HYDROGEOLOGICAL RISK ASSESSMENT

SANDY LANE QUARRY

Report Reference: 3308/HRA
Final Version F3
May 2025

Report prepared for:

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GENERAL NOTES

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Site: Sandy Lane Quarry

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F1	August 2022	
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https://hafrenw.sharepoint.com/sites/HafrenWater/Shared Documents/General/Projects/Sandy Lane Quarry (3084)/2022_Permit application/Reports/HRA/3308-HRA F3 (May 2025).docx

CONTENTS

TABLES

DRAWINGS

APPENDICES

1 INTRODUCTION

1.1 Report context

The site at Sandy Lane, Bromsgrove, Worcestershire (the 'site') comprises a former sand quarry owned by NRS Bromsgrove Aggregates Limited (NRS). The Sandy Lane complex comprises three main areas: in the centre is the completed Veolia Landfill, to the east former silt settlement lagoons and in the west a disused quarry void. This NRS site comprises the western quarry void only.

It is proposed to remove final sand reserves, provide buttress support to the eastern quarry face and restore the remainder of site using inert fill back to approximately pre-quarrying ground levels. The proposed after-use for the site comprises creation of wildlife habitat.

The proposed stabilisation the failing eastern quarry face (western sidewall of the Veolia landfill) will comprise the construction of a foundation buttress using selected fill. The importation of 975,000 m^3 of inert fill is required to complete the site restoration.

It is intended to apply for a permit for importation of inert fill to restore the site as a waste recovery operation under the Environmental Permitting (England and Wales) Regulations (EPR) (2016). No waste has been placed at the site historically.

This report sets out the Hydrogeological Risk Assessment (HRA) that has been prepared in support of the Environmental Permit Application for the proposed inert waste recovery. The HRA has been prepared with due regard to the hydrogeological risk assessment guidance (Environment Agency, 2020) and reporting guidance (Environment Agency, February 2022) provided by the Environment Agency.

This version F2 of the report has been generated to take into account the construction of site-specific boreholes and comments from the Environment Agency dated 9th May 2024.

1.2 Conceptual hydrogeological site model

The conceptual hydrogeological model for the proposed waste operation is described in Section 4 of the ESSD report and illustrated on *Drawing 3308/HRA/01*. The proposed permit boundary covers the site and access road and totals approximately 5.5 hectares (ha). Sandy Lane parallels the southern boundary of the Site and land to the north comprises grazing pasture. A footpath lies between Madeley Road and the western boundary of the site and between the northern boundary and the adjacent pasture.

Geological and hydrogeological setting

Sandy Lane Quarry lies within the Wildmoor Sandstone Member, the outcrop of which is bounded by north-south aligned faults to the east and west. The Formation comprises a red brown silty, fine to medium-grained weak sandstone with subordinate and discontinuous siltstone and mudstone layers. It is reported to be up to 284 m thick in the Worcester Basin and in the Wildmoor N° 2 borehole the base is reported to be at a depth of approximately 143 m. The BGS hold records for two boreholes within the adjacent Veolia site (SO97NE457 and SO97NE456) which prove sandstone to a depth of 50 m bgl. The strata dip at around 8° to the southwest (BGS, 2009).

Superficial deposits are relatively sparse in the area and none are present in the immediate vicinity of the site.

Groundwater monitoring has been undertaken at boreholes in the adjacent Veolia site. During February 2021, boreholes adjacent to the eastern site boundary indicate groundwater is at approximately 143 m AOD and 146 m AOD (approximately 4 to 7m below the base of final extraction at Sandy Lane Quarry). The monitoring indicated groundwater flow to be east-southeastwards, with an estimated gradient of 0.02 to 0.03. Monitoring undertaken in 2001 indicates groundwater flow towards the southeast, however it is not clear what has caused this change in flow direction.

Four groundwater level boreholes were constructed around the site in July 2023. Borehole BH1 is in the northwest and the remaining boreholes are located along the southern site boundary. Groundwater levels have been recorded on three occasions, in July 2023, October 2023 and June 2024. Surveyed ground levels and borehole datum elevations are needed to confirm absolute groundwater levels under the site. Further site data is required hence this HRA continues to be based upon data from the adjacent Veolia site. .

Mineral extraction of the remaining sand reserves will remain above the water table.

Engineering/waste recovery construction

A natural geological barrier does not exist at the site and it has been decided that an artificial geological barrier will be placed against the base and sides of the quarry void due to the sensitive site location. This will be undertaken using suitable imported inert material. This barrier will have a minimum thickness of 1 m placed to achieve a maximum permeability of 5×10^{-9} m/s, or equivalent (See section 2.5).

A cap is not required at the site, in accordance with the Landfill Directive.

Source

The waste recovery area will receive inert waste which complies with the Landfill Directive description for Inert Waste. This will be ensured by appropriately trained staff and by the application of strict Waste Acceptance Criteria and Procedures (WAC) (provided elsewhere in the application). All incoming waste will be from known sources. Any waste that has not been identified as acceptable without testing, will be subject to Inert WAC testing in addition to waste classification analyses.

Approximately 975,000 m^3 of inert fill will be required to achieve the agreed restoration contours.

Pathways

Strata from the Sherwood Sandstone will remain in place below the geological barrier and waste. There is, therefore, a potential pathway through the base of the site via the geological barrier.

Receptors

Groundwater exists below the base of the site with the Sherwood Sandstone aquifer, which forms the primary groundwater receptor.

The site lies within the catchment of a Severn Trent Water public supply borehole, this is considered a secondary groundwater receptor. Other licensed abstractions within the area are either up hydraulic gradient or further away from the site than the public supply borehole.

Groundwater flow is to the east and may provide some baseflow to Battlefield Brook which flows southwestwards, east of the site. Battlefield Brook forms a secondary receptor.

Identified receptors and pathways are summarised in *Table 3308/HRA/T1* below.

3308/HRA/T1: Summary of identified receptors and pathways	
Hazard	The proposed waste at the site will be inert in nature (see Section 2.2 of the ESSD report) therefore it is considered that the site poses minimal potential hazard to nearby surface and groundwater. An estimated 975,000 m^3 of inert material will be imported.
Source	All waste to be deposited will adhere to Waste Acceptance Criteria and Procedures which shall ensure the waste is correctly characterised and inert in accordance with Environment Agency guidance. No Hazardous substances are expected to be present and Non-hazardous pollutants, if present within the leachate, will be of low concentration such that pollution of nearby groundwater and surface water will not occur.

3308/HRA/T1: Summary of identified receptors and pathways	
Potential primary pathway	Primary pathways may exist via the artificial geological barrier vertically into the Sherwood Sandstone aquifer.
Potential secondary pathway	A secondary pathway exists via groundwater flow through the Sherwood Sandstone.
Potential primary receptor	Sherwood Sandstone principal aquifer
Potential secondary receptor	Groundwater – Severn Trent public water supply Surface Water – Battlefield Brook
Compliance point	For Hazardous substances –Groundwater on the east site boundary For Non-hazardous pollutants – as above

2 HYDROGEOLOGICAL RISK ASSESSMENT

2.1 Nature of the Hydrogeological Risk Assessment

Environment Agency guidance proposes a tiered approach to risk assessment such that the degree of effort and complexity reflects the potential risk posed by a particular site or situation, the sensitivity of the site setting, and the degree of uncertainty and likelihood of the risk being realised. To meet the requirements a robust conceptual model for the site has been set out and a risk screen undertaken. The conceptual model is set out in the ESSD report (3308/ESSD vn F2. Jun 24) and the risk screening is summarised in Section 2.2 and 2.3 below. A risk screening exercise is used to determine whether the proposed waste recovery operation represents, or potentially represents, a risk to groundwater or surface water resources.

2.2 Policy

Compliance with Environmental Permitting (England and Wales) Regulations (2016)

Based upon the inert waste types to be accepted at the site, the site should not produce leachate (defined here as water coming into contact with the waste) that could result in the discharge of Hazardous substances or Non-hazardous pollutants. Hence the site falls outside the scope of the Environmental Permitting (England and Wales) Regulations (2016), Schedule 22 Groundwater Activities.

Environment Agency Landfill location Policy

The proposed waste recovery operation is located within a bedrock classified as a Principal Aquifer. The sandstone aquifer is in hydraulic continuity with the nearby Battlefield Brook. The site is located within Source Protection Zone 3 (SPZ 3) for a Severn Trent public water supply located approximately 1 km southeast of the site. The Environment Agency's position statement indicates that non-landfill waste activities can be located within SPZ3 where the risk can be appropriately controlled by an environmental permit or a relevant waste exemption.

The proposed waste recovery at Sandy Lane Quarry will receive only Landfill Directive compliant inert wastes, hence long-term site management will not be required to prevent groundwater pollution. The ESSD report, together with this HRA, constitutes a site-specific risk assessment.

It is therefore concluded that the site complies with the Environment Agency landfill location policy.

2.3 Risk screening

The proposed waste acceptance criteria (Inert WAC) have been compared with appropriate environmental assessment limits (EALs) to identify any contaminants in the waste that, if leached, could exceed relevant standards at the site boundary. Hazardous substances were compared with Minimum Reporting Values (MRVs) or, where these were not available, with limits of qualification (LoQ) defined by UKTAG.

The screening assessment entailed applying a dilution factor for the site to Inert WAC concentrations to identify any substances where dilution within the aquifer would not be sufficient to prevent the EALs from being breached in the groundwater beneath the site.

The infiltration rate to imported fill is estimated as 50.29 m^3/day based on the rainfall values provided in Section 3.4.1 of the ESSD and the site dimensions. The rate of groundwater flow beneath the site has been estimated as 12,372 m^3/day based on approximate dimensions of the site, a permeability for the sandstone of 12.1 m/day and a hydraulic gradient of 0.02.

This equates to a dilution factor of 246. Based on this dilution factor, dilution alone would be insufficient to dilute a constant source of leachate with maximum Inert WAC concentrations for certain substances. Further quantitative risk assessment modelling for mercury, lead, benzene and benzo-a-pyrene was, therefore, undertaken as described in Section 2.5.

Further details of the quantitative risk screen are provided in *Appendix 3308/HRA/A1*.

2.4 Proposed assessment scenarios

Lifecycle phases

Environment Agency guidance states that a Hydrogeological Risk Assessment must be carried out for the whole lifecycle of the waste operation, ie from the start of the operational phase until the point at which the site is no longer capable of posing an unacceptable environmental risk.

The restored site has been modelled as this represents the largest volume of waste present within the site. Operational phases have not been modelled as there will be no active management of leachate or groundwater during the wate recovery operation.

2.5 Failure scenarios and accidents

Failure scenarios

Due to the inert nature of the proposed waste stream and the location of the site above the watertable, there are no engineering management structures are required to prevent the ingress of groundwater or the egress of leachate. Failure of such systems is, therefore, not possible and failure scenarios will not be considered.

Accidents

Accidents are considered to be unintentional incidents that could reasonably occur, which are unforeseeable at their time of occurrence. An assessment of the potential impacts of accidents, together with the likelihood of their occurrence and magnitude of the consequences (in relation to compliance with the Environmental Permitting (England and Wales) Regulations, 2016 (EPR, 2016)) is presented below.

Accidents at the site could include the acceptance of contaminated material. Due to the proposed Waste Acceptance Criteria and Procedures and absence of any historical waste on-site, it is considered highly unlikely that 'rogue loads' will be accidentally accepted at the site. However, a rogue load assessment has been undertaken and is described in Section 2.6.

2.6 Risk Assessment Modelling

To support the application for bespoke environmental permit, the completed Site has been modelled using the RAM spreadsheet modelling software. The software was used to assess natural attenuation capacity at the Site and surrounding area and model the potential for contaminants at the Site to impact on water quality of sensitive controlled water receptors.

The contaminant species identified by the Risk Screening as being at risk of breaching their respective EAL's have been modelled, and include mercury, lead, benzene and benzo- a- pyrene.

Initial runs of the model indicated that an artificial geological barrier will be required to provide sufficient attenuation to ensure compliance with the EAL's can be achieved. The artificial geological barrier will be constructed across the base and sides of the waste recovery area to separate the waste from the surrounding sandstone strata. Sensitivity analysis of the barrier indicates that the barrier will need to be 1 m thick with a hydraulic conductivity of $5x10^{-9}$ m/s, or 2 m thick with a hydraulic conductivity of 1 $x10^{-8}$ m/s, or equivalent.

Model parameterisation

The parameters used in the RAM assessment are described together with justification for their use within the RAM model and in *Table 3308/HRA/T2*. A printout of the RAM model is provided as *Appendix 3308/HRA/A2* and an electronic version will be e-mailed.

Two pathways have been modelled:

a) From the source, through the geological barrier vertically and into the underlying sandstone aquifer

b) From the source, through the geological barrier and transport through the sandstone aquifer to the site boundary (although results for this pathway are not reported as no Non-hazardous substances were modelled)

The RAM model simulates the resultant concentrations in groundwater surrounding the site based on a declining source term. It also calculates what the maximum leachable concentrations could be before failure of the EAL's at the modelled receptors (similar to the remedial targets calculated in the Environment Agency's Annex J5 spreadsheet) occurs.

Parameter values were determined from information directly measured on-site or, in the absence of site data, other recognised sources. The results of the assessment are discussed below.

3308/HRA/T2: Model input parameters		
Parameter	**Value/distribution**	**Justification**
SOURCE TERM		
Waste volume (m^3)	975000	
GENERAL CONTAMINANT INFORMATION		
Free water diffusion coefficient (m^2/s): Mercury Lead Benzene Benzo-a-pyrene	 2.00×10^{-9} 1.00×10^{-9} 6.64×10^{-10} 6.90×10^{-10}	Environment Agency, Soil Guideline Values US EPA SR7 2008
HYDROGEOLOGICAL UNITS		
Thickness (m): Artificial geological barrier Unsaturated zone Saturated Sandstone	 1 3.5 10	 Assumed likely achievable value Minimum based on borehole SAN821 Conservative estimate base on likely mixing depth.

3308/HRA/T2: Model input parameters		
Parameter	**Value/distribution**	**Justification**
Hydraulic conductivity (m/s): Artificial geological barrier Sandstone	 5×10^{-9} m/s 1.4×10^{-4} m/s (12.1 m/d)	 Assumed likely achievable value Median value BGS Aquifer Properties manual[1]
Hydraulic gradient: Artificial geological barrier Saturated aquifer	 1 0.02	 Assumed vertical Average gradient from boreholes in adjacent Veolia site.
Porosity: Artificial geological barrier Sandstone	 0.4 0.27	
Tortuosity	5	Assumed generic value for all hydrogeological layers
Horizontal travel distance in sandstone (m)	103.5	Half the length of the site perpendicular to groundwater flow direction.
ATTENUATION PARAMETERS		
Dispersivity	Unit thickness/10	Standard assumption
Mixing depth in Sandstone (m)	10	Assumed
Bulk density (kg/m^3): Artificial clay barrier Sandstone Fraction of organic carbon: Artificial geological barrier Sandstone	 1600 2500 0.01 0.001	 Estimate Key GS Stability Assessment Feb 2021
<u>Mercury</u> Partition coefficient (k_d) (L/kg) Artificial geological barrier Sandstone <u>Lead</u> Partition coefficient (k_d) (L/kg) Artificial geological barrier Sandstone <u>Benzene</u> Partition coefficient (k_d) (L/kg) Artificial geological barrier Sandstone Half life (days)	 450 450 220 220 0.066 0.66 198	 Consim Suarez & Rifai (1999), Median value for mixed redox processes.

3308/HRA/T2: Model input parameters		
Parameter	**Value/distribution**	**Justification**
Benzo-a-pyrene		
Partition coefficient (k_d) (L/kg)		
Artificial geological barrier	1170	
Sandstone	11700	
Half life (days)	830	Wild et al (1992)
WATER BALANCE		
Precipitation (mm/yr)	800.3	Rain gauge SO 9509 7629, LTA.
Effective Precipitation (mm/yr)	359.1	Rainfall minus potential evapotranspiration from Area 30, MAFF Technical Bulletin 34

2.7 Whole site assessment

Modelling Approach

Modelling of the whole restored site has been undertaken as this represents the largest volume of waste present within the site. Initial modelling was undertaken without a geological barrier present. The results from the initial model indicated that a geological barrier would be required to prevent exceedance of the relevant EAL's.

Subsequent modelling comprised sensitivity analysis to determine the range of thickness and hydraulic conductivity values that would be required to provide sufficient attenuation to prevent exceedance of the EAL's.

Environmental Assessment Levels

Environmental Assessment Levels (EALs) are used to determine the local sensitivity of the groundwater and are a measure against which the results of models can be compared. EALs are determined on the basis of available water quality standards and concentrations.

All of the substances to be modelled (following the risk screening), are Hazardous Substances. The EPR (2016) requires there to be no discernible discharge of Hazardous substances to groundwater. Therefore, the appropriate EAL would be the concentration at which they become 'discernible'. The EAL's have been adopted as the Minimum Reporting Value (MRV), where these were not available for a contaminant the Limit of Quantification (LoQ) was adopted.

The adopted EAL's are presented in *Table 3308/HRA/T3*.

3308/HRA/T3: Summary of adopted EALs	
Determinand	**EAL (µg/l)**
Mercury	0.01
Lead	0.2*
Benzene	1
Benzo-a-pyrene	$5x10^{-5}$ *
* LoQ adopted as EAL	

Results

Sensitivity analysis indicates that in order to prevent exceedance of the EAL's the geological barrier will need to be 1 m thick with a hydraulic conductivity of 5 $x10^{-9}$ m/s or, 2 m thick with a hydraulic conductivity of 1 x 10^{-8} m/s, or equivalent. With this in place the following peak concentrations are recorded at the compliance point.

3308/HRA/T4: Peak concentrations	
Determinand	**Peak concentration at the appropriate receptor (time to peak in years)**
Hazardous: Mercury Lead Benzene Benzo-a-pyrene	 $2x10^{-7}$ mg/l / $2x10^{-4}$µg/l (1200 years)* $1.6x10^{-4}$ mg/l / 0.16 µg/l (1200 years)* $4.1x10^{-4}$ mg/l / 0.41 µg/l (5 years) No concentration detectable
*Model run to 1200 years, concentrations appear to be peaking. Actual peaks will be broader, shallower and arrive earlier as waste will be progressively placed.	

2.8 Rogue load assessment

Modelling Approach

The waste acceptance procedures to be applied at the site make the deposition of rogue loads unlikely and the potential risk to groundwater minimal. However, due to the sensitivity of the site setting, risk assessment modelling of acceptance of an accidental rogue load has been undertaken.

It is not possible to model a number of rogue loads distributed throughout the waste body. Therefore, for the purposes of the rough load assessment the initial contaminant concentrations have been assumed as a weighted average with 90% of the waste at half the Inert WAC concentrations (based on the likely nature of the waste to be accepted) and the

remaining 10%, representing rogue loads, being modelled at three times Inert WAC concentrations.

The rogue load analysis forms an assessment of a plausible failure scenario and as such is not expected to occur. The scenario modelled is very conservative, in that 1 in 10 loads received by the site exceed the Inert WAC levels. A printout of the results has been included in Appendix 3308/HRA/A3.

Results of rogue load risk assessment

The rogue load assessment did not result in a breach of the EAL by any of the determinands modelled. The results of the modelling indicate that unlikely event that rogue loads are deposited at the site, 10% non-conforming waste with concentrations up to 3 times the inert WAC can be accepted at the site without breach of the EALs at the compliance point.

2.9 Review of technical precautions

Due to the inert nature of the waste it is considered that the proposed essential and technical precautions detailed below are appropriate and sufficient to prevent any unacceptable discharge from the site:

- Strict control of waste types sourced and accepted
- Strict adherence to Waste Acceptance Criteria and Procedures, including Inert WAC analyses
- Removal of standing water in areas of waste recovery prior to commencement of waste placement
- Provision of an artificial geological barrier as determined by the HRA
- Progressive restoration to a suitable profile to encourage surface water run-off and minimise water ingress
- Provision of ditches or berms on the western boundary to minimise surface water ingress to the operational waste recovery area
- Groundwater monitoring

It is considered that leachate monitoring and management is not required due to the inert nature of the waste.

2.10 Emissions to groundwater

One of the main purposes of the HRA is to establish whether the predicted discharge from the waste recovery area complies with the requirements of the Environmental Permitting (England and Wales) Regulations (2016) Schedule 22 Groundwater activities.

Hazardous substances

The HRA must demonstrate that the proposed technical precautions will prevent Hazardous substances from entering groundwater. Consequently it must consider whether there is likely to be a discernible discharge of Hazardous substances to groundwater. The compliance point is, therefore, the watertable prior to any dilution occurring.

Due to the provision of an artificial geological barrier, there is considered to be no direct discharge to groundwater. Potential exists for an indirect discharge to the underlying sandstone. However, given the strictly inert nature of the waste to be imported, together with the provision of a geological barrier the results of the HRA indicate that during normal operation and through to long-term post-closure there will be no discernible discharge of Hazardous substances to groundwater.

Non-hazardous pollutants

The HRA must demonstrate that technical precautions will limit the introduction of Non- hazardous pollutants into groundwater so as to avoid pollution. Consequently, it must consider whether predicted concentrations of Non-hazardous pollutants are likely to exceed relevant standards and other environmental quality criteria, or cause an unacceptable deterioration in groundwater quality following dilution.

A pathway exists for Non-hazardous pollutants. However, given the inert nature of the waste and the provision of a geological barrier, it is concluded that under normal operation and through to long-term post-closure concentrations of Non-hazardous pollutants would be sufficiently low as to avoid pollution of the groundwater.

2.11 Surface water management

The proposed inert waste recovery area is not located in an area that is liable to flood. However, given that the void represents a topographic low, run-off will need to be managed.

During the operational phase, run-off will be directed away from the areas of active waste recovery. Run-off from the adjacent Veolia site will be prevented from entering the site via a cut-off ditch located between the two sites. This will allow collection of run-off and will channel it southward to a new retention basin located north of the site access road and east of the area subject to infilling. From here run-off will be allowed to soakaway into the in-situ sandstone.

Post-operation, the restoration profile of the inert waste recovery area will be domed and run-off collect in perimeter drains and be directed to the northwestern corner of the site where it will collect in a pool adjacent to a residual sandstone face. Infiltration will occur via the face and base together with loss through evaporation. There will be no need to actively manage surface water post-closure. These arrangements have been agreed with the Planning Authority through discharge of Planning Conditions.

2.12 Emissions to surface water

Given the geometry of the restoration profile, the inert nature of the waste and the other technical precautions in place, it is concluded that during normal operation and through to long-term post-closure, concentrations of Hazardous substances will not be discernible and Non-hazardous pollutants will be sufficiently low as to avoid pollution of surface water.

2.13 Hydrogeological completion criteria

Hydrogeological completion criteria refer to the conditions that must be met before an Environmental Permit can be surrendered, ie Permit Completion attained. Completion relating to hydrogeological risk will have been achieved when there is no longer any unacceptable risk of pollution from the waste recovery area, ie the site complies with the Environmental Permitting (England and Wales) Regulations (2016) Section 22 Groundwater Activities without any active leachate management. It is suggested that assessment of completion should be with reference to the recommended Environmental Assessment Levels (EALs).

As the site is inert and unacceptable discharge is unlikely, it is considered that hydrogeological completion criteria will not be the controlling factor in the ultimate surrender of the Environmental Permit. Guidance issued by the Environment Agency[1] states that for inert waste permitted under the Landfill Directive "you should be able to demonstrate, through waste records, that the waste accepted is genuinely inert", and this could form the basis for Permit Surrender, together with appropriate construction quality assurance (CQA) reports and review of relevant environmental monitoring.

1 Environment Agency, 13/12/2012. Additional guidance for Landfill (EPR 5.0) and other permanent deposits of waste: how to surrender your permit

3 REQUISITE SURVEILLANCE

3.1 Risk-based monitoring scheme

Under the Environmental Permitting (England and Wales) Regulations (2016), there is a requirement for 'requisite surveillance' in the form of leachate, groundwater and surface water monitoring.

Environmental monitoring is a crucial element of the risk assessment process as it:

- Allows for validation of the risk assessment
- Can confirm whether risk management options are meeting their aims
- Provides a warning mechanism if adverse impacts are found

Leachate monitoring

There is no requirement for collection and management of leachate, hence leachate monitoring is not proposed.

Groundwater Monitoring

Groundwater monitoring boreholes have been drilled at the site with response zones within the Wildmoor Sandstone. Four boreholes were drilled at the locations shown on *Drawing 3308/HRA/02v2*. These will be monitored in addition to Veolia boreholes 800, 810 and 821 providing up gradient and down gradient boreholes, based on the current groundwater flow direction.

The monitoring suite proposed for these locations is shown in *Table 3048/HRA/T5*.

3308/HRA/T5: Proposed monitoring suite for groundwater samples	
Frequency	**Suite**
Quarterly	Level, pH, conductivity, ammoniacal nitrogen, chloride, Chemical Oxygen Demand, Nitrate, Sulphate, Mercury, Nickle, Lead, benzene, arsenic.
Annually	As quarterly suite plus total alkalinity, sodium, magnesium, potassium, copper, zinc, chromium, iron, manganese, cadmium, BTEX total petroleum hydrocarbons, polyaromatic hydrocarbons

Surface water monitoring

No run-off will be discharge from the site and there are no watercourses or waterbodies in close proximity to the site. Therefore no surface water monitoring is proposed.

4 CONCLUSIONS

4.1 Compliance with the Landfill Directive

It is considered that the artificial geological barrier to be constructed on the sides to provide a maximum permeability of 1 m at 5 x 10^{-9} m/s, or equivalent, is such that the Landfill Regulations requirement for a geological barrier will be met. There is no requirement for an artificial sealing liner or leachate management system due to the inert nature of the waste. **It is therefore considered that the waste recovery site will be compliant with the requirements of the Landfill Directive**.

4.2 Compliance with the Environmental Permitting (England and Wales) Regulations (2016)

The risk assessment has demonstrated that under normal operational and post-operational phases, Hazardous substances will not be present in groundwater beneath the site in concentrations discernible above background. **It is therefore considered that the site will be compliant with respect to the Environmental Permitting (England and Wales) Regulations (2016).**

5 REFERENCES

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Environment Agency, October 2020. Landfill developments: groundwater risk assessment for leachate. https://www.gov.uk/guidance/landfill-developments-groundwater-risk-assessment-for-leachate.

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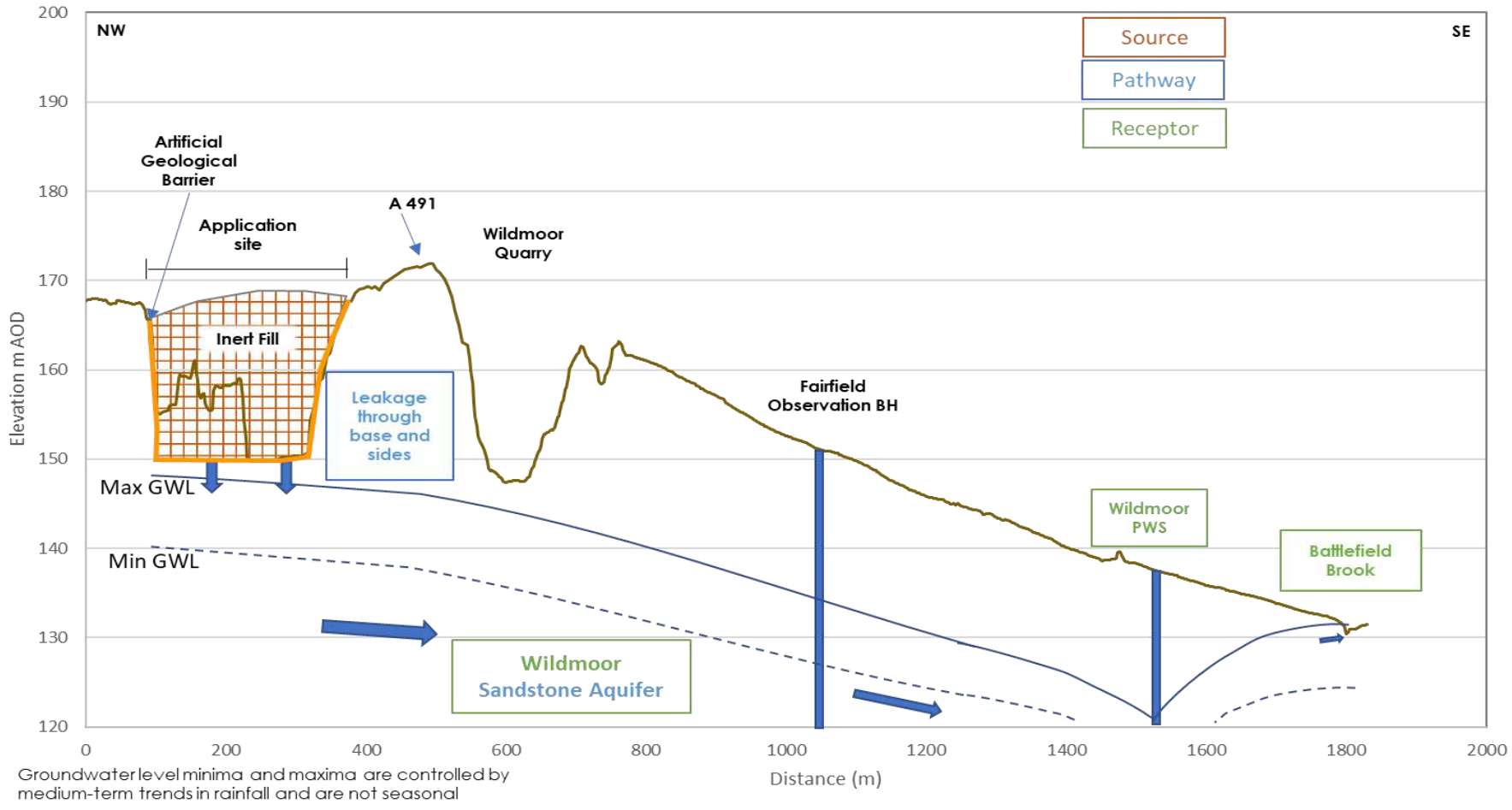
DRAWINGS



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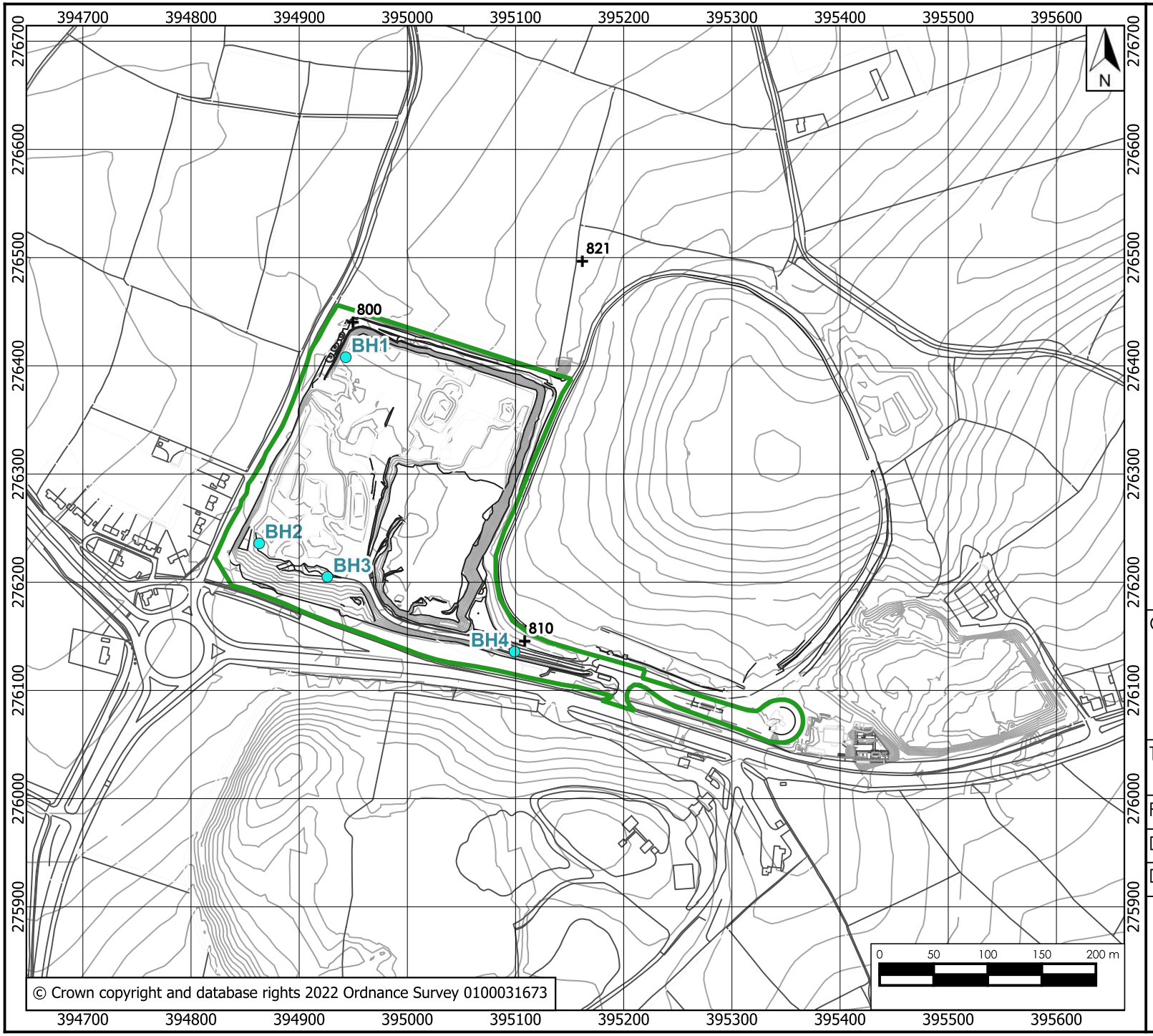
Client	NRS Bromsgrove Aggregates		
Title	Conceptual model		
Project	Sandy Lane Quarry		
Drawing	3308/HRA/01	Version	1
Date	Aug-22	Scale	



Legend

- Site Boundary
- 2023 monitoring boreholes
- Veolia Monitoring Borehole

Scale correct at A4

Client	NRS Bromsgrove Aggregates
Title	Monitoring Borehole Locations
Project	Sandy Lane Quarry
Drawing	3308/HRA/02
Version	2
Date	Jun 24
Scale	1:5,000

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APPENDIX 3308/HRA/A1

Tier 1 Risk Screening

hafrenwater
environmental water management

Calc sheet by:	DI	Yellow	Data entry
Version number:	1	Green	Formulae
Date:	07/07/2021	Blue	Select from list

Generic inert Waste Acceptance Criteria (WAC) limits have been compared to appropriate screening values.

A screening exercise has been undertaken using a calculated dilution factor.

Hazardous Substances have been compared against the Minimum Reporting Values (MRV)

Non-Hazardous Substances have been compared againts DWS values

Type of Dilution Aquifer

Screening Values (µg/l)

Parameter	Inert WAC	MRV	DWS	EQS	User Defined
Arsenic (As)$^{+}$	500	5	10	50	
Cadmium (Cd)	40	0.1	5	0.08	
Copper (Cu)	2000		2000	1	
Total Chromium (Cr)	500	37.5	50	4.7	
Chromium VI^{+}		1		3.4	
Nickel (Ni)	400		20	4	
Mercury (Hg)	10	0.01	1	0.07	
Lead (Pb)$^{+}$	500	0.2	10		
Selenium (Se)	100		10		
Chloride (Cl^{-})	8.0E+05		250000		
Sulphate (SO_4^{2-})	1.0E+06		250000		
Benzene	6000	1	1	10	
Benzo-a-pyrene^{+}	1.0E+05	5.0E-05	1.0E-02	1.7E-04	

Hazardous substance

$^{+}$ *MRV assumed as Limit of Quantification (LoQ)*

Calculation of Dilution Factor

Site Parameters			Data Source
Rainfall infiltration rate	359.0	mm/yr	MAFF data and CEH-GEAR
Area of landfill	51128	m^2	measured
Total infiltration	50.29	m^3/day	

Aquifer Dilution			
Hydraulic Conductivity (k)	12.1000	m/day	Allen et al. 1997
Hydraulic Gradient (i)	0.0200		Estimated from water strike data
Area	51128	m^2	Measured site area
Flow Rate (Q)	12372.976	m^3/day	

Waterbody Dilution			
Waterbody Area		m^2	
Waterbody Depth		m	
Waterbody Volume	NA	m^3	

Watercourse Dilution			
Flow Rate		m^3/sec	
Volume	NA	m^3/day	

Dilution Factor 246.04

Screening Assessment

Parameter	WAC after dilution	Exceeds selected screening value?	Max allowable concentration		
Arsenic (As)+	2	No	NA	µg/l	
Cadmium (Cd)	0.16	No	NA	µg/l	
Copper (Cu)	8	No	NA	µg/l	
Total Chromium (Cr)	2.0	No	NA	µg/l	
Chromium VI+	No Value	No Value	NA	µg/l	
Nickel (Ni)	2	No	NA	µg/l	
Mercury (Hg)	0.04	Yes	2.46	µg/l	modelled in RAM
Lead (Pb)+	2.0	Yes	49.2	µg/l	modelled in RAM
Selenium (Se)	0.4	No	NA	µg/l	
Chloride (Cl^-)	3251	No	NA	µg/l	
Sulphate (SO_4^{2-})	4064	No	NA	µg/l	
Benzene	24	Yes	246.04	µg/l	modelled in RAM
Benzo-a-pyrene+	406	Yes	1.2E-02	µg/l	modelled in RAM

Hazardous substance

+ *MRV assumed as Limit of Quantification (LoQ)*

Notes

Non-Hazardous substances have been compared against DWS values as groundwater is the primary receptor.
The EQS value for Cadmium is determined by the water hardness. As the hardness is unknown, the most stringent value has been adopted.
The EQS value for Copper is based on the bioavailable fraction.

Common Assumptions & References

Benzene concentrations are assumed as indicative of BTEX concentrations.
Benzo(a)pyrene concentrations are assumed as indicative of PAH concentrations.
Hazardous substances as defined by List I Substances under Groundwater Directive 2006/118/EC
Assumes 'leachate' density equals that of water and hence 1 mg/kg is equivalent to 1 mg/l

Council Decision Annex 2003/33/EC

The Water Supply (Water Quality) Regulations 2016

UKTAG Technical Report on Groundwater Hazardous Substances 11b(iii) v12, Sep 2016

APPENDIX 3308/HRA/A2

Whole Site RAM model

Source Type

☐ Soil Source ☐ Groundwater Source

Level Number

◉ Advanced

Parameter Values

◉ Deterministic ○ Probabilistic

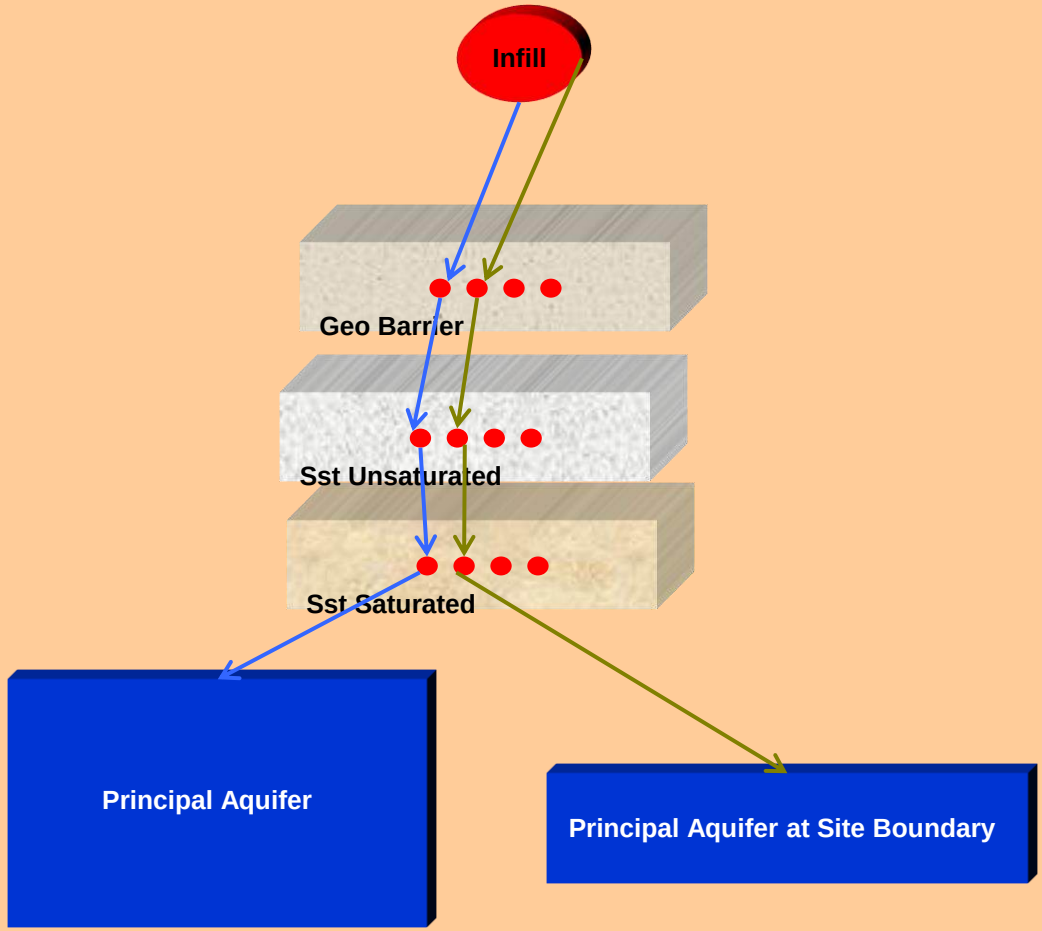
Created: 14/07/2022 11:35:25

by: Heather MacLeod

Version: 3.06.00x StdBmb

Site: Sandy Lane RAM1

Numerical value
Suggested formula
Probabilistic parameters
Data specified elsewhere
Suggested formula edited



SOURCE CONCENTRATIONS: Infill

Source Data Options

- (●) Pore water concentrations
- ( ) Leaching test
- ( ) Soil contaminant concentrations

Source Type

- ( ) Constant source
- (●) Declining source

Source Geometry

Infill_Source_length	207	**m**
Infill_Source_width	246	**m**
Infill_Source_area	51128	**m2**
Infill_Source_thickness		**m**
Infill_Source_volume	975000	**m3**

General Source Properties

Infill_Source_field_capacity	**[-]**	0.2

Source Contaminant Information

Source determinand names		Hg	Pb	Benzene	BaP
Infill_Pore_water_concentration	**mg/L**	0.01	0.5	6	100
Infill_Initial_inventory	**kg**	1.95	97.5	1170	19500
Infill_Input_concentration	**mg/L**	0.01	0.5	6	100

CONTAMINANT INFORMATION

		Species1	Species2	Species3	Species4
Source determinand names	4	Hg	Pb	Benzene	BaP

Receptor Target Concentrations

	Name	Values in mg/L			
Quality Standard 1	MRV	0.00001	0.0002	1.00E-03	5.00E-08
Quality Standard 2					
Quality Standard 3					
Quality Standard 4					

Generic Contaminant Properties

Contaminants_Organic_Carbon_Water_Partition_Coefficient_Koc	**L/kg**			66	1.17E+06
Contaminants_Free_Water_Diffusion_Coefficient	**m2/s**	2.00E-09	1.00E-09	6.64E-10	6.90E-10

HYDROGEOLOGICAL UNITS

Hydrogeological Units		Sst Unsaturated	Sst Saturated	Geo Barrier
Hydrogeology_Unit_Thickness	m	3.5	10	1
Hydrogeology_Log_Hydraulic_Conductivity	log(m/s)			
Hydrogeology_Hydraulic_Conductivity	m/s	1.40E-04	1.40E-04	5.00E-09
Hydrogeology_Head	m			
Hydrogeology_Hydraulic_Gradient	[-]	1	0.02	1
Hydrogeology_Porosity	[-]	0.27	0.27	0.4
Hydrogeology_Velocity	m/s	0.000518519	1.03704E-05	1.25E-08
Hydrogeology_Tortuosity	[-]	5	5	5

ATTENUATION PARAMETERS

Hydrogeological Units		Sst Unsaturated	Sst Saturated	Geo Barrier
General properties				
Attenuation_Dry_bulk_density	kg/m3	2200	2200	1600
Attenuation_Fraction_organic_carbon	[-]	0.001	0.001	0.01
Contaminant specific parameters				
Hg				
Attenuation_Partition_Coefficient_Kd_Species_1	L/kg	450	450	450
Attenuation_Retardation_Species_1	[-]	3667.666667	3667.666667	1801
Attenuation_Half_Life_Species_1	days	No Decay	No Decay	No Decay
Attenuation_Decay_Coefficient_Species_1	1/s	0	0	0
Pb				
Attenuation_Partition_Coefficient_Kd_Species_2	L/kg	220	220	220
Attenuation_Retardation_Species_2	[-]	1793.592593	1793.592593	881
Attenuation_Half_Life_Species_2	days	No Decay	No Decay	No Decay
Attenuation_Decay_Coefficient_Species_2	1/s	0	0	0
Benzene				
Attenuation_Partition_Coefficient_Kd_Species_3	L/kg	0.066	0.066	0.66
Attenuation_Retardation_Species_3	[-]	1.537777778	1.537777778	3.64
Attenuation_Half_Life_Species_3	days	198	198	198
Attenuation_Decay_Coefficient_Species_3	1/s	4.05179E-08	4.05179E-08	4.05E-08
BaP				
Attenuation_Partition_Coefficient_Kd_Species_4	L/kg	1170	1170	11700
Attenuation_Retardation_Species_4	[-]	9534.333333	9534.333333	46801
Attenuation_Half_Life_Species_4	days	830	830	830
Attenuation_Decay_Coefficient_Species_4	1/s	9.66571E-09	9.66571E-09	9.67E-09

WATER BALANCE

User defined

Enter your own calculations for the water balance
Carry fluxes and velocities over onto the Pathway sheet

Infiltration through the soil zone source

Source Name: Infill

Effective_Rainfall	359.1	**mm/year**
Infiltration_Factor	1	**[-]**
Infiltration_Rate	359.1	**mm/year**
Infiltration_Area	51128	**m2**
Q_Infiltration	0.000582	**m3/s**

	Jan	feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainfall (m	65.2	53.2	46.5	57.8	69.7	64.9	76.2	70.4	54.8	91.2	79.3	71.1
Potential transpiration (mm)	1	8	30	55	80	93	93	72	43	19	4	0
Effective rainfall (mm)	64.2	45.2	16.5	2.8					11.8	72.2	75.3	71.1
											Total ER	359.1

PATHWAY SUMMARY

Path 1	Section 1		Section 2		Section 3		Section 4		Section 5	
Path 1 Type	Source		Unit		Unit		Unit		Receptor	
Path 1 Name	**Infill**		**Geo Barrier: Node 1**		**Sst Unsaturated: Node 1**		**Sst Saturated: Node 1**		**Principal Aquifer**	
Path 1 Process	Declining source		ADRD (1D) + Dilution		ADRD (1D) + Dilution		ADRD (1D) + Dilution		Monitoring Borehole	
Path 1 Standards									Target Standard	MRV
Path 1 Parameter1	**Q_managed [m3/s]**	0.000E+00	**Velocity [m/s]**	1.250E-08	**Velocity [m/s]**	5.185E-04	**Velocity [m/s]**	1.037E-05		
Path 1 Parameter2	**Managed time [years]**	0.000E+00	**Dispersivity [m]**	0.1	**Dispersivity [m]**	0.4	**Dispersivity [m]**	0.0		
Path 1 Parameter3	**Q_path [m3/s]**	5.818E-04	**Travel Distance [m]**	1.0	**Travel Distance [m]**	3.5	**Travel Distance [m]**	0.0		
Path 1 Parameter4	**Q_decline [m3/s]**	5.818E-04	**Mixing Depth [m]**		**Mixing Depth [m]**		**Mixing Depth [m]**	10.0		
Path 1 Parameter5			**Mixing Width [m]**		**Mixing Width [m]**		**Mixing Width [m]**	246.0		
Path 1 Parameter6			**Q_Dilute [m3/s]**	0.000E+00	**Q_Dilute [m3/s]**	0.000E+00	**Q_Dilute [m3/s]**	6.888E-03	**Q_dilute [m3/s]**	0.000E+00

Path 2	Section 1		Section 2		Section 3		Section 4		Section 5	
Path 2 Type	Source		Unit		Unit		Unit		Receptor	
Path 2 Name	**Infill**		**Geo Barrier: Node 2**		**Sst Unsaturated: Node 2**		**Sst Saturated: Node 2**		**Principal Aquifer at Site Boundary**	
Path 2 Process	Declining source		ADRD (1D) + Dilution		ADRD (1D) + Dilution		ADRD (1D) + Dilution		Monitoring Borehole	
Path 2 Standards									Target Standard	MRV
Path 2 Parameter1	**Q_managed [m3/s]**	0.000E+00	**Velocity [m/s]**	1.250E-08	**Velocity [m/s]**	5.185E-04	**Velocity [m/s]**	1.037E-05		
Path 2 Parameter2	**Managed time [years]**	0.000E+00	**Dispersivity [m]**	0.1	**Dispersivity [m]**	0.4	**Dispersivity [m]**	10.4		
Path 2 Parameter3	**Q_path [m3/s]**	5.818E-04	**Travel Distance [m]**	1.0	**Travel Distance [m]**	3.5	**Travel Distance [m]**	103.5		
Path 2 Parameter4	**Q_decline [m3/s]**	5.818E-04	**Mixing Depth [m]**		**Mixing Depth [m]**		**Mixing Depth [m]**	10.0		
Path 2 Parameter5			**Mixing Width [m]**		**Mixing Width [m]**		**Mixing Width [m]**	246.0		
Path 2 Parameter6			**Q_Dilute [m3/s]**	0.000E+00	**Q_Dilute [m3/s]**	0.000E+00	**Q_Dilute [m3/s]**	6.888E-03	**Q_dilute [m3/s]**	0.000E+00

SIMULATION PARAMETERS

Monte Carlo Analysis with Crystal Ball

Reported Percentile	95
Number of simulations	10000

☐ Stop on calculation error

☐ Use same sequence of random numbers

Minimise while running:

◉ Nothing

○ All Spreadsheets (faster)

○ Microsoft Excel (fastest)

Named Constants

s_per_year	31557600
s_per_day	86400

Laplace Transform Solution Parameters

sigma	0
nu	1
nsum	16
omega	11

Reporting Options

☑ Include Remedial Targets and Attenuation Factors on the results sheets in Advanced level

☐ Use the array form of the RAM function

☑ Include a set of timeslices for each contaminant in each pathway

Number of timeslices for breakthrough curves: 20

The timeslices specified on the results sheets are saved below.

Path1 timeslices in years

TS_Path1_Spec1	TS_Path1_Spec2	TS_Path1_Spec3	TS_Path1_Spec4
1	1	1	1
2	2	2	2
5	5	5	5
10	10	10	10
15	15	15	15
20	20	20	20
30	30	30	30
40	40	40	40
50	50	50	50
60	60	60	60
70	70	70	70
80	80	80	80
90	90	90	90
100	100	100	100
120	120	120	120
140	140	140	140
160	160	160	160
180	180	180	180
200	200	200	200
250	250	250	250

Path2 timeslices in years

TS_Path2_Spec1	TS_Path2_Spec2	TS_Path2_Spec3	TS_Path2_Spec4
1	1	1	1
2	2	2	2
5	5	5	5
10	10	10	10
15	15	15	15
20	20	20	20
30	30	30	30
40	40	40	40
50	50	50	50
60	60	60	60
70	70	70	70
80	80	80	80
90	90	90	90
100	100	100	100
120	120	120	120
140	140	140	140
160	160	160	160
180	180	180	180
200	200	200	200
250	250	250	250

BREAKTHROUGH RESULTS

Site Name: "Sandy Lane RAM1"

Advanced

Barrier Thickness	1 m	Benzene Half Life	198 Days
Barrier k	5.00E-09 m/s		

Pollutant Linkage: Infill, Geo Barrier, Sst Unsaturated, Sst Saturated, Principal Aquifer

Concentrations in mg/L in Principal Aquifer

Compared with MRV target concentration in mg/L

1.000E-05	2.000E-04	1.000E-03	5.000E-08

	Species1		Species2		Species3		Species4
Time(years	**Hg**	Time(years	**Pb**	Time(years	**Benzene**	Time(years	**BaP**
1	0.000E+00	1	0.000E+00	1	1.049E-09	1	0.000E+00
2	0.000E+00	2	0.000E+00	2	1.290E-05	2	0.000E+00
5	0.000E+00	5	0.000E+00	5	4.138E-04	5	0.000E+00
10	0.000E+00	10	0.000E+00	10	3.028E-04	10	0.000E+00
15	0.000E+00	15	0.000E+00	15	1.892E-04	15	0.000E+00
20	0.000E+00	20	0.000E+00	20	1.181E-04	20	0.000E+00
30	0.000E+00	30	9.626E-33	30	4.607E-05	30	0.000E+00
40	0.000E+00	40	0.000E+00	40	1.797E-05	40	0.000E+00
50	1.597E-36	50	0.000E+00	50	7.009E-06	50	0.000E+00
60	4.977E-33	60	8.848E-24	60	2.734E-06	60	0.000E+00
70	0.000E+00	70	0.000E+00	70	1.066E-06	70	0.000E+00
80	7.049E-29	80	1.102E-21	80	4.158E-07	80	0.000E+00
90	0.000E+00	90	0.000E+00	90	1.622E-07	90	0.000E+00
100	9.883E-27	100	4.467E-20	100	6.326E-08	100	0.000E+00
120	0.000E+00	120	3.278E-19	120	9.622E-09	120	0.000E+00
140	9.992E-24	140	1.897E-16	140	1.463E-09	140	0.000E+00
160	0.000E+00	160	1.375E-14	160	2.214E-10	160	0.000E+00
180	4.191E-22	180	3.786E-13	180	3.252E-11	180	0.000E+00
200	0.000E+00	200	5.276E-12	200	3.728E-12	200	0.000E+00
250	1.529E-18	250	5.681E-10	250	0.000E+00	250	0.000E+00
300	4.594E-16	300	1.198E-08	300	0.000E+00	300	0.000E+00
350	2.591E-14	350	1.000E-07	350	0.000E+00	350	0.000E+00
400	5.143E-13	400	4.699E-07	400	0.000E+00	400	0.000E+00
450	5.102E-12	450	1.510E-06	450	0.000E+00	450	0.000E+00
500	3.121E-11	500	3.730E-06	500	0.000E+00	500	0.000E+00
550	1.346E-10	550	7.624E-06	550	0.000E+00	550	0.000E+00
600	4.472E-10	600	1.354E-05	600	0.000E+00	600	0.000E+00
650	1.217E-09	650	2.161E-05	650	0.000E+00	650	0.000E+00
700	2.834E-09	700	3.175E-05	700	0.000E+00	700	0.000E+00
750	5.830E-09	750	4.367E-05	750	0.000E+00	750	0.000E+00
800	1.085E-08	800	5.697E-05	800	0.000E+00	800	0.000E+00
850	1.861E-08	850	7.120E-05	850	0.000E+00	850	0.000E+00
900	2.982E-08	900	8.588E-05	900	0.000E+00	900	0.000E+00
950	4.515E-08	950	1.006E-04	950	0.000E+00	950	0.000E+00
1000	6.516E-08	1000	1.149E-04	1000	0.000E+00	1000	0.000E+00
1050	9.027E-08	1050	1.285E-04	1050	0.000E+00	1050	0.000E+00
1100	1.207E-07	1100	1.411E-04	1100	0.000E+00	1100	0.000E+00
1150	1.567E-07	1150	1.527E-04	1150	0.000E+00	1150	0.000E+00
1200	1.980E-07	1200	1.629E-04	1200	0.000E+00	1200	0.000E+00

Pollutant Linkage: Infill, Geo Barrier, Sst Unsaturated, Sst Saturated, Principal Aquifer at Site Boundary

Concentrations in mg/L in Principal Aquifer at Site Boundary

Compared with MRV target concentration in mg/L

1.000E-05	2.000E-04	1.000E-03	5.000E-08

	Species1		Species2		Species3		Species4
Time(years	**Hg**	Time(years	**Pb**	Time(years	**Benzene**	Time(years	**BaP**
1	0.000E+00	1	0.000E+00	1	6.293E-13	1	0.000E+00
2	0.000E+00	2	0.000E+00	2	1.005E-06	2	0.000E+00
5	0.000E+00	5	0.000E+00	5	2.157E-04	5	0.000E+00
10	0.000E+00	10	0.000E+00	10	1.753E-04	10	0.000E+00
15	0.000E+00	15	0.000E+00	15	1.095E-04	15	0.000E+00
20	0.000E+00	20	0.000E+00	20	6.841E-05	20	0.000E+00
30	0.000E+00	30	0.000E+00	30	2.668E-05	30	0.000E+00
40	0.000E+00	40	0.000E+00	40	1.041E-05	40	0.000E+00
50	0.000E+00	50	0.000E+00	50	4.059E-06	50	0.000E+00
60	0.000E+00	60	8.965E-35	60	1.583E-06	60	0.000E+00
70	0.000E+00	70	3.464E-31	70	6.175E-07	70	0.000E+00
80	0.000E+00	80	2.467E-29	80	2.408E-07	80	0.000E+00
90	0.000E+00	90	0.000E+00	90	9.393E-08	90	0.000E+00
100	1.147E-38	100	7.180E-26	100	3.663E-08	100	0.000E+00
120	1.900E-35	120	0.000E+00	120	5.572E-09	120	0.000E+00
140	3.768E-32	140	2.782E-22	140	8.473E-10	140	0.000E+00
160	0.000E+00	160	0.000E+00	160	1.284E-10	160	0.000E+00
180	1.840E-29	180	3.686E-20	180	1.893E-11	180	0.000E+00
200	3.107E-27	200	0.000E+00	200	2.241E-12	200	0.000E+00
250	1.224E-24	250	0.000E+00	250	0.000E+00	250	0.000E+00
300	0.000E+00	300	3.245E-16	300	0.000E+00	300	0.000E+00
350	0.000E+00	350	5.920E-14	350	0.000E+00	350	0.000E+00
400	1.552E-21	400	2.988E-12	400	0.000E+00	400	0.000E+00
450	5.329E-22	450	6.013E-11	450	0.000E+00	450	0.000E+00
500	0.000E+00	500	6.376E-10	500	0.000E+00	500	0.000E+00
550	1.143E-18	550	4.249E-09	550	0.000E+00	550	0.000E+00
600	2.382E-17	600	2.001E-08	600	0.000E+00	600	0.000E+00
650	3.402E-16	650	7.223E-08	650	0.000E+00	650	0.000E+00
700	3.272E-15	700	2.118E-07	700	0.000E+00	700	0.000E+00
750	2.289E-14	750	5.263E-07	750	0.000E+00	750	0.000E+00
800	1.238E-13	800	1.144E-06	800	0.000E+00	800	0.000E+00
850	5.418E-13	850	2.229E-06	850	0.000E+00	850	0.000E+00
900	1.990E-12	900	3.967E-06	900	0.000E+00	900	0.000E+00
950	6.305E-12	950	6.541E-06	950	0.000E+00	950	0.000E+00
1000	1.763E-11	1000	1.012E-05	1000	0.000E+00	1000	0.000E+00
1050	4.429E-11	1050	1.481E-05	1050	0.000E+00	1050	0.000E+00
1100	1.015E-10	1100	2.070E-05	1100	0.000E+00	1100	0.000E+00
1150	2.146E-10	1150	2.777E-05	1150	0.000E+00	1150	0.000E+00
1200	4.233E-10	1200	3.597E-05	1200	0.000E+00	1200	0.000E+00

Pollutant Linkage: Infill, Geo Barrier, Sst Unsaturated, Sst Saturated, Principal Aquifer

Remedial Target Concentrations in mg/L in Infill

Species1		Species2		Species3		Species4	
Time(years	**Hg**	Time(years	**Pb**	Time(years	**Benzene**	Time(years	**BaP**
1	1.000E+40	1	1.000E+40	1	5.720E+06	1	1.000E+40
2	1.000E+40	2	1.000E+40	2	4.653E+02	2	1.000E+40
5	1.000E+40	5	1.000E+40	5	1.450E+01	5	1.000E+40
10	1.000E+40	10	1.000E+40	10	1.982E+01	10	1.000E+40
15	1.000E+40	15	1.000E+40	15	3.172E+01	15	1.000E+40
20	1.000E+40	20	1.000E+40	20	5.079E+01	20	1.000E+40
30	1.000E+40	30	1.039E+28	30	1.302E+02	30	1.000E+40
40	1.000E+40	40	1.000E+40	40	3.339E+02	40	1.000E+40
50	6.261E+28	50	1.000E+40	50	8.561E+02	50	1.000E+40
60	2.009E+25	60	1.130E+19	60	2.195E+03	60	1.000E+40
70	1.000E+40	70	1.000E+40	70	5.628E+03	70	1.000E+40
80	1.419E+21	80	9.072E+16	80	1.443E+04	80	1.000E+40
90	1.000E+40	90	1.000E+40	90	3.699E+04	90	1.000E+40
100	1.012E+19	100	2.239E+15	100	9.485E+04	100	1.000E+40
120	1.000E+40	120	3.050E+14	120	6.236E+05	120	1.000E+40
140	1.001E+16	140	5.272E+11	140	4.102E+06	140	1.000E+40
160	1.000E+40	160	7.275E+09	160	2.709E+07	160	1.000E+40
180	2.386E+14	180	2.641E+08	180	1.845E+08	180	1.000E+40
200	1.000E+40	200	1.896E+07	200	1.610E+09	200	1.000E+40
250	6.541E+10	250	1.760E+05	250	1.000E+40	250	1.000E+40

Compared with source concentrations in mg/L

1.000E-02	5.000E-01	6.000E+00	1.000E+02

Pollutant Linkage: Infill, Geo Barrier, Sst Unsaturated, Sst Saturated, Principal Aquifer at Site Boundary

Remedial Target Concentrations in mg/L in Infill

Species1		Species2		Species3		Species4	
Time(years	**Hg**	Time(years	**Pb**	Time(years	**Benzene**	Time(years	**BaP**
1	1.000E+40	1	1.000E+40	1	9.534E+09	1	1.000E+40
2	1.000E+40	2	1.000E+40	2	5.969E+03	2	1.000E+40
5	1.000E+40	5	1.000E+40	5	2.781E+01	5	1.000E+40
10	1.000E+40	10	1.000E+40	10	3.422E+01	10	1.000E+40
15	1.000E+40	15	1.000E+40	15	5.477E+01	15	1.000E+40
20	1.000E+40	20	1.000E+40	20	8.770E+01	20	1.000E+40
30	1.000E+40	30	1.000E+40	30	2.249E+02	30	1.000E+40
40	1.000E+40	40	1.000E+40	40	5.765E+02	40	1.000E+40
50	1.000E+40	50	1.000E+40	50	1.478E+03	50	1.000E+40
60	1.000E+40	60	1.115E+30	60	3.790E+03	60	1.000E+40
70	1.000E+40	70	2.887E+26	70	9.717E+03	70	1.000E+40
80	1.000E+40	80	4.054E+24	80	2.491E+04	80	1.000E+40
90	1.000E+40	90	1.000E+40	90	6.388E+04	90	1.000E+40
100	8.718E+30	100	1.393E+21	100	1.638E+05	100	1.000E+40
120	5.263E+27	120	1.000E+40	120	1.077E+06	120	1.000E+40
140	2.654E+24	140	3.595E+17	140	7.082E+06	140	1.000E+40
160	1.000E+40	160	1.000E+40	160	4.674E+07	160	1.000E+40
180	5.434E+21	180	2.713E+15	180	3.169E+08	180	1.000E+40
200	3.219E+19	200	1.000E+40	200	2.677E+09	200	1.000E+40
250	8.168E+16	250	1.000E+40	250	1.000E+40	250	1.000E+40

Compared with source concentrations in mg/L

1.000E-02	5.000E-01	6.000E+00	1.000E+02

Pollutant Linkage: Infill, Geo Barrier, Sst Unsaturated, Sst Saturated, Principal Aquifer

Dilution Factor

1.284E+01 *for all species and timeslices*

Pollutant Linkage: Infill, Geo Barrier, Sst Unsaturated, Sst Saturated, Principal Aquifer at Site Boundary

Dilution Factor

1.284E+01 *for all species and timeslices*

Pollutant Linkage: Infill, Geo Barrier, Sst Unsaturated, Sst Saturated, Principal Aquifer

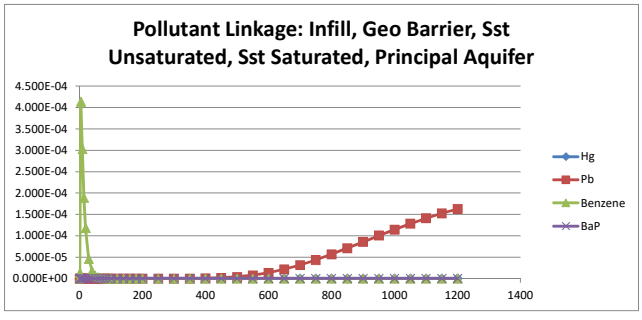
Attenuation Factor

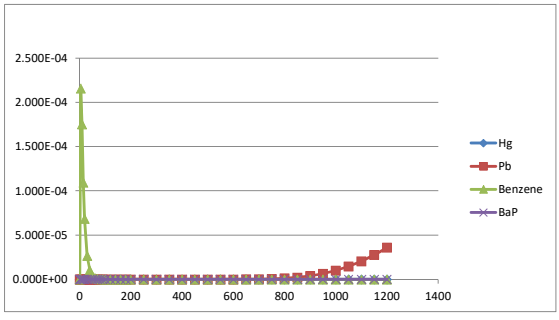
Species1		Species2		Species3		Species4	
Time(years	**Hg**	Time(years	**Pb**	Time(years	**Benzene**	Time(years	**BaP**
1	1.000E+40	1	3.894E-02	1	1.000E+40	1	7.789E+00
2	1.000E+40	2	1.947E-02	2	1.000E+40	2	3.894E+00
5	1.000E+40	5	7.789E-03	5	1.000E+40	5	1.558E+00
10	1.000E+40	10	3.894E-03	10	1.000E+40	10	7.789E-01
15	1.000E+40	15	2.596E-03	15	1.000E+40	15	5.192E-01
20	1.000E+40	20	1.947E-03	20	1.000E+40	20	3.894E-01
30	1.000E+40	30	1.298E-03	30	4.855E+31	30	2.596E-01
40	1.000E+40	40	9.736E-04	40	1.000E+40	40	1.947E-01
50	4.877E+32	50	7.789E-04	50	1.000E+40	50	1.558E-01
60	1.565E+29	60	6.491E-04	60	5.282E+22	60	1.298E-01
70	1.000E+40	70	5.563E-04	70	1.000E+40	70	1.113E-01
80	1.105E+25	80	4.868E-04	80	4.240E+20	80	9.736E-02
90	1.000E+40	90	4.327E-04	90	1.000E+40	90	8.654E-02
100	7.881E+22	100	3.894E-04	100	1.046E+19	100	7.789E-02
120	1.000E+40	120	3.245E-04	120	1.425E+18	120	6.491E-02
140	7.795E+19	140	2.782E-04	140	2.464E+15	140	5.563E-02
160	1.000E+40	160	2.434E-04	160	3.400E+13	160	4.868E-02
180	1.859E+18	180	2.164E-04	180	1.234E+12	180	4.327E-02
200	1.000E+40	200	1.947E-04	200	8.858E+10	200	3.894E-02
250	5.094E+14	250	1.558E-04	250	8.226E+08	250	3.115E-02

Pollutant Linkage: Infill, Geo Barrier, Sst Unsaturated, Sst Saturated, Principal Aquifer at Site Boundary

Attenuation Factor

Species1		Species2		Species3		Species4	
Time(years	**Hg**	Time(years	**Pb**	Time(years	**Benzene**	Time(years	**BaP**
1	1.000E+40	1	3.894E-02	1	1.000E+40	1	7.789E+00
2	1.000E+40	2	1.947E-02	2	1.000E+40	2	3.894E+00
5	1.000E+40	5	7.789E-03	5	1.000E+40	5	1.558E+00
10	1.000E+40	10	3.894E-03	10	1.000E+40	10	7.789E-01
15	1.000E+40	15	2.596E-03	15	1.000E+40	15	5.192E-01
20	1.000E+40	20	1.947E-03	20	1.000E+40	20	3.894E-01
30	1.000E+40	30	1.298E-03	30	1.000E+40	30	2.596E-01
40	1.000E+40	40	9.736E-04	40	1.000E+40	40	1.947E-01
50	1.000E+40	50	7.789E-04	50	1.000E+40	50	1.558E-01
60	1.000E+40	60	6.491E-04	60	5.213E+33	60	1.298E-01
70	1.000E+40	70	5.563E-04	70	1.349E+30	70	1.113E-01
80	1.000E+40	80	4.868E-04	80	1.895E+28	80	9.736E-02
90	1.000E+40	90	4.327E-04	90	1.000E+40	90	8.654E-02
100	6.790E+34	100	3.894E-04	100	6.509E+24	100	7.789E-02
120	4.100E+31	120	3.245E-04	120	1.000E+40	120	6.491E-02
140	2.067E+28	140	2.782E-04	140	1.680E+21	140	5.563E-02
160	1.000E+40	160	2.434E-04	160	1.000E+40	160	4.868E-02
180	4.232E+25	180	2.164E-04	180	1.268E+19	180	4.327E-02
200	2.507E+23	200	1.947E-04	200	1.000E+40	200	3.894E-02
250	6.362E+20	250	1.558E-04	250	1.000E+40	250	3.115E-02





APPENDIX 3308/HRA/A3

Rogue Load Assessment RAM model

SOURCE CONCENTRATIONS: Infill

Source Data Options

- (●) Pore water concentrations
- ( ) Leaching test
- ( ) Soil contaminant concentrations

Source Type

- ( ) Constant source
- (●) Declining source

Source Geometry

Infill_Source_length	207	**m**
Infill_Source_width	246	**m**
Infill_Source_area	51128	**m2**
Infill_Source_thickness		**m**
Infill_Source_volume	975000	**m3**

General Source Properties

Infill_Source_field_capacity	**[-]**	0.2

Source Contaminant Information

Source determinand names		Hg	Pb	Benzene	BaP
Infill_Pore_water_concentration	**mg/L**	7.50E-03	0.375	4.5	75
Infill_Initial_inventory	**kg**	1.4625	73.125	877.5	14625
Infill_Input_concentration	**mg/L**	0.0075	0.375	4.5	75

Pollutant Linkage: Infill, Geo Barrier, Sst Unsaturated, Sst Saturated, Principal Aquifer

Concentrations in mg/L in Principal Aquifer

Compared with MRV target concentration in mg/L

1.000E-05	2.000E-04	1.000E-03	5.000E-08

Species1		Species2		Species3		Species4	
Time(years	Hg	Time(years	Pb	Time(years	Benzene	Time(years	BaP
1	0.000E+00	1	0.000E+00	1	7.867E-10	1	0.000E+00
2	0.000E+00	2	0.000E+00	2	9.672E-06	2	0.000E+00
5	0.000E+00	5	0.000E+00	5	3.103E-04	5	0.000E+00
10	0.000E+00	10	0.000E+00	10	2.271E-04	10	0.000E+00
15	0.000E+00	15	0.000E+00	15	1.419E-04	15	0.000E+00
20	0.000E+00	20	0.000E+00	20	8.860E-05	20	0.000E+00
30	0.000E+00	30	7.220E-33	30	3.456E-05	30	0.000E+00
40	0.000E+00	40	0.000E+00	40	1.348E-05	40	0.000E+00
50	1.198E-36	50	0.000E+00	50	5.257E-06	50	0.000E+00
60	3.733E-33	60	6.636E-24	60	2.050E-06	60	0.000E+00
70	0.000E+00	70	0.000E+00	70	7.996E-07	70	0.000E+00
80	5.287E-29	80	8.267E-22	80	3.119E-07	80	0.000E+00
90	0.000E+00	90	0.000E+00	90	1.216E-07	90	0.000E+00
100	7.412E-27	100	3.350E-20	100	4.744E-08	100	0.000E+00
120	0.000E+00	120	2.459E-19	120	7.216E-09	120	0.000E+00
140	7.494E-24	140	1.423E-16	140	1.097E-09	140	0.000E+00
160	0.000E+00	160	1.031E-14	160	1.661E-10	160	0.000E+00
180	3.143E-22	180	2.840E-13	180	2.439E-11	180	0.000E+00
200	0.000E+00	200	3.957E-12	200	2.796E-12	200	0.000E+00
250	1.147E-18	250	4.261E-10	250	0.000E+00	250	0.000E+00

Pollutant Linkage: Infill, Geo Barrier, Sst Unsaturated, Sst Saturated, Principal Aquifer at Site Boundary

Concentrations in mg/L in Principal Aquifer at Site Boundary

Compared with MRV target concentration in mg/L

1.000E-05	2.000E-04	1.000E-03	5.000E-08

Species1		Species2		Species3		Species4	
Time(years	Hg	Time(years	Pb	Time(years	Benzene	Time(years	BaP
1	0.000E+00	1	0.000E+00	1	4.720E-13	1	0.000E+00
2	0.000E+00	2	0.000E+00	2	7.539E-07	2	0.000E+00
5	0.000E+00	5	0.000E+00	5	1.618E-04	5	0.000E+00
10	0.000E+00	10	0.000E+00	10	1.315E-04	10	0.000E+00
15	0.000E+00	15	0.000E+00	15	8.216E-05	15	0.000E+00
20	0.000E+00	20	0.000E+00	20	5.131E-05	20	0.000E+00
30	0.000E+00	30	0.000E+00	30	2.001E-05	30	0.000E+00
40	0.000E+00	40	0.000E+00	40	7.805E-06	40	0.000E+00
50	0.000E+00	50	0.000E+00	50	3.044E-06	50	0.000E+00
60	0.000E+00	60	6.724E-35	60	1.187E-06	60	0.000E+00
70	0.000E+00	70	2.598E-31	70	4.631E-07	70	0.000E+00
80	0.000E+00	80	1.850E-29	80	1.806E-07	80	0.000E+00
90	0.000E+00	90	0.000E+00	90	7.045E-08	90	0.000E+00
100	8.603E-39	100	5.385E-26	100	2.748E-08	100	0.000E+00
120	1.425E-35	120	0.000E+00	120	4.179E-09	120	0.000E+00
140	2.826E-32	140	2.086E-22	140	6.354E-10	140	0.000E+00
160	0.000E+00	160	0.000E+00	160	9.627E-11	160	0.000E+00
180	1.380E-29	180	2.764E-20	180	1.420E-11	180	0.000E+00
200	2.330E-27	200	0.000E+00	200	1.681E-12	200	0.000E+00
250	9.182E-25	250	0.000E+00	250	0.000E+00	250	0.000E+00

Pollutant Linkage: Infill, Geo Barrier, Sst Unsaturated, Sst Saturated, Principal Aquifer

Remedial Target Concentrations in mg/L in Infill

Species1		Species2		Species3		Species4	
Time(years	Hg	Time(years	Pb	Time(years	Benzene	Time(years	BaP
1	1.000E+40	1	1.000E+40	1	5.720E+06	1	1.000E+40
2	1.000E+40	2	1.000E+40	2	4.653E+02	2	1.000E+40
5	1.000E+40	5	1.000E+40	5	1.450E+01	5	1.000E+40
10	1.000E+40	10	1.000E+40	10	1.982E+01	10	1.000E+40
15	1.000E+40	15	1.000E+40	15	3.172E+01	15	1.000E+40
20	1.000E+40	20	1.000E+40	20	5.079E+01	20	1.000E+40
30	1.000E+40	30	1.039E+28	30	1.302E+02	30	1.000E+40
40	1.000E+40	40	1.000E+40	40	3.339E+02	40	1.000E+40
50	6.261E+28	50	1.000E+40	50	8.561E+02	50	1.000E+40
60	2.009E+25	60	1.130E+19	60	2.195E+03	60	1.000E+40
70	1.000E+40	70	1.000E+40	70	5.628E+03	70	1.000E+40
80	1.419E+21	80	9.072E+16	80	1.443E+04	80	1.000E+40
90	1.000E+40	90	1.000E+40	90	3.699E+04	90	1.000E+40
100	1.012E+19	100	2.239E+15	100	9.485E+04	100	1.000E+40
120	1.000E+40	120	3.050E+14	120	6.236E+05	120	1.000E+40
140	1.001E+16	140	5.272E+11	140	4.102E+06	140	1.000E+40
160	1.000E+40	160	7.275E+09	160	2.709E+07	160	1.000E+40
180	2.386E+14	180	2.641E+08	180	1.845E+08	180	1.000E+40
200	1.000E+40	200	1.896E+07	200	1.609E+09	200	1.000E+40
250	6.541E+10	250	1.760E+05	250	1.000E+40	250	1.000E+40

Compared with source concentrations in mg/L

7.500E-03	3.750E-01	4.500E+00	7.500E+01

Pollutant Linkage: Infill, Geo Barrier, Sst Unsaturated, Sst Saturated, Principal Aquifer at Site Boundary

Remedial Target Concentrations in mg/L in Infill

Species1		Species2		Species3		Species4	
Time(years	Hg	Time(years	Pb	Time(years	Benzene	Time(years	BaP
1	1.000E+40	1	1.000E+40	1	9.534E+09	1	1.000E+40
2	1.000E+40	2	1.000E+40	2	5.969E+03	2	1.000E+40
5	1.000E+40	5	1.000E+40	5	2.781E+01	5	1.000E+40
10	1.000E+40	10	1.000E+40	10	3.422E+01	10	1.000E+40
15	1.000E+40	15	1.000E+40	15	5.477E+01	15	1.000E+40
20	1.000E+40	20	1.000E+40	20	8.770E+01	20	1.000E+40
30	1.000E+40	30	1.000E+40	30	2.249E+02	30	1.000E+40
40	1.000E+40	40	1.000E+40	40	5.765E+02	40	1.000E+40
50	1.000E+40	50	1.000E+40	50	1.478E+03	50	1.000E+40
60	1.000E+40	60	1.115E+30	60	3.790E+03	60	1.000E+40
70	1.000E+40	70	2.887E+26	70	9.717E+03	70	1.000E+40
80	1.000E+40	80	4.054E+24	80	2.491E+04	80	1.000E+40
90	1.000E+40	90	1.000E+40	90	6.388E+04	90	1.000E+40
100	8.718E+30	100	1.393E+21	100	1.638E+05	100	1.000E+40
120	5.263E+27	120	1.000E+40	120	1.077E+06	120	1.000E+40
140	2.654E+24	140	3.595E+17	140	7.082E+06	140	1.000E+40
160	1.000E+40	160	1.000E+40	160	4.674E+07	160	1.000E+40
180	5.434E+21	180	2.713E+15	180	3.169E+08	180	1.000E+40
200	3.219E+19	200	1.000E+40	200	2.677E+09	200	1.000E+40
250	8.168E+16	250	1.000E+40	250	1.000E+40	250	1.000E+40

Compared with source concentrations in mg/L

7.500E-03	3.750E-01	4.500E+00	7.500E+01

Pollutant Linkage: Infill, Geo Barrier, Sst Unsaturated, Sst Saturated, Principal Aquifer

Dilution Factor

1.284E+01 *for all species and timeslices*

Pollutant Linkage: Infill, Geo Barrier, Sst Unsaturated, Sst Saturated, Principal Aquifer at Site Boundary

Dilution Factor

1.284E+01 *for all species and timeslices*

Pollutant Linkage: Infill, Geo Barrier, Sst Unsaturated, Sst Saturated, Principal Aquifer

Attenuation Factor

Species1		Species2		Species3		Species4	
Time(years	Hg	Time(years	Pb	Time(years	Benzene	Time(years	BaP
1	1.000E+40	1	2.921E-02	1	1.000E+40	1	5.841E+00
2	1.000E+40	2	1.460E-02	2	1.000E+40	2	2.921E+00
5	1.000E+40	5	5.841E-03	5	1.000E+40	5	1.168E+00
10	1.000E+40	10	2.921E-03	10	1.000E+40	10	5.841E-01
15	1.000E+40	15	1.947E-03	15	1.000E+40	15	3.894E-01
20	1.000E+40	20	1.460E-03	20	1.000E+40	20	2.921E-01
30	1.000E+40	30	9.736E-04	30	4.855E+31	30	1.947E-01
40	1.000E+40	40	7.302E-04	40	1.000E+40	40	1.460E-01
50	4.877E+32	50	5.841E-04	50	1.000E+40	50	1.168E-01
60	1.565E+29	60	4.868E-04	60	5.282E+22	60	9.736E-02
70	1.000E+40	70	4.172E-04	70	1.000E+40	70	8.345E-02
80	1.105E+25	80	3.651E-04	80	4.240E+20	80	7.302E-02
90	1.000E+40	90	3.245E-04	90	1.000E+40	90	6.491E-02
100	7.881E+22	100	2.921E-04	100	1.046E+19	100	5.841E-02
120	1.000E+40	120	2.434E-04	120	1.425E+18	120	4.868E-02
140	7.795E+19	140	2.086E-04	140	2.464E+15	140	4.172E-02
160	1.000E+40	160	1.825E-04	160	3.400E+13	160	3.651E-02
180	1.859E+18	180	1.623E-04	180	1.234E+12	180	3.245E-02
200	1.000E+40	200	1.460E-04	200	8.858E+10	200	2.921E-02
250	5.094E+14	250	1.168E-04	250	8.226E+08	250	2.337E-02

Pollutant Linkage: Infill, Geo Barrier, Sst Unsaturated, Sst Saturated, Principal Aquifer at Site Boundary

Attenuation Factor

Species1		Species2		Species3		Species4	
Time(years	Hg	Time(years	Pb	Time(years	Benzene	Time(years	BaP
1	1.000E+40	1	2.921E-02	1	1.000E+40	1	5.841E+00
2	1.000E+40	2	1.460E-02	2	1.000E+40	2	2.921E+00
5	1.000E+40	5	5.841E-03	5	1.000E+40	5	1.168E+00
10	1.000E+40	10	2.921E-03	10	1.000E+40	10	5.841E-01
15	1.000E+40	15	1.947E-03	15	1.000E+40	15	3.894E-01
20	1.000E+40	20	1.460E-03	20	1.000E+40	20	2.921E-01
30	1.000E+40	30	9.736E-04	30	1.000E+40	30	1.947E-01
40	1.000E+40	40	7.302E-04	40	1.000E+40	40	1.460E-01
50	1.000E+40	50	5.841E-04	50	1.000E+40	50	1.168E-01
60	1.000E+40	60	4.868E-04	60	5.213E+33	60	9.736E-02
70	1.000E+40	70	4.172E-04	70	1.349E+30	70	8.345E-02
80	1.000E+40	80	3.651E-04	80	1.895E+28	80	7.302E-02
90	1.000E+40	90	3.245E-04	90	1.000E+40	90	6.491E-02
100	6.790E+34	100	2.921E-04	100	6.509E+24	100	5.841E-02
120	4.100E+31	120	2.434E-04	120	1.000E+40	120	4.868E-02
140	2.067E+28	140	2.086E-04	140	1.680E+21	140	4.172E-02
160	1.000E+40	160	1.825E-04	160	1.000E+40	160	3.651E-02
180	4.232E+25	180	1.623E-04	180	1.268E+19	180	3.245E-02
200	2.507E+23	200	1.460E-04	200	1.000E+40	200	2.921E-02
250	6.362E+20	250	1.168E-04	250	1.000E+40	250	2.337E-02