE SWS11-004

					AADT24										
Link ID	Node A	Node B	Road Class	Speed limit (kph)	All Vehicles - Flow (veh/day)	% HDV	HDV value	Speed (kph)	Comments	Speed-band	Link Length (km)	Link Length (m)	NatureCarr	Classification	UrbanRural
75209_75211	75209	75211			1455	1%	18	65.91			0.1	100			
75211_75209	75211	75209			1988	1%	13	67.30			0.1	100			

TOTAL TRAFFIC FLOW FOR 7	3443.03
Average %HDV for all nodes in catchment	1%
Sum value of HDV traffic in catchment	30.34
% of HDV for catchment	0.88

Spillage Traffic Input SWALE SWS11-005

					AADT24										
Link ID	Node A	Node B	Road Class	Speed limit (kph)	All Vehicles - Flow (veh/day)	% HDV	HDV value	Speed (kph)	Comments	Speed-band	Link Length (km)	Link Length (m)	NatureCarr	Classification	UrbanRural
75211_76343	75211	76343			12070	1%	170				0.112	112			
76343_75211	76343	75211			14477	1%	207				0.112	112			

Spillage Traffic Input SWALE SWS11-006

TOTAL TRAFFIC FLOW FOR 7	26546.96
Average %HDV for all nodes in catchment	1%
Sum value of HDV traffic in catchment	377.04
% of HDV for catchment	1.42

					AADT24										
Link ID	Node A	Node B	Road Class	Speed limit (kph)	All Vehicles - Flow (veh/day)	% HDV	HDV value	Speed (kph)	Comments	Speed-band	Link Length (km)	Link Length (m)	NatureCarr	Classification	UrbanRural
71902_71907	71902	71907			13364	1%	196				0.091	91			
71907_71902	71907	71902			11597	1%	166				0.091	91			
71907_76343	71907	76343			13364	1%	196				0.218	218			
76343_71907	76343	71907			11597	1%	166				0.218	218			

Spillage Traffic Input SWALE SWS11-002A

TOTAL TRAFFIC FLOW FOR 7	49922.25
Average %HDV for all nodes in catchment	1%
Sum value of HDV traffic in catchment	724.24
% of HDV for catchment	1.45

					AADT24										
Link ID	Node A	Node B	Road Class	Speed limit (kph)	All Vehicles - Flow (veh/day)	% HDV	HDV value	Speed (kph)	Comments	Speed-band	Link Length (km)	Link Length (m)	NatureCarr	Classification	UrbanRural
83753_83754	83753	83754			3733	17%	638				0.513	513			

TOTAL TRAFFIC FLOW FOR 7	3733.29
Average %HDV for all nodes in catchment	17%
Sum value of HDV traffic in catchment	638.26
% of HDV for catchment	17.10

Spillage Traffic Input SWALE SWS11-008

					AADT24										
Link ID	Node A	Node B	Road Class	Speed limit (kph)	All Vehicles - Flow (veh/day)	% HDV	HDV value	Speed (kph)	Comments	Speed-band	Link Length (km)	Link Length (m)	NatureCarr	Classification	UrbanRural
75361_75364	75361	75364			2481	2%	47				0.164	164			
75364_75361	75364	75361			3698	1%	55				0.164	164			

TOTAL TRAFFIC FLOW FOR 7	6179.02
Average %HDV for all nodes in catchment	2%
Sum value of HDV traffic in catchment	101.98
% of HDV for catchment	1.65

Spillage Traffic Input SWALE SWS11-013

					AADT24										
Link ID	Node A	Node B	Road Class	Speed limit (kph)	All Vehicles - Flow (veh/day)	% HDV	HDV value	Speed (kph)	Comments	Speed-band	Link Length (km)	Link Length (m)	NatureCarr	Classification	UrbanRural
75361_75364	75361	75364			2481	2%	47				0.054	54			
75364_75361	75364	75361			3698	1%	55				0.054	54			

TOTAL TRAFFIC FLOW FOR 7	6179.02
Average %HDV for all nodes in catchment	2%
Sum value of HDV traffic in catchment	101.98
% of HDV for catchment	1.65

Spillage Traffic Input SWALE SWS11-014

					AADT24										
Link ID	Node A	Node B	Road Class	Speed limit (kph)	All Vehicles - Flow (veh/day)	% HDV	HDV value	Speed (kph)	Comments	Speed-band	Link Length (km)	Link Length (m)	NatureCarr	Classification	UrbanRural
75361_75364	75361	75364			2481	2%	47				0.054	54			
75364_75361	75364	75361			3698	1%	55				0.054	54			

TOTAL TRAFFIC FLOW FOR 7	6179.02
Average %HDV for all nodes in catchment	2%
Sum value of HDV traffic in catchment	101.98
% of HDV for catchment	1.65

Spillage Traffic Input SWALE SWS11-015

					AADT24										
Link ID	Node A	Node B	Road Class	Speed limit (kph)	All Vehicles - Flow (veh/day)	% HDV	HDV value	Speed (kph)	Comments	Speed-band	Link Length (km)	Link Length (m)	NatureCarr	Classification	UrbanRural
75361_75364	75361	75364			2481	2%	47				0.101	101			
75364_75361	75364	75361			3698	1%	55				0.101	101			

TOTAL TRAFFIC FLOW FOR 7	6179.02
Average %HDV for all nodes in catchment	2%
Sum value of HDV traffic in catchment	101.98
% of HDV for catchment	1.65

Spillage Traffic Input SWALE SWS11-016

					AADT24										
Link ID	Node A	Node B	Road Class	Speed limit (kph)	All Vehicles - Flow (veh/day)	% HDV	HDV value	Speed (kph)	Comments	Speed-band	Link Length (km)	Link Length (m)	NatureCarr	Classification	UrbanRural
89549_80136	89549	80136			8015	3%	244				0.173	173			
80136_89549	80136	89549			7818	3%	220				0.173	173			

TOTAL TRAFFIC FLOW FOR 7	15832.72
Average %HDV for all nodes in catchment	3%
Sum value of HDV traffic in catchment	463.87
% of HDV for catchment	2.93

Spillage Traffic Input SWALE SWS12-004

					AADT24										
Link ID	Node A	Node B	Road Class	Speed limit (kph)	All Vehicles - Flow (veh/day)	% HDV	HDV value	Speed (kph)	Comments	Speed-band	Link Length (km)	Link Length (m)	NatureCarr	Classification	UrbanRural
89549_80136	89549	80136			8015	3%	244				0.106	106			
80136_89549	80136	89549			7818	3%	220				0.106	106			

TOTAL TRAFFIC FLOW FOR 7	15832.72
Average %HDV for all nodes in catchment	3%
Sum value of HDV traffic in catchment	463.87
% of HDV for catchment	2.93

Spillage Traffic Input SWALE SWS12-005

					AADT24										
Link ID	Node A	Node B	Road Class	Speed limit (kph)	All Vehicles - Flow (veh/day)	% HDV	HDV value	Speed (kph)	Comments	Speed-band	Link Length (km)	Link Length (m)	NatureCarr	Classification	UrbanRural
89549_80136	89549	80136			8015	3%	244				0.142	142			
80136_89549	80136	89549			7818	3%	220				0.142	142			

Spillage Traffic Input SWALE SWS12-006

TOTAL TRAFFIC FLOW FOR 7	15832.72
Average %HDV for all nodes in catchment	3%
Sum value of HDV traffic in catchment	463.87
% of HDV for catchment	2.93

					AADT24										
Link ID	Node A	Node B	Road Class	Speed limit (kph)	All Vehicles - Flow (veh/day)	% HDV	HDV value	Speed (kph)	Comments	Speed-band	Link Length (km)	Link Length (m)	NatureCarr	Classification	UrbanRural
89549_80136	89549	80136			8015	3%	244				0.1	100			
80136_89549	80136	89549			7818	3%	220				0.1	100			

TOTAL TRAFFIC FLOW FOR 7	15832.72
Average %HDV for all nodes in catchment	3%
Sum value of HDV traffic in catchment	463.87
% of HDV for catchment	2.93

Spillage Traffic Input SWALE SWS12-007

					AADT24										
Link ID	Node A	Node B	Road Class	Speed limit (kph)	All Vehicles - Flow (veh/day)	% HDV	HDV value	Speed (kph)	Comments	Speed-band	Link Length (km)	Link Length (m)	NatureCarr	Classification	UrbanRural
71902_75210	71902	75210			0	0%	0				0.052	52			
75210_71902	75210	71902			0	0%	0				0.052	52			

TOTAL TRAFFIC FLOW FOR 7	0.17
Average %HDV for all nodes in catchment	0%
Sum value of HDV traffic in catchment	0.00
% of HDV for catchment	0.00

Spillage Traffic Input SWALE SWS11-002

Annex C HEWRAT output values

User parameters 1a_POS01-001

Location Details

Road Number			**Assessment type**	Non-cumulative assessment (single outfall)
HE Area/DBFO number				
OS grid reference of assessment point (m)	**Easting**	569895	**Receiving watercourse**	Groundwater
	Northing	169733	**EA receiving water Detailed River Network ID**	
OS grid reference of outfall structure (m)	**Easting**		**Assessor and affiliation** [redacted]	[redacted]
	Northing		**Date of assessment**	31/01/2020
Outfall number	1a_POS01-001		**Version of assessment**	
List of outfalls in cumulative assessment				
Notes				

Parameter	Units	Default Value	Value used	Notes	
Runoff Risk Assessments					
AADT	vpd	>10,000 and <50,000	***>10,000 and <50,000***		
Climatic Region	-	Warm Dry	***Warm Dry***		
Rainfall Site	-	Ashford (SAAR 710mm)	***Ashford (SAAR 710mm)***		
Q95 River flow	m3/s	0	***0***		
Baseflow Index	-	0.5	***0.5***		
Impermeable road area drained	ha	1	***1***		
Permeable area draining to outfall	ha	0	***0***		
Is the discharge in or within 1 km upstream of a protected site for conservation?	-	No	***No***		
Is there a downstream structure, lake, pond or canal that reduces the velocity within 100m of the point of discharge?	-	No	***No***		
Hardness	-	Low = <50mg CaCO3/l	***Low = <50mg CaCO3/l***		
Use Tier 1	-	TRUE	***TRUE***		
Use Tier 2	-	FALSE	***FALSE***		
Tier 1 Estimated river width at Q95	0	5	***5***		
Tier2 Bed width	m	3	***3***		
Tier2 Side slope	m/m	0.5	***0.5***		
Tier2 Long slope	m/m	0.0001	***0.0001***		
Tier2 Mannings' n	-	0.07	***0.07***		
Existing treatment for solubles	%	0	***0***	***Description for existing measures***	
Existing attenuation -restricted discharge rate	l/s	No restriction	***No restriction***		
Existing settlement of sediments	%	0	***0***		
Proposed treatment for solubles	%	0	***0***	***Description for proposed measures***	
Proposed attenuation -restricted discharge rate	l/s	No restriction	***No restriction***		
Proposed settlement of sediments	%	0	***0***		
EQS, bio avail dissolved Cu	ug/l	1	***1***		
EQS, bio avail dissolved Zn	ug/l	10.9	***10.9***		
Ambient background concentration, dissolved copper	ug/l	0	***0***		
Spillage Risk Assessments					
A MainRoad					
Water body type	-	-	***Groundwater***		
Length of road draining to outfall	m	-	***215.6715506***		
Road Type (A-road or Motorway)	-	-	***M***		
If A road, is site urban or rural?	-	-			
Junction type	-	-	***No junction***		

Location	-	-	***< 20 minutes***	
Traffic flow (AADT two way)	-	-	***85639.2505***	
% HGV	-	-	***8.5***	
Spillage factor	no/109HGVkm/year	-	***0.36***	
Existing measures factor	-	-	***1***	
Proposed measures factor	-	-	***0.6***	
B				
Water body type	-	-	***Groundwater***	
Length of road draining to outfall	m	-	***1980.852342***	
Road Type (A-road or Motorway)	-	-	***A***	
If A road, is site urban or rural?	-	-	***Rural***	
Junction type	-	-	***No junction***	
Location	-	-	***< 20 minutes***	
Traffic flow (AADT two way)	-	-	***69329.05575***	
% HGV	-	-	***10.1***	
Spillage factor	no/109HGVkm/year	-	***0.29***	
Existing measures factor	-	-	***1***	
Proposed measures factor	-	-	***0.6***	
C				
Water body type	-	-	***Groundwater***	
Length of road draining to outfall	m	-	***868.46217***	
Road Type (A-road or Motorway)	-	-	***A***	
If A road, is site urban or rural?	-	-	***Rural***	
Junction type	-	-	***No junction***	
Location	-	-	***< 20 minutes***	
Traffic flow (AADT two way)	-	-	***67405.84183***	
% HGV	-	-	***10.3***	
Spillage factor	no/109HGVkm/year	-	***0.29***	
Existing measures factor	-	-	***1***	
Proposed measures factor	-	-	***0.6***	
D				
Water body type	-	-	***Groundwater***	
Length of road draining to outfall	m	-	***1827.219351***	
Road Type (A-road or Motorway)	-	-	***A***	
If A road, is site urban or rural?	-	-	***Rural***	
Junction type	-	-	***No junction***	
Location	-	-	***< 20 minutes***	
Traffic flow (AADT two way)	-	-	***67405.84183***	
% HGV	-	-	***10.3***	
Spillage factor	no/109HGVkm/year	-	***1***	
Existing measures factor	-	-	***0.6***	
Proposed measures factor	-	-	***0.45***	

E				
Water body type	-	-	***Groundwater***	
Length of road draining to outfall	m	-	***657.4191388***	
Road Type (A-road or Motorway)	-	-	***M***	
If A road, is site urban or rural?	-	-		
Junction type	-	-	***No junction***	
Location	-	-	***< 20 minutes***	
Traffic flow (AADT two way)	-	-	***38036.23767***	
% HGV	-	-	***4.5***	
Spillage factor	no/109HGVkm/year	-	***0.36***	
Existing measures factor	-	-	***1***	
Proposed measures factor	-	-	***0.6***	
F				
Water body type	-	-	***Groundwater***	
Length of road draining to outfall	m	-	***526.5594176***	
Road Type (A-road or Motorway)	-	-	***A***	
If A road, is site urban or rural?	-	-	***Rural***	
Junction type	-	-	***No junction***	
Location	-	-	***< 20 minutes***	
Traffic flow (AADT two way)	-	-	***36837.7586***	
% HGV	-	-	***5***	
Spillage factor	no/109HGVkm/year	-	***0.29***	
Existing measures factor	-	-	***1***	
Proposed measures factor	-	-	***0.6***	
Justification for choice of existing measures factors				No existing measures
Justification for choice of proposed measures factors				Proposed infiltration basin with infiltration basins at the base
Groundwater Assessments				
Traffic flow	-	-	***>=100,000 AADT***	
Rainfall depth (annual averages)	-	-	***<=740 mm rainfall***	
Drainage area ratio	-	-	***>=150***	
Infiltration method	-	-	***"Region", shallow infiltration systems (e***	
Unsaturated zone	-	-	***Depth to water table >=15 m***	
Flow type (Incorporates flow type an effective grain size)	-	-	***Flow dominated by fractures/ fissures (e***	
Unsaturated Zone Clay Content	-	-	***<=1% clay minerals***	
Organic Carbon	-	-	***<=1% SOM***	
Unsaturated zone soil pH	-	-	***pH >=8***	

1a_POS01-001

Groundwater Assessment

Component Number		Weighting Factor	Property or Parameter	Risk Score	Component score	Weighted component score
1	SOURCE	10	Traffic flow	>=100,000 AADT	3	30
2		10	Rainfall depth (annual averages)	<=740 mm rainfall	1	10
3		10	Drainage area ratio	>=150	3	30
4	PATHWAY	15	Infiltration method	"Region", shallow infiltration systems (e.g. infiltration basin)	2	30
5		20	Unsaturated zone	Depth to water table >=15 m	1	20
6		20	Flow type (Incorporates flow type an effective grain size)	Flow dominated by fractures/ fissures (e.g. well consolidated sedimentary deposits, igneous and metamorphic rocks or unconsolidated deposits of very coarse sand and coarser)	3	60
7		5	Unsaturated Zone Clay Content	<=1% clay minerals	3	15
8		5	Organic Carbon	<=1% SOM	3	15
9		5	Unsaturated zone soil pH	pH >=8	1	5

TOTAL SCORE	**215**
RISK SCREENING LEVEL	**Medium**

1a_POS01-001

Assessment of Priority Outfalls

Method D - assessment of risk from accidental spillage

		A (main road)	B	C	D	E	F	Totals	Return Period (years)
			Additional columns for use if other roads drain to the same outfall						
D1	Water body type	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater		
D2	Length of road draining to outfall (m)	216	1,981	868	1,827	657	526.5594176		
D3	Road Type (A-road or Motorway)	M	A	A	A	M	A		
D4	If A road, is site urban or rural?		Rural	Rural	Rural		Rural		
D5	Junction type	No junction	No junction	No junction	No junction	No junction	No junction		
D6	Location (response time for emergency services)	< 20 minutes	< 20 minutes	< 20 minutes	< 20 minutes	< 20 minutes	< 20 minutes		
D7	Traffic flow (AADT two way)	85,639	69,329	67,406	67,406	38,036	36837.7586		
D8	% HGV	8.5	10.1	10.3	10.3	4.5	5		
D8	Spillage factor (no/109HGVkm/year)	0.36	0.29	0.29	0.29	0.36	0.29		
D9	Risk of accidental spillage	0.00021	0.00147	0.00064	0.00134	0.00015	0.00010		
D10	Probability factor	0.45	0.45	0.45	0.45	0.45	0.45		
D11	Risk of pollution incident	0.00009	0.00066	0.00029	0.00060	0.00007	0.00005		
D12	Is risk greater than 0.01?	**No**	**No**	**No**	**No**	**No**	**No**		
D13	Return period without pollution reduction measures	0.00009	0.00066	0.00029	0.00060	0.00007	0.00005	0.0018	569
D14	Existing measures factor	1	1	1	1	1	1		
D15	Return period with existing pollution reduction measures	0.00009	0.00066	0.00029	0.00060	0.00007	0.00005	0.0018	569
D16	Proposed measures factor	0.6	0.6	0.6	0.6	0.6	0.6		
D17	Residual with proposed Pollution reduction measures	0.00006	0.00040	0.00017	0.00036	0.00004	0.00003	0.0011	948

Justification for choice of existing measures factors:

No existing measures

Justification for choice of proposed measures factors:

Proposed infiltration basin with infiltration basins at the base

The worksheet should be read in conjunction with DMRB 11.3.10.

1b_EXPOS01_001

Groundwater Assessment

Component Number		Weighting Factor	Property or Parameter	Risk Score	Component score	Weighted component score
1	SOURCE	10	Traffic flow	>=100,000 AADT	3	30
2		10	Rainfall depth (annual averages)	<=740 mm rainfall	1	10
3		10	Drainage area ratio	>50 to <150	2	20
4	PATHWAY	15	Infiltration method	"Region", shallow infiltration systems (e.g. infiltration basin)	2	30
5		20	Unsaturated zone	Depth to water table >=15 m	1	20
6		20	Flow type (Incorporates flow type an effective grain size)	Flow dominated by fractures/ fissures (e.g. well consolidated sedimentary deposits, igneous and metamorphic rocks or unconsolidated deposits of very coarse sand and coarser)	3	60
7		5	Unsaturated Zone Clay Content	<=1% clay minerals	3	15
8		5	Organic Carbon	<=1% SOM	3	15
9		5	Unsaturated zone soil pH	pH >=8	1	5

TOTAL SCORE	**205**
RISK SCREENING LEVEL	**Medium**

1b_EXPOS01_001

Assessment of Priority Outfalls

Method D - assessment of risk from accidental spillage

		A (main road)	B	C	D	E	F	Totals	Return Period (years)
			Additional columns for use if other roads drain to the same outfall						
D1	Water body type	Groundwater	Groundwater	Groundwater					
D2	Length of road draining to outfall (m)	1,980	362	266					
D3	Road Type (A-road or Motorway)	A	A	A					
D4	If A road, is site urban or rural?	Rural	Rural	Rural					
D5	Junction type	No junction	No junction	No junction					
D6	Location (response time for emergency services)	< 20 minutes	< 20 minutes	< 20 minutes					
D7	Traffic flow (AADT two way)	69,329	38,999	38,999					
D8	% HGV	10	6	6					
D8	Spillage factor (no/109HGVkm/year)	0.29	0.29	0.29					
D9	Risk of accidental spillage	0.00145	0.00009	0.00007	0.00000	0.00000	0.00000		
D10	Probability factor	0.45	0.45	0.45					
D11	Risk of pollution incident	0.00065	0.00004	0.00003	0.00000	0.00000	0.00000		
D12	Is risk greater than 0.01?	**No**	**No**	**No**					
D13	Return period without pollution reduction measures	0.00065	0.00004	0.00003	0.00000	0.00000	0.00000	0.0007	1381
D14	Existing measures factor	0.6	0.6	0.6					
D15	Return period with existing pollution reduction measures	0.00039	0.00002	0.00002	0.00000	0.00000	0.00000	0.0004	2302
D16	Proposed measures factor	0.6	0.6	0.6					
D17	Residual with proposed Pollution reduction measures	0.00024	0.00001	0.00001	0.00000	0.00000	0.00000	0.0003	3837

Justification for choice of existing measures factors:

Existing pond

Justification for choice of proposed measures factors:

To be used as a infiltration basin

The worksheet should be read in conjunction with DMRB 11.3.10.

User parameters 1b EXPOS01 001

Location Details

Road Number			**Assessment type**	Non-cumulative assessment (single outfall)
HE Area/DBFO number				
OS grid reference of assessment point (m)	**Easting**	569708	**Receiving watercourse**	Groundwater
	Northing	169488	**EA receiving water Detailed River Network ID**	
OS grid reference of outfall structure (m)	**Easting**		**Assessor and affiliation**	[redacted]
	Northing		**Date of assessment**	18/06/2020
Outfall number			**Version of assessment**	v1
List of outfalls in cumulative assessment				
Notes				

Parameter	Units	Default Value	Value used	Notes
Runoff Risk Assessments				
AADT	vpd	>10,000 and <50,000	***>10,000 and <50,000***	
Climatic Region	-	Warm Dry	***Warm Dry***	
Rainfall Site	-	Ashford (SAAR 710mm)	***Ashford (SAAR 710mm)***	
Q95 River flow	m3/s	0	***0***	
Baseflow Index	-	0.5	***0.5***	
Impermeable road area drained	ha	1	***1***	
Permeable area draining to outfall	ha	0	***0***	
Is the discharge in or within 1 km upstream of a protected site for conservation?	-	No	***No***	
Is there a downstream structure, lake, pond or canal that reduces the velocity within 100m of the point of discharge?	-	No	***No***	
Hardness	-	Low = <50mg CaCO3/l	***Low = <50mg CaCO3/l***	
Use Tier 1	-	TRUE	***TRUE***	
Use Tier 2	-	FALSE	***FALSE***	
Tier 1 Estimated river width at Q95	0	5	***5***	
Tier2 Bed width	m	3	***3***	
Tier2 Side slope	m/m	0.5	***0.5***	
Tier2 Long slope	m/m	0.0001	***0.0001***	
Tier2 Mannings' n	-	0.07	***0.07***	
Existing treatment for solubles	%	0	***0***	***Description for existing measures***
Existing attenuation -restricted discharge rate	l/s	No restriction	***No restriction***	
Existing settlement of sediments	%	0	***0***	
Proposed treatment for solubles	%	0	***0***	***Description for proposed measures***
Proposed attenuation -restricted discharge rate	l/s	No restriction	***No restriction***	
Proposed settlement of sediments	%	0	***0***	
EQS, bio avail dissolved Cu	ug/l	1	***1***	
EQS, bio avail dissolved Zn	ug/l	10.9	***10.9***	
Ambient background concentration, dissolved copper	ug/l	0	***0***	
Spillage Risk Assessments				
A MainRoad				
Water body type	-	-	***Groundwater***	
Length of road draining to outfall	m	-	***1980***	
Road Type (A-road or Motorway)	-	-	***A***	
If A road, is site urban or rural?	-	-	***Rural***	
Junction type	-	-	***No junction***	
Location	-	-	***< 20 minutes***	
Traffic flow (AADT two way)	-	-	***69329***	
% HGV	-	-	***10***	
Spillage factor	no/109HGVkm/year	-	***0.29***	
Existing measures factor	-	-	***0.6***	
Proposed measures factor	-	-	***0.6***	
B				
Water body type	-	-	***Groundwater***	
Length of road draining to outfall	m	-	***362***	
Road Type (A-road or Motorway)	-	-	***A***	
If A road, is site urban or rural?	-	-	***Rural***	
Junction type	-	-	***No junction***	
Location	-	-	***< 20 minutes***	
Traffic flow (AADT two way)	-	-	***38999***	
% HGV	-	-	***6***	
Spillage factor	no/109HGVkm/year	-	***0.29***	
Existing measures factor	-	-	***0.6***	
Proposed measures factor	-	-	***0.6***	
C				
Water body type	-	-	***Groundwater***	
Length of road draining to outfall	m	-	***266***	
Road Type (A-road or Motorway)	-	-	***A***	
If A road, is site urban or rural?	-	-	***Rural***	
Junction type	-	-	***No junction***	
Location	-	-	***< 20 minutes***	
Traffic flow (AADT two way)	-	-	***38999***	
% HGV	-	-	***6***	
Spillage factor	no/109HGVkm/year	-	***0.29***	
Existing measures factor	-	-	***0.6***	
Proposed measures factor	-	-	***0.6***	
D				
Water body type	-	-		
Length of road draining to outfall	m	-		
Road Type (A-road or Motorway)	-	-		
If A road, is site urban or rural?	-	-		
Junction type	-	-		
Location	-	-		
Traffic flow (AADT two way)	-	-		
% HGV	-	-		
Spillage factor	no/109HGVkm/year	-		
Existing measures factor	-	-		
Proposed measures factor	-	-		
E				
Water body type	-	-		
Length of road draining to outfall	m	-		
Road Type (A-road or Motorway)	-	-		
If A road, is site urban or rural?	-	-		
Junction type	-	-		
Location	-	-		
Traffic flow (AADT two way)	-	-		
% HGV	-	-		
Spillage factor	no/109HGVkm/year	-		
Existing measures factor	-	-		
Proposed measures factor	-	-		
F				
Water body type	-	-		
Length of road draining to outfall	m	-		
Road Type (A-road or Motorway)	-	-		
If A road, is site urban or rural?	-	-		
Junction type	-	-		
Location	-	-		
Traffic flow (AADT two way)	-	-		
% HGV	-	-		
Spillage factor	no/109HGVkm/year	-		

Existing measures factor	-	-		
Proposed measures factor	-	-		
Justification for choice of existing measures factors				Existing pond
Justification for choice of proposed measures factors				To be used as a infiltration basin
Groundwater Assessments				
Traffic flow	-	-	***>=100,000 AADT***	
Rainfall depth (annual averages)	-	-	***<=740 mm rainfall***	
Drainage area ratio	-	-	***>50 to <150***	
Infiltration method	-	-	***"Region", shallow infiltration systems (e***	
Unsaturated zone	-	-	***Depth to water table >=15 m***	
Flow type (Incorporates flow type an effective grain size)	-	-	***Flow dominated by fractures/ fissures (***	
Unsaturated Zone Clay Content	-	-	***<=1% clay minerals***	
Organic Carbon	-	-	***<=1% SOM***	
Unsaturated zone soil pH	-	-	***pH >=8***	

User parameters 2a_EXPOS02-001

Location Details

Road Number			**Assessment type**		Non-cumulative assessment (single outfall)	
HE Area/DBFO number						
OS grid reference of assessment point (m)	**Easting**	565786	**Receiving watercourse**			
	Northing	170495	**EA receiving water Detailed River Network ID**			
OS grid reference of outfall structure (m)	**Easting**		**Assessor and affiliation**	[redacted]	[redacted]	
	Northing		**Date of assessment**	**31/01/2020**		
Outfall number	2a_EXPOS02-001		**Version of assessment**	**V2**		
List of outfalls in cumulative assessment						
Notes						

Parameter	Units	Default Value	Value used	Notes	
Runoff Risk Assessments					
AADT	vpd	>10,000 and <50,000	***>10,000 and <50,000***		
Climatic Region	-	Warm Dry	***Warm Dry***		
Rainfall Site	-	Ashford (SAAR 710mm)	***Ashford (SAAR 710mm)***		
Q95 River flow	m3/s	0	***0***		
Baseflow Index	-	0.5	***0.5***		
Impermeable road area drained	ha	1	***1***		
Permeable area draining to outfall	ha	0	***0***		
Is the discharge in or within 1 km upstream of a protected site for conservation?	-	No	***No***		
Is there a downstream structure, lake, pond or canal that reduces the velocity within 100m of the point of discharge?	-	No	***No***		
Hardness	-	Low = <50mg CaCO3/l	***Low = <50mg CaCO3/l***		
Use Tier 1	-	TRUE	***TRUE***		
Use Tier 2	-	FALSE	***FALSE***		
Tier 1 Estimated river width at Q95	0	5	***5***		
Tier2 Bed width	m	3	***3***		
Tier2 Side slope	m/m	0.5	***0.5***		
Tier2 Long slope	m/m	0.0001	***0.0001***		
Tier2 Mannings' n	-	0.07	***0.07***		
Existing treatment for solubles	%	0	***0***	***Description for existing measures***	
Existing attenuation -restricted discharge rate	l/s	No restriction	***No restriction***		
Existing settlement of sediments	%	0	***0***		
Proposed treatment for solubles	%	0	***0***	***Description for proposed measures***	
Proposed attenuation -restricted discharge rate	l/s	No restriction	***No restriction***		
Proposed settlement of sediments	%	0	***0***		
EQS, bio avail dissolved Cu	ug/l	1	***1***		
EQS, bio avail dissolved Zn	ug/l	10.9	***10.9***		
Ambient background concentration, dissolved copper	ug/l	0	***0***		
Spillage Risk Assessments					
A MainRoad					
Water body type	-	-	***Groundwater***		
Length of road draining to outfall	m	-	***510.7486634***		
Road Type (A-road or Motorway)	-	-	***A***		
If A road, is site urban or rural?	-	-	***Rural***		
Junction type	-	-	***No junction***		

Location	-	-	***< 20 minutes***	
Traffic flow (AADT two way)	-	-	***70109.82759***	
% HGV	-	-	***5.3***	
Spillage factor	no/109HGVkm/year	-	***0.29***	
Existing measures factor	-	-	***1***	
Proposed measures factor	-	-	***0.6***	
B				
Water body type	-	-	***Groundwater***	
Length of road draining to outfall	m	-	***297.9795579***	
Road Type (A-road or Motorway)	-	-	***A***	
If A road, is site urban or rural?	-	-	***Rural***	
Junction type	-	-	***No junction***	
Location	-	-	***< 20 minutes***	
Traffic flow (AADT two way)	-	-	***63442.68687***	
% HGV	-	-	***5.3***	
Spillage factor	no/109HGVkm/year	-	***0.29***	
Existing measures factor	-	-	***1***	
Proposed measures factor	-	-	***0.6***	
C				
Water body type	-	-	***Groundwater***	
Length of road draining to outfall	m	-	***287.7894319***	
Road Type (A-road or Motorway)	-	-	***A***	
If A road, is site urban or rural?	-	-	***Rural***	
Junction type	-	-	***No junction***	
Location	-	-	***< 20 minutes***	
Traffic flow (AADT two way)	-	-	***63442.68687***	
% HGV	-	-	***5.3***	
Spillage factor	no/109HGVkm/year	-	***0.29***	
Existing measures factor	-	-	***1***	
Proposed measures factor	-	-	***0.6***	
D				
Water body type	-	-	***Groundwater***	
Length of road draining to outfall	m	-	***204.4582421***	
Road Type (A-road or Motorway)	-	-	***A***	
If A road, is site urban or rural?	-	-	***Rural***	
Junction type	-	-	***No junction***	
Location	-	-	***< 20 minutes***	
Traffic flow (AADT two way)	-	-	***60557.95041***	
% HGV	-	-	***5.4***	
Spillage factor	no/109HGVkm/year	-	***1***	
Existing measures factor	-	-	***0.6***	
Proposed measures factor	-	-	***0.45***	

E				
Water body type	-	-	***Groundwater***	
Length of road draining to outfall	m	-	***688.8891429***	
Road Type (A-road or Motorway)	-	-	***A***	
If A road, is site urban or rural?	-	-	***Rural***	
Junction type	-	-	***No junction***	
Location	-	-	***< 20 minutes***	
Traffic flow (AADT two way)	-	-	***36359.97575***	
% HGV	-	-	***6.8***	
Spillage factor	no/109HGVkm/year	-	***0.29***	
Existing measures factor	-	-	***1***	
Proposed measures factor	-	-	***0.6***	
F				
Water body type	-	-	***Groundwater***	
Length of road draining to outfall	m	-	***96.20112775***	
Road Type (A-road or Motorway)	-	-		
If A road, is site urban or rural?	-	-	***Rural***	
Junction type	-	-	***No junction***	
Location	-	-	***< 20 minutes***	
Traffic flow (AADT two way)	-	-	***33936.63154***	
% HGV	-	-	***2.1***	
Spillage factor	no/109HGVkm/year	-	***0.29***	
Existing measures factor	-	-	***1***	
Proposed measures factor	-	-	***0.6***	
Justification for choice of existing measures factors				No existing measures
Justification for choice of proposed measures factors				Proposed infiltration basin with infiltration basins at the base
Groundwater Assessments				
Traffic flow	-	-	***>=100,000 AADT***	
Rainfall depth (annual averages)	-	-	***<=740 mm rainfall***	
Drainage area ratio	-	-	***>50 to <150***	
Infiltration method	-	-	***"Region", shallow infiltration systems (e***	
Unsaturated zone	-	-	***Depth to water table >=15 m***	
Flow type (Incorporates flow type an effective grain size)	-	-	***Flow dominated by fractures/ fissures (e***	
Unsaturated Zone Clay Content	-	-	***<=1% clay minerals***	
Organic Carbon	-	-	***<=1% SOM***	
Unsaturated zone soil pH	-	-	***pH >=8***	

2a_EXPOS02-001

Groundwater Assessment

Component Number		Weighting Factor	Property or Parameter	Risk Score	Component score	Weighted component score
1	SOURCE	10	Traffic flow	>=100,000 AADT	3	30
2		10	Rainfall depth (annual averages)	<=740 mm rainfall	1	10
3		10	Drainage area ratio	>50 to <150	2	20
4	PATHWAY	15	Infiltration method	"Region", shallow infiltration systems (e.g. infiltration basin)	2	30
5		20	Unsaturated zone	Depth to water table >=15 m	1	20
6		20	Flow type (Incorporates flow type an effective grain size)	Flow dominated by fractures/ fissures (e.g. well consolidated sedimentary deposits, igneous and metamorphic rocks or unconsolidated deposits of very coarse sand and coarser)	3	60
7		5	Unsaturated Zone Clay Content	<=1% clay minerals	3	15
8		5	Organic Carbon	<=1% SOM	3	15
9		5	Unsaturated zone soil pH	pH >=8	1	5

TOTAL SCORE	**205**
RISK SCREENING LEVEL	**Medium**

2a_EXPOS02-001

Assessment of Priority Outfalls

Method D - assessment of risk from accidental spillage

		A (main road)	B	C	D	E	F	Totals	Return Period (years)
			Additional columns for use if other roads drain to the same outfall						
D1	Water body type	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater		
D2	Length of road draining to outfall (m)	511	298	288	204	689	96.20112775		
D3	Road Type (A-road or Motorway)	A	A	A	A	A			
D4	If A road, is site urban or rural?	Rural	Rural	Rural	Rural	Rural	Rural		
D5	Junction type	No junction	No junction	No junction	No junction	No junction	No junction		
D6	Location (response time for emergency services)	< 20 minutes	< 20 minutes	< 20 minutes	< 20 minutes	< 20 minutes	< 20 minutes		
D7	Traffic flow (AADT two way)	70,110	63,443	63,443	60,558	36,360	33936.63154		
D8	% HGV	5.3	5.3	5.3	5.4	6.8	2.1		
D8	Spillage factor (no/109HGVkm/year)	0.29	0.29	0.29	0.29	0.29	0.29		
D9	Risk of accidental spillage	0.00020	0.00011	0.00010	0.00007	0.00018	0.00001		
D10	Probability factor	0.45	0.45	0.45	0.45	0.45	0.45		
D11	Risk of pollution incident	0.00009	0.00005	0.00005	0.00003	0.00008	0.00000		
D12	Is risk greater than 0.01?	**No**	**No**	**No**	**No**	**No**	**No**		
D13	Return period without pollution reduction measures	0.00009	0.00005	0.00005	0.00003	0.00008	0.00000	0.0003	3328
D14	Existing measures factor	1	1	1	1	1	1		
D15	Return period with existing pollution reduction measures	0.00009	0.00005	0.00005	0.00003	0.00008	0.00000	0.0003	3328
D16	Proposed measures factor	0.6	0.6	0.6	0.6	0.6	0.6		
D17	Residual with proposed Pollution reduction measures	0.00005	0.00003	0.00003	0.00002	0.00005	0.00000	0.0002	5547

Justification for choice of existing measures factors:

No existing measures

Justification for choice of proposed measures factors:

Proposed infiltration basin with infiltration basins at the base

The worksheet should be read in conjunction with DMRB 11.3.10.

2b_POS02-004

Groundwater Assessment

Component Number		Weighting Factor	Property or Parameter	Risk Score	Component score	Weighted component score
1	SOURCE	10	Traffic flow	>=100,000 AADT	3	30
2		10	Rainfall depth (annual averages)	<=740 mm rainfall	1	10
3		10	Drainage area ratio	>=150	3	30
4	PATHWAY	15	Infiltration method	"Region", shallow infiltration systems (e.g. infiltration basin)	2	30
5		20	Unsaturated zone	Depth to water table >=15 m	1	20
6		20	Flow type (Incorporates flow type an effective grain size)	Flow dominated by fractures/ fissures (e.g. well consolidated sedimentary deposits, igneous and metamorphic rocks or unconsolidated deposits of very coarse sand and coarser)	3	60
7		5	Unsaturated Zone Clay Content	<=1% clay minerals	3	15
8		5	Organic Carbon	<=1% SOM	3	15
9		5	Unsaturated zone soil pH	pH >=8	1	5

TOTAL SCORE	**215**
RISK SCREENING LEVEL	**Medium**

2b_POS02-004

Assessment of Priority Outfalls

Method D - assessment of risk from accidental spillage

		A (main road)	B	C	D	E	F	Totals	Return Period (years)
			Additional columns for use if other roads drain to the same outfall						
D1	Water body type	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater		
D2	Length of road draining to outfall (m)	204	315	361	689	820	540.7478978		
D3	Road Type (A-road or Motorway)	A	A	M	A	A	A		
D4	If A road, is site urban or rural?	Rural	Rural	Rural	Rural	Rural	Rural		
D5	Junction type	No junction	No junction	No junction	No junction	No junction	No junction		
D6	Location (response time for emergency services)	< 20 minutes	< 20 minutes	< 20 minutes	< 20 minutes	< 20 minutes	< 20 minutes		
D7	Traffic flow (AADT two way)	60,558	44,234	41,658	36,360	36,360	34296.48637		
D8	% HGV	5.4	3.9	14.4	6.8	6.8	5		
D8	Spillage factor (no/109HGVkm/year)	0.29	0.29	0.36	0.29	0.29	0.29		
D9	Risk of accidental spillage	0.00007	0.00006	0.00028	0.00018	0.00021	0.00010		
D10	Probability factor	0.45	0.45	0.45	0.45	0.45	0.45		
D11	Risk of pollution incident	0.00003	0.00003	0.00013	0.00008	0.00010	0.00004		
D12	Is risk greater than 0.01?	**No**	**No**	**No**	**No**	**No**	**No**		
D13	Return period without pollution reduction measures	0.00003	0.00003	0.00013	0.00008	0.00010	0.00004	0.0004	2453
D14	Existing measures factor	1	1	1	1	1	1		
D15	Return period with existing pollution reduction measures	0.00003	0.00003	0.00013	0.00008	0.00010	0.00004	0.0004	2453
D16	Proposed measures factor	0.6	0.6	0.6	0.6	0.6	0.6		
D17	Residual with proposed Pollution reduction measures	0.00002	0.00002	0.00008	0.00005	0.00006	0.00003	0.0002	4088

Justification for choice of existing measures factors:

No existing measures

Justification for choice of proposed measures factors:

Proposed infiltration basin with infiltration basins at the base

The worksheet should be read in conjunction with DMRB 11.3.10.

User parameters 2b_POS02-004

Location Details

Road Number			**Assessment type**	Non-cumulative assessment (single outfall)
HE Area/DBFO number				
OS grid reference of assessment point (m)	**Easting**	566744	**Receiving watercourse**	Groundwater
	Northing	170271	**EA receiving water Detailed River Network ID**	
OS grid reference of outfall structure (m)	**Easting**		**Assessor and affiliation** [redacted]	[redacted]
	Northing		**Date of assessment**	31/01/2020
Outfall number	2b_POS02-004		**Version of assessment**	V2
List of outfalls in cumulative assessment				
Notes				

Parameter	Units	Default Value	Value used	Notes	
Runoff Risk Assessments					
AADT	vpd	>10,000 and <50,000	***>10,000 and <50,000***		
Climatic Region	-	Warm Dry	***Warm Dry***		
Rainfall Site	-	Ashford (SAAR 710mm)	***Ashford (SAAR 710mm)***		
Q95 River flow	m3/s	0	***0***		
Baseflow Index	-	0.5	***0.5***		
Impermeable road area drained	ha	1	***1***		
Permeable area draining to outfall	ha	0	***0***		
Is the discharge in or within 1 km upstream of a protected site for conservation?	-	No	***No***		
Is there a downstream structure, lake, pond or canal that reduces the velocity within 100m of the point of discharge?	-	No	***No***		
Hardness	-	Low = <50mg CaCO3/l	***Low = <50mg CaCO3/l***		
Use Tier 1	-	TRUE	***TRUE***		
Use Tier 2	-	FALSE	***FALSE***		
Tier 1 Estimated river width at Q95	0	5	***5***		
Tier2 Bed width	m	3	***3***		
Tier2 Side slope	m/m	0.5	***0.5***		
Tier2 Long slope	m/m	0.0001	***0.0001***		
Tier2 Mannings' n	-	0.07	***0.07***		
Existing treatment for solubles	%	0	***0***	***Description for existing measures***	
Existing attenuation -restricted discharge rate	l/s	No restriction	***No restriction***		
Existing settlement of sediments	%	0	***0***		
Proposed treatment for solubles	%	0	***0***	***Description for proposed measures***	
Proposed attenuation -restricted discharge rate	l/s	No restriction	***No restriction***		
Proposed settlement of sediments	%	0	***0***		
EQS, bio avail dissolved Cu	ug/l	1	***1***		
EQS, bio avail dissolved Zn	ug/l	10.9	***10.9***		
Ambient background concentration, dissolved copper	ug/l	0	***0***		
Spillage Risk Assessments					
A MainRoad					
Water body type	-	-	***Groundwater***		
Length of road draining to outfall	m	-	***204.4582421***		
Road Type (A-road or Motorway)	-	-	***A***		
If A road, is site urban or rural?	-	-	***Rural***		
Junction type	-	-	***No junction***		

Location	-	-	< 20 minutes	
Traffic flow (AADT two way)	-	-	60557.95041	
% HGV	-	-	5.4	
Spillage factor	no/109HGVkm/year	-	0.29	
Existing measures factor	-	-	1	
Proposed measures factor	-	-	0.6	
B				
Water body type	-	-	Groundwater	
Length of road draining to outfall	m	-	315.4844743	
Road Type (A-road or Motorway)	-	-	A	
If A road, is site urban or rural?	-	-	Rural	
Junction type	-	-	No junction	
Location	-	-	< 20 minutes	
Traffic flow (AADT two way)	-	-	44233.569	
% HGV	-	-	3.9	
Spillage factor	no/109HGVkm/year	-	0.29	
Existing measures factor	-	-	1	
Proposed measures factor	-	-	0.6	
C				
Water body type	-	-	Groundwater	
Length of road draining to outfall	m	-	361.1658281	
Road Type (A-road or Motorway)	-	-	M	
If A road, is site urban or rural?	-	-	Rural	
Junction type	-	-	No junction	
Location	-	-	< 20 minutes	
Traffic flow (AADT two way)	-	-	41657.75114	
% HGV	-	-	14.4	
Spillage factor	no/109HGVkm/year	-	0.36	
Existing measures factor	-	-	1	
Proposed measures factor	-	-	0.6	
D				
Water body type	-	-	Groundwater	
Length of road draining to outfall	m	-	688.8891429	
Road Type (A-road or Motorway)	-	-	A	
If A road, is site urban or rural?	-	-	Rural	
Junction type	-	-	No junction	
Location	-	-	< 20 minutes	
Traffic flow (AADT two way)	-	-	36359.97575	
% HGV	-	-	6.8	
Spillage factor	no/109HGVkm/year	-	1	
Existing measures factor	-	-	0.6	
Proposed measures factor	-	-	0.45	

E				
Water body type	-	-	***Groundwater***	
Length of road draining to outfall	m	-	***819.8252482***	
Road Type (A-road or Motorway)	-	-	***A***	
If A road, is site urban or rural?	-	-	***Rural***	
Junction type	-	-	***No junction***	
Location	-	-	***< 20 minutes***	
Traffic flow (AADT two way)	-	-	***36359.97575***	
% HGV	-	-	***6.8***	
Spillage factor	no/109HGVkm/year	-	***0.29***	
Existing measures factor	-	-	***1***	
Proposed measures factor	-	-	***0.6***	
F				
Water body type	-	-	***Groundwater***	
Length of road draining to outfall	m	-	***540.7478978***	
Road Type (A-road or Motorway)	-	-	***A***	
If A road, is site urban or rural?	-	-	***Rural***	
Junction type	-	-	***No junction***	
Location	-	-	***< 20 minutes***	
Traffic flow (AADT two way)	-	-	***34296.48637***	
% HGV	-	-	***5***	
Spillage factor	no/109HGVkm/year	-	***0.29***	
Existing measures factor	-	-	***1***	
Proposed measures factor	-	-	***0.6***	
Justification for choice of existing measures factors				No existing measures
Justification for choice of proposed measures factors				Proposed infiltration basin with infiltration basins at the base
Groundwater Assessments				
Traffic flow	-	-	***>=100,000 AADT***	
Rainfall depth (annual averages)	-	-	***<=740 mm rainfall***	
Drainage area ratio	-	-	***>=150***	
Infiltration method	-	-	***"Region", shallow infiltration systems (e***	
Unsaturated zone	-	-	***Depth to water table >=15 m***	
Flow type (Incorporates flow type an effective grain size)	-	-	***Flow dominated by fractures/ fissures (e***	
Unsaturated Zone Clay Content	-	-	***<=1% clay minerals***	
Organic Carbon	-	-	***<=1% SOM***	
Unsaturated zone soil pH	-	-	***pH >=8***	

2c_POS02-001

Groundwater Assessment

Component Number		Weighting Factor	Property or Parameter	Risk Score	Component score	Weighted component score
1	SOURCE	10	Traffic flow	>50,000 to <100,000 AADT	2	20
2		10	Rainfall depth (annual averages)	<=740 mm rainfall	1	10
3		10	Drainage area ratio	>50 to <150	2	20
4	PATHWAY	15	Infiltration method	"Region", shallow infiltration systems (e.g. infiltration basin)	2	30
5		20	Unsaturated zone	Depth to water table >=15 m	1	20
6		20	Flow type (Incorporates flow type an effective grain size)	Flow dominated by fractures/ fissures (e.g. well consolidated sedimentary deposits, igneous and metamorphic rocks or unconsolidated deposits of very coarse sand and coarser)	3	60
7		5	Unsaturated Zone Clay Content	<=1% clay minerals	3	15
8		5	Organic Carbon	<=1% SOM	3	15
9		5	Unsaturated zone soil pH	pH >=8	1	5

TOTAL SCORE	**195**
RISK SCREENING LEVEL	**Medium**

2c_POS02-001

Assessment of Priority Outfalls

Method D - assessment of risk from accidental spillage

		A (main road)	B	C	D	E	F	Totals	Return Period (years)
			Additional columns for use if other roads drain to the same outfall						
D1	Water body type	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater		
D2	Length of road draining to outfall (m)	27	82	437	53	151	365.4039159		
D3	Road Type (A-road or Motorway)			A					
D4	If A road, is site urban or rural?			Rural					
D5	Junction type	Slip road	Slip road	Slip road	Slip road	Slip road	Slip road		
D6	Location (response time for emergency services)	< 20 minutes	< 20 minutes	< 20 minutes	< 20 minutes	< 20 minutes	< 20 minutes		
D7	Traffic flow (AADT two way)	21,551	15,713	15,037	10,699	9,216	5850.433404		
D8	% HGV	3.5	2.1	2.2	3.6	1.8	7.2		
D8	Spillage factor (no/109HGVkm/year)	0.83	0.83	0.83	0.83	0.83	0.83		
D9	Risk of accidental spillage	0.00001	0.00001	0.00004	0.00001	0.00001	0.00005		
D10	Probability factor	0.45	0.45	0.45	0.45	0.45	0.45		
D11	Risk of pollution incident	0.00000	0.00000	0.00002	0.00000	0.00000	0.00002		
D12	Is risk greater than 0.01?	**No**	**No**	**No**	**No**	**No**	**No**		
D13	Return period without pollution reduction measures	0.00000	0.00000	0.00002	0.00000	0.00000	0.00002	0.0001	18745
D14	Existing measures factor	1	1	1	1	1	1		
D15	Return period with existing pollution reduction measures	0.00000	0.00000	0.00002	0.00000	0.00000	0.00002	0.0001	18745
D16	Proposed measures factor	0.6	0.6	0.6	0.6	0.6	0.6		
D17	Residual with proposed Pollution reduction measures	0.00000	0.00000	0.00001	0.00000	0.00000	0.00001	0.0000	31241

Justification for choice of existing measures factors:

No existing measures

Justification for choice of proposed measures factors:

Proposed infiltration basin with infiltration basins at the base

The worksheet should be read in conjunction with DMRB 11.3.10.

User parameters 2c_POS02-001

Location Details

Road Number			**Assessment type**		Non-cumulative assessment (single outfall)		
HE Area/DBFO number							
OS grid reference of assessment point (m)	**Easting**	566025	**Receiving watercourse**				
	Northing	170302	**EA receiving water Detailed River Network ID**				
OS grid reference of outfall structure (m)	**Easting**		**Assessor and affiliation**	[redacted]	[redacted]		
	Northing		**Date of assessment**				
Outfall number	2c_POS02-001		**Version of assessment**				
List of outfalls in cumulative assessment							
Notes							

Parameter	Units	Default Value	Value used	Notes	
Runoff Risk Assessments					
AADT	vpd	>10,000 and <50,000	***>10,000 and <50,000***		
Climatic Region	-	Warm Dry	***Warm Dry***		
Rainfall Site	-	Ashford (SAAR 710mm)	***Ashford (SAAR 710mm)***		
Q95 River flow	m3/s	0	***0***		
Baseflow Index	-	0.5	***0.5***		
Impermeable road area drained	ha	1	***1***		
Permeable area draining to outfall	ha	0	***0***		
Is the discharge in or within 1 km upstream of a protected site for conservation?	-	No	***No***		
Is there a downstream structure, lake, pond or canal that reduces the velocity within 100m of the point of discharge?	-	No	***No***		
Hardness	-	Low = <50mg CaCO3/l	***Low = <50mg CaCO3/l***		
Use Tier 1	-	TRUE	***TRUE***		
Use Tier 2	-	FALSE	***FALSE***		
Tier 1 Estimated river width at Q95	0	5	***5***		
Tier2 Bed width	m	3	***3***		
Tier2 Side slope	m/m	0.5	***0.5***		
Tier2 Long slope	m/m	0.0001	***0.0001***		
Tier2 Mannings' n	-	0.07	***0.07***		
Existing treatment for solubles	%	0	***0***	***Description for existing measures***	
Existing attenuation -restricted discharge rate	l/s	No restriction	***No restriction***		
Existing settlement of sediments	%	0	***0***		
Proposed treatment for solubles	%	0	***0***	***Description for proposed measures***	
Proposed attenuation -restricted discharge rate	l/s	No restriction	***No restriction***		
Proposed settlement of sediments	%	0	***0***		
EQS, bio avail dissolved Cu	ug/l	1	***1***		
EQS, bio avail dissolved Zn	ug/l	10.9	***10.9***		
Ambient background concentration, dissolved copper	ug/l	0	***0***		
Spillage Risk Assessments					
A MainRoad					
Water body type	-	-	***Groundwater***		
Length of road draining to outfall	m	-	***27.03326895***		
Road Type (A-road or Motorway)	-	-			
If A road, is site urban or rural?	-	-			
Junction type	-	-	***Slip road***		

Location	-	-	< 20 minutes	
Traffic flow (AADT two way)	-	-	21551.02512	
% HGV	-	-	3.5	
Spillage factor	no/109HGVkm/year	-	0.83	
Existing measures factor	-	-	1	
Proposed measures factor	-	-	0.6	
B				
Water body type	-	-	Groundwater	
Length of road draining to outfall	m	-	81.97261578	
Road Type (A-road or Motorway)	-	-		
If A road, is site urban or rural?	-	-		
Junction type	-	-	Slip road	
Location	-	-	< 20 minutes	
Traffic flow (AADT two way)	-	-	15712.88682	
% HGV	-	-	2.1	
Spillage factor	no/109HGVkm/year	-	0.83	
Existing measures factor	-	-	1	
Proposed measures factor	-	-	0.6	
C				
Water body type	-	-	Groundwater	
Length of road draining to outfall	m	-	436.5925255	
Road Type (A-road or Motorway)	-	-	A	
If A road, is site urban or rural?	-	-	Rural	
Junction type	-	-	Slip road	
Location	-	-	< 20 minutes	
Traffic flow (AADT two way)	-	-	15037.31949	
% HGV	-	-	2.2	
Spillage factor	no/109HGVkm/year	-	0.83	
Existing measures factor	-	-	1	
Proposed measures factor	-	-	0.6	
D				
Water body type	-	-	Groundwater	
Length of road draining to outfall	m	-	53.19688938	
Road Type (A-road or Motorway)	-	-		
If A road, is site urban or rural?	-	-		
Junction type	-	-	Slip road	
Location	-	-	< 20 minutes	
Traffic flow (AADT two way)	-	-	10699.07001	
% HGV	-	-	3.6	
Spillage factor	no/109HGVkm/year	-	1	
Existing measures factor	-	-	0.6	
Proposed measures factor	-	-	0.45	

E				
Water body type	-	-	***Groundwater***	
Length of road draining to outfall	m	-	***150.9796374***	
Road Type (A-road or Motorway)	-	-		
If A road, is site urban or rural?	-	-		
Junction type	-	-	***Slip road***	
Location	-	-	***< 20 minutes***	
Traffic flow (AADT two way)	-	-	***9216.450216***	
% HGV	-	-	***1.8***	
Spillage factor	no/109HGVkm/year	-	***0.83***	
Existing measures factor	-	-	***1***	
Proposed measures factor	-	-	***0.6***	
F				
Water body type	-	-	***Groundwater***	
Length of road draining to outfall	m	-	***365.4039159***	
Road Type (A-road or Motorway)	-	-		
If A road, is site urban or rural?	-	-		
Junction type	-	-	***Slip road***	
Location	-	-	***< 20 minutes***	
Traffic flow (AADT two way)	-	-	***5850.433404***	
% HGV	-	-	***7.2***	
Spillage factor	no/109HGVkm/year	-	***0.83***	
Existing measures factor	-	-	***1***	
Proposed measures factor	-	-	***0.6***	
Justification for choice of existing measures factors				No existing measures
Justification for choice of proposed measures factors				Proposed infiltration basin with infiltration basins at the base
Groundwater Assessments				
Traffic flow	-	-	***>50,000 to <100,000 AADT***	
Rainfall depth (annual averages)	-	-	***<=740 mm rainfall***	
Drainage area ratio	-	-	***>50 to <150***	
Infiltration method	-	-	***"Region", shallow infiltration systems (e***	
Unsaturated zone	-	-	***Depth to water table >=15 m***	
Flow type (Incorporates flow type an effective grain size)	-	-	***Flow dominated by fractures/ fissures (e***	
Unsaturated Zone Clay Content	-	-	***<=1% clay minerals***	
Organic Carbon	-	-	***<=1% SOM***	
Unsaturated zone soil pH	-	-	***pH >=8***	

User parameters 2d_POS02-002

Location Details

Road Number			Assessment type		Non-cumulative assessment (single outfall)
HE Area/DBFO number					
OS grid reference of assessment point (m)	Easting	566642	Receiving watercourse		
	Northing	170264	EA receiving water Detailed River Network ID		
OS grid reference of outfall structure (m)	Easting		Assessor and affiliation	[redacted]	[redacted]
	Northing		Date of assessment	31/01/2020	
Outfall number	2d_POS02-002		Version of assessment	V2	
List of outfalls in cumulative assessment					
Notes					

Parameter	Units	Default Value	Value used	Notes	
Runoff Risk Assessments					
AADT	vpd	>10,000 and <50,000	***>10,000 and <50,000***		
Climatic Region	-	Warm Dry	***Warm Dry***		
Rainfall Site	-	Ashford (SAAR 710mm)	***Ashford (SAAR 710mm)***		
Q95 River flow	m3/s	0	***0***		
Baseflow Index	-	0.5	***0.5***		
Impermeable road area drained	ha	1	***1***		
Permeable area draining to outfall	ha	0	***0***		
Is the discharge in or within 1 km upstream of a protected site for conservation?	-	No	***No***		
Is there a downstream structure, lake, pond or canal that reduces the velocity within 100m of the point of discharge?	-	No	***No***		
Hardness	-	Low = <50mg CaCO3/l	***Low = <50mg CaCO3/l***		
Use Tier 1	-	TRUE	***TRUE***		
Use Tier 2	-	FALSE	***FALSE***		
Tier 1 Estimated river width at Q95	0	5	***5***		
Tier2 Bed width	m	3	***3***		
Tier2 Side slope	m/m	0.5	***0.5***		
Tier2 Long slope	m/m	0.0001	***0.0001***		
Tier2 Mannings' n	-	0.07	***0.07***		
Existing treatment for solubles	%	0	***0***	***Description for existing measures***	
Existing attenuation -restricted discharge rate	l/s	No restriction	***No restriction***		
Existing settlement of sediments	%	0	***0***		
Proposed treatment for solubles	%	0	***0***	***Description for proposed measures***	
Proposed attenuation -restricted discharge rate	l/s	No restriction	***No restriction***		
Proposed settlement of sediments	%	0	***0***		
EQS, bio avail dissolved Cu	ug/l	1	***1***		
EQS, bio avail dissolved Zn	ug/l	10.9	***10.9***		
Ambient background concentration, dissolved copper	ug/l	0	***0***		
Spillage Risk Assessments					
A MainRoad					
Water body type	-	-	***Groundwater***		
Length of road draining to outfall	m	-	***234.1962477***		
Road Type (A-road or Motorway)	-	-	***M***		
If A road, is site urban or rural?	-	-			
Junction type	-	-	***Slip road***		

Location	-	-	*< 20 minutes*	
Traffic flow (AADT two way)	-	-	*9657.934116*	
% HGV	-	-	*4*	
Spillage factor	no/109HGVkm/year	-	*0.43*	
Existing measures factor	-	-	*1*	
Proposed measures factor	-	-	*0.6*	
B				
Water body type	-	-	*Groundwater*	
Length of road draining to outfall	m	-	*267.1703471*	
Road Type (A-road or Motorway)	-	-		
If A road, is site urban or rural?	-	-		
Junction type	-	-	*Slip road*	
Location	-	-	*< 20 minutes*	
Traffic flow (AADT two way)	-	-	*9657.934116*	
% HGV	-	-	*4*	
Spillage factor	no/109HGVkm/year	-	*0.83*	
Existing measures factor	-	-	*1*	
Proposed measures factor	-	-	*0.6*	
C				
Water body type	-	-	*Groundwater*	
Length of road draining to outfall	m	-	*710.5133929*	
Road Type (A-road or Motorway)	-	-	*M*	
If A road, is site urban or rural?	-	-		
Junction type	-	-	*Slip road*	
Location	-	-	*< 20 minutes*	
Traffic flow (AADT two way)	-	-	*6817.870772*	
% HGV	-	-	*5.5*	
Spillage factor	no/109HGVkm/year	-	*0.43*	
Existing measures factor	-	-	*1*	
Proposed measures factor	-	-	*0.6*	
D				
Water body type	-	-	*Groundwater*	
Length of road draining to outfall	m	-	*440.6298296*	
Road Type (A-road or Motorway)	-	-	*M*	
If A road, is site urban or rural?	-	-		
Junction type	-	-	*Slip road*	
Location	-	-	*< 20 minutes*	
Traffic flow (AADT two way)	-	-	*2839.90371*	
% HGV	-	-	*0.4*	
Spillage factor	no/109HGVkm/year	-	*1*	
Existing measures factor	-	-	*0.6*	
Proposed measures factor	-	-	*0.45*	

E				
Water body type	-	-		
Length of road draining to outfall	m	-		
Road Type (A-road or Motorway)	-	-		
If A road, is site urban or rural?	-	-		
Junction type	-	-		
Location	-	-		
Traffic flow (AADT two way)	-	-		
% HGV	-	-		
Spillage factor	no/109HGVkm/year	-		
Existing measures factor	-	-		
Proposed measures factor	-	-		
F				
Water body type	-	-		
Length of road draining to outfall	m	-		
Road Type (A-road or Motorway)	-	-		
If A road, is site urban or rural?	-	-		
Junction type	-	-		
Location	-	-		
Traffic flow (AADT two way)	-	-		
% HGV	-	-		
Spillage factor	no/109HGVkm/year	-		
Existing measures factor	-	-		
Proposed measures factor	-	-		
Justification for choice of existing measures factors				No existing measures
Justification for choice of proposed measures factors				Proposed infiltration basin with infiltration basins at the base
Groundwater Assessments				
Traffic flow	-	-	***>50,000 to <100,000 AADT***	
Rainfall depth (annual averages)	-	-	***<=740 mm rainfall***	
Drainage area ratio	-	-	***>50 to <150***	
Infiltration method	-	-	***"Region", shallow infiltration systems (e***	
Unsaturated zone	-	-	***Depth to water table >=15 m***	
Flow type (Incorporates flow type an effective grain size)	-	-	***Flow dominated by fractures/ fissures (e***	
Unsaturated Zone Clay Content	-	-	***<=1% clay minerals***	
Organic Carbon	-	-	***<=1% SOM***	
Unsaturated zone soil pH	-	-	***pH >=8***	

2d_POS02-002

Groundwater Assessment

Component Number		Weighting Factor	Property or Parameter	Risk Score	Component score	Weighted component score
1	SOURCE	10	Traffic flow	>50,000 to <100,000 AADT	2	20
2		10	Rainfall depth (annual averages)	<=740 mm rainfall	1	10
3		10	Drainage area ratio	>50 to <150	2	20
4	PATHWAY	15	Infiltration method	"Region", shallow infiltration systems (e.g. infiltration basin)	2	30
5		20	Unsaturated zone	Depth to water table >=15 m	1	20
6		20	Flow type (Incorporates flow type an effective grain size)	Flow dominated by fractures/ fissures (e.g. well consolidated sedimentary deposits, igneous and metamorphic rocks or unconsolidated deposits of very coarse sand and coarser)	3	60
7		5	Unsaturated Zone Clay Content	<=1% clay minerals	3	15
8		5	Organic Carbon	<=1% SOM	3	15
9		5	Unsaturated zone soil pH	pH >=8	1	5

TOTAL SCORE	**195**
RISK SCREENING LEVEL	**Medium**

2d_POS02-002

Assessment of Priority Outfalls

Method D - assessment of risk from accidental spillage

		A (main road)	B	C	D	E	F	Totals	Return Period (years)
			Additional columns for use if other roads drain to the same outfall						
D1	Water body type	Groundwater	Groundwater	Groundwater	Groundwater				
D2	Length of road draining to outfall (m)	234	267	711	441				
D3	Road Type (A-road or Motorway)	M		M	M				
D4	If A road, is site urban or rural?								
D5	Junction type	Slip road	Slip road	Slip road	Slip road				
D6	Location (response time for emergency services)	< 20 minutes	< 20 minutes	< 20 minutes	< 20 minutes				
D7	Traffic flow (AADT two way)	9,658	9,658	6,818	2,840				
D8	% HGV	4	4	5.5	0.4				
D8	Spillage factor (no/109HGVkm/year)	0.43	0.83	0.43	0.43				
D9	Risk of accidental spillage	0.00001	0.00003	0.00004	0.00000	0.00000	0.00000		
D10	Probability factor	0.45	0.45	0.45	0.45				
D11	Risk of pollution incident	0.00001	0.00001	0.00002	0.00000	0.00000	0.00000		
D12	Is risk greater than 0.01?	**No**	**No**	**No**	**No**				
D13	Return period without pollution reduction measures	0.00001	0.00001	0.00002	0.00000	0.00000	0.00000	0.0000	25232
D14	Existing measures factor	1	1	1	1				
D15	Return period with existing pollution reduction measures	0.00001	0.00001	0.00002	0.00000	0.00000	0.00000	0.0000	25232
D16	Proposed measures factor	0.6	0.6	0.6	0.6				
D17	Residual with proposed Pollution reduction measures	0.00000	0.00001	0.00001	0.00000	0.00000	0.00000	0.0000	42054

Justification for choice of existing measures factors:

No existing measures

Justification for choice of proposed measures factors:

Proposed infiltration basin with infiltration basins at the base

The worksheet should be read in conjunction with DMRB 11.3.10.

User parameters 2e_POS02-003

Location Details

Road Number			**Assessment type**	Non-cumulative assessment (single outfall)
HE Area/DBFO number				
OS grid reference of assessment point (m)	**Easting**	567459	**Receiving watercourse**	Groundwater
	Northing	171346	**EA receiving water Detailed River Network ID**	
OS grid reference of outfall structure (m)	**Easting**		**Assessor and affiliation** [redacted]	[redacted]
	Northing		**Date of assessment**	31/01/2020
Outfall number	2e_POS02-003		**Version of assessment**	V2
List of outfalls in cumulative assessment				
Notes				

Parameter	Units	Default Value	Value used	Notes
Runoff Risk Assessments				
AADT	vpd	>10,000 and <50,000	***>10,000 and <50,000***	
Climatic Region	-	Warm Dry	***Warm Dry***	
Rainfall Site	-	Ashford (SAAR 710mm)	***Ashford (SAAR 710mm)***	
Q95 River flow	m3/s	0	***0***	
Baseflow Index	-	0.5	***0.5***	
Impermeable road area drained	ha	1	***1***	
Permeable area draining to outfall	ha	0	***0***	
Is the discharge in or within 1 km upstream of a protected site for conservation?	-	No	***No***	
Is there a downstream structure, lake, pond or canal that reduces the velocity within 100m of the point of discharge?	-	No	***No***	
Hardness	-	Low = <50mg CaCO3/l	***Low = <50mg CaCO3/l***	
Use Tier 1	-	TRUE	***TRUE***	
Use Tier 2	-	FALSE	***FALSE***	
Tier 1 Estimated river width at Q95	0	5	***5***	
Tier2 Bed width	m	3	***3***	
Tier2 Side slope	m/m	0.5	***0.5***	
Tier2 Long slope	m/m	0.0001	***0.0001***	
Tier2 Mannings' n	-	0.07	***0.07***	
Existing treatment for solubles	%	0	***0***	***Description for existing measures***
Existing attenuation -restricted discharge rate	l/s	No restriction	***No restriction***	
Existing settlement of sediments	%	0	***0***	
Proposed treatment for solubles	%	0	***0***	***Description for proposed measures***
Proposed attenuation -restricted discharge rate	l/s	No restriction	***No restriction***	
Proposed settlement of sediments	%	0	***0***	
EQS, bio avail dissolved Cu	ug/l	1	***1***	
EQS, bio avail dissolved Zn	ug/l	10.9	***10.9***	
Ambient background concentration, dissolved copper	ug/l	0	***0***	
Spillage Risk Assessments				
A MainRoad				
Water body type	-	-	***Groundwater***	
Length of road draining to outfall	m	-	***666.0981045***	
Road Type (A-road or Motorway)	-	-	***A***	
If A road, is site urban or rural?	-	-	***Rural***	
Junction type	-	-	***No junction***	

Location	-	-	*< 20 minutes*	
Traffic flow (AADT two way)	-	-	*69329.01202*	
% HGV	-	-	*10.1*	
Spillage factor	no/109HGVkm/year	-	*0.29*	
Existing measures factor	-	-	*1*	
Proposed measures factor	-	-	*0.6*	
B				
Water body type	-	-	*Groundwater*	
Length of road draining to outfall	m	-	*279.9927901*	
Road Type (A-road or Motorway)	-	-	*A*	
If A road, is site urban or rural?	-	-	*Rural*	
Junction type	-	-	*No junction*	
Location	-	-	*< 20 minutes*	
Traffic flow (AADT two way)	-	-	*67405.85445*	
% HGV	-	-	*10.3*	
Spillage factor	no/109HGVkm/year	-	*0.29*	
Existing measures factor	-	-	*1*	
Proposed measures factor	-	-	*0.6*	
C				
Water body type	-	-	*Groundwater*	
Length of road draining to outfall	m	-	*1827.219351*	
Road Type (A-road or Motorway)	-	-	*A*	
If A road, is site urban or rural?	-	-	*Rural*	
Junction type	-	-	*No junction*	
Location	-	-	*< 20 minutes*	
Traffic flow (AADT two way)	-	-	*67405.84183*	
% HGV	-	-	*10.3*	
Spillage factor	no/109HGVkm/year	-	*0.29*	
Existing measures factor	-	-	*1*	
Proposed measures factor	-	-	*0.6*	
D				
Water body type	-	-	*Groundwater*	
Length of road draining to outfall	m	-	*270.8925716*	
Road Type (A-road or Motorway)	-	-	*M*	
If A road, is site urban or rural?	-	-		
Junction type	-	-	*No junction*	
Location	-	-	*< 20 minutes*	
Traffic flow (AADT two way)	-	-	*54117.5043*	
% HGV	-	-	*11.9*	
Spillage factor	no/109HGVkm/year	-	*1*	
Existing measures factor	-	-	*0.6*	
Proposed measures factor	-	-	*0.45*	

E				
Water body type	-	-	***Groundwater***	
Length of road draining to outfall	m	-	***915.7270359***	
Road Type (A-road or Motorway)	-	-	***M***	
If A road, is site urban or rural?	-	-		
Junction type	-	-	***No junction***	
Location	-	-	***< 20 minutes***	
Traffic flow (AADT two way)	-	-	***54117.5043***	
% HGV	-	-	***11.9***	
Spillage factor	no/109HGVkm/year	-	***0.36***	
Existing measures factor	-	-	***1***	
Proposed measures factor	-	-	***0.6***	
F				
Water body type	-	-	***Groundwater***	
Length of road draining to outfall	m	-	***83.34814693***	
Road Type (A-road or Motorway)	-	-	***A***	
If A road, is site urban or rural?	-	-	***Rural***	
Junction type	-	-	***No junction***	
Location	-	-	***< 20 minutes***	
Traffic flow (AADT two way)	-	-	***52682.25498***	
% HGV	-	-	***7.2***	
Spillage factor	no/109HGVkm/year	-	***0.29***	
Existing measures factor	-	-	***1***	
Proposed measures factor	-	-	***0.6***	
Justification for choice of existing measures factors				No existing measures
Justification for choice of proposed measures factors				Proposed infiltration basin with infiltration basins at the base
Groundwater Assessments				
Traffic flow	-	-	***>=100,000 AADT***	
Rainfall depth (annual averages)	-	-	***<=740 mm rainfall***	
Drainage area ratio	-	-	***>=150***	
Infiltration method	-	-	***"Region", shallow infiltration systems (e***	
Unsaturated zone	-	-	***Depth to water table >=15 m***	
Flow type (Incorporates flow type an effective grain size)	-	-	***Flow dominated by fractures/ fissures (e***	
Unsaturated Zone Clay Content	-	-	***<=1% clay minerals***	
Organic Carbon	-	-	***<=1% SOM***	
Unsaturated zone soil pH	-	-	***pH >=8***	

2e_POS02-003

Groundwater Assessment

Component Number		Weighting Factor	Property or Parameter	Risk Score	Component score	Weighted component score
1	SOURCE	10	Traffic flow	>=100,000 AADT	3	30
2		10	Rainfall depth (annual averages)	<=740 mm rainfall	1	10
3		10	Drainage area ratio	>=150	3	30
4	PATHWAY	15	Infiltration method	"Region", shallow infiltration systems (e.g. infiltration basin)	2	30
5		20	Unsaturated zone	Depth to water table >=15 m	1	20
6		20	Flow type (Incorporates flow type an effective grain size)	Flow dominated by fractures/ fissures (e.g. well consolidated sedimentary deposits, igneous and metamorphic rocks or unconsolidated deposits of very coarse sand and coarser)	3	60
7		5	Unsaturated Zone Clay Content	<=1% clay minerals	3	15
8		5	Organic Carbon	<=1% SOM	3	15
9		5	Unsaturated zone soil pH	pH >=8	1	5

TOTAL SCORE	**215**
RISK SCREENING LEVEL	**Medium**

2e_POS02-003

Assessment of Priority Outfalls

Method D - assessment of risk from accidental spillage

		A (main road)	B	C	D	E	F	Totals	Return Period (years)
			Additional columns for use if other roads drain to the same outfall						
D1	Water body type	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater		
D2	Length of road draining to outfall (m)	666	280	1,827	271	916	83.34814693		
D3	Road Type (A-road or Motorway)	A	A	A	M	M	A		
D4	If A road, is site urban or rural?	Rural	Rural	Rural			Rural		
D5	Junction type	No junction	No junction	No junction	No junction	No junction	No junction		
D6	Location (response time for emergency services)	< 20 minutes	< 20 minutes	< 20 minutes	< 20 minutes	< 20 minutes	< 20 minutes		
D7	Traffic flow (AADT two way)	69,329	67,406	67,406	54,118	54,118	52682.25498		
D8	% HGV	10.1	10.3	10.3	11.9	11.9	7.2		
D8	Spillage factor (no/109HGVkm/year)	0.29	0.29	0.29	0.36	0.36	0.29		
D9	Risk of accidental spillage	0.00049	0.00021	0.00134	0.00023	0.00077	0.00003		
D10	Probability factor	0.45	0.45	0.45	0.45	0.45	0.45		
D11	Risk of pollution incident	0.00022	0.00009	0.00060	0.00010	0.00035	0.00002		
D12	Is risk greater than 0.01?	**No**	**No**	**No**	**No**	**No**	**No**		
D13	Return period without pollution reduction measures	0.00022	0.00009	0.00060	0.00010	0.00035	0.00002	0.0014	722
D14	Existing measures factor	1	1	1	1	1	1		
D15	Return period with existing pollution reduction measures	0.00022	0.00009	0.00060	0.00010	0.00035	0.00002	0.0014	722
D16	Proposed measures factor	0.6	0.6	0.6	0.6	0.6	0.6		
D17	Residual with proposed Pollution reduction measures	0.00013	0.00006	0.00036	0.00006	0.00021	0.00001	0.0008	1203

Justification for choice of existing measures factors:

No existing measures

Justification for choice of proposed measures factors:

Proposed infiltration basin with infiltration basins at the base

The worksheet should be read in conjunction with DMRB 11.3.10.

User parameters 2f_EXPOS02-005

Location Details

Road Number			**Assessment type**	Non-cumulative assessment (single outfall)
HE Area/DBFO number				
OS grid reference of assessment point (m)	**Easting**	566778	**Receiving watercourse**	Groundwater
	Northing	169977	**EA receiving water Detailed River Network ID**	
OS grid reference of outfall structure (m)	**Easting**		**Assessor and affiliation** [redacted]	[redacted]
	Northing		**Date of assessment**	31/01/2020
Outfall number	2f_EXPOS02-005		**Version of assessment**	V2
List of outfalls in cumulative assessment				
Notes				

Parameter	Units	Default Value	Value used	Notes	
Runoff Risk Assessments					
AADT	vpd	>10,000 and <50,000	***>10,000 and <50,000***		
Climatic Region	-	Warm Dry	***Warm Dry***		
Rainfall Site	-	Ashford (SAAR 710mm)	***Ashford (SAAR 710mm)***		
Q95 River flow	m3/s	0	***0***		
Baseflow Index	-	0.5	***0.5***		
Impermeable road area drained	ha	1	***1***		
Permeable area draining to outfall	ha	0	***0***		
Is the discharge in or within 1 km upstream of a protected site for conservation?	-	No	***No***		
Is there a downstream structure, lake, pond or canal that reduces the velocity within 100m of the point of discharge?	-	No	***No***		
Hardness	-	Low = <50mg CaCO3/l	***Low = <50mg CaCO3/l***		
Use Tier 1	-	TRUE	***TRUE***		
Use Tier 2	-	FALSE	***FALSE***		
Tier 1 Estimated river width at Q95	0	5	***5***		
Tier2 Bed width	m	3	***3***		
Tier2 Side slope	m/m	0.5	***0.5***		
Tier2 Long slope	m/m	0.0001	***0.0001***		
Tier2 Mannings' n	-	0.07	***0.07***		
Existing treatment for solubles	%	0	***0***	***Description for existing measures***	
Existing attenuation -restricted discharge rate	l/s	No restriction	***No restriction***		
Existing settlement of sediments	%	0	***0***		
Proposed treatment for solubles	%	0	***0***	***Description for proposed measures***	
Proposed attenuation -restricted discharge rate	l/s	No restriction	***No restriction***		
Proposed settlement of sediments	%	0	***0***		
EQS, bio avail dissolved Cu	ug/l	1	***1***		
EQS, bio avail dissolved Zn	ug/l	10.9	***10.9***		
Ambient background concentration, dissolved copper	ug/l	0	***0***		
Spillage Risk Assessments					
A MainRoad					
Water body type	-	-	***Groundwater***		
Length of road draining to outfall	m	-	***271.5362499***		
Road Type (A-road or Motorway)	-	-	***A***		
If A road, is site urban or rural?	-	-	***Rural***		
Junction type	-	-	***Slip road***		

Location	-	-	*< 20 minutes*	
Traffic flow (AADT two way)	-	-	*28676.24991*	
% HGV	-	-	*5.5*	
Spillage factor	no/109HGVkm/year	-	*0.83*	
Existing measures factor	-	-	*1*	
Proposed measures factor	-	-	*0.6*	
B				
Water body type	-	-	*Groundwater*	
Length of road draining to outfall	m	-	*426.510415*	
Road Type (A-road or Motorway)	-	-	*A*	
If A road, is site urban or rural?	-	-	*Rural*	
Junction type	-	-	*Slip road*	
Location	-	-	*< 20 minutes*	
Traffic flow (AADT two way)	-	-	*26257.79892*	
% HGV	-	-	*6*	
Spillage factor	no/109HGVkm/year	-	*0.83*	
Existing measures factor	-	-	*1*	
Proposed measures factor	-	-	*0.6*	
C				
Water body type	-	-	*Groundwater*	
Length of road draining to outfall	m	-	*170.7059184*	
Road Type (A-road or Motorway)	-	-	*A*	
If A road, is site urban or rural?	-	-	*Rural*	
Junction type	-	-	*Slip road*	
Location	-	-	*< 20 minutes*	
Traffic flow (AADT two way)	-	-	*16313.90333*	
% HGV	-	-	*9.7*	
Spillage factor	no/109HGVkm/year	-	*0.83*	
Existing measures factor	-	-	*1*	
Proposed measures factor	-	-	*0.6*	
D				
Water body type	-	-	*Groundwater*	
Length of road draining to outfall	m	-	*23.17360849*	
Road Type (A-road or Motorway)	-	-		
If A road, is site urban or rural?	-	-		
Junction type	-	-	*Slip road*	
Location	-	-	*< 20 minutes*	
Traffic flow (AADT two way)	-	-	*8647.480545*	
% HGV	-	-	*0.8*	
Spillage factor	no/109HGVkm/year	-	*1*	
Existing measures factor	-	-	*0.6*	
Proposed measures factor	-	-	*0.45*	

E				
Water body type	-	-	***Groundwater***	
Length of road draining to outfall	m	-	***528.7663665***	
Road Type (A-road or Motorway)	-	-		
If A road, is site urban or rural?	-	-		
Junction type	-	-	***Slip road***	
Location	-	-	***< 20 minutes***	
Traffic flow (AADT two way)	-	-	***7296.329435***	
% HGV	-	-	***0.6***	
Spillage factor	no/109HGVkm/year	-	***0.83***	
Existing measures factor	-	-	***1***	
Proposed measures factor	-	-	***0.6***	
F				
Water body type	-	-	***Groundwater***	
Length of road draining to outfall	m	-	***102.6052472***	
Road Type (A-road or Motorway)	-	-		
If A road, is site urban or rural?	-	-		
Junction type	-	-	***Slip road***	
Location	-	-	***< 20 minutes***	
Traffic flow (AADT two way)	-	-	***7296.329435***	
% HGV	-	-	***0.6***	
Spillage factor	no/109HGVkm/year	-	***0.83***	
Existing measures factor	-	-	***1***	
Proposed measures factor	-	-	***0.6***	
Justification for choice of existing measures factors				No existing measures
Justification for choice of proposed measures factors				Proposed infiltration basin with infiltration basins at the base
Groundwater Assessments				
Traffic flow	-	-	***>=100,000 AADT***	
Rainfall depth (annual averages)	-	-	***<=740 mm rainfall***	
Drainage area ratio	-	-	***>=150***	
Infiltration method	-	-	***"Region", shallow infiltration systems (e***	
Unsaturated zone	-	-	***Depth to water table >=15 m***	
Flow type (Incorporates flow type an effective grain size)	-	-	***Flow dominated by fractures/ fissures (e***	
Unsaturated Zone Clay Content	-	-	***<=1% clay minerals***	
Organic Carbon	-	-	***<=1% SOM***	
Unsaturated zone soil pH	-	-	***pH >=8***	

2f_EXPOS02-005

Groundwater Assessment

Component Number		Weighting Factor	Property or Parameter	Risk Score	Component score	Weighted component score
1	SOURCE	10	Traffic flow	>=100,000 AADT	3	30
2		10	Rainfall depth (annual averages)	<=740 mm rainfall	1	10
3		10	Drainage area ratio	>=150	3	30
4	PATHWAY	15	Infiltration method	"Region", shallow infiltration systems (e.g. infiltration basin)	2	30
5		20	Unsaturated zone	Depth to water table >=15 m	1	20
6		20	Flow type (Incorporates flow type an effective grain size)	Flow dominated by fractures/ fissures (e.g. well consolidated sedimentary deposits, igneous and metamorphic rocks or unconsolidated deposits of very coarse sand and coarser)	3	60
7		5	Unsaturated Zone Clay Content	<=1% clay minerals	3	15
8		5	Organic Carbon	<=1% SOM	3	15
9		5	Unsaturated zone soil pH	pH >=8	1	5

TOTAL SCORE	**215**
RISK SCREENING LEVEL	**Medium**

2f_EXPOS02-005

Assessment of Priority Outfalls

Method D - assessment of risk from accidental spillage

		A (main road)	B	C	D	E	F	Totals	Return Period (years)
			Additional columns for use if other roads drain to the same outfall						
D1	Water body type	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater		
D2	Length of road draining to outfall (m)	272	427	171	23	529	102.6052472		
D3	Road Type (A-road or Motorway)	A	A	A					
D4	If A road, is site urban or rural?	Rural	Rural	Rural					
D5	Junction type	Slip road	Slip road	Slip road	Slip road	Slip road	Slip road		
D6	Location (response time for emergency services)	< 20 minutes	< 20 minutes	< 20 minutes	< 20 minutes	< 20 minutes	< 20 minutes		
D7	Traffic flow (AADT two way)	28,676	26,258	16,314	8,647	7,296	7296.329435		
D8	% HGV	5.5	6	9.7	0.8	0.6	0.6		
D8	Spillage factor (no/109HGVkm/year)	0.83	0.83	0.83	0.83	0.83	0.83		
D9	Risk of accidental spillage	0.00013	0.00020	0.00008	0.00000	0.00001	0.00000		
D10	Probability factor	0.45	0.45	0.45	0.45	0.45	0.45		
D11	Risk of pollution incident	0.00006	0.00009	0.00004	0.00000	0.00000	0.00000		
D12	Is risk greater than 0.01?	**No**	**No**	**No**	**No**	**No**	**No**		
D13	Return period without pollution reduction measures	0.00006	0.00009	0.00004	0.00000	0.00000	0.00000	0.0002	5241
D14	Existing measures factor	1	1	1	1	1	1		
D15	Return period with existing pollution reduction measures	0.00006	0.00009	0.00004	0.00000	0.00000	0.00000	0.0002	5241
D16	Proposed measures factor	0.6	0.6	0.6	0.6	0.6	0.6		
D17	Residual with proposed Pollution reduction measures	0.00004	0.00005	0.00002	0.00000	0.00000	0.00000	0.0001	8735

Justification for choice of existing measures factors:

No existing measures

Justification for choice of proposed measures factors:

Proposed infiltration basin with infiltration basins at the base

The worksheet should be read in conjunction with DMRB 11.3.10.

User parameters 4a_POS04-001

Location Details

Road Number			**Assessment type**	Non-cumulative assessment (single outfall)
HE Area/DBFO number				
OS grid reference of assessment point (m)	**Easting**	568486	**Receiving watercourse**	Groundwater
	Northing	171877	**EA receiving water Detailed River Network ID**	
OS grid reference of outfall structure (m)	**Easting**		**Assessor and affiliation** [redacted]	[redacted]
	Northing		**Date of assessment**	31/01/2020
Outfall number	4a_POS04-001		**Version of assessment**	V2
List of outfalls in cumulative assessment				
Notes				

Parameter	Units	Default Value	Value used	Notes	
Runoff Risk Assessments					
AADT	vpd	>10,000 and <50,000	***>10,000 and <50,000***		
Climatic Region	-	Warm Dry	***Warm Dry***		
Rainfall Site	-	Ashford (SAAR 710mm)	***Ashford (SAAR 710mm)***		
Q95 River flow	m3/s	0	***0***		
Baseflow Index	-	0.5	***0.5***		
Impermeable road area drained	ha	1	***1***		
Permeable area draining to outfall	ha	0	***0***		
Is the discharge in or within 1 km upstream of a protected site for conservation?	-	No	***No***		
Is there a downstream structure, lake, pond or canal that reduces the velocity within 100m of the point of discharge?	-	No	***No***		
Hardness	-	Low = <50mg CaCO3/l	***Low = <50mg CaCO3/l***		
Use Tier 1	-	TRUE	***TRUE***		
Use Tier 2	-	FALSE	***FALSE***		
Tier 1 Estimated river width at Q95	0	5	***5***		
Tier2 Bed width	m	3	***3***		
Tier2 Side slope	m/m	0.5	***0.5***		
Tier2 Long slope	m/m	0.0001	***0.0001***		
Tier2 Mannings' n	-	0.07	***0.07***		
Existing treatment for solubles	%	0	***0***	***Description for existing measures***	
Existing attenuation -restricted discharge rate	l/s	No restriction	***No restriction***		
Existing settlement of sediments	%	0	***0***		
Proposed treatment for solubles	%	0	***0***	***Description for proposed measures***	
Proposed attenuation -restricted discharge rate	l/s	No restriction	***No restriction***		
Proposed settlement of sediments	%	0	***0***		
EQS, bio avail dissolved Cu	ug/l	1	***1***		
EQS, bio avail dissolved Zn	ug/l	10.9	***10.9***		
Ambient background concentration, dissolved copper	ug/l	0	***0***		
Spillage Risk Assessments					
A MainRoad					
Water body type	-	-	***Groundwater***		
Length of road draining to outfall	m	-	***826.5086763***		
Road Type (A-road or Motorway)	-	-	***M***		
If A road, is site urban or rural?	-	-			
Junction type	-	-	***No junction***		

Location	-	-	***< 20 minutes***	
Traffic flow (AADT two way)	-	-	***54117.5043***	
% HGV	-	-	***11.9***	
Spillage factor	no/109HGVkm/year	-	***0.36***	
Existing measures factor	-	-	***1***	
Proposed measures factor	-	-	***0.6***	
B				
Water body type	-	-	***Groundwater***	
Length of road draining to outfall	m	-	***915.7270359***	
Road Type (A-road or Motorway)	-	-	***M***	
If A road, is site urban or rural?	-	-		
Junction type	-	-	***No junction***	
Location	-	-	***< 20 minutes***	
Traffic flow (AADT two way)	-	-	***54117.5043***	
% HGV	-	-	***11.9***	
Spillage factor	no/109HGVkm/year	-	***0.36***	
Existing measures factor	-	-	***1***	
Proposed measures factor	-	-	***0.6***	
C				
Water body type	-	-	***Groundwater***	
Length of road draining to outfall	m	-	***1075.631729***	
Road Type (A-road or Motorway)	-	-	***M***	
If A road, is site urban or rural?	-	-		
Junction type	-	-	***No junction***	
Location	-	-	***< 20 minutes***	
Traffic flow (AADT two way)	-	-	***46910.59645***	
% HGV	-	-	***11.7***	
Spillage factor	no/109HGVkm/year	-	***0.36***	
Existing measures factor	-	-	***1***	
Proposed measures factor	-	-	***0.6***	
D				
Water body type	-	-	***Groundwater***	
Length of road draining to outfall	m	-	***918.2195312***	
Road Type (A-road or Motorway)	-	-	***M***	
If A road, is site urban or rural?	-	-		
Junction type	-	-	***No junction***	
Location	-	-	***< 20 minutes***	
Traffic flow (AADT two way)	-	-	***46910.59645***	
% HGV	-	-	***11.7***	
Spillage factor	no/109HGVkm/year	-	***1***	
Existing measures factor	-	-	***0.6***	
Proposed measures factor	-	-	***0.45***	

E				
Water body type	-	-		
Length of road draining to outfall	m	-		
Road Type (A-road or Motorway)	-	-		
If A road, is site urban or rural?	-	-		
Junction type	-	-		
Location	-	-		
Traffic flow (AADT two way)	-	-		
% HGV	-	-		
Spillage factor	no/109HGVkm/year	-		
Existing measures factor	-	-		
Proposed measures factor	-	-		
F				
Water body type	-	-		
Length of road draining to outfall	m	-		
Road Type (A-road or Motorway)	-	-		
If A road, is site urban or rural?	-	-		
Junction type	-	-		
Location	-	-		
Traffic flow (AADT two way)	-	-		
% HGV	-	-		
Spillage factor	no/109HGVkm/year	-		
Existing measures factor	-	-		
Proposed measures factor	-	-		
Justification for choice of existing measures factors				No existing measures
Justification for choice of proposed measures factors				Proposed infiltration basin with infiltration basins at the base
Groundwater Assessments				
Traffic flow	-	-	***>=100,000 AADT***	
Rainfall depth (annual averages)	-	-	***<=740 mm rainfall***	
Drainage area ratio	-	-	***>=150***	
Infiltration method	-	-	***"Region", shallow infiltration systems (e***	
Unsaturated zone	-	-	***Depth to water table >=15 m***	
Flow type (Incorporates flow type an effective grain size)	-	-	***Flow dominated by fractures/ fissures (e***	
Unsaturated Zone Clay Content	-	-	***<=1% clay minerals***	
Organic Carbon	-	-	***<=1% SOM***	
Unsaturated zone soil pH	-	-	***pH >=8***	

4a_POS04-001

Groundwater Assessment

Component Number		Weighting Factor	Property or Parameter	Risk Score	Component score	Weighted component score
1	SOURCE	10	Traffic flow	>=100,000 AADT	3	30
2		10	Rainfall depth (annual averages)	<=740 mm rainfall	1	10
3		10	Drainage area ratio	>=150	3	30
4	PATHWAY	15	Infiltration method	"Region", shallow infiltration systems (e.g. infiltration basin)	2	30
5		20	Unsaturated zone	Depth to water table >=15 m	1	20
6		20	Flow type (Incorporates flow type an effective grain size)	Flow dominated by fractures/ fissures (e.g. well consolidated sedimentary deposits, igneous and metamorphic rocks or unconsolidated deposits of very coarse sand and coarser)	3	60
7		5	Unsaturated Zone Clay Content	<=1% clay minerals	3	15
8		5	Organic Carbon	<=1% SOM	3	15
9		5	Unsaturated zone soil pH	pH >=8	1	5

TOTAL SCORE	**215**
RISK SCREENING LEVEL	**Medium**

4a_POS04-001

Assessment of Priority Outfalls

Method D - assessment of risk from accidental spillage

		A (main road)	B	C	D	E	F	Totals	Return Period (years)
			Additional columns for use if other roads drain to the same outfall						
D1	Water body type	Groundwater	Groundwater	Groundwater	Groundwater				
D2	Length of road draining to outfall (m)	827	916	1,076	918				
D3	Road Type (A-road or Motorway)	M	M	M	M				
D4	If A road, is site urban or rural?								
D5	Junction type	No junction	No junction	No junction	No junction				
D6	Location (response time for emergency services)	< 20 minutes	< 20 minutes	< 20 minutes	< 20 minutes				
D7	Traffic flow (AADT two way)	54,118	54,118	46,911	46,911				
D8	% HGV	11.9	11.9	11.7	11.7				
D8	Spillage factor (no/109HGVkm/year)	0.36	0.36	0.36	0.36				
D9	Risk of accidental spillage	0.00070	0.00077	0.00078	0.00066	0.00000	0.00000		
D10	Probability factor	0.45	0.45	0.45	0.45				
D11	Risk of pollution incident	0.00031	0.00035	0.00035	0.00030	0.00000	0.00000		
D12	Is risk greater than 0.01?	**No**	**No**	**No**	**No**				
D13	Return period without pollution reduction measures	0.00031	0.00035	0.00035	0.00030	0.00000	0.00000	0.0013	763
D14	Existing measures factor	1	1	1	1				
D15	Return period with existing pollution reduction measures	0.00031	0.00035	0.00035	0.00030	0.00000	0.00000	0.0013	763
D16	Proposed measures factor	0.6	0.6	0.6	0.6				
D17	Residual with proposed Pollution reduction measures	0.00019	0.00021	0.00021	0.00018	0.00000	0.00000	0.0008	1272

Justification for choice of existing measures factors:

No existing measures

Justification for choice of proposed measures factors:

Proposed infiltration basin with infiltration basins at the base

The worksheet should be read in conjunction with DMRB 11.3.10.

User parameters 11c_POS11-003

Location Details

Road Number			**Assessment type**	Non-cumulative assessment (single outfall)
HE Area/DBFO number				
OS grid reference of assessment point (m)	**Easting**	563771	**Receiving watercourse**	
	Northing	180571	**EA receiving water Detailed River Network ID**	
OS grid reference of outfall structure (m)	**Easting**		**Assessor and affiliation** [redacted]	[redacted]
	Northing		**Date of assessment**	31/01/2020
Outfall number	11c_POS11-003		**Version of assessment**	V2
List of outfalls in cumulative assessment				
Notes				

Parameter	Units	Default Value	Value used	Notes	
Runoff Risk Assessments					
AADT	vpd	>10,000 and <50,000	***>10,000 and <50,000***		
Climatic Region	-	Warm Dry	***Warm Dry***		
Rainfall Site	-	Ashford (SAAR 710mm)	***Ashford (SAAR 710mm)***		
Q95 River flow	m3/s	0	***0***		
Baseflow Index	-	0.5	***0.5***		
Impermeable road area drained	ha	1	***1***		
Permeable area draining to outfall	ha	0	***0***		
Is the discharge in or within 1 km upstream of a protected site for conservation?	-	No	***No***		
Is there a downstream structure, lake, pond or canal that reduces the velocity within 100m of the point of discharge?	-	No	***No***		
Hardness	-	Low = <50mg CaCO3/l	***Low = <50mg CaCO3/l***		
Use Tier 1	-	TRUE	***TRUE***		
Use Tier 2	-	FALSE	***FALSE***		
Tier 1 Estimated river width at Q95	0	5	***5***		
Tier2 Bed width	m	3	***3***		
Tier2 Side slope	m/m	0.5	***0.5***		
Tier2 Long slope	m/m	0.0001	***0.0001***		
Tier2 Mannings' n	-	0.07	***0.07***		
Existing treatment for solubles	%	0	***0***	***Description for existing measures***	
Existing attenuation -restricted discharge rate	l/s	No restriction	***No restriction***		
Existing settlement of sediments	%	0	***0***		
Proposed treatment for solubles	%	0	***0***	***Description for proposed measures***	
Proposed attenuation -restricted discharge rate	l/s	No restriction	***No restriction***		
Proposed settlement of sediments	%	0	***0***		
EQS, bio avail dissolved Cu	ug/l	1	***1***		
EQS, bio avail dissolved Zn	ug/l	10.9	***10.9***		
Ambient background concentration, dissolved copper	ug/l	0	***0***		
Spillage Risk Assessments					
A MainRoad					
Water body type	-	-	***Groundwater***		
Length of road draining to outfall	m	-	***277.58012***		
Road Type (A-road or Motorway)	-	-	***A***		
If A road, is site urban or rural?	-	-	***Urban***		
Junction type	-	-	***Side road***		

Location	-	-	*< 20 minutes*	
Traffic flow (AADT two way)	-	-	*18683.17724*	
% HGV	-	-	*4*	
Spillage factor	no/109HGVkm/year	-	*1.81*	
Existing measures factor	-	-	*1*	
Proposed measures factor	-	-	*0.6*	
B				
Water body type	-	-	*Groundwater*	
Length of road draining to outfall	m	-	*220.1072155*	
Road Type (A-road or Motorway)	-	-	*A*	
If A road, is site urban or rural?	-	-	*Urban*	
Junction type	-	-	*Side road*	
Location	-	-	*< 20 minutes*	
Traffic flow (AADT two way)	-	-	*17155.69091*	
% HGV	-	-	*4.3*	
Spillage factor	no/109HGVkm/year	-	*1.81*	
Existing measures factor	-	-	*1*	
Proposed measures factor	-	-	*0.6*	
C				
Water body type	-	-	*Groundwater*	
Length of road draining to outfall	m	-	*780.9208066*	
Road Type (A-road or Motorway)	-	-	*A*	
If A road, is site urban or rural?	-	-	*Urban*	
Junction type	-	-	*Side road*	
Location	-	-	*< 20 minutes*	
Traffic flow (AADT two way)	-	-	*4606.866871*	
% HGV	-	-	*7*	
Spillage factor	no/109HGVkm/year	-	*1.81*	
Existing measures factor	-	-	*1*	
Proposed measures factor	-	-	*0.6*	
D				
Water body type	-	-	*Groundwater*	
Length of road draining to outfall	m	-	*677.5496037*	
Road Type (A-road or Motorway)	-	-	*A*	
If A road, is site urban or rural?	-	-	*Urban*	
Junction type	-	-	*Side road*	
Location	-	-	*< 20 minutes*	
Traffic flow (AADT two way)	-	-	*3441.160226*	
% HGV	-	-	*4.6*	
Spillage factor	no/109HGVkm/year	-	*1*	
Existing measures factor	-	-	*0.6*	
Proposed measures factor	-	-	*0.45*	

E				
Water body type	-	-	***Groundwater***	
Length of road draining to outfall	m	-	***114.3249285***	
Road Type (A-road or Motorway)	-	-		
If A road, is site urban or rural?	-	-		
Junction type	-	-	***Side road***	
Location	-	-	***< 20 minutes***	
Traffic flow (AADT two way)	-	-	***1527.496687***	
% HGV	-	-	***0.5***	
Spillage factor	no/109HGVkm/year	-	***1.81***	
Existing measures factor	-	-	***1***	
Proposed measures factor	-	-	***0.6***	
F				
Water body type	-	-		
Length of road draining to outfall	m	-		
Road Type (A-road or Motorway)	-	-		
If A road, is site urban or rural?	-	-		
Junction type	-	-		
Location	-	-		
Traffic flow (AADT two way)	-	-		
% HGV	-	-		
Spillage factor	no/109HGVkm/year	-		
Existing measures factor	-	-		
Proposed measures factor	-	-		
Justification for choice of existing measures factors				No existing measures
Justification for choice of proposed measures factors				Proposed infiltration basin with infiltration basins at the base
Groundwater Assessments				
Traffic flow	-	-	***<=50,000 AADT***	
Rainfall depth (annual averages)	-	-	***<=740 mm rainfall***	
Drainage area ratio	-	-	***>50 to <150***	
Infiltration method	-	-	***"Region", shallow infiltration systems (e***	
Unsaturated zone	-	-	***Depth to water table <15 m to >5 m***	
Flow type (Incorporates flow type an effective grain size)	-	-	***Mixed fracture and intergranular flow (e.***	
Unsaturated Zone Clay Content	-	-	***>=15% clay minerals***	
Organic Carbon	-	-	***<15% to >1% SOM***	
Unsaturated zone soil pH	-	-	***pH <8 to >5***	

11c_POS11-003

Groundwater Assessment

Component Number		Weighting Factor	Property or Parameter	Risk Score	Component score	Weighted component score
1	SOURCE	10	Traffic flow	<=50,000 AADT	1	10
2		10	Rainfall depth (annual averages)	<=740 mm rainfall	1	10
3		10	Drainage area ratio	>50 to <150	2	20
4	PATHWAY	15	Infiltration method	"Region", shallow infiltration systems (e.g. infiltration basin)	2	30
5		20	Unsaturated zone	Depth to water table <15 m to >5 m	2	40
6		20	Flow type (Incorporates flow type an effective grain size)	Mixed fracture and intergranular flow (e.g. consolidated deposits or unconsolidated deposits of medium – coarse sand)	2	40
7		5	Unsaturated Zone Clay Content	>=15% clay minerals	1	5
8		5	Organic Carbon	<15% to >1% SOM	2	10
9		5	Unsaturated zone soil pH	pH <8 to >5	2	10

TOTAL SCORE	**175**
RISK SCREENING LEVEL	**Medium**

11c_POS11-003

Assessment of Priority Outfalls

Method D - assessment of risk from accidental spillage

		A (main road)	B	C	D	E	F	Totals	Return Period (years)
			Additional columns for use if other roads drain to the same outfall						
D1	Water body type	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater			
D2	Length of road draining to outfall (m)	278	220	781	678	114			
D3	Road Type (A-road or Motorway)	A	A	A	A				
D4	If A road, is site urban or rural?	Urban	Urban	Urban	Urban				
D5	Junction type	Side road	Side road	Side road	Side road	Side road			
D6	Location (response time for emergency services)	< 20 minutes	< 20 minutes	< 20 minutes	< 20 minutes	< 20 minutes			
D7	Traffic flow (AADT two way)	18,683	17,156	4,607	3,441	1,527			
D8	% HGV	4	4.3	7	4.6	0.5			
D8	Spillage factor (no/109HGVkm/year)	1.81	1.81	1.81	1.81	1.81			
D9	Risk of accidental spillage	0.00014	0.00011	0.00017	0.00007	0.00000	0.00000		
D10	Probability factor	0.45	0.45	0.45	0.45	0.45			
D11	Risk of pollution incident	0.00006	0.00005	0.00007	0.00003	0.00000	0.00000		
D12	Is risk greater than 0.01?	**No**	**No**	**No**	**No**	**No**			
D13	Return period without pollution reduction measures	0.00006	0.00005	0.00007	0.00003	0.00000	0.00000	0.0002	4609
D14	Existing measures factor	1	1	1	1	1			
D15	Return period with existing pollution reduction measures	0.00006	0.00005	0.00007	0.00003	0.00000	0.00000	0.0002	4609
D16	Proposed measures factor	0.6	0.6	0.6	0.6	0.6			
D17	Residual with proposed Pollution reduction measures	0.00004	0.00003	0.00004	0.00002	0.00000	0.00000	0.0001	7682

Justification for choice of existing measures factors:

No existing measures

Justification for choice of proposed measures factors:

Proposed infiltration basin with infiltration basins at the base

The worksheet should be read in conjunction with DMRB 11.3.10.

Groundwater Assessment for SWS10-001				
	Parameter	Weighting factor	SCORE	RESULTS
Source	Traffic Flow	10	1	10
	Rainfall depth (annual averages)	10	1	10
	Drainage area ratio	10	1	10
Pathway	Infiltration method	15	1	15
	Unsaturated zone	20	2	40
	Flow type	20	1	20
	Unsaturated zone clay content	5	2	10
	Organic carbon	5	3	15
	Unsaturated zone soil pH	5	2	10
TOTAL Score				140
RISK SCREENING LEVEL				LOW

Method D - assessment of risk from accidental spillage		SWS10-001	Additional columns for use if other roads drain to the same outfall						
		A (main road)	B	C	D	E	F	**Totals**	**Return Period (years)**
D1	Water body type	Groundwater							
D2	Length of road draining to outfall *(m)*	188							
D3	Road Type *(A-road or Motorway)*	A							
D4	If A road, is site urban or rural?	Rural							
D5	Junction type	No junction							
D6	Location (response time for emergency services)	< 20 minutes							
D7	Traffic flow (AADT two way)	4400							
D8	% HGV	2							
D8	Spillage factor *(no/10^{9} HGVkm/year)*	0.29							
D9	Risk of accidental spillage	0.00000							
D10	Probability factor	0.45							
D11	Risk of pollution incident	0.00000							
D12	Is risk greater than 0.01?	**No**							
D13	Return period without pollution reduction measures	0.00000						0.0000	1268984
D14	Existing measures factor	1							
D15	Return period with existing pollution reduction measures	0.00000						0.0000	1268984
D16	Proposed measures factor	0.6							
D17	Residual with proposed Pollution reduction measures	0.00000						0.0000	2114973

Groundwater Assessment for SWS10-002				
	Parameter	Weighting factor	SCORE	RESULTS
Source	Traffic Flow	10	1	10
	Rainfall depth (annual averages)	10	1	10
	Drainage area ratio	10	1	10
Pathway	Infiltration method	15	1	15
	Unsaturated zone	20	2	40
	Flow type	20	1	20
	Unsaturated zone clay content	5	2	10
	Organic carbon	5	3	15
	Unsaturated zone soil pH	5	2	10
TOTAL				140
RISK SCREENING LEVEL				LOW

Method D - assessment of risk from accidental spillage		SWS10-002	Additional columns for use if other roads drain to the same outfall						
		A (main road)	B	C	D	E	F		
D1	Water body type	Groundwater							
D2	Length of road draining to outfall *(m)*	150							
D3	Road Type *(A-road or Motorway)*	A							
D4	If A road, is site urban or rural?	Rural							
D5	Junction type	No junction							
D6	Location (response time for emergency services)	< 20 minutes							
D7	Traffic flow (AADT two way)	4400							
D8	% HGV	2							
D8	Spillage factor *(no/10^9 HGVkm/year)*	0.29							
D9	Risk of accidental spillage	0.00000							
D10	Probability factor	0.45							
D11	Risk of pollution incident	0.00000							
D12	Is risk greater than 0.01?	**No**						**Totals**	**Return Period (years)**
D13	Return period without pollution reduction measures	0.00000						0.0000	1590460
D14	Existing measures factor	1							
D15	Return period with existing pollution reduction measures	0.00000						0.0000	1590460
D16	Proposed measures factor	0.6							
D17	Residual with proposed Pollution reduction measures	0.00000						0.0000	2650766

Groundwater Assessment for SWS10-004				
	Parameter	Weighting factor	SCORE	RESULTS
Source	Traffic Flow	10	1	10
	Rainfall depth (annual averages)	10	1	10
	Drainage area ratio	10	1	10
Pathway	Infiltration method	15	1	15
	Unsaturated zone	20	2	40
	Flow type	20	1	20
	Unsaturated zone clay content	5	2	10
	Organic carbon	5	3	15
	Unsaturated zone soil pH	5	2	10
TOTAL				140
RISK SCREENING LEVEL				LOW

	Method D - assessment of risk from accidental spillage	SWS10-004	Additional columns for use if other roads drain to the same outfall						
		A (main road)	B	C	D	E	F	Totals	Return Period (years)
D1	Water body type	Groundwater							
D2	Length of road draining to outfall *(m)*	238							
D3	Road Type *(A-road or Motorway)*	A							
D4	If A road, is site urban or rural?	Rural							
D5	Junction type	No junction							
D6	Location (response time for emergency services)	< 20 minutes							
D7	Traffic flow (AADT two way)	4400							
D8	% HGV	2							
D8	Spillage factor *(no/10^9 HGVkm/year)*	0.29							
D9	Risk of accidental spillage	0.00000							
D10	Probability factor	0.45							
D11	Risk of pollution incident	0.00000							
D12	Is risk greater than 0.01?	**No**							
D13	Return period without pollution reduction measures	0.00000						0.0000	1002391
D14	Existing measures factor	1							
D15	Return period with existing pollution reduction measures	0.00000						0.0000	1002391
D16	Proposed measures factor	0.6							
D17	Residual with proposed Pollution reduction measures	0.00000						0.0000	1670651

Groundwater Assessment for SWS10-009				
	Parameter	Weighting factor	SCORE	RESULTS
Source	Traffic Flow	10	1	10
	Rainfall depth (annual averages)	10	1	10
	Drainage area ratio	10	1	10
Pathway	Infiltration method	15	1	15
	Unsaturated zone	20	2	40
	Flow type	20	2	40
	Unsaturated zone clay content	5	2	10
	Organic carbon	5	2	10
	Unsaturated zone soil pH	5	2	10
TOTAL				155
RISK SCREENING LEVEL				MEDIUM

Method D - assessment of risk from accidental spillage		SWS10-009	Additional columns for use if other roads drain to the same outfall						
		A (main road)	B	C	D	E	F		
D1	Water body type	Groundwater							
D2	Length of road draining to outfall *(m)*	288							
D3	Road Type *(A-road or Motorway)*	A							
D4	If A road, is site urban or rural?	Rural							
D5	Junction type	Slip road							
D6	Location (response time for emergency services)	< 20 minutes							
D7	Traffic flow (AADT two way)	0							
D8	% HGV	2							
D8	Spillage factor *(no/10^9 HGVkm/year)*	0.83							
D9	Risk of accidental spillage	0.00000							
D10	Probability factor	0.45							
D11	Risk of pollution incident	0.00000							
D12	Is risk greater than 0.01?	**No**						**Totals**	**Return Period (years)**
D13	Return period without pollution reduction measures	0.00000						0.0000	#DIV/0!
D14	Existing measures factor	1							
D15	Return period with existing pollution reduction measures	0.00000						0.0000	#DIV/0!
D16	Proposed measures factor	0.6							
D17	Residual with proposed Pollution reduction measures	0.00000						0.0000	#DIV/0!

Groundwater Assessment for SWS10-011				
	Parameter	Weighting	SCORE	RESULTS
Source	Traffic Flow	10	1	10
	Rainfall depth (annual averages)	10	1	10
	Drainage area ratio	10	1	10
Pathway	Infiltration method	15	1	15
	Unsaturated zone	20	2	40
	Flow type	20	2	40
	Unsaturated zone clay content	5	2	10
	Organic carbon	5	2	10
	Unsaturated zone soil pH	5	2	10
TOTAL				155
RISK SCREENING LEVEL				MEDIUM

	Method D - assessment of risk from accidental spillage	SWS10-011	Additional columns for use if other roads drain to the same outfall						
		A (main road)	B	C	D	E	F	Totals	Return Period (years)
D1	Water body type	Groundwater							
D2	Length of road draining to outfall *(m)*	245							
D3	Road Type *(A-road or Motorway)*	A							
D4	If A road, is site urban or rural?	Rural							
D5	Junction type	Slip road							
D6	Location (response time for emergency services)	< 20 minutes							
D7	Traffic flow (AADT two way)	0							
D8	% HGV	2							
D8	Spillage factor *(no/10^9 HGVkm/year)*	0.83							
D9	Risk of accidental spillage	0.00000							
D10	Probability factor	0.45							
D11	Risk of pollution incident	0.00000							
D12	Is risk greater than 0.01?	**No**							
D13	Return period without pollution reduction measures	0.00000						0.0000	#DIV/0!
D14	Existing measures factor	1							
D15	Return period with existing pollution reduction measures	0.00000						0.0000	#DIV/0!
D16	Proposed measures factor	0.6							
D17	Residual with proposed Pollution reduction measures	0.00000						0.0000	#DIV/0!

Groundwater Assessment for SWS11-004				
	Parameter	Weighting factor	SCORE	RESULTS
Source	Traffic Flow	10	1	10
	Rainfall depth (annual averages)	10	1	10
	Drainage area ratio	10	1	10
Pathway	Infiltration method	15	1	15
	Unsaturated zone	20	2	40
	Flow type	20	2	40
	Unsaturated zone clay content	5	2	10
	Organic carbon	5	3	15
	Unsaturated zone soil pH	5	2	10
TOTAL				160
RISK SCREENING LEVEL				MEDIUM

Method D - assessment of risk from accidental spillage		SWS11-004	Additional columns for use if other roads drain to the same outfall						
		A (main road)	B	C	D	E	F		
D1	Water body type	Groundwater							
D2	Length of road draining to outfall *(m)*	120							
D3	Road Type *(A-road or Motorway)*	A							
D4	If A road, is site urban or rural?	Rural							
D5	Junction type	No junction							
D6	Location (response time for emergency services)	< 20 minutes							
D7	Traffic flow (AADT two way)	0							
D8	% HGV	0							
D8	Spillage factor *(no/10^9 HGVkm/year)*	0.29							
D9	Risk of accidental spillage	0.00000							
D10	Probability factor	0.45							
D11	Risk of pollution incident	0.00000						**Totals**	**Return Period (years)**
D12	Is risk greater than 0.01?	**No**							
D13	Return period without pollution reduction measures	0.00000						0.0000	#DIV/0!
D14	Existing measures factor	1							
D15	Return period with existing pollution reduction measures	0.00000						0.0000	#DIV/0!
D16	Proposed measures factor	0.6							
D17	Residual with proposed Pollution reduction measures	0.00000						0.0000	#DIV/0!

Groundwater Assessment for SWS11-003				
	Parameter	Weighting factor	SCORE	RESULTS
Source	Traffic Flow	10	1	10
	Rainfall depth (annual averages)	10	1	10
	Drainage area ratio	10	1	10
Pathway	Infiltration method	15	1	15
	Unsaturated zone	20	2	40
	Flow type	20	2	40
	Unsaturated zone clay content	5	2	10
	Organic carbon	5	3	15
	Unsaturated zone soil pH	5	2	10
TOTAL				160
RISK SCREENING LEVEL				MEDIUM

Method D - assessment of risk from accidental spillage		SWS11-003	Additional columns for use if other roads drain to the same outfall						
		A (main road)	B	C	D	E	F	Totals	Return Period (years)
D1	Water body type	Groundwater							
D2	Length of road draining to outfall *(m)*	46							
D3	Road Type *(A-road or Motorway)*	A							
D4	If A road, is site urban or rural?	Rural							
D5	Junction type	No junction							
D6	Location (response time for emergency services)	< 20 minutes							
D7	Traffic flow (AADT two way)	0							
D8	% HGV	0							
D8	Spillage factor *(no/10^9 HGVkm/year)*	0.29							
D9	Risk of accidental spillage	0.00000							
D10	Probability factor	0.45							
D11	Risk of pollution incident	0.00000							
D12	Is risk greater than 0.01?	**No**							
D13	Return period without pollution reduction measures	0.00000						0.0000	#DIV/0!
D14	Existing measures factor	1							
D15	Return period with existing pollution reduction measures	0.00000						0.0000	#DIV/0!
D16	Proposed measures factor	0.6							
D17	Residual with proposed Pollution reduction measures	0.00000						0.0000	#DIV/0!

Groundwater Assessment for SWS11-005				
	Parameter	Weighting factor	SCORE	RESULTS
Source	Traffic Flow	10	1	10
	Rainfall depth (annual averages)	10	1	10
	Drainage area ratio	10	1	10
Pathway	Infiltration method	15	1	15
	Unsaturated zone	20	2	40
	Flow type	20	2	40
	Unsaturated zone clay content	5	2	10
	Organic carbon	5	2	10
	Unsaturated zone soil pH	5	2	10
TOTAL				155
RISK SCREENING LEVEL				MEDIUM

Method D - assessment of risk from accidental spillage		SWS11-005	Additional columns for use if other roads drain to the same outfall						
		A (main road)	B						
D1	Water body type	Groundwater							
D2	Length of road draining to outfall *(m)*	100							
D3	Road Type *(A-road or Motorway)*	A							
D4	If A road, is site urban or rural?	Urban							
D5	Junction type	Side road							
D6	Location (response time for emergency services)	< 20 minutes							
D7	Traffic flow (AADT two way)	0							
D8	% HGV	1							
D8	Spillage factor *(no/10^9 HGVkm/year)*	1.81							
D9	Risk of accidental spillage	0.00000							
D10	Probability factor	0.45							
D11	Risk of pollution incident	0.00000							
D12	Is risk greater than 0.01?	**No**						**Totals**	**Return Period (years)**
D13	Return period without pollution reduction measures	0.00000						0.0000	#DIV/0!
D14	Existing measures factor	1							
D15	Return period with existing pollution reduction measures	0.00000						0.0000	#DIV/0!
D16	Proposed measures factor	0.6							
D17	Residual with proposed Pollution reduction measures	0.00000						0.0000	#DIV/0!

Groundwater Assessment for SWS11-006				
	Parameter	Weighting factor	SCORE	RESULTS
Source	Traffic Flow	10	1	10
	Rainfall depth (annual averages)	10	1	10
	Drainage area ratio	10	1	10
Pathway	Infiltration method	15	1	15
	Unsaturated zone	20	2	40
	Flow type	20	2	40
	Unsaturated zone clay content	5	2	10
	Organic carbon	5	2	10
	Unsaturated zone soil pH	5	2	10
TOTAL				155
RISK SCREENING LEVEL				MEDIUM

Method D - assessment of risk from accidental spillage		SWS11-006	Additional columns for use if other roads drain to the same outfall						
		A (main road)	B					**Totals**	**Return Period (years)**
D1	Water body type	Groundwater							
D2	Length of road draining to outfall *(m)*	112							
D3	Road Type *(A-road or Motorway)*	A							
D4	If A road, is site urban or rural?	Urban							
D5	Junction type	Side road							
D6	Location (response time for emergency services)	< 20 minutes							
D7	Traffic flow (AADT two way)	0							
D8	% HGV	1							
D8	Spillage factor *(no/10^9 HGVkm/year)*	1.81							
D9	Risk of accidental spillage	0.00000							
D10	Probability factor	0.45							
D11	Risk of pollution incident	0.00000							
D12	Is risk greater than 0.01?	**No**							
D13	Return period without pollution reduction measures	0.00000						0.0000	#DIV/0!
D14	Existing measures factor	1							
D15	Return period with existing pollution reduction measures	0.00000						0.0000	#DIV/0!
D16	Proposed measures factor	0.6							
D17	Residual with proposed Pollution reduction measures	0.00000						0.0000	#DIV/0!

Groundwater Assessment for SWS11-002A				
	Parameter	Weighting factor	SCORE	RESULTS
Source	Traffic Flow	10	1	10
	Rainfall depth (annual averages)	10	1	10
	Drainage area ratio	10	1	10
Pathway	Infiltration method	15	1	15
	Unsaturated zone	20	2	40
	Flow type	20	2	40
	Unsaturated zone clay content	5	1	5
	Organic carbon	5	2	10
	Unsaturated zone soil pH	5	2	10
TOTAL				150
RISK SCREENING LEVEL				MEDIUM

Method D - assessment of risk from accidental spillage		SWS11-002A	Additional columns for use if other roads drain to the same outfall						
		A (main road)	B	C	D	E	F	Totals	Return Period (years)
D1	Water body type	Groundwater	Groundwater						
D2	Length of road draining to outfall *(m)*	91	218						
D3	Road Type *(A-road or Motorway)*	A	A						
D4	If A road, is site urban or rural?	Urban	Urban						
D5	Junction type	Side road	Side road						
D6	Location (response time for emergency services)	< 20 minutes	< 20 minutes						
D7	Traffic flow (AADT two way)	24,961	24,961						
D8	% HGV	1	1						
D8	Spillage factor *(no/10^9 HGVkm/year)*	1.81	1.81						
D9	Risk of accidental spillage	0.00002	0.00004						
D10	Probability factor	0.45	0.45						
D11	Risk of pollution incident	0.00001	0.00002						
D12	Is risk greater than 0.01?	**No**	**No**						
D13	Return period without pollution reduction measures	0.00001	0.00002					0.0000	43611
D14	Existing measures factor	1	1						
D15	Return period with existing pollution reduction measures	0.00001	0.00002					0.0000	43611
D16	Proposed measures factor	0.6	0.6						
D17	Residual with proposed Pollution reduction measures	0.00000	0.00001					0.0000	72685

Groundwater Assessment for SWS11-008				
	Parameter	Weighting factor	SCORE	RESULTS
Source	Traffic Flow	10	1	10
	Rainfall depth (annual averages)	10	1	10
	Drainage area ratio	10	1	10
Pathway	Infiltration method	15	1	15
	Unsaturated zone	20	2	40
	Flow type	20	2	40
	Unsaturated zone clay content	5	1	5
	Organic carbon	5	2	10
	Unsaturated zone soil pH	5	2	10
TOTAL				150
RISK SCREENING LEVEL				MEDIUM

	Method D - assessment of risk from accidental spillage	SWS11-008	Additional columns for use if other roads drain to the same outfall						
		A (main road)	B	C	D	E	F	Totals	Return Period (years)
D1	Water body type	Groundwater							
D2	Length of road draining to outfall *(m)*	513							
D3	Road Type *(A-road or Motorway)*	A							
D4	If A road, is site urban or rural?	Rural							
D5	Junction type	Side road							
D6	Location (response time for emergency services)	< 20 minutes							
D7	Traffic flow (AADT two way)	0							
D8	% HGV	17							
D8	Spillage factor *(no/10^9 HGVkm/year)*	1.81							
D9	Risk of accidental spillage	0.00000							
D10	Probability factor	0.45							
D11	Risk of pollution incident	0.00000							
D12	Is risk greater than 0.01?	**No**							
D13	Return period without pollution reduction measures	0.00000						0.0000	#DIV/0!
D14	Existing measures factor	1							
D15	Return period with existing pollution reduction measures	0.00000						0.0000	#DIV/0!
D16	Proposed measures factor	0.6							
D17	Residual with proposed Pollution reduction measures	0.00000						0.0000	#DIV/0!

Groundwater Assessment for SWS11-013				
	Parameter	Weighting factor	SCORE	RESULTS
Source	Traffic Flow	10	1	10
	Rainfall depth (annual averages)	10	1	10
	Drainage area ratio	10	1	10
Pathway	Infiltration method	15	1	15
	Unsaturated zone	20	2	40
	Flow type	20	2	40
	Unsaturated zone clay content	5	1	5
	Organic carbon	5	2	10
	Unsaturated zone soil pH	5	2	10
TOTAL				150
RISK SCREENING LEVEL				MEDIUM

Method D - assessment of risk from accidental spillage		SWS11-013	Additional columns for use if other roads drain to the same outfall						
		A (main road)	B	C	D	E	F		
D1	Water body type	Groundwater							
D2	Length of road draining to outfall *(m)*	164							
D3	Road Type *(A-road or Motorway)*	A							
D4	If A road, is site urban or rural?	Rural							
D5	Junction type	No junction							
D6	Location (response time for emergency services)	< 20 minutes							
D7	Traffic flow (AADT two way)	0							
D8	% HGV	2							
D8	Spillage factor *(no/10^9 HGVkm/year)*	0.29							
D9	Risk of accidental spillage	0.00000							
D10	Probability factor	0.45							
D11	Risk of pollution incident	0.00000							
D12	Is risk greater than 0.01?	**No**						**Totals**	**Return Period (years)**
D13	Return period without pollution reduction measures	0.00000						0.0000	#DIV/0!
D14	Existing measures factor	1							
D15	Return period with existing pollution reduction measures	0.00000						0.0000	#DIV/0!
D16	Proposed measures factor	0.6							
D17	Residual with proposed Pollution reduction measures	0.00000						0.0000	#DIV/0!

Groundwater Assessment for SWS11-014				
	Parameter	Weighting factor	SCORE	RESULTS
Source	Traffic Flow	10	1	10
	Rainfall depth (annual averages)	10	1	10
	Drainage area ratio	10	1	10
Pathway	Infiltration method	15	1	15
	Unsaturated zone	20	2	40
	Flow type	20	2	40
	Unsaturated zone clay content	5	1	5
	Organic carbon	5	2	10
	Unsaturated zone soil pH	5	2	10
TOTAL				150
RISK SCREENING LEVEL				MEDIUM

Method D - assessment of risk from accidental spillage		SWS11-014	Additional columns for use if other roads drain to the same outfall						
		A (main road)	B	C	D	E	F	Totals	Return Period (years)
D1	Water body type	Groundwater							
D2	Length of road draining to outfall *(m)*	54							
D3	Road Type *(A-road or Motorway)*	A							
D4	If A road, is site urban or rural?	Rural							
D5	Junction type	No junction							
D6	Location (response time for emergency services)	< 20 minutes							
D7	Traffic flow (AADT two way)	0							
D8	% HGV	2							
D8	Spillage factor *(no/10^9 HGVkm/year)*	0.29							
D9	Risk of accidental spillage	0.00000							
D10	Probability factor	0.45							
D11	Risk of pollution incident	0.00000							
D12	Is risk greater than 0.01?	**No**							
D13	Return period without pollution reduction measures	0.00000						0.0000	#DIV/0!
D14	Existing measures factor	1							
D15	Return period with existing pollution reduction measures	0.00000						0.0000	#DIV/0!
D16	Proposed measures factor	0.6							
D17	Residual with proposed Pollution reduction measures	0.00000						0.0000	#DIV/0!

Groundwater Assessment for SWS11-015				
	Parameter	Weighting factor	SCORE	RESULTS
Source	Traffic Flow	10	1	10
	Rainfall depth (annual averages)	10	1	10
	Drainage area ratio	10	1	10
Pathway	Infiltration method	15	1	15
	Unsaturated zone	20	2	40
	Flow type	20	2	40
	Unsaturated zone clay content	5	1	5
	Organic carbon	5	2	10
	Unsaturated zone soil pH	5	2	10
TOTAL				150
RISK SCREENING LEVEL				MEDIUM

Method D - assessment of risk from accidental spillage		SWS11-015	Additional columns for use if other roads drain to the same outfall						
		A (main road)	B	C	D	E	F		
D1	Water body type	Groundwater							
D2	Length of road draining to outfall *(m)*	54							
D3	Road Type *(A-road or Motorway)*	A							
D4	If A road, is site urban or rural?	Rural							
D5	Junction type	No junction							
D6	Location (response time for emergency services)	< 20 minutes							
D7	Traffic flow (AADT two way)	0							
D8	% HGV	2							
D8	Spillage factor *(no/10^9 HGVkm/year)*	0.29							
D9	Risk of accidental spillage	0.00000							
D10	Probability factor	0.45							
D11	Risk of pollution incident	0.00000							**Return Period**
D12	Is risk greater than 0.01?	**No**						**Totals**	**(years)**
D13	Return period without pollution reduction measures	0.00000						0.0000	#DIV/0!
D14	Existing measures factor	1							
D15	Return period with existing pollution reduction measures	0.00000						0.0000	#DIV/0!
D16	Proposed measures factor	0.6							
D17	Residual with proposed Pollution reduction measures	0.00000						0.0000	#DIV/0!

Groundwater Assessment for SWS11-016				
	Parameter	Weighting factor	SCORE	RESULTS
Source	Traffic Flow	10	1	10
	Rainfall depth (annual averages)	10	1	10
	Drainage area ratio	10	1	10
Pathway	Infiltration method	15	1	15
	Unsaturated zone	20	2	40
	Flow type	20	2	40
	Unsaturated zone clay content	5	1	5
	Organic carbon	5	2	10
	Unsaturated zone soil pH	5	2	10
TOTAL				150
RISK SCREENING LEVEL				MEDIUM

Method D - assessment of risk from accidental spillage		SWS11-016	Additional columns for use if other roads drain to the same outfall						
		A (main road)	B	C	D	E	F		
D1	Water body type	Groundwater							
D2	Length of road draining to outfall *(m)*	101							
D3	Road Type *(A-road or Motorway)*	A							
D4	If A road, is site urban or rural?	Rural							
D5	Junction type	No junction							
D6	Location (response time for emergency services)	< 20 minutes							
D7	Traffic flow (AADT two way)	0							
D8	% HGV	2							
D8	Spillage factor *(no/10^9 HGVkm/year)*	0.29							
D9	Risk of accidental spillage	0.00000							
D10	Probability factor	0.45							
D11	Risk of pollution incident	0.00000							
D12	Is risk greater than 0.01?	**No**						**Totals**	**Return Period (years)**
D13	Return period without pollution reduction measures	0.00000						0.0000	#DIV/0!
D14	Existing measures factor	1							
D15	Return period with existing pollution reduction measures	0.00000						0.0000	#DIV/0!
D16	Proposed measures factor	0.6							
D17	Residual with proposed Pollution reduction measures	0.00000						0.0000	#DIV/0!

Groundwater Assessment for SWS11-002				
	Parameter	Weighting factor	SCORE	RESULTS
Source	Traffic Flow	10	1	10
	Rainfall depth (annual averages)	10	1	10
	Drainage area ratio	10	1	10
Pathway	Infiltration method	15	1	15
	Unsaturated zone	20	2	40
	Flow type	20	2	40
	Unsaturated zone clay content	5	3	15
	Organic carbon	5	2	10
	Unsaturated zone soil pH	5	2	10
TOTAL				160
RISK SCREENING LEVEL				MEDIUM

Method D - assessment of risk from accidental spillage		SWS11-002	Additional columns for use if other roads drain to the same outfall						
		A (main road)	B	C	D	E	F	Totals	Return Period (years)
D1	Water body type	Groundwater							
D2	Length of road draining to outfall *(m)*	52							
D3	Road Type *(A-road or Motorway)*	A							
D4	If A road, is site urban or rural?	Rural							
D5	Junction type	No junction							
D6	Location (response time for emergency services)	< 20 minutes							
D7	Traffic flow (AADT two way)	0							
D8	% HGV	0							
D8	Spillage factor *(no/10^9 HGVkm/year)*	0.29							
D9	Risk of accidental spillage	0.00000							
D10	Probability factor	0.45							
D11	Risk of pollution incident	0.00000							
D12	Is risk greater than 0.01?	**No**							
D13	Return period without pollution reduction measures	0.00000						0.0000	
D14	Existing measures factor	1							
D15	Return period with existing pollution reduction measures	0.00000						0.0000	
D16	Proposed measures factor	0.6							
D17	Residual with proposed Pollution reduction measures	0.00000						0.0000	

Groundwater Assessment for SWS12-004				
	Parameter	Weighting factor	SCORE	RESULTS
Source	Traffic Flow	10	1	10
	Rainfall depth (annual averages)	10	1	10
	Drainage area ratio	10	1	10
Pathway	Infiltration method	15	1	15
	Unsaturated zone	20	1	20
	Flow type	20	3	60
	Unsaturated zone clay content	5	1	5
	Organic carbon	5	1	5
	Unsaturated zone soil pH	5	2	10
TOTAL				145
RISK SCREENING LEVEL				LOW

Method D - assessment of risk from accidental spillage		SWS12-004	Additional columns for use if other roads drain to the same outfall						
		A (main road)	B	C	D	E	F	**Totals**	**Return Period (years)**
D1	Water body type	Groundwater							
D2	Length of road draining to outfall *(m)*	173							
D3	Road Type *(A-road or Motorway)*	A							
D4	If A road, is site urban or rural?	Rural							
D5	Junction type	No junction							
D6	Location (response time for emergency services)	< 20 minutes							
D7	Traffic flow (AADT two way)	0							
D8	% HGV	3							
D8	Spillage factor *(no/10^9 HGVkm/year)*	0.29							
D9	Risk of accidental spillage	0.00000							
D10	Probability factor	0.45							
D11	Risk of pollution incident	0.00000							
D12	Is risk greater than 0.01?	**No**							
D13	Return period without pollution reduction measures	0.00000						0.0000	#DIV/0!
D14	Existing measures factor	1							
D15	Return period with existing pollution reduction measures	0.00000						0.0000	#DIV/0!
D16	Proposed measures factor	0.6							
D17	Residual with proposed Pollution reduction measures	0.00000						0.0000	#DIV/0!

Groundwater Assessment for SWS12-005				
	Parameter	Weighting factor	SCORE	RESULTS
Source	Traffic Flow	10	1	10
	Rainfall depth (annual averages)	10	1	10
	Drainage area ratio	10	1	10
Pathway	Infiltration method	15	1	15
	Unsaturated zone	20	1	20
	Flow type	20	2	40
	Unsaturated zone clay content	5	1	5
	Organic carbon	5	1	5
	Unsaturated zone soil pH	5	2	10
TOTAL				125
RISK SCREENING LEVEL				LOW

	Method D - assessment of risk from accidental spillage	SWS12-005	Additional columns for use if other roads drain to the same outfall						
		A (main road)	B	C	D	E	F	Totals	Return Period (years)
D1	Water body type	Groundwater							
D2	Length of road draining to outfall *(m)*	106							
D3	Road Type *(A-road or Motorway)*	A							
D4	If A road, is site urban or rural?	Rural							
D5	Junction type	No junction							
D6	Location (response time for emergency services)	< 20 minutes							
D7	Traffic flow (AADT two way)	0							
D8	% HGV	3							
D8	Spillage factor *(no/10^9 HGVkm/year)*	0.29							
D9	Risk of accidental spillage	0.00000							
D10	Probability factor	0.45							
D11	Risk of pollution incident	0.00000							
D12	Is risk greater than 0.01?	**No**							
D13	Return period without pollution reduction measures	0.00000						0.0000	#DIV/0!
D14	Existing measures factor	1							
D15	Return period with existing pollution reduction measures	0.00000						0.0000	#DIV/0!
D16	Proposed measures factor	0.6							
D17	Residual with proposed Pollution reduction measures	0.00000						0.0000	#DIV/0!

Groundwater Assessment for SWS12-006				
	Parameter	Weighting factor	SCORE	RESULTS
Source	Traffic Flow	10	1	10
	Rainfall depth (annual averages)	10	1	10
	Drainage area ratio	10	1	10
Pathway	Infiltration method	15	1	15
	Unsaturated zone	20	1	20
	Flow type	20	3	60
	Unsaturated zone clay content	5	1	5
	Organic carbon	5	1	5
	Unsaturated zone soil pH	5	2	10
TOTAL				145
RISK SCREENING LEVEL				LOW

Method D - assessment of risk from accidental spillage		SWS12-006	Additional columns for use if other roads drain to the same outfall						
		A (main road)	B	C	D	E	F	Totals	Return Period (years)
D1	Water body type	Groundwater							
D2	Length of road draining to outfall *(m)*	142							
D3	Road Type *(A-road or Motorway)*	A							
D4	If A road, is site urban or rural?	Rural							
D5	Junction type	No junction							
D6	Location (response time for emergency services)	< 20 minutes							
D7	Traffic flow (AADT two way)	0							
D8	% HGV	3							
D8	Spillage factor *(no/10^9 HGVkm/year)*	0.29							
D9	Risk of accidental spillage	0.00000							
D10	Probability factor	0.45							
D11	Risk of pollution incident	0.00000							
D12	Is risk greater than 0.01?	**No**							
D13	Return period without pollution reduction measures	0.00000						0.0000	#DIV/0!
D14	Existing measures factor	1							
D15	Return period with existing pollution reduction measures	0.00000						0.0000	#DIV/0!
D16	Proposed measures factor	0.6							
D17	Residual with proposed Pollution reduction measures	0.00000						0.0000	#DIV/0!

Groundwater Assessment for SWS12-007				
	Parameter	Weighting factor	SCORE	RESULTS
Source	Traffic Flow	10	1	10
	Rainfall depth (annual averages)	10	1	10
	Drainage area ratio	10	1	10
Pathway	Infiltration method	15	1	15
	Unsaturated zone	20	1	20
	Flow type	20	2	40
	Unsaturated zone clay content	5	1	5
	Organic carbon	5	1	5
	Unsaturated zone soil pH	5	2	10
TOTAL				125
RISK SCREENING LEVEL				LOW

Method D - assessment of risk from accidental spillage		SWS12-007	Additional columns for use if other roads drain to the same outfall						
		A (main road)	B	C	D	E	F	Totals	Return Period (years)
D1	Water body type	Groundwater							
D2	Length of road draining to outfall *(m)*	100							
D3	Road Type *(A-road or Motorway)*	A							
D4	If A road, is site urban or rural?	Rural							
D5	Junction type	No junction							
D6	Location (response time for emergency services)	< 20 minutes							
D7	Traffic flow (AADT two way)	0							
D8	% HGV	3							
D8	Spillage factor *(no/10^9 HGVkm/year)*	0.29							
D9	Risk of accidental spillage	0.00000							
D10	Probability factor	0.45							
D11	Risk of pollution incident	0.00000							
D12	Is risk greater than 0.01?	**No**							
D13	Return period without pollution reduction measures	0.00000						0.0000	#DIV/0!
D14	Existing measures factor	1							
D15	Return period with existing pollution reduction measures	0.00000						0.0000	#DIV/0!
D16	Proposed measures factor	0.6							
D17	Residual with proposed Pollution reduction measures	0.00000						0.0000	#DIV/0!

Annex P Groundwater Dependent Terrestrial Ecosystems assessment

Annex P Groundwater Dependent Terrestrial Ecosystem Assessment

1.1.1 The Water Framework Directive (WFD) defines a Groundwater Dependent Terrestrial Ecosystem (GWDTE) as a wetland that is directly dependent on groundwater bodies (Environment Agency, 2014). More specifically, they are wetlands which critically depend on groundwater flows and/or chemistries (WG-C; Schutten *et al*., 2011 shown in UK Technical Advisory Group (UKTAG) (2014)). The WFD includes all wetlands that are GWDTEs and not just designated sites (e.g. Sites of Special Scientific Interest (SSSIs)); nor is there a minimum defined size (Environment Agency, 2014). Where springs feed a permanent lake or river system these do not qualify as GWDTEs but as aquatic ecosystems (European Communities, 2012).

1.1.2 Design Manual for Roads and Bridges (DMRB) LA 113 (Highways England, 2020a) lists five steps in the methodology for assessing the impact of a Project on GWDTEs. These are identification of potential linkages, identification of GWDTE importance, assessment of potential impacts, establishing risk to the GWDTE and, finally, where necessary, identification of robust mitigation measures.

1.1.3 The first four steps comprise a simple assessment, as defined by DMRB LA 113 as one relying on readily available information to reach an understanding of the likely environmental effects of a project. Risk to a GWDTE is assessed using a matrix shown in DMRB LA 113 Table B.4 and which is reproduced in Chapter 14: Road Drainage and the Water Environment (Application Document 6.1). When the simple assessment identifies that there is a significant risk to a GWDTE, a more detailed assessment and step 5 is triggered.

1.1.4 Potential GWDTEs within a 3km study area from the Order Limits have been identified and assigned importance using vegetation mapping, in line with DMRB LA 113 (Highways England, 2020a). Details of vegetation mapping are shown in Appendix 8.2: Plants and Habitats (Application Document 6.3). All vegetation mapping has been screened to check for groundwater dependency, and only those sites that showed potential groundwater dependency are discussed in this annex. Where no vegetation mapping is available, published information has been used including the Environment Agency (2020) mapping of GWDTEs (SSSIs) (Plate 3.2 in Section 3.9 of Appendix 14.5: Hydrogeological Risk Assessment (Application Document 6.3)) and citations of non-SSSIs. The assessment of citations of non-SSSIs has been targeted in the area of the proposed cutting near the A122 Lower Thames Crossing/M25 junction.

Project vegetation surveys

1.1.5 In compliance with the methodology set out in DMRB LA 113 Appendix B (Highways England, 2020a), data from National Vegetation Classification (NVC) surveys and Phase 1 habitat survey data (Application Document 6.1, Chapter 8: Terrestrial Biodiversity) were screened to confirm whether any of the plant communities recorded within 50m of the Order Limits are indictive of groundwater dependency (Application Document 6.3, Appendix 8.2: Plants and Habitats) and therefore indicate the presence of a potential GWDTE.

1.1.6 Due to land access restrictions, Phase 1 habitat survey was carried out from Public Rights of Way at Cranham Marsh Local Nature Reserve (LNR), with the exception of Bonus Wood where there is no public access.

1.1.7 The locations of all the potential GWDTEs identified are presented in Figure 14.2: Groundwater Receptors and Resources (Application Document 6.2).

Project Phase 1 habitat surveys/UKTAG Wetland Task Team (WTT)

1.1.8 Table 1.1 shows sites which have been screened for the presence of any of the UKTAG WTT habitats, detailed in DMRB LA 113 (Highways England, 2020a). Target note numbers shown cross-reference with detailed survey information presented in Appendix 8.2: Plants and Habitats (Application Document 6.3).

Table 1.1 Groundwater dependence using UKTAG habitat categories

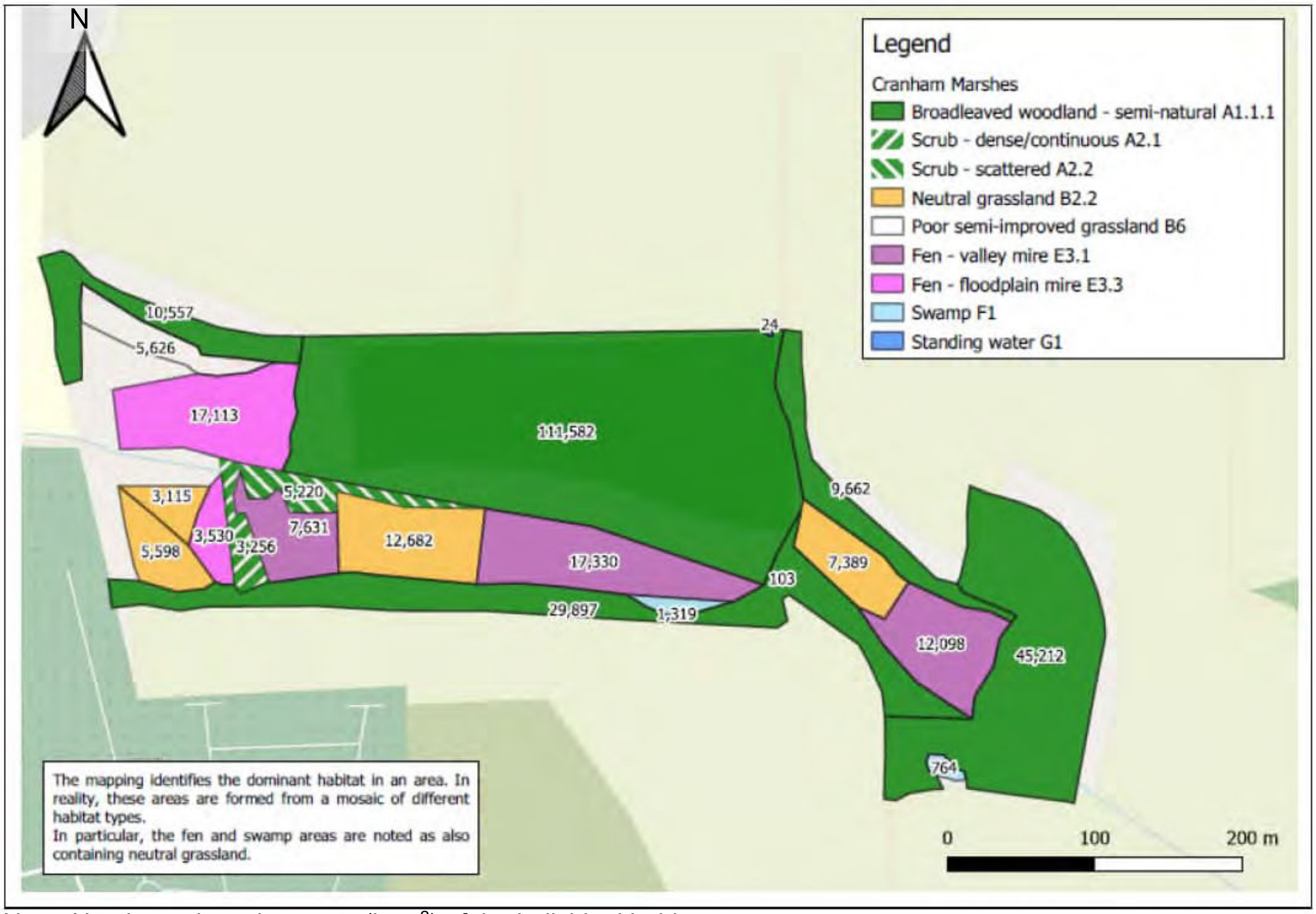
UKTAG WTT broad categories (UKTAG, 2014)	Project assessed occurrence (target note (TN) number)
Quaking bog	None
Wet dune	None
Fen (mesotrophic)	Yes (fen (valley mire) habitat identified from Phase 1 habitat survey used as an equivalent) and found at the following: • Three locations at Cranham Marsh LNR (Plate 1.1). Phase 1 habitat type E3.1.
Fen (oligotrophic)	None
Wet grassland (B5 marshy grassland from Phase 1 habitat survey used as an equivalent)	Yes, B5 found at the following: • Filborough Marsh, one ditch on the Ramsar western boundary (TN059) • Low Street Pit (TN139) • North Ockendon Pit Site of Importance for Nature Conservation (SINC) –small areas (TN141) • M25 motorway drainage attenuation basin (TN140)
Wet heath	None
Peat bog and woodland on peat bog	None
Wetland directly irrigated by spring or seepage	None
Swamp (mesotrophic) and reed bed	Yes (F1 from Phase 1 habitat survey used as an equivalent) and found at the following: • Pond/attenuation basin at Jeskyns Country Park car park (TN063)
Swamp (oligotrophic)	

UKTAG WTT broad categories (UKTAG, 2014)	Project assessed occurrence (target note (TN) number)
	• Denton New Cut main river (part) – two locations (of which the target number of TN064 has been given to one of the locations) • Mucking Flats SSSI – wide area (TN145) • Cooper Shaw Road, Tilbury – small areas (TN144) • Ditch on west border of Goshems Farm Landfill (TN143) • Main river near Tilbury Fort (TN142) • Gabions Sewer and pond near Linford (TN146) • North Ockendon Pit SINC – small areas (TN147) • Small locations in the Thames Chase area and two M25 motorway drainage attenuation basins (all are target note TN148) • One small area of Cranham Marsh LNR (common reed)
Wet woodland	None

Cranham Marsh LNR

1.1.9 Project Phase 1 habitat survey information for Cranham Marsh LNR is detailed below. Due to land access restrictions (paragraph 1.1.6), Bonus Wood was not accessed. However, bluebell woods are a feature of Bonus Wood (Natural England, 2020) which indicates that Bonus Wood is generally well drained and unlikely to be a wetland. Figure 14.2 (Application Document 6.2) shows the location of Cranham LNR. Plate 1.1 presents the Phase 1 habitat areas mapped at the end of May 2020 for the Project. The dominant habitats in each area are shown only and further notes are shown on the plate.

Plate 1.1 Project Phase 1 habitat vegetation survey of Cranham Marsh LNR (except Bonus Wood area)



Note: Numbers show the areas (in m^2) of the individual habitat areas

1.1.10 Within the fen (valley mire) habitat, the survey identified three species comprising common sedge *Carex nigra*, betony *Stachys officinalis* and common knapweed *Centaurea nigra*. However, other species could not be identified due to access restrictions.

Project NVC surveys

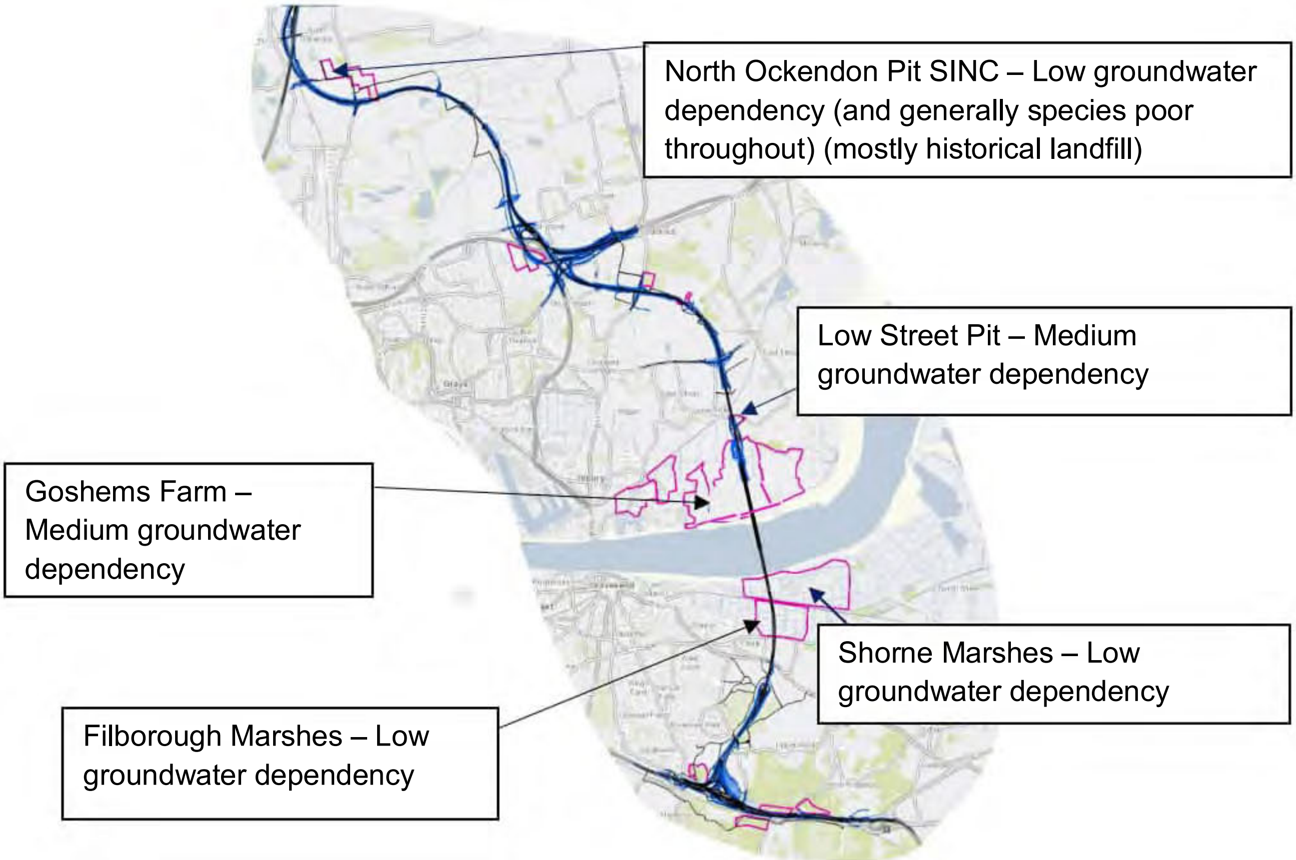
1.1.11 DMRB LA 113 (Highways England, 2020a) directs the use of UKTAG-listed NVC plant communities together with a groundwater dependency score that uses a scale of low, medium and high. A score of 3 means low groundwater dependency, 2 means medium and 1 means high groundwater dependency. Communities not listed are assumed not groundwater dependent. Table 1.2 summarises the GWDTEs identified through NVC surveys.

Table 1.2 Identified potential GWDTEs (NVC)

Location	Groundwater dependency score
Filborough Marshes	3 (low)
Shorne Mashes	3 (low)
Goshems Farm Landfill	2 (medium)
Low Street Pit	2 (medium)
North Ockendon Pit SINC	3 (low)

1.1.12 Plate 1.2 shows the Project's NVC survey areas.

Plate 1.2 Project NVC surveyed areas and groundwater dependency based on plant communities



1.1.13 NVC surveys were conducted at Hall Farm moat, paddock, and St Mary Magdalene Churchyard SINC and Thames Chase Forest Centre SINC on the 25 and 26 April 2022. Both sites contained small and very discreet areas (less than 2m by 2m areas) of fen (swamp and mire) marginal habitat, however both sites were generally species poor. It is noted that fen (swamp and mire) habitats are indicative of low groundwater dependency (groundwater dependency score of 3) (UKTAG, 2004). Hall Farm moat, paddock, and St Mary Magdalene Churchyard SINC is characterised by permanent ponds, rather than wetland and therefore is not a GWDTE (Environment Agency, 2014). Thames Chase Forest Centre SINC key area of interest for groundwater is Hobbs Hole (a pond), due to historical mapping of it as a spring (Section 3.6). Again, because it is a permanent pond, it is not a GWDTE and therefore has not been assessed as a GWDTE. Of secondary interest is a mapped watercourse orientated northwards from the pond but the watercourse was dry when surveyed (also it has been verbally reported as dry, by Project ecologists, during monthly bird surveys conducted for one year at the site). Details of the NVC surveys are presented in Appendix 8.2: Plants and Habitats(Application Document 6.3).

Sites of Importance for Nature Conservation

1.1.14 London Borough of Havering Sites of Importance for Nature Conservation (SINCs) are based on an ecological data search of information held by Greenspace Information for Greater London CIC and reported on by eCountability Ltd (2020). A desk study review of the published citations, contained within the data search report, identified some habitats indicative of groundwater dependency at seven SINCs located north of the River Thames near the M25. Two of these sites, North Ockendon Pit SINC and Thames Chase Forest Centre SINC, have been assessed previously using the Phase 1 habitat surveys (Table 1.1). Hall Farm moat, paddock, and St Mary Magdalene Churchyard SINC (HVBII25) is not a GWDTE since the water interest is an open water body and therefore is not assessed further in this annex. However the results of the NVC survey are discussed in the above paragraph. A summary of the habitats using the UKTAG categories is presented in Table 1.3.

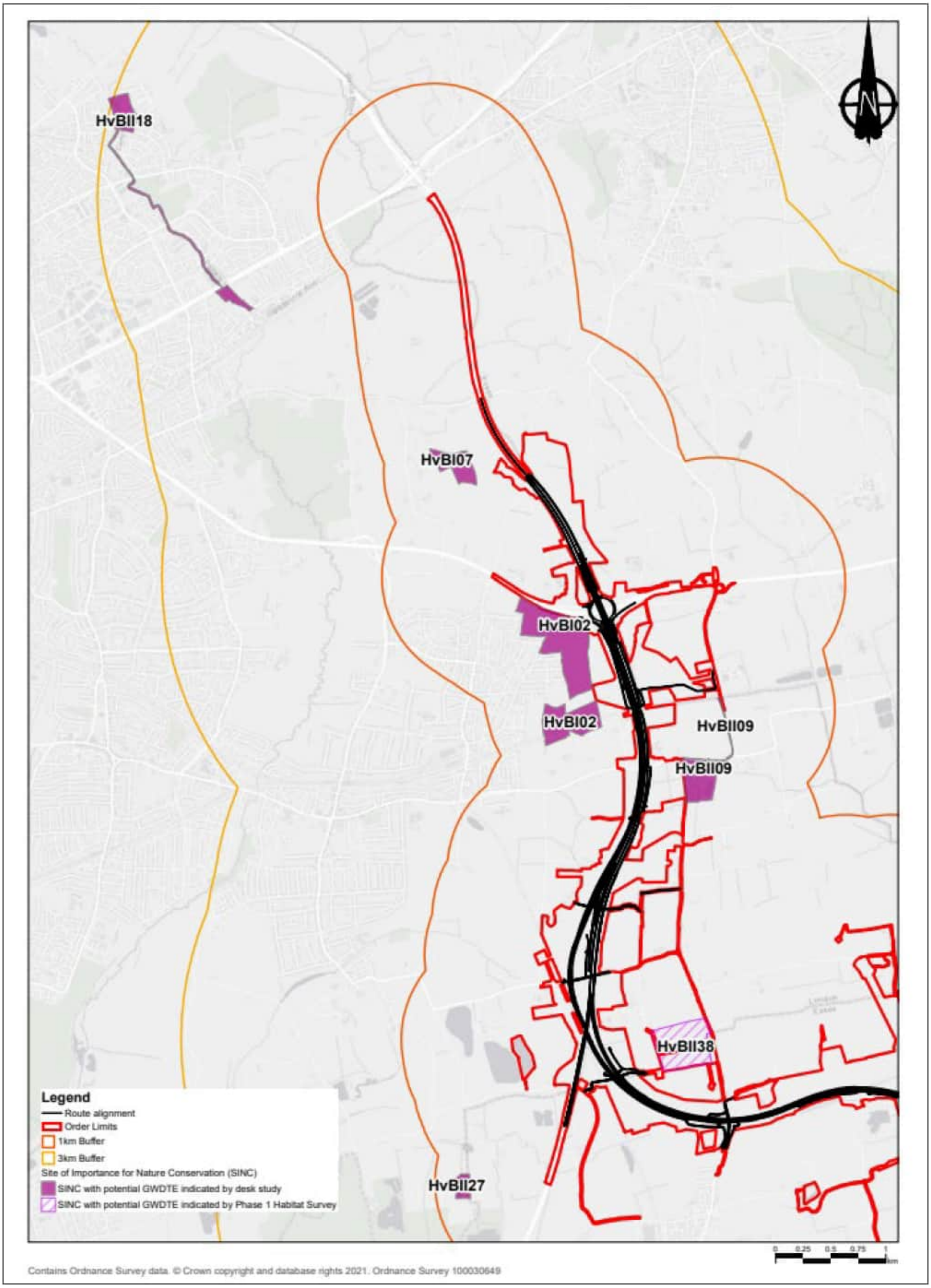
Table 1.3 Groundwater dependence of SINC sites using UKTAG habitat categories

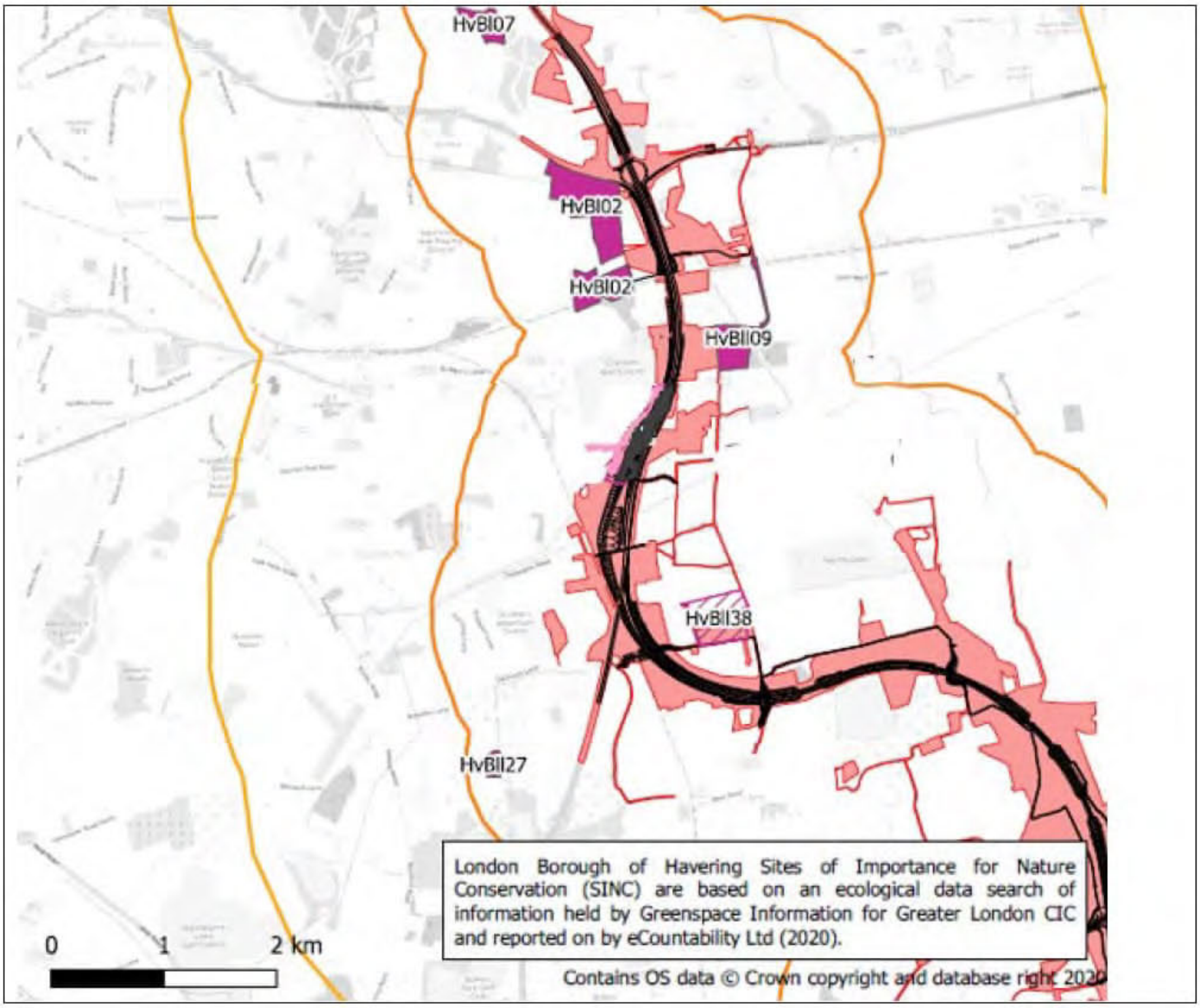
UKTAG WTT broad categories (UKTAG, 2014)	Project assessed occurrence (from a desk study review of citations)
Quaking bog	None
Wet dune	None
Fen (mesotrophic)	None
Fen (oligotrophic)	None
Wet grassland (B5 marshy grassland from Phase 1 habit survey used as an equivalent)	Yes, desk study shows the habitat is found at the following: • North Ockendon Pit SINC (HvBII38) • Puddle Dock Angling Centre SINC (HvBII09) • Franks Wood and Cranham Brickfields SINC (HvBI02) • Tomkyns East Pastures SINC (HvBI07) • Carter's Brook and Paine's Brook SINC (HvBII18)
Wet heath	None
Peat bog and woodland on peat bog	None
Wetland directly irrigated by spring or seepage	None
Swamp (mesotrophic) and reed bed	The desk study did not identify swamp as a habitat.
Swamp (oligotrophic)	
Wet woodland	Yes, desk study shows the habitat is found at the following: • Redlands Angling Centre SINC (HvBII27)

Note: SINC reference numbers shown in the eCountability 2020 reference are reproduced in the above table.

1.1.15 The locations of the SINC sites, including those which show potential groundwater dependency, are shown in Plate 1.3.

Plate 1.3 SINC sites and groundwater dependency based on desk study review of citations





Simple assessment of GWDTEs

1.1.16 The simple assessment of environmental impacts on the identified potential GWDTEs is presented in Table 1.4. The assessment has followed the methodology set out in Tables B.1, B.2 and B.3 of DMRB LA 113 (Highways England, 2020a). Commentary is included, where specific information suggests that a site may not be groundwater dependent.

1.1.17 Section 8 of Appendix 14.5 (Application Document 6.3) and Chapter 14: Road Drainage and the Water Environment (Application Document 6.1) present a discussion of the results of the simple assessment.

Table 1.4 Simple assessment of risk of impact to identified potential GWDTEs (NVC and UKTAG WTT)

Location (data source)	Importance (with respect to GWDTEs)	Magnitude of impact	Risk
South of the River Thames			
Pond/attenuation basin at **Jeskyns Country Park car park** (UKTAG WTT habitat area based on Phase 1 habitat survey)	Scale of biodiversity: Local. Site designated for protection at national or regional level: No. Habitats recognised as intact or unique or areas recognised by non-governmental organisations as having high environmental value: No. Difficult for habit to recover following disturbance: No, as the habitat can recover quickly. The habitat is suffering significant decline at national or regional level: No. Habitat of high species number or habitat diversity or "naturalness": No. **LOW IMPORTANCE**	Change in discharge groundwater via springs and seepages: Negligible. Change in groundwater flow or flux through GWDTE: Negligible. Change in water level beneath the GWDTE: Negligible. Change in upward hydraulic gradient and/or flow from a deeper groundwater body to the near surface deposits: Negligible. Change to nutrient loading to GWDTE: Negligible. Change in quantities of potentially toxic chemicals derived from road runoff and drainage: Negligible. **NEGLIGIBLE**	Low importance x negligible magnitude = **NEGLIGIBLE RISK**
Filborough Marshes (NVC surveyed area)	Species are protected or listed: Yes, e.g. marsh ragwort *Senecio aquaticus* (Red List). Species are scarce or rare: Yes, Nationally Scarce species (e.g. sharp rush *Juncus acutus*). Species are crucial for GWDTE functions, such as predator/prey species. Species are host flora for protected or listed species: Not relevant – see below assessment. NVC groundwater dependence score: 3 (low). Other information: • The marginal/bankside vegetation comprised of S18 and S4 communities; both have a groundwater dependency score of 3 (low). The aquatic vegetation present within the ditches comprised aquatic communities (A1, A2, A5 and A6) and none of these show dependencies on groundwater (Application Document 6.3, Appendix 8.2: Plants and Habitats). • Project ground investigation monitored water levels and ground conditions (Sections 3 and 4 of Appendix 14.5), the Ramsar water balance assessment (Annex D of Appendix 14.5) and the Ramsar conceptual site model (Figure 4 of Appendix 14.5) indicate generally negligible groundwater inflow to Filborough Marshes within the Order Limits. These data and assessments demonstrate that Filborough Marshes is not a GWDTE, at least within the Order Limits. • Environment Agency published mapping shows no GWDTE at this location (Environment Agency, 2020b). Considering the low or no groundwater dependency score of the vegetation as a key factor, supported by the above water balance study and data, then the designated site is: **ASSESSED AS NOT A GWDTE**	Change in discharge groundwater via springs and seepages or groundwater flow or flux through a GWDTE: Negligible change of Chalk aquifer water level at southern boundary, due to ground improvement tunnel and shafts, i.e. Negligible. Change in water level beneath the GWDTE: Minor change in underlying Chalk aquifer which would result in negligible change to water levels in the Ramsar shallow water system, i.e. Negligible. Change in upward hydraulic gradient and/or flow from a deeper groundwater body to the near surface deposits: No dewatering proposed for shafts, tunnel portal or cross-passages so no large groundwater drawdown is expected. Upwards flow assessed as proportionally small in the Ramsar water balance as the piezometric levels of underlying Chalk aquifer and shallow and often slightly lower than Alluvium water levels, i.e. Negligible. Change to nutrient loading to GWDTE: No change as no Project sewage soakaways are proposed which could increase nitrogen or phosphorus loading via groundwater (note: there is an existing domestic sewage discharge to ground consent in Filborough Marshes), i.e. Negligible. Change in quantities of potentially toxic chemicals derived from road runoff and drainage: Highway runoff would be discharged to infiltration basins which would be fitted with treatment systems as identified in Annex A, Negligible. **ASSESSED AS NOT A GWDTE (magnitude of impacts discussed for completeness only**)	**ASSESSED AS NOT A GWDTE**
Shorne Marshes (NVC surveyed area)	Species are protected or listed: Yes, Red List species (e.g. frogbit *Hydrocharis morsus-ranae*, common sea-lavender *Limonium vulgare*, parsley water-dropwort *Oenanthe lachenalia*, lesser spearwort *Ranunculus flammula* and marsh ragwort *Senecio aquaticus*). Species are scarce or rare: Yes, Nationally Scarce species (e.g. golden-samphire *Inula crithmoides* and sharp rush *Juncus acutus*)	Change in discharge groundwater via springs and seepages or groundwater flow or flux through a GWDTE: No measurable change in groundwater levels and flows, i.e. Negligible. Change in water level beneath the GWDTE: Negligible change in underlying Chalk aquifer and, further, likely not to be measurable due to proximity to the River Thames and managed shallow water level at the RSPB Reserve, i.e. Negligible.	**ASSESSED AS NOT A GWDTE**

Location (data source)	Importance (with respect to GWDTEs)	Magnitude of impact	Risk
	Species are crucial for GWDTE functions, such as predator/prey species. Species are host flora for protected or listed species: Not relevant – see below assessment. NVC groundwater dependence score: 3 (low). Other information: • The emergent, bankside and pond vegetation communities were generally listed as having a groundwater dependency score of 3 (low groundwater dependency). • The aquatic vegetation present within the ditches comprised aquatic communities which showed no dependency on groundwater (Application Document 6.3, Appendix 8.2: Plants and Habitats). • Main water supply comprises surface water pumping of water into Shorne Marshes (Royal Society for the Protection of Birds (RSPB), 2018 and Appendix 14.2 (Application Document 6.3)). • Environment Agency published mapping shows no GWDTE at this location (Environment Agency, 2020b). Considering the low or no groundwater dependency score of the vegetation as a key factor, supported by the above bullet points, then the site is: **ASSESSED AS NOT A GWDTE**	Change in upward hydraulic gradient and/or flow from a deeper groundwater body to the near surface deposits: No dewatering proposed. Baseline upwards flow is expected to be negligible because the Alluvium is of very low permeability (particularly in the vertical direction) for Shorne Marshes i.e. Negligible. Change to nutrient loading to GWDTE: No change as no Project sewage soakaways are proposed which could increase nitrogen or phosphorus loading via groundwater. (Note: there is an existing sewage discharge consent to surface water from the Apex Business Park which is 450m from a main river culvert that flows northwards to Shorne Marshes). Negligible. Change in quantities of potentially toxic chemicals derived from road runoff and drainage: Highway runoff would be discharged to infiltration basins which would be fitted with treatment systems as identified in Annex A. Assessment of infiltration basin operation shows negligible impact (Annex M). Negligible. **ASSESSED AS NOT A GWDTE** **(magnitude of impacts discussed for completeness only)**	
Filborough Marshes, ditch (UKTAG WTT habitat area – wet grassland based on Phase 1 habitat survey)	Scale of biodiversity: International. Site designated for protection at national or regional level: Yes. Habitats recognised as intact or unique or areas recognised by non-governmental organisations as having high environmental value: Yes. Difficult for habit to recover following disturbance: Yes, habitats are unlikely to return to natural conditions without some intervention, but are capable of assisted recovery. Habitat is suffering significant decline at national or regional level: No. Habitat is of high species number or habitat diversity or “naturalness”: No. **ASSESSED AS NOT A GWDTE** **(reasons are listed in Filborough Marshes NVC row)**	Change in discharge groundwater via springs and seepages or groundwater flow or flux through a GWDTE: See **Filborough Marshes NVC row**. Change in water level beneath the GWDTE: See **Filborough Marshes NVC row**. Change in upward hydraulic gradient and/or flow from a deeper groundwater body to the near surface deposits: See **Filborough Marshes NVC row**. Change to nutrient loading to GWDTE: See **Filborough Marshes NVC row**. Change in quantities of potentially toxic chemicals derived from road runoff and drainage: Negligible as detailed assessment in Annex M. Also see **Filborough Marshes NVC row**. **ASSESSED AS NOT A GWDTE** **(magnitude of impacts discussed for completeness only**)	**ASSESSED AS NOT A GWDTE**
Swamp habitat at Denton New Cut (part) – two small locations at the downstream end (of which one has a target number of TN064) (UKTAG WTT habitat area based on Phase 1 habitat survey) (within a Local Wildlife Site)	Scale of biodiversity: Local. Site designated for protection at national or regional level: No. Habitats are recognised as intact or unique or areas recognised by non-governmental organisations as having high environmental value: Yes. Difficult for habit to recover following disturbance: No, as would recover quickly following disturbance. Habitat is suffering significant decline at national or regional level: No. Habitat is of high species number or habitat diversity or “naturalness”: No. Other information: • Swamp habitat is shown as being of low groundwater dependency (Environment Agency, 2014). • Denton New Cut is a main river (part of a permanent river system) and therefore is not a wetland (European Communities, 2012).	Change in discharge groundwater via springs and seepages, groundwater flow or flux through GWDTE: Negligible. Change in water level beneath the GWDTE: Negligible. Change in upward hydraulic gradient and/or flow from a deeper groundwater body to the near surface deposits: Negligible. Change to nutrient loading to GWDTE: Project construction phase discharge water would not include sewage related water. Further information is presented in Chapter 14: Road Drainage and the Water Environment (Application Document 6.1). Change in quantities of potentially toxic chemicals derived from road runoff and drainage: Project construction phase discharge water would be of clean water. Further information is presented in Chapter 14: Road Drainage and the Water Environment (Application Document 6.1).	**ASSESSED AS NOT A GWDTE**

Location (data source)	Importance (with respect to GWDTEs)	Magnitude of impact	Risk
	Considering the above then the site is: **ASSESSED AS NOT A GWDTE**	**ASSESSED AS NOT A GWDTE (see second column)** **(magnitude of impacts discussed for completeness only)**	
North of the River Thames			
Swamp habitat at Mucking Flats SSSI – wide area (TN144) (UKTAG WTT habitat area based on Phase 1 habitat survey) (SSSI)	Scale of biodiversity: National. Site designated for protection at national or regional level: Yes. Habitats are recognised as intact or unique or areas recognised by non-governmental organisations as having high environmental value: Yes. Difficult for habit to recover following disturbance: Yes, habitats are unlikely to return to natural conditions without some intervention but are capable of assisted recovery. Habitat is suffering significant decline at national or regional level: Yes. Habitat of high species number or habitat diversity or “naturalness”: Yes. Other information: • Swamp habitat is shown as being of low groundwater dependency (Environment Agency, 2014). • The SSSI is located immediately beside the River Thames and so is likely to be influenced by river water. • Environment Agency published mapping shows no GWDTE at this location (Environment Agency, 2020b). Considering the above bullet points then the site is: **ASSESSED AS NOT A GWDTE**	Change in discharge groundwater via springs and seepages or groundwater flow or flux through GWDTE: Negligible as there would be no significant change of groundwater levels. Change in water level beneath the GWDTE: No changes are anticipated in the Alluvium soils. Change in upward hydraulic gradient and/or flow from a deeper groundwater body to the near surface deposits: Negligible as no significant change of groundwater levels, especially because of nearby River Thames and distance to Project construction works. Change to nutrient loading to GWDTE: Negligible as no sewage outfalls. Change in quantities of potentially toxic chemicals derived from road runoff and drainage: Highway drainage as described in Chapter 14: Road Drainage and the Water Environment (Application Document 6.1). **ASSESSED AS NOT A GWDTE** **(magnitude of impacts discussed for completeness only)**	**ASSESSED AS NOT A GWDTE**
Low Street Pit (TN139) (NVC surveyed area) (and UKTAG WTT habitat area based on Phase 1 habitat survey)	NVC groundwater dependence score: 2 (moderate). Note: Mitigation is proposed for habitat loss since Low Street Pit would be partly lost due to construction of the Project. The proposed mitigation, including alternative provision of habitat, is assessed in Chapter 8: Terrestrial Biodiversity and is not discussed further in Chapter 14: Road Drainage and the Water Environment (Application Document 6.1), which this report supports.	Site is not discussed further in this report (see column 2).	Not assessed (see column 2)
Swamp habitats at Cooper Shaw Road, Tilbury (UKTAG WTT habitat area based on Phase 1 habitat survey)	Scale of biodiversity: Local. Site designated for protection at national or regional level: No. Habitats are recognised as intact or unique or areas recognised by non-governmental organisations as having high environmental value: No. Difficult for habit to recover following disturbance: No, as would recover quickly following disturbance. Habitat is suffering significant decline at national or regional level: No. Habitat of high species number or habitat diversity or “naturalness”: No. Other information: • Swamp habitat is shown as being of low groundwater dependency (Environment Agency, 2014). Considering the above then the site with respect to a GWDTE assessment, is assessed as: **LOW IMPORTANCE**	Change in discharge groundwater via springs and seepages or groundwater flow or flux through GWDTE: Negligible as there would be no significant change of groundwater levels. Change in water level beneath the GWDTE. Not significant in terms of likely local water balance. Change in upward hydraulic gradient and/or flow from a deeper groundwater body to the near surface deposits: Likely to be negligible as site is underlain by Alluvium, expected to be of low hydraulic conductivity and nearby surface water is likely to dominate the water balance. Change to nutrient loading to GWDTE: Negligible as location is distant from proposed Project construction works (350m to the nearest point and on the other side of the Tilbury Loop railway line). Change in quantities of potentially toxic chemicals derived from road runoff and drainage: Cooper Shaw Road is within the Order Limits. However, there are no proposals for a road drainage outfall here, so negligible magnitude. **NEGLIGIBLE**	Low importance x negligible magnitude = **NEGLIGIBLE RISK**

Location (data source)	Importance (with respect to GWDTEs)	Magnitude of impact	Risk
Goshems Farm Landfill (NVC)	Species are protected or listed: No wetland species. Species are scarce or rare: Not relevant. Species are crucial for GWDTE functions, such as predator/prey species: Not relevant. Species are host flora for protected or listed species: Not relevant. NVC groundwater dependence score: 2 (moderate). Note: Ingrebourne Valley Ltd own the site and are currently filling the area. Therefore, the ecology assessment to assess the importance of the area would need to be done after proposed landscaping is finished in order to assess the baseline before the proposed Project works. The Project would cause the direct physical loss of part of Goshems Farm Landfill Local Wildlife Site. This site is assessed in Chapter 8: Terrestrial Biodiversity (Application Document 6.1) and, therefore, is not discussed further in this report.	Site is not discussed further in this report (see column 2).	Not assessed (see column 2)
Swamp habitat in ditch on west border of Goshems Farm Landfill (TN143) (UKTAG WTT habitat area based on Phase 1 habitat survey)	This site is assessed in Chapter 8: Terrestrial Biodiversity (Application Document 6.1) and, therefore, is not discussed further in this report.	Site is not discussed further in this report (see column 2).	Not assessed (see column 2)
Swamp habitat in main river near Tilbury Fort (TN142) (UKTAG WTT habitat area based on Phase 1 habitat survey)	Scale of biodiversity: Local. Site designated for protection at national or regional level: No. Habitats recognised as intact or unique or areas recognised by non-governmental organisations as having high environmental value: Yes. Difficult for habit to recover following disturbance: No, as would recover quickly following disturbance. Habitat that is suffering significant decline at national or regional level: No. Habitat of high species number or habitat diversity or “naturalness”: No. Other information: • Swamp habitat is shown as being of low groundwater dependency (Environment Agency, 2014). • The site is a main river (part of a permanent river system) and therefore is not a wetland (European Communities, 2012). Considering the above then the site is: **ASSESSED AS NOT A GWDTE**	Change in discharge groundwater via springs and seepages or change in groundwater flow or flux through GWDTE: Negligible due to large distance (greater than 1km) from the Project construction works. Change in water level beneath the GWDTE: Negligible due to large distance from Project works. Change in upward hydraulic gradient and/or flow from a deeper groundwater body to the near surface deposits: Negligible as no upward gradient expected. Change to nutrient loading to GWDTE: Negligible as no change is anticipated. Change in quantities of potentially toxic chemicals derived from road runoff and drainage: See Chapter 14: Road Drainage and the Water Environment (Application Document 6.1) for discussion on drainage. **ASSESSED AS NOT A GWDTE** **(magnitude of impacts discussed for completeness only)**	**ASSESSED AS NOT A GWDTE**
Swamp habitat at Gobians Sewer and pond near Linford (TN146) (UKTAG WTT habitat area based on Phase 1 habitat survey)	Scale of biodiversity: Local. Site designated for protection at national or regional level: No. Habitats recognised as intact or unique or areas recognised by non-governmental organisations as having high environmental value: No. Difficult for habit to recover following disturbance: No, as would recover quickly following disturbance. Habitat is suffering significant decline at national or regional level: No. Habitat of high species number or habitat diversity or “naturalness”: No. Other information: • Swamp habitat is shown as being of low groundwater dependency (Environment Agency, 2014).	Change in discharge groundwater via springs and seepages or in groundwater flow or flux through GWDTE: Project earthworks (embankment) would mostly cover the pond area and water would be re-routed as discussed in Chapter 14: Road Drainage and the Water Environment (Application Document 6.1). Change in water level beneath the GWDTE: Project embankment would mostly cover the pond area and water would be re-routed as discussed in Chapter 14: Road Drainage and the Water Environment (Application Document 6.1). Change in upward hydraulic gradient and/or flow from a deeper groundwater body to the near surface deposits: No significant	**ASSESSED AS NOT A GWDTE**

Location (data source)	Importance (with respect to GWDTEs)	Magnitude of impact	Risk
	• The site is a main river (part of a permanent river system) and therefore is not a wetland (European Communities, 2012). Considering the above then the site is: **ASSESSED AS NOT A GWDTE**	changes from proposed Project cuttings and embankments (Sections 6.2 and 6.3 of this report). Change to nutrient loading to GWDTE: Negligible as no sewage outfalls or interception proposed at this location. Change in quantities of potentially toxic chemicals derived from road runoff and drainage: See Chapter 14: Road Drainage and the Water Environment (Application Document 6.1) for discussion on drainage. **ASSESSED AS NOT A GWDTE** **(magnitude of impacts discussed for completeness only)**	
North Ockendon Pit SINC – small areas of swamp and small areas of wet grassland (TN147) (NVC surveyed areas and UKTAG WTT habitat area based on Phase 1 habitat survey). It is noted that older information is available in the 2005 citation (eCountability, 2020), but the citation is likely to be less reliable due to it being older information.	Species are protected or listed: Yes, vulnerable (e.g. lesser spearwort *Ranunculus flammula* (in wetter areas)). Species are scarce or rare: No not in wetter areas. Species are crucial for GWDTE functions, such as predator/prey species: See general discussion in Chapter 8: Terrestrial Biodiversity (Application Document 6.1). Species are host flora for protected or listed species: See general discussion in Chapter 8: Terrestrial Biodiversity (Application Document 6.1). NVC groundwater dependence score: 3 (low). Considering the NVC habitat low groundwater dependency score, then the site, with respect to a GWDTE assessment, is assessed as: **LOW IMPORTANCE**	Change in discharge groundwater via springs and seepages or groundwater flow or flux through GWDTE: Minor to moderate adverse (Section 6.8). Change in water level beneath the GWDTE: Minor to moderate adverse (Section 6.8). Change in upward hydraulic gradient and/or flow from a deeper groundwater body to the near surface deposits: Minor to moderate adverse (Section 6.8). Change in water level beneath the GWDTE: Minor to moderate adverse (Section 6.8). Change to nutrient loading to GWDTE: Location is mostly on historical landfill, so changes to groundwater flow directions have the potential to change quality, but historical landfill is likely to represent a worst case with respect to nutrient loading. Change in quantities of potentially toxic chemicals derived from road runoff and drainage: No discharges to ground here. The following has been assessed using the precautionary principle: **MODERATE ADVERSE**	Low importance x moderate adverse magnitude = **NEGLIGIBLE RISK**
Small locations outside of and north of Thames Chase Forest Centre (TN148) (UKTAG WTT habitat area – swamp habitat based on Phase 1 habitat survey).	Scale of biodiversity: Local. Site designated for protection at national or regional level: No. Habitats recognised as intact or unique or areas recognised by non-governmental organisations as having high environmental value: No. Difficult for habit to recover following disturbance: No, as would recover quickly following disturbance. Habitat is suffering significant decline at national or regional level: No. Habitat is of high species number or habitat diversity or "naturalness": No. **LOW IMPORTANCE** Note: the areas are within a golf course and are therefore within manmade ponds	Change in discharge groundwater via springs and seepages or groundwater flow or flux through GWDTE: Locations are distant (800m) from the proposed cutting at the A122 Lower Thames Crossing/M25 junction and on other side of the Mardyke West tributary, so no groundwater hydraulic connection to the cutting at the A122 Lower Thames Crossing/M25 junction is likely. Negligible magnitude of impact. Change in water level beneath the GWDTE: Not likely, as described above. Negligible. Change in upward hydraulic gradient and/or flow from a deeper groundwater body to the near surface deposits: Not likely, as described above. Negligible. Change to nutrient loading to GWDTE: No proposed discharges to ground. Negligible. Change in quantities of potentially toxic chemicals derived from road runoff and drainage: See Chapter 14: Road Drainage and the Water Environment (Application Document 6.1) for discussion on drainage. **NEGLIGIBLE**	Low importance x negligible magnitude = **NEGLIGIBLE RISK**

Location (data source)	Importance (with respect to GWDTEs)	Magnitude of impact	Risk
Cranham Marsh LNR • Three areas of fen (see sketch map in Annex O) • small area of swamp (see sketch map in Annex O) (UKTAG WTT habitat areas based on Phase 1 habitat survey)	Scale of biodiversity: Regional. Site designated for protection at national or regional level: Yes. Habitats recognised as intact or unique or areas recognised by non-governmental organisations as having high environmental value: Yes. Difficult for habitat to recover following disturbance: Habitats are assessed as being capable of unassisted recovery albeit not quickly. The fen habitat in particular would be difficult to recover (see DMRB LA 113 Table B.1). Habitat is suffering significant decline at national or regional level: Yes. Habitat is of high species number or habitat diversity or "naturalness": Yes, on a precautionary basis since an NVC survey could not be undertaken and therefore a full species list could not be recorded. Note: • Bonus Wood was not surveyed. At least part of this is a bluebell wood (Natural England, 2020), and this flora is typical of well drained soils (i.e. not a wet environment). • Swamp habitat is likely to be of low groundwater dependency (Environment Agency, 2014). • Fen (valley mire) (Phase 1 habitat E3.1) is likely to be of high groundwater dependency (Environment Agency, 2014). • The E3.1 habitat is located in three discrete areas, and within these areas are also neutral grassland. However, access restrictions means that it was not possible to assign proportions of habitat in these areas. The E3.1 habitat has been assessed as of moderate importance since it is located in discrete areas within a site of county importance for ecology. • No wet woodland habitat was found in Spring Wood or Middle Wood although this is listed in the citation (Natural England, 2020). • Much of the LNR is broadleaved woodland which is not groundwater dependent. The discrete areas of fen (valley mire) habitat recorded in the Middle Wood and Spring Wood parts of the LNR are assessed, with respect to a GWDTE assessment, as having a: **MODERATE IMPORTANCE**	Change in discharge groundwater via springs and seepages or change in groundwater flow or flux through GWDTE: • Without mitigation, shallow groundwater levels could be reduced as a result of the proposed cutting at the A122 Lower Thames Crossing/M25 junction, with drawdown effects reducing stream flow. However, mapped geology suggests moderately low permeability strata may be present beneath Middle Wood and Spring Wood. The following magnitude of impact has been assessed using the precautionary principle (based on the conservative geological interpretation used in Annex L): – **Minor to moderate adverse (without essential mitigation) for fen (valley mire) habitat areas near Middle Wood and Spring Wood** – **Minor to moderate adverse (without essential mitigation) for swamp habitat** – **Negligible (without essential mitigation) for broad-leaved woodland habitat and all other habitat** Change in water level beneath the GWDTE: As discussed above. Change in upward hydraulic gradient and/or flow from a deeper groundwater body to the near surface deposits: • No upwards flow from the Chalk aquifer occurs (Section 5). There may be layering of shallow superficial deposits beneath parts of the LNR, although upwards flow is likely to be small due to probable low vertical permeability of a layered lithology. Change to nutrient loading to GWDTE: Negligible as no change anticipated. Change in quantities of potentially toxic chemicals derived from road runoff and drainage: Negligible as no highway drainage runoff to discharge at this location, or upgradient of the site (see Chapter 14 (Application Document 6.1) for discussion on drainage). The following magnitude of impact has been assessed using the precautionary principle (see above): **MODERATE ADVERSE (without essential mitigation) for the fen (valley mire) habitat** **NEGLIGIBLE impact for all other habitats** **Essential mitigation is proposed and is discussed in Chapter 14: Road Drainage and the Water Environment (Application Document 6.1) and REAC Ref. RDWE038**	For the **fen (valley mire) habitat (with essential mitigation**) Moderate importance x negligible magnitude = **NEGLIGIBLE RISK** **(which is not significant)** For all other habitats (without mitigation) Low importance x negligible magnitude = **NEGLIGIBLE RISK** **(which is not significant)** **Mitigation is discussed in Chapter 14: Road Drainage and the Water Environment (Application Document 6.1)**
Ingrebourne Marshes SSSI	See Plate 3.2 in Section 3.9 of Appendix 14.5: Hydrogeological Risk Assessment (Application Document 6.3), which shows that the location is designated as a GWDTE by the Environment Agency. Therefore, since it is an SSSI, the location is assessed, with respect to a GWDTE assessment, as having: **HIGH IMPORTANCE**	No measurable change of groundwater levels has been predicted for the SSSI since the numerical modelling of the proposed A122 Lower Thames Crossing/M25 junction cutting (Annex L) shows that the SSSI is 2.5km away from the nearest modelled drawdown contour (0.5m). No measurable change of groundwater quality has been assessed since there are no proposed highway drainage outfalls upgradient of the SSSI. **NEGLIGIBLE**	High importance x negligible magnitude = **NEGLIGIBLE RISK** **(which is not significant)**

Location (data source)	Importance (with respect to GWDTEs)	Magnitude of impact	Risk
Redlands Angling Centre SINC Wet woodland UKTAG WTT habitat area(s) (based on a desk study review of the citation)	Scale of biodiversity: County level importance potentially as a SINC, but note that site is small at 2.43ha and the wet woodland (willow) is a small part of the site. Site designated for protection at national or regional level: Not assessed. Habitats recognised as intact or unique or areas recognised by non-governmental organisations as having high environmental value: Not assessed. Difficult for habit to recover following disturbance: Not assessed. Habitat is suffering significant decline at national or regional level: Not assessed. Habitat is of high species number or habitat diversity or "naturalness": Not assessed. Available information is limited, although it is noted that the wet woodland habitat is a small part of a small site. Therefore, the following has been assessed using the precautionary principle: **LOW to MODERATE IMPORTANCE**	Change in discharge groundwater via springs and seepages or change in groundwater flow or flux through GWDTE: • Magnitude of impact: No measurable change in groundwater levels or flow, as shown by the groundwater level drawdown contours in the M25 groundwater impact assessment numerical model (Annex L of Appendix 14.5). In addition, site appears to be within an extensive area of historical gravel extraction, so no or limited hydraulic connection between the Project and the SINC site is anticipated. Change in water level beneath the GWDTE: No measurable change as detailed above. Change in upward hydraulic gradient and/or flow from a deeper groundwater body to the near surface deposits: No measurable change as detailed above. Change to nutrient loading to GWDTE: No Project drainage outfalls near to or upstream of the SINC site, so no measurable change. Change in quantities of potentially toxic chemicals derived from road runoff and drainage: No Project drainage outfalls near to or upstream of the SINC site. **NEGLIGIBLE**	Low to moderate importance x negligible magnitude = **NEGLIGIBLE RISK** **(which is not significant)**
Puddle Dock Angling Centre SINC Wet grassland UKTAG WTT habitat area(s) (based on a desk study review of the citation)	Scale of biodiversity: County level importance potentially as a SINC. Site designated for protection at national or regional level: Not assessed. Habitats recognised as intact or unique or areas recognised by non-governmental organisations as having high environmental value: Not assessed. Difficult for habit to recover following disturbance: Not assessed. Habitat is suffering significant decline at national or regional level: Not assessed. Habitat is of high species number or habitat diversity or "naturalness": Not assessed. Other information: • Wet grassland habitat is shown as being of high groundwater dependency (Environment Agency, 2014), although the proportion of this habitat is not known. • Site is a managed angling centre and the open water features may be the result of historical or recent excavations. • Site is next to the Mardyke West tributary, a main river (alongside the northern riverbank), and therefore river water is likely to have a significant influence at the SINC site. Available information is limited, but considering the potential high groundwater dependency of the wet grassland habitat but likely artificial and surface water influences at the site, the following has been assessed using the precautionary principle: **LOW to MODERATE IMPORTANCE**	Change in discharge groundwater via springs and seepages or change in groundwater flow or flux through GWDTE: • Magnitude of impact: SINC site water levels are likely to be significantly influenced by the adjacent Mardyke West watercourse. The site is located at a position where numerical modelling of potential groundwater drawdown due the proposed cutting at the A122 Lower Thames Crossing/M25 junction is within the model's limit of accuracy (M25 groundwater impact assessment numerical model in Annex L of Appendix 14.5). Therefore, no measurable change in groundwater levels or flow is assessed, meaning a negligible magnitude of impact. Change in water level beneath the GWDTE: No measurable change as detailed above. Change in upward hydraulic gradient and/or flow from a deeper groundwater body to the near surface deposits: No measurable change as detailed above. Change to nutrient loading to GWDTE: Proposed Project drainage would outfall to new surface water attenuation ponds upstream of the Mardyke West watercourse as described in Chapter 14: Road Drainage and the Water Environment (Application Document 6.1). No soakaways to groundwater are proposed. No measurable change. Change in quantities of potentially toxic chemicals derived from road runoff and drainage: No measurable change as discussed regarding nutrient loading. **NEGLIGIBLE**	Low to moderate importance x negligible magnitude = **NEGLIGIBLE RISK** **(which is not significant)**

Location (data source)	Importance (with respect to GWDTEs)	Magnitude of impact	Risk
Franks Wood and Cranham Brickfields SINC, Wet grassland UKTAG WTT habitat area(s) (based on a desk study review of the citation)	Scale of biodiversity: County level importance of the SINC. Cranham Ingrebourne is an LNR and is therefore of regional importance. Site designated for protection at national or regional level: Not assessed. Habitats recognised as intact or unique or areas recognised by non-governmental organisations as having high environmental value: Not assessed. Difficult for habit to recover following disturbance: Not assessed. Habitat is suffering significant decline at national or regional level: Not assessed. Habitat is of high species number or habitat diversity or "naturalness": Not assessed. Other information: • Wet grassland habitat is shown as being of high groundwater dependency (Environment Agency, 2014). • Separate desk study review of citations for Cranfield Brickfields LNR did not identify wetland habitats within the LNR and therefore the LNR is not a GWDTE. Using the above available information and the precautionary principle, the site is assessed as being: **LOW to MODERATE IMPORTANCE**	Change in discharge groundwater via springs and seepages or change in groundwater flow or flux through GWDTE: The proposed new north link road at the A122 Lower Thames Crossing/M25 junction, approaching M25 junction 29 from the south, includes a partial cutting into hillside. The new north link road would be at a higher elevation than the existing M25. The geology comprises mostly Head Deposits over London Clay Formation at the SINC site. The cutting type and the likely low permeability of superficial deposits suggests that there would be negligible changes to groundwater levels at the SINC site. Change in water level beneath the GWDTE: Negligible change as detailed in the above paragraph. Change in upward hydraulic gradient and/or flow from a deeper groundwater body to the near surface deposits: Negligible change as detailed in the above paragraph. Change to nutrient loading to GWDTE: No measurable change as no soakaways are proposed. Change in quantities of potentially toxic chemicals derived from road runoff and drainage: No measurable change as no soakaways are proposed. **NEGLIGIBLE**	Low to moderate importance x negligible magnitude = **NEGLIGIBLE RISK** **(which is not significant)**
Tomkyns East Pastures SINC Wet grassland UKTAG WTT habitat area(s) (based on a desk study review of the citation)	Scale of biodiversity: County level importance. Site designated for protection at national or regional level: Not assessed. Habitats recognised as intact or unique or areas recognised by non-governmental organisations as having high environmental value: Difficult for habit to recover following disturbance: Not assessed. Habitat is suffering significant decline at national or regional level: Not assessed. Habitat is of high species number or habitat diversity or "naturalness": Not assessed. Other information: • Wet grassland habitat is shown as being of high groundwater dependency (Environment Agency, 2014). • Citation describes an area of traditional countryside with flower-rich pastures divided by ancient hedgerows. Habitats are listed as hedge, scattered trees, scrub, secondary woodland, semi-improved neutral grassland, tall herbs, unimproved neutral grassland, wet grassland. This list suggests that wet grassland is not the main habitat. Using the above available information and the precautionary principle, the site is assessed as being: **LOW to MODERATE IMPORTANCE**	Change in discharge groundwater via springs and seepages or change in groundwater flow or flux through GWDTE: No measurable change would occur as no significant earthworks are proposed along the existing M25. Magnitude of impact: No measurable change as above. Change in water level beneath the GWDTE: No measurable change as above. Change in upward hydraulic gradient and/or flow from a deeper groundwater body to the near surface deposits: No measurable change as above. Change to nutrient loading to GWDTE: No measurable change as no soakaways or discharge of sewerage to ground is proposed. Change in quantities of potentially toxic chemicals derived from road runoff and drainage: No measurable change as no soakaways are proposed near this site. **NEGLIGIBLE**	Low to moderate importance x negligible magnitude = **NEGLIGIBLE RISK** **(which is not significant)**
Carter's Brook and Paine's Brook SINC Wet grassland UKTAG WTT habitat area(s) (based on a desk study review of the citation)	Scale of biodiversity: County level importance. Site designated for protection at national or regional level: Not assessed. Habitats recognised as intact or unique or areas recognised by non-governmental organisations as having high environmental value: Not assessed. Difficult for habit to recover following disturbance: Not assessed. Habitat is suffering significant decline at national or regional level: Not assessed. Habitat is of high species number or habitat diversity or "naturalness": Not assessed.	Change in discharge groundwater via springs and seepages or change in groundwater flow or flux through GWDTE: No measurable change as the SINC site is nearly 3km from the Order Limits at the northern extremity of the Project, where no significant earthworks are proposed. Change in water level beneath the GWDTE: No measurable change as above.	Low to moderate importance x negligible magnitude = **NEGLIGIBLE RISK** **(which is not significant)**

Location (data source)	Importance (with respect to GWDTEs)	Magnitude of impact	Risk
	Other information: • Wet grassland habitat is shown as being of high groundwater dependency (Environment Agency, 2014). • Citation quotes '*Two streams lined with woodland and grassland, forming a valuable green corridor across the north of Havering*'. Using the above available information and the precautionary principle, the site is assessed as being: **LOW to MODERATE IMPORTANCE**	Change in upward hydraulic gradient and/or flow from a deeper groundwater body to the near surface deposits: No measurable change as above. Change to nutrient loading to GWDTE: No measurable change as no soakaways or discharge of sewerage to ground is proposed. Change in quantities of potentially toxic chemicals derived from road runoff and drainage: No measurable change as no soakaways are proposed. **NEGLIGIBLE**	

Red List: Great Britain or England Red Listed Species (Joint Nature Conservation Committee, 2019) based on 2001 International Union for the Conservation of Nature (IUCN) Guidelines (IUCN Species Survival Commission, 2012).

'Nationally Scarce' (NS) refers to species that have been recorded in 16–100 10km squares of the National Grid (hectads) in Great Britain (Joint Nature Conservation Committee, 2019). 'Vulnerable' (VU) refers to species that are not Critically Endangered or Endangered but are facing a high risk of extinction in the wild in the medium-term future.

Habitat information has been assessed by the Project's biodiversity specialists (Application Document 6.1, Chapter 8: Terrestrial Biodiversity).

Annex Q Utilities assessment (groundwater)

Annex Q Utilities Hydrogeological Assessment

1.1 Introduction

1.1.1 Utility works include the diversion of, protection of and connection to, the utility networks and are required as part of the Project. Electricity, water, gas and telecommunications utilities would need to be provided, replaced or rerouted as part of the Project and are summarised in Chapter 2: Project Description (Application Document 6.1), Appendix 2.1 (Application Document 6.3) and Figure 2.2 and Figure 2.5 (Application Document 6.2). In total, there are approximately 130 proposed underground utility diversion corridors of 125km overall length. It is estimated that 95% of the proposed total underground utility corridor distance would be laid in shallow (within 3m depth) open cut trenches.

1.1.2 A summary of the proposed utilities works is presented in Chapter 2: Project Description (Application Document 6.1). This describes utility corridors as well as associated infrastructure such as substations. Further description is also presented in Appendix 2.1: Construction Supporting Information (Application Document 6.3). The information should be read in conjunction with Schedule 1 (Authorised Development) of the Development Consent Order (application document reference TR010032/APP/3.1) and the Works Plans (application document reference TR010032/APP/2.6). The Works Plans show the layout of the proposed utilities and the works number for each utility corridor.

1.1.3 Four utility diversions constitute Nationally Significant Infrastructure Projects (NSIP) in their own right, and therefore the Project will also be assessed against the Overarching National Policy Statement for Energy (EN-1), National Policy Statement for Gas Supply Infrastructure and Gas and Oil Pipelines (EN-4) and National Policy Statement for Electricity Network Infrastructure (EN-5). However, the NPS NN forms the “case-making” basis for the Project, and the need for nationally significant utilities diversions arises solely from the need for the road element of the Project.

1.1.4 The utility diversions that are NSIPs are the following gas (G) and overhead electricity (OH) utility corridors:

a. Work number G2 – high pressure gas pipeline located within the vicinity of Claylane Wood, Singlewell

b. Work number G3 – high pressure gas pipeline, between Claylane Wood to east of Thong

c. Work number G4 - high pressure gas pipeline, between north east of Claylane Wood to Gravesend Road (A226)

d. Work number OH7- new 275kV network, south west and west of the A13 LTC junction heading north to Orsett Fen area

1.1.5 Construction of new utilities has the potential to impact groundwater flows and levels, where assets are below ground level. In addition, potential operational phase impacts could result from permanent drainage or below ground barriers to groundwater flow. Alteration of groundwater flow paths may also impact groundwater quality. Whilst these aspects are the focus of this annex, it is noted that the design of the diverted or protected utilities assets would follow best practice and has been developed to be compliant with industry codes of practice, standards, legislative requirements and the utilities providers' specific standards and guidance. Further discussion of the general design approach is presented in Chapter 2: Project Description.

1.1.6 This hydrogeological assessment of utility diversions has evaluated impacts of below ground utility works. The assessment does not include overhead electricity corridors (Work numbers OH1 to OH8), other than with reference to pylon foundations. Substations have not been assessed as underground cabling would be addressed as part of the utility corridor information assessed in this annex and any foundations of substation structures would be addressed by the Project commitment to conduct foundation risk assessments, as described in the Register of Environmental Actions and Commitments (REAC) (detailed in the Code of Construction Practice, Application Document 6.3), REAC reference GS026. Utilities inside the main tunnel crossing, would be sealed by the tunnel construction from the ground and groundwater, and therefore, are not assessed in this annex. All other proposed below ground utility corridors have been assessed.

1.2 Methodology

1.2.1 This annex presents the simple assessment of impacts that the proposed utility diversions may have on the groundwater environment (during the construction phase and operational phase) comprising groundwater flow and levels (Section 6.1 of Appendix 14.5 in Application Document 6.3) and groundwater quality (saline intrusion only) (Section 7.1 of Appendix 14.5 in Application Document 6.3). The approach to the simple assessment is in accordance with DMRB LA 113 and uses information presented in the Hydrogeological Impact Assessment (Appendix 14.5), has comprised the following assessment steps:

a. Step 1: establish the regional groundwater status

b. Step 2: develop a conceptual model of the surrounding area

c. Step 3: identify potential features that are susceptible

1.2.2 This annex also considers the assessment requirements for NSIPs which are stated in Appendix 14.8: Legislation and Policy (Application Document 6.3).

1.2.3 National Policy Statements (NPSs) require a description of impacts of a proposed project on water resources and water quality. For groundwater, impacts that are required to be assessed are:

a. physical modifications to the quantity and dynamics of groundwater flow

b. impacts on water bodies (Water Framework Directive)

c. impacts on source protection zones (SPZs) around potable groundwater abstractions)

d. impacts on groundwater quality

1.2.4 For this annex, the water quality aspect is focused on whether saline intrusion effects could be increased. The main cause would be if significant dewatering caused drawdown near a tidal river. It should be noted that pollution issues related to contaminated land are assessed separately in Chapter 10: Geology and Soils.

1.2.5 Groundwater features that are related to groundwater flow and levels have also been assessed in this annex, such as licensed groundwater abstractions, springs and potentially groundwater fed surface water bodies that may be near proposed utility corridors.

1.2.6 This assessment similarly considers whether there would be construction of utilities near or on protected wildlife areas that could impact groundwater levels and flows there and therefore have potential to impact water related attributes of the wildlife site.

1.2.7 Utility information used for this simple assessment has comprised indicative design information about location, depth, construction methodology and duration presented in Chapter 2: Project Description. The assessment has been informed via collaborative dialogue between the Project and the Statutory Undertakers utilising their construction and design experience, including adherence to all relevant design standards, guidance and legislation.

1.3 Typical depths of utility corridors

1.3.1 Most utility corridors are open cut trenches and are therefore shallow (within 3m depth). Table 1.1 details the typical depths of excavations for utility corridors from the open cut trench method to specialised deep rock tunnel boring machine techniques. These depths have informed the assessment presented in this annex.

Table 1.1 Depths of utility works

Works	Typical dimensions
Open cut trenches:	
Multiutility open cut trench	1m -1.5m depth
Temporary multi utility open cut trench	1m -1.5m depth
Multi utility works crossing each other, open cut trenches	1m -3m depth
Multi utility works beneath a proposed road, open cut trench	1.5-2m depth below formation level (approximately 2.75 to 3.25m below road level)[1]
Gas open cut trench	1.5m -2.1m depth (unless otherwise stated)
Gas connections comprising open cut excavation	3m -6m] depth
Gas pipe works beneath a proposed road, open cut trench	4m depth below formation level (approximately 5.25m below road level)[1]
Trenchless methods:	
Trenchless installation – small Horizontal Direction Drilling (HDD) rig	Crossing depth is typically invert level of feature plus 5m [to be confirmed] additional depth. Launch and reception pits are normally shallow, as small as 1m by 1m by 1m. However most pits would be 3m wide by 3m long by 2m deep.

Works	Typical dimensions
Trenchless installation – large HDD rig	Crossing depth is typically the invert level of feature plus 5m additional depth. Launch and reception pits are typically up to a maximum of 15m long, 5m wide and 3m deep. Details would vary depending on site circumstances
Trenchless installation –Thrust bore (also known as Pipejack)	Crossing depth 5m – 10m (unless otherwise stated) Shafts of 5m -10m diameter and depths of shafts of between 6m and 11m
Trenchless installation – micro tunnel boring machine (TBM)	Typically deep with depths depending on utility work requirements. Diameter of tunnel would be small (for example G1b micro-tunnel would be approximately 1.4m diameter, based on the indicative design) with detail depending on the permanent pipework design
Other:	
Overhead power lines – pylon foundation	Pad foundation would be 7-10m wide by 7-10m long by 2m depth

Notes: [1] assuming road construction depth of 1250mm

1.3.2 Where multiple utilities along a corridor are proposed then at Detailed Design stage the merits of constructing three separate trenches or one bigger trench would be assessed. Usually, spreading the pipes and ducts to take up a wider trench as opposed to a deeper trench would be promoted. For multiple utility trenches, utility companies would require a 600mm utility separation in the vertical direction. Typically, the maximum depth of a multiutility trench would be 3m.

1.3.3 Gas pipes would normally be placed at a depth of 1.2m to the crown of the pipe so that the maximum depth would depend on the pipe diameter plus the thickness of the bedding material beneath. Connection of a diverted gas pipe to a live main gas pipe requires temporary construction of a stopple connection and hence a temporary excavation of a wide, shallow pit, often 3m deep.

1.3.4 Pylon foundations for overhead powerlines would be pad foundations and are therefore shallow as shown in Table 1.1.

1.3.5 Trenchless installations are often used to cross beneath existing features such as the strategic road network, railway, local road network and watercourses. An example would be a crossing beneath an existing road where road closures would have a significant impact on the users of the network (for example Works number G3 beneath Thong Lane). Horizontal directional drilling (HDD) is the preferred industry method, as launch pits and receptor pits can be shallow as shown in Table 1.1. However, thrust boring (trenchless method of installing horizontal pipes by applying a force to push a pipe through the ground) may be required. Finally, the last main group of trenchless methods comprise micro tunnel boring machines (TBM) which can bore a tunnel through rock and require a shaft at either end of the tunnel for the TBM to be launched and received.

1.3.6 The deepest trenchless construction is proposed immediately north of the A2/A122 Lower Thames Crossing junction area where a medium pressure gas pipe and high pressure gas pipelines are required to cross beneath the proposed A122 Lower Thames Crossing alignment. Overall, for the whole Project, trenchless installation lengths would vary between 40-200m.

Construction methods

1.3.7 Construction methods and plant are described in Chapter 2: Project description. Typical depths of trenchless methods of construction are shown in Table 1.1. As summary of typical open cut trench construction materials and thicknesses is shown in Table 1.2, which is relevant when considering interaction with water potentially infiltrating the ground or movement of groundwater if present at shallow depths. All these details have informed the assessment presented in this annex.

Table 1.2 Typical open cut trench details

Layer or horizon	Detail
Vertical:	
Ground surface	Backfill of arisings to ground surface unless protection or ground strengthening is required
Backfill above pipe cover	Backfill of soil arisings excavated from the trench. Where contaminated ground is present, or strength is required then engineered fill would be placed instead.
Pipe cover thickness and material	300mm thickness of sand or gravel (40mm sized clasts or less). Generally sand is preferred to reduce the risk of pipe puncture. The 40mm gravel would be used for large bore pipework.
Pipe or cable	Diameter of pipe or duct as required
Bed beneath pipe or cable	150mm thick layer of sand or gravel placed on base of excavated trench
Horizontal:	
Side of trench, measured, from the pipe outside diameter to the trench wall	150mm minimum horizontal thickness

1.3.8 Utility open cut trenches are sized to contain the utility pipe diameter with typical cover and bed thicknesses and materials as shown in Table 1.1. Construction industry wide best practice is to avoid trenches being wider or deeper than necessary.

1.3.9 Table 1.3 summarises groundwater control methods that may be necessary should groundwater be encountered for the utility diversion construction methods shown in Table 1.1. Overall, open cut trenches are often shallow and so are above groundwater. Similarly, HDD methods require only shallow launch and reception pits, especially for the small HDD rigs, so again are typically above groundwater. Thrust bore and micro TBM methods both require dry shafts, often relatively deep compared to the other methods. The shafts can be constructed by various methods, of which groundwater exclusion and wet working methods are available to reduce the need for large scale pumping should the shafts be below the water table. These groundwater control considerations have informed the assessment presented in this annex.

Table 1.3 Utility diversion construction methods and groundwater control

Method	Groundwater control method
Open cut trenches	Typically trenches would be shallow and therefore would be above groundwater with no requirement for groundwater control. Should water be expected when a trench is cut (i.e. shallow groundwater conditions), then side collapse and any water ingress would be managed, and the risk would be assessed for the safety of the workforce, on a case-by-case basis. Methods would include stepping the excavation and banking the sides to 2m depth. If deeper than 2m, a temporary trench box system would be used. Dewatering is infrequently done before works commence (to avoid wet running sands that a pump could not deal with). However more frequently short sections of a trench would be temporarily dewatered via the movement of a pump in the trench to remove the water as the trench is constructed
Small HDD	Launch and reception pits would be normally shallow and therefore would be above groundwater with no requirement for groundwater control. The pits would usually be of small dimensions (Table 1.1). The directional boring and pipe placement could be conducted above or below the water table.
Large HDD	Launch and reception pits are typically much shallower compared to pits or shafts for thrust bore or TBM methodologies, since the directional boring means depth can be achieved mostly by drilling. Therefore, often there would be no requirement for groundwater control at the pits. Small scale sump pumping of pits is likely the worst case scenario for shallow groundwater conditions at pit locations.
Thrust bore tunnels and associated shafts	The thrust bore shafts and reception shafts need to be dry. A range of physical cut-off techniques (temporary or permanent) can be employed to control groundwater ingress, if groundwater is present. Dewatering can be avoided for shafts constructed as flooded or "wet" caissons. However limited groundwater pumping could be proposed where partial physical cut-off techniques have been employed and/or the ground conditions would allow manageable quantities of groundwater to be removed, which would be subject to Environmental Permitting Regulations.
Micro tunnel boring machine and shafts	Micro TBM tunnelling would also require dry shafts. The only Project examples of micro TBM tunnelling would be where the Chalk aquifer water table is tens of metres deeper so no or limited groundwater control would be needed. Grouting or other shaft water proofing methods may be necessary to exclude shallow water ingress.

1.4 NSIP utilities

1.4.1 Table 1.4 lists the NSIP utility corridors that would be underground and summarises the results of the assessment of their potential impact on groundwater. The construction methods are summarised in Chapter 2: Project Description and in Table 1.4. All are located south of the River Thames.

Table 1.4 NSIP utilities and summary of impact assessment

Utility corridor[1]	Summary description [2]	Groundwater resources	Residual significance (construction phase and operational phase)
Work number G2	100m long corridor. Typical depths of 1.2m to 2.1m. Locally deeper for crossing other utilities. Open cut trench. No trenchless crossing.	SPZ3, Lower London Tertiaries groundwater body (Thanet Formation) North Kent Medway Chalk groundwater body. No protected site	**Not significant** No change to negligible magnitude of impact to groundwater levels and flows of the medium value aquifer (perched water is not present in the Thanet Formation here, as evidenced by BH01005 and BH01018). No change to groundwater levels and flows of the very high value Chalk aquifer (the underlying Chalk aquifer water table is more than 40m deep).
Work number G3	1650m long corridor. Typical depth of 2.1m and an open cut trench construction method. Locally deeper for crossing other utilities. One trenchless crossing, including shafts (maximum 20m depth) beneath the proposed A122 and a second trenchless method crossing (6m depth) beneath Thong Lane.	SPZ3, Lower London Tertiaries groundwater body, North Kent Medway Chalk groundwater body. No protected site	**Not significant** No change to negligible change to groundwater levels and flows of the medium value (perched water is not present in the Thanet Formation at the southern end of the utility corridor as evidenced by BH01005 and BH01018 and further north the Thanet Formation is either absent or the utility corridor would be located along the edge of the outcrop so the strata would be expected to be only thin, including at the locations of the proposed trenchless sections). No change to groundwater levels and flows of the very high value Chalk aquifer (the underlying Chalk aquifer water table is greater than 40m deep at the southern end and at the northern end).
Work number G4	2650m long corridor Typical depths of 1.2m to 2.1m. Locally deeper for crossing other utilities. Open cut trench method. One 200m long trenchless crossing (maximum 20m depth), including shafts,	SPZ3 (30m at southern end of utility corridor) Lower London Tertiaries groundwater	**Not significant** No change to negligible change to groundwater levels and flows of the medium value Lower London Tertiaries aquifer (perched water is not present in the Thanet Formation at the southern end of the utility corridor

Utility corridor[1]	Summary description [2]	Groundwater resources	Residual significance (construction phase and operational phase)
	beneath the proposed A122 and a second trenchless method construction crossing, 45m long and 6m depth beneath Thong Lane.	body, North Kent Medway Chalk groundwater body. 170m corridor within ancient woodland (Claylane Wood)	as evidenced by BH01005 and BH01018 and further north the Thanet Formation is either absent or the utility corridor would be located along the edge of the outcrop so the strata would be expected to be only thin, including at the locations of the proposed trenchless sections). No change to groundwater levels and flows of the very high value Chalk aquifer (the underlying Chalk aquifer water table is greater than 40m deep at the southern end and approximately 25m deep at the northern end). Due to shallow excavation and probable dry shallow strata (eg BH01019 in Thanet Formation) then no change due to groundwater related matters would be caused to the ancient woodland

Note: ! Underground NSIP utilities only are shown. OH7 utility corridor has not been assessed as the majority of works would be overhead. The G3 and G4 (gas pipeline) trenchless crossings are also discussed later in this annex, when discussing deeper sections of utility corridors.

2 Local deepening due to gas pipe connections or utility services crossing each other may occur as described in Table 1.1.

1.4.2 Table 1.4 demonstrates the residual significance to groundwater flow and levels due to utility corridors Work numbers G2, G3 and G4 is not significant. Consequently, saline intrusion would not occur due to no change of groundwater levels in the Chalk aquifer and due to the distance of over 3km (Works Number G2 and Works Number G3) and over 2.25km (Works Number G4) to the tidal River Thames.

1.4.3 NSIP utility Work number OH7, north of the River Thames, has not been assessed because most of the works are overhead and therefore would not impact groundwater. In addition, foundations for the pylons would be pad foundations and therefore of shallow depth. For Work number OH7 the pylon foundations are located outside of a source protection zone one (SPZ1), although in a SPZ3. Since the foundations are shallow no change to the groundwater environment would be caused. Discussion regarding pylon foundations associated with overhead powerlines diversions which do not constitute NSIPs are discussed in the below paragraphs for locations within SPZs.

1.5 Utilities south of the River Thames

General description

1.5.1 South of the River Thames, Project underground utilities would comprise approximately:

a. 23km of multiple utilities (MU) corridors

b. 1.5km temporary multiple utilities (MUT)

c. 10km of Gas (G) pipeline utility corridors (including the NSIP utilities detailed above)

d. Overhead electricity pylon foundations

1.5.2 Long sections of MU corridors are proposed south of the River Thames, of which the longest are a power supply from Northfleet and MU corridors parallel to the A2 road, including provision of utilities to the South Portal. Approximately 22.5km of the MU corridors would be in open cut trenches and, therefore, shallow at 1-1.5m depth except for short distance of utility crossings of locally 3m depth maximum.

1.5.3 The relatively shorter MUT corridors mostly comprise temporary supplies of power, water, foul water, and communication connections for the main works compounds, CA2, CA3 and CA3a (Figure 2.5 in Application Document 6.3). Nearly all would be open cut trenches with one including small HDD.

1.5.4 Over 9km of the G corridors would be open cut trenches and therefore for these sections the corridors would be shallow at 1.5-2.1m depth except for short sections of down to 6m depth (Table 1.1). The deepest proposed trenchless sections of the Project comprise crossings for some of the G corridors south of the River Thames and these are detailed elsewhere in this annex.

Assessment of stated open cut trenches and small HDD trenchless crossings – south of the River Thames

1.5.5 The long sections of utility corridors that would be constructed by open cut trenches methods to depths described above, would be above groundwater, with two possible exceptions. These open cut trenches above groundwater would consequently have a magnitude of impact of no change to the groundwater environment during construction and operation, south of the River Thames. Stated utility corridors beside New Fish Pond near Shorne and Works number MU26 on Lower Higham Road have the potential to extend into groundwater and are discussed separately, further below.

1.5.6 Relatively small sections of trenchless techniques (small HDD) are proposed on parts of the work numbers MU1, MU10, MU15 and MU16 corridors. Here, since the small HDD rigs are proposed and typically require only shallow pits (Table 1.1), a magnitude of impact of no change to the groundwater environment during construction and operation has been assessed.

1.5.7 For the MUT corridors, considering Table 1.1, all excavation below ground would be shallow, or, for the small HDD section, would have shallow pits, so a magnitude of impact of no change to the groundwater environment during construction and operation has been assessed for the MUT corridors south of the River Thames.

Assessment of deeper sections of utility corridors – south of the River Thames

1.5.8 For the gas pipeline corridors, there would be the following trenchless crossings beneath proposed or existing roads as follows:

a. Work number G1b beneath the proposed A122 Lower Thames Crossing alignment

b. Work number G3 beneath the proposed A122 Lower Thames Crossing alignment

c. Work number G4 beneath the proposed A122 Lower Thames Crossing alignment

d. Work numbers G3 and G4 beneath Thong Lane if traffic closures were not possible

1.5.9 Table 1.5 shows that the main or largest trenchless utility corridor sections are for new gas pipelines south of the River Thames to be constructed beneath the proposed route of the A122 Lower Thames Crossing at the A122 Lower Thames Crossing/A2 junction. Work numbers G1b, G3 and G4 deepest sections would each be formed by construction of two shafts (circa 12-20m depth) and a joining tunnel (circa 185-200m length). The tunnels would be formed by micro-tunnel boring machine techniques. The assessed impacts to the Chalk aquifer groundwater levels is no change because the water table is approximately 25m lower than the base of the deepest shaft. Therefore, no dewatering would be required in the North Kent and Medway Chalk. At the shafts of the deepest section of Work number G1b, Lower London Tertiaries (Thanet Formation) may be present above the chalk strata. However, there would be no impact to the ponds (including New Fish Pond) that are situated on Lower London Tertiaries strata beside the Inn on the Lake, Shorne due to the 900m distance and laterally discontinuous nature of any perched water bodies. Should perched water be present, at the Work number G1b deep crossing of the A122 Lower Thames Crossing, there could be potential for a permanent draining effect of the shafts on the medium value groundwater body (Thanet Formation). Therefore, there is a Project commitment to reduce the local potential draining effect at the Work number G1b crossing of the A122 Lower Thames Crossing, as referenced in Table 1.5.

Table 1.5 Main trenchless sections of utilities– south of the River Thames

Utility corridor section	Summary description of trenchless section [1]	Groundwater resources[2,3]	Residual significance (construction phase and operational phase) [ref.]
South of the River Thames:			

Utility corridor section	Summary description of trenchless section [1]	Groundwater resources[2,3]	Residual significance (construction phase and operational phase) [ref.]
Work number G1b under the A122	Length of deep section:185m. Maximum depth: 15m	Lower London Tertiaries groundwater body, North Kent Medway Chalk groundwater body	Not significant [Following a precautionary principle, a Project commitment has been added, comprising REAC ref. - RDWE051]
Work number G3 under the A122	Length of deep section:200m Maximum depth: 20m	Lower London Tertiaries groundwater body, North Kent Medway Chalk groundwater body	Not significant
Work number G3 under Thong Lane	Length of deep section:45 m Maximum depth: 6m	Lower London Tertiaries groundwater body, North Kent Medway Chalk groundwater body	Not significant
Work number G4 under the A122	Length of deep section:200m Maximum depth: 20m	Lower London Tertiaries groundwater body, North Kent Medway Chalk groundwater body	Not significant
Work number G4 under Thong Lane	Length of deep section:45m Maximum depth: 6m	Lower London Tertiaries groundwater body, North Kent Medway Chalk groundwater body	Not significant

Notes: 1 Length of trenchless section is the length of the micro tunnel and distance between shafts. Depth is metres below ground level (mbgl) from the existing ground level.

2. shows WFD groundwater bodies.

3 Where no SPZ, protected site, groundwater abstraction, spring or potentially groundwater fed surface water body is mentioned then none is present at the location of the utility nor within a professionally judged impact distance.

1.5.10 South of the River Thames, the remaining trenchless utility corridor sections comprise crossings beneath Thong Lane. Work numbers G3 and G4 would each comprise two pits (circa 6m depth) and a joining tunnel (circa 45m length). Neither crossing would require dewatering in the North Kent and Medway Chalk because the water table would be approximately 40m deeper than the base of the pits. The edge of the Lower London Tertiaries may be encountered at the Work number G3 crossing. However, there would be no impact to the Inn on the Lake ponds features due to the 1km distance and likely laterally discontinuous nature of any perched water bodies.

Assessment of SPZs, licensed groundwater abstractions and springs – south of the River Thames

1.5.11 No utility works would be located next to an abstraction or spring nor are any utility works proposed in SPZ1, south of the River Thames. A small number of the proposed utility corridors would be located in SPZ2 or SPZ3. However, for all, the utility works would not impact the Chalk aquifer for which the source protection zones relate, since the Chalk aquifer water table is tens of metres deeper than the proposed works.

Assessment of groundwater dependent surface water bodies and protected wildlife areas – south of the River Thames

1.5.12 There are only a few low groundwater dependency terrestrial ecosystems south of the River Thames (Annex P) and none are close to a proposed utility diversion. For example, Jeskyns Country Park car park pond (possible attenuation basin) (Annex P) is of low importance as a groundwater dependent terrestrial ecosystem (GWDTE) and is south of, and on the other side of, HS1 from the nearest utility corridor which is 260m away.

1.5.13 The potential for hydraulic interaction between perched groundwater and New Fish Pond, near the Inn on the Lake at Shorne, is uncertain. Therefore, there is a Project commitment to reduce the potential draining effect of utility trenches. Gas pipeline Work number G1b (western section), multiple utility Work number MU12 and temporary multiple utility Work number MUT2, all slope away from the pond and shall be constructed to reduce the potential draining effect away from the pond area. (REAC reference RDWE052).

1.5.14 There is a requirement to replace a section of existing water pipeline approximately 100 metres in length along Lower Higham Road. This utility diversion, Work number MU26, would be approximately 10m south of the very high value South Thames Estuary and Marshes SSSI and Thames Estuary & Marshes Ramsar. Therefore, the Project has committed to ensure that any pumped water removal and subsequent disposal of water from the utility works would comply with Environment Permitting Regulations to protect the adjacent areas of nature conservation (REAC reference RDWE053).

Assessment of groundwater quality (saline intrusion) – south of the River Thames

1.5.15 No saline intrusion would be caused by the proposed deep utility works since no deep utilities are proposed close to a tidal river and no significant dewatering is proposed.

1.6 Utilities north of the River Thames

General description

1.6.1 North of the River Thames, Project underground utilities would comprise approximately:

a. 47km of multiple utilities (MU) corridors

b. 37km temporary multiple utilities (MUT)

c. 8km of Gas (G) pipeline utility corridors

d. Overhead electricity pylon foundations

1.6.2 The longest underground MU corridors would comprise, in order of decreasing distance, provision of utilities to the North Portal, diversions through and around the proposed A13/A1089/A12

1.6.3 Lower Thames Crossing junction (including Brentwood Road and Stifford Road), and various diversions on Muckingford Road. Other shorter lengths of MU corridors would be constructed near Ockendon link, the A122 Lower Thames Crossing/M25 junction and north and south of M25 junction 29. Overall, approximately 43km of the MU corridors would be in open cut trenches, and therefore shallow at 1-1.5m depth except for short distances of approximately 3m depth where there are crossings beneath other utilities or beneath road (Table 1.1).

1.6.4 MUT corridors mostly comprise temporary supplies of power, water, foul water and communication connections for the temporary main works compounds, CA6, CA7, CA9, CA10 & CA11 (Figure 2.5 in Application Document 6.3). Assets would be removed as part of compound demobilisation. Additionally, water supply and power supply for the main crossing (River Thames) tunnel boring machine would be provided by MUT corridors north of the River Thames. The water pipeline would not carry water after completion of the tunnel construction and would be proposed for removal, except for a short section that would be abandoned beneath a railway, as required by Network Rail. Overall, approximately 36km of the MUT corridors would be in open cut trenches, and therefore be shallow at 1-1.5m depth except for short distances of approximately 3m depth where there are crossings beneath other utilities or beneath road (Table 1.1).

1.6.5 G6 comprises most of the relatively short total length of G corridors and is located at the A13/A1089/A122 Lower Thames Crossing junction area. Overall there would be over 7.5km of opencut trench for the G corridors which would be shallow at 1.5-2.1m depth except for short sections of down to 6m depth (Table 1.1).

Assessment of stated open cut trenches and small HDD trenchless crossings – north of the River Thames

1.6.6 The long sections of utility corridors that would be constructed by open cut trenches methods to depths described above, would be above groundwater, except for corridors stated below. The open cut trenches above groundwater would consequently have a magnitude of impact no change to the groundwater environment during construction and operation. Stated utility corridors immediately beside the irrigation reservoir at Low Street and stated utility corridors in the Chadwell St Mary link area (Hoford Road and Brentwood Road) have the potential to extend into groundwater and are discussed separately, further below. Open cut trench utility corridors are also proposed in areas of non-aquifer (unproductive strata), such as the clayey Alluvium at the Tilbury Marshes (for example, Works number MU29) and the clayey Head Deposits and clayey Alluvium at the Mardyke (for example, MU61 and MUT25). These deposits may contain small volumes of shallow water, but because they are unproductive strata (low value), there would be a no change magnitude of impact to the groundwater environment because any seepages into the excavations would be small and the effects would be local due to the low permeability of the strata.

1.6.7 Sections of small HDD trenchless techniques are proposed within approximately 10 MU or MUT corridors. Considering Table 1.1 and the small pits described the magnitude of impact to any groundwater body would be no change to negligible.

Deeper sections of utility corridors – north of the River Thames

1.6.8 For the gas pipeline corridors, there would be the following trenchless crossings beneath proposed or existing roads as follows:

a. Work number G6 installation of a high pressure gas pipeline near Green Lane beneath the proposed A122 Lower Thames Crossing, beneath Brentwood Road and beneath the A13

b. Work number G7 installation of a high pressure pipeline north of Green Lane, beneath the proposed A122 Lower Thames Crossing

c. Work number G10 installation of a high pressure gas pipeline beneath the M25

1.6.9 Table 1.6 shows that north of the River Thames the main or largest trenchless utility sections would be mostly gas pipelines at locations where roads are crossed beneath the A13/A1089/A122 Lower Thames Crossing junction area. Groundwater bodies in these areas comprise Lower London Tertiaries or no waterbody. No WFD groundwater body is present at the Work number G6 crossing (160m length) beneath minor roads and the Work number G7 crossing (190m length) beneath the A122 Lower Thames crossing; therefore, since only low permeability Head Deposits are present on top of unproductive bedrock (London Clay Formation), there would be no significant effect to groundwater at these locations. Elsewhere, at the deep sections of Work number G6 (Brentwood Road and the A13 crossings), the magnitude of impact on groundwater levels would be no change or negligible during construction phase and no change in the operational phase. This is because strata at the depths proposed for these utility works are dry, based on Phase 2 Ground Investigations (GI). In addition, should perched water be encountered then any construction phase dewatering would be limited due to the short duration of construction and the moderately shallow excavations. There would be no change in the operational phase because the encountered strata would either by dry or should there be perched water then there would be no overall draining effect as any water seeping into a trench would seep back into the same Lower London Tertiaries strata at the deeper sections.

Table 1.6 Main trenchless sections of utilities - north of the River Thames

Utility corridor section	Summary description of trenchless section [1]	Water resources[2, 4]	Residual significance (construction phase and operational phase) [REAC ref.]
North of the River Thames (gas):			
Work number G6 at Green Lane	Length of deep section:160m Maximum depth: 5m	SPZ3 [3] No groundwater body	Not significant
Work number G6 under Brentwood Road	Length of deep section:90m Maximum depth: 7m	SPZ3 Lower London Tertiaries groundwater body	Not significant
Work number G6 under the A13	Length of deep section:90m Maximum depth: 8m	SPZ3 Lower London Tertiaries groundwater body	Not significant
Work number G7 under the A122	Length of deep section:190m Maximum depth: 6m	SPZ3 [3] No groundwater body	Not significant
Work number G10 under the M25	Length of deep section:120m Maximum depth: 10m	SPZ3 [3] No groundwater body	Not significant
North of the River Thames (multi-utility):			
Work number MU72 under the railway	Length of deep section:80m, maximum depth: 11m Proposed utility construction method: Thrust bore trenchless method	SPZ3 [3] Essex Gravels groundwater body Fields south of Cranham Marsh SINC (50m west), Thames Chase Forest Centre SINC (250m north)	Not significant [Following the precautionary principle. a Project commitment has been added, comprising [REAC ref. - number to be confirmed]
Work number MU73	Length of deep section [number to be confirmed] beneath the London, Tilbury and Southend railway line, beneath the proposed A122 cutting and beneath the existing M25 cutting. Proposed utility construction method: Large HDD trenchless method	SPZ3 [3] Essex Gravels groundwater body Fields south of Cranham Marsh SINC (300m north west), Hall Farm moat, paddock and St Mary Magdalene Churchyard SINC (275m south east)	Not significant [Following the precautionary principle. a Project commitment has been added, comprising [REAC ref. - number to be confirmed]

Note: 1. Length of deep section is the length of the micro tunnel and distance between shafts. Depth is metres below ground level (mbgl) from the existing ground level.

2. shows WFD groundwater bodies.

3. A SPZ3 is present at the section of the utility corridor but relates to the Chalk aquifer which is confined beneath clay strata and is not in hydraulic contact with soils within which the utility corridor would be constructed.

4. Where no, protected site, groundwater abstraction, spring or potentially groundwater fed surface water body is mentioned then none is present at the location of the utility nor within a professionally judged impact distance.

1.6.10 Multiple utility Work number MU72 has a deep section at the proposed crossing beneath the London, Tilbury and Southend railway line. Multiple utility Work number MU73 has a deep section at the proposed crossing beneath the same railway and continuing beneath the A122 Lower Thames Crossing/M25 junction cutting and the existing M25. The Phase 2 and Phase 3 GI long term groundwater monitoring confirms that the excavations would be beneath the water table. Applying the precautionary principle, this annex proposes Project commitments in the REAC to ensure any potential impact on the medium value designated groundwater body and nearby medium value sites of interest for nature conservation (SINC) is reduced.

Groundwater levels and flows – shallower utilities – north of the River Thames

1.6.11 Potential local draining effects or barrier effects in shallow groundwater level areas near the Low Street irrigation reservoir and adjacent Well 1 at Polwicks (Work numbers MU28 and MU33). Local draining effects could also occur at the shallow groundwater level areas in the Chadwell St Mary link area (Hoford Road and Brentwood Road) (Work numbers MU37, MU38 and MU40), could be caused by open cut trenches, depending on depth and backfill material. Applying the precautionary principle, the REAC sets out Project commitments to prevent drainage from the reservoir, or barrier effects reducing groundwater flow to the reservoir, REAC references RDWE054 and RDWE055.

SPZs, licensed groundwater abstractions and springs – north of the River Thames

1.6.12 The temporary water pipeline for the Lower Thames Crossing TBM supply (Work number MUT6) and sections of Work numbers MU28 and MU36 corridors are proposed within the Linford SPZ1. All works here, except a possible short trenchless crossing beneath Gobions Sewer by Work number MUT6, would be shallow, being normal open cut excavations, and therefore there would be no change of magnitude of impact to groundwater levels and flows to the very high importance Chalk aquifer and the very high importance SPZ1. For the potential trenchless crossing beneath Gobions Sewer by Work number MUT6, prevention of detriment to the Linford groundwater source of the published SPZ1 would be addressed by the Project commitment to design and conduct Work number MUT6 below ground works in consultation with Northumbrian Water and the Environment Agency, REAC reference RDWE058.

1.6.13 Utility works do include the replacement and diversion of overhead power lines at Linford. Here, within the SPZ1, there would be one new temporary pylon, one new permanent pylon plus two new pylons, where the footprint of these pylons would overlap those of existing pylons. The overhead electricity routes here are Work numbers OHT2, OHT3, OH3 and OH4. Shallow, pad, foundations are anticipated and therefore these would not penetrate the aquifer source of the abstraction well. Any foundations of pylons or other structures would be addressed by the Project commitment to conduct foundation risk assessments, REAC reference GS026. In addition, prevention of pollution from spillages associated with the utility works would be addressed by the Project commitment to prohibit Project storage of fuels or refuelling within the SPZ1, REAC references GS004 and GS005.

1.6.14 Licensed wells at RWE Generation UK PLC at Low Street, East Tilbury have a default 500m radius SPZ2 in which works numbers MU27, MU28, MU29, MU30, MU31, MU32, MU33, MUT6, MUT9 and OH4 would be located. The source is the Chalk aquifer which is below the outcrop geology of superficial deposits and the Thanet Formation. The utility corridors would be mostly shallow (within 3m) open cut trenches, locally deeper for crossings beneath other utilities. Monitoring data collection suggests that the wells are not in use (Perfect Circle, 2020). However, given the shallow depth of utility corridors and the different well aquifer source, no change to negligible magnitude of impact is assessed for the construction phase and no change for the operational phase.

1.6.15 Licensed wells at Hobletts Farm and Botney Farm may include a potable water use and therefore would have a 50m radius default SPZ1 and potentially a default 250m radius SPZ2. Temporary multi-utility Work number MUT22 and Work number MUT25 would pass within 50m of the former well and within 250m of the latter well and would be shallow (within 3m depth and likely to be shallower due to it being temporary). The magnitude of impact to the wells would be neutral as the well aquifer source is a confined aquifer and therefore not in hydraulic connection with the shallow soils in which the utility corridor would be placed.

1.6.16 No discreet springs are located close to proposed utility corridors.

Groundwater dependent surface water bodies and protected wildlife areas – north of the River Thames

1.6.17 There are no groundwater dependent terrestrial ecosystems close to proposed utility corridors. However, in the A122 Lower Thames Crossing/M25 junction area there are sites of interest for nature conservation, i.e., Thames Chase Forest Centre SINC and Hall Farm moat, paddock and St Mary Magdalene Churchyard SINC that may partly depend on groundwater for their surface water levels. These SINC sites have been considered in the proposed Project commitments for Work numbers MU72 and MU73, as discussed above.

Groundwater quality (saline intrusion) – north of the River Thames

1.6.18 No saline intrusion would be caused by the proposed deep utility works since no deep utilities are proposed close to a tidal river and no significant dewatering is proposed.

1.7 Conclusions

1.7.1 The simple assessment of underground utility diversions and impact on the groundwater environment is presented in this annex. The assessment has followed the methodology set out in DMRB LA 113 (Highways England, 2020a) and for NSIPs.

1.7.2 This assessment of the indicative design of underground utilities demonstrates that there would be no significant impact to the groundwater environment after mitigation.

1.7.3 Chapter 14: Road Drainage and the Water Environment (Application Document 6.1) presents a discussion of the results of this simple assessment.

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