



global environmental solutions

**New England Quarry Resource Recovery Centre - Landfill
Nr Ivybridge, Devon**

**Environmental Permit (EP) Application
Hydrogeological Risk Assessment**

Viridor

**February 2011
SLR Ref: 407.00036.00463/HRA**

CONTENTS

1.0	INTRODUCTION	1
2.0	SITE SETTING	2
2.1	Geological Setting.....	2
2.2	Landfill Source	3
2.3	Hydrogeological Setting	7
2.4	Hydrological Setting.....	11
3.0	CONCEPTUAL HYDROGEOLOGICAL MODEL	14
4.0	HYDROGEOLOGICAL RISK ASSESSMENT	17
4.1	The Nature of the Hydrogeological Risk Assessment.....	17
4.2	The Proposed Modelling Scenarios.....	17
4.3	Determination of Environmental Assessment Limits (EALS)	22
4.4	Numerical Modelling	24
4.5	Emissions to Groundwater.....	25
4.6	Essential and Technical Precautions	28
4.7	Hydrogeological Completion Criteria.....	29
4.8	Sensitivity Analysis and Model Calibration	29
5.0	REQUISITE SURVEILLANCE	32
5.1	The Risk Based Monitoring Scheme	32
5.2	Leachate Monitoring	32
5.3	Groundwater Monitoring.....	33
5.4	Surface Water Monitoring.....	34
5.5	Control and compliance limits	35
6.0	CONCLUSIONS	37
6.1	Compliance with Schedule 10 (Landfill) of the Environmental Permitting Regulations, 2010.....	37
6.2	Compliance with Schedule 22 (Groundwater Activities) of the Environmental Permitting Regulations, 2010	37
7.0	CLOSURE	38

TABLES

Table 2-1	New England Landfill Engineering	3
Table 2-2	Leachate Concentrations from Literature Review.....	5
Table 2-3	Inputs to Weighted Mean Calculation.....	6
Table 2-4	Leachate Source Term Weighted Means	6
Table 2-5	Hydraulic Conductivity Test Results	7
Table 2-6	Calculated Hydraulic Conductivities Based on Aquifer Thickness of 3m ...	8
Table 2-7	Summary of Groundwater Monitoring Data.....	8
Table 2-8	Groundwater Abstractions within 3km of the Site Boundary	9
Table 2-9	Background Groundwater Quality of Key parameters.....	10
Table 2-10	Summary of Daily Rainfall Statistics	11
Table 2-11	Surface Water Quality in the River Yealm at Popples Bridge (1990 - 2009)	12
Table 2-12	Discharge Consents to Surface Water within 1km of the Site Boundary	13
Table 3-1	Summary of Conceptual Hydrogeological Model.....	14
Table 4-1	Hydrogeological Risk Assessment Scenarios	19
Table 4-2	Qualitative Assessment of Accidents and their Consequences.....	21
Table 4-3	Derivation of Environmental Assessment Limits.....	23
Table 4-4	Maximum Concentration of Non-Hazardous Pollutants at the Base of the Unsaturated Zone at Years 4 and 7.....	25

Table 4-5 Maximum Concentration of Hazardous Substances at the Base of the Unsaturated Zone at Years 4 and 7.....	26
Table 4-6 Hazardous Substance Concentrations at Outside Edge of Liner (Prior to Dilution).....	27
Table 4-7 Non-Hazardous Pollutant Concentrations at Down-Gradient Compliance Point	27
Table 4-8 Sensitivity Analysis Input Parameters	30
Table 5-1 Proposed Leachate Monitoring Schedule.....	32
Table 5-2 Proposed Groundwater Monitoring Schedule.....	33
Table 5-3 Proposed Surface Water Monitoring Schedule	35
Table 5-4 Groundwater Control and compliance limits for Hazardous Substances and Non-Hazardous Pollutants	36

DRAWINGS

Drawing No. HRA1	Geological Setting
Drawing No. HRA2	Groundwater Contour Plan
Drawing No. HRA3	Regional Hydrological plan
Drawing No. HRA4	Site Conceptual Models
Drawing No. HRA5	Monitoring Plan

APPENDICES

Appendix HRA1	Groundwater Hydrographs
Appendix HRA2	Groundwater Quality Results
Appendix HRA3	LandSim Parameterisation Table
Appendix HRA4	Diffusion Model Parameterisation Table
Appendix HRA5	LandSim Result Graphs
Appendix HRA6	Diffusion Model Results Graphs
Appendix HRA7	Electronic Copies of LandSim and Diffusion Models (on CD)
Appendix HRA8	Sensitivity Analysis
Appendix HRA9	Leachate Balance
Appendix HRA10	Estimation of Hydraulic Conductivity

1.0 INTRODUCTION

SLR Consulting Limited (SLR) has been instructed by Viridor Waste Management Ltd (Viridor) to prepare an Environmental Permit (EP) application to operate a non hazardous landfill as part of the proposed Resource Recovery Centre (RRC) at New England Quarry, Devon.

The RRC will include a non hazardous landfill and an Energy from Waste (EfW) facility that will be permitted separately. The landfill will be fully engineered and contained in accordance with the Landfill Directive and Environmental Permitting (England and Wales) Regulations, 2010, which implements the Directive.

The site is located at National Grid Reference (NGR) SX 595 548, approximately 3km south-west of Ivybridge and 1km south of the A38 Trunk Road, the principal route between Plymouth and Exeter.

A hydrogeological risk assessment¹ is required to demonstrate that the installation will be compliant with the Environmental Permitting (England and Wales) Regulations, 2010. These Regulations require that hazardous substances (formerly known as List I substances) are not input to groundwater, and that the discharge of non-hazardous pollutants (formerly known as List II and general substances) is limited “so as to prevent pollution”. This means that the hydrogeological risk assessment must demonstrate that hazardous substances will not reach groundwater at discernable concentrations at the compliance point (ignoring attenuation and dispersion) and that non-hazardous pollutants will not be present at a compliance point above a level that may constitute pollution.

¹ Environment Agency, (2010), *H1 - Technical Annex to Annex (j): Hydrogeological Risk Assessments for Landfills and the Derivation of Groundwater Control Levels and Compliance Limits Compliance Limit*

2.0 SITE SETTING

The setting of the proposed landfill is presented in the following sections. This is based on published and site specific information from the following sources:

- site specific information provided by Viridor for New England Quarry, including:
 - quarterly groundwater level and quality data for ten monitoring boreholes for the period November 2006 to September 2009;
 - a plan of the site and the adjacent areas; and
 - quarry operational details.
- published information as follows:
 - British Geological Survey (2002) Sheet 1:50,000 scale, Sheet No. 349 (Solid and Drift Edition) – Ivybridge;
 - Environment Agency (1998): Groundwater Vulnerability Map 1:100,000 scale, Sheet 49 – South Devon;
 - Environment Agency website (www.environment-agency.gov.uk);
 - Ministry of Agriculture, Fisheries and Food (MAFF) (1975): *Climate and Drainage Technical Bulletin 34*;
 - British Geological Survey *The Physical Properties of Minor Aquifers in England and Wales*, Technical Report.
 - British Geological Survey (1975) *British Regional Geology: South-West England*;
 - Peter Brett Associates (2008) *New England Quarry, Ivybridge, Devon: Engineering Geological Assessment*, Project Ref: 15932/002;
 - E.C.C. Quarries Ltd (1977) *New England Quarry Geological Investigation*, Report No. GR.7/77;
 - Devon County Council (2004) *Devon County Minerals Local Plan*.

2.1 Geological Setting

The geological setting is shown in Drawing HRA1. The published geological map² for the area indicates that the proposed development is underlain by igneous diabase or dolerite, which is intruded into the surrounding Middle Devonian slate. The intrusion has an east to west trend and the slates outcrop on the northern and southern sides of the site. The Middle Devonian slates dip steeply to the south. Normal faulting in the area is generally north-north-east to south-south-west. The proposed landfill will be located entirely within the quarry void located within the dolerite.

The outcrop of the dolerite is approximately 250m wide at the quarry void but thins to less than 50m wide to the west and is terminated abruptly by a fault trending north to south, approximately 150m west of the quarry void. Tuffs outcrop to the west of this fault.

² British Geological Survey, Sheet 349, Ivybridge (Solid and Drift), 2002.

2.2 Landfill Source

Characterisation of the source requires a consideration of the site design and construction, leachate management and leachate quality. These elements are considered in detail below.

2.2.1 Site Design and Construction

New England Landfill will comprise 10 cells that will fill the void of the former quarry. The base of the landfill lies at approximately 35mOD, up to 30m below surrounding ground level. The landfill will ultimately be capped at a pre-settlement elevation of 90mOD and an ultimate post settlement elevation of 84mOD. The base of the landfill will lie beneath the groundwater table.

The nature of the engineering systems for the proposed landfill is presented in Table 2-1 below.

**Table 2-1
 New England Landfill Engineering**

Landfill Component	Description
Landfill Cap	The site will be restored with a low hydraulic conductivity cap
Leachate Drainage	Each cell will be completed with a granular leachate drainage blanket
Artificial Sealing Liner	2mm thick double textured high density polyethylene geomembrane
Basal Mineral Liner	Minimum 1.0m thick clay liner (or equivalent) of maximum hydraulic conductivity 1×10^{-9} m/s.
Sidewall Mineral Liner	Minimum 1.0m thick mineral liner of maximum hydraulic conductivity 1×10^{-9} m/s.
Groundwater Control	Drainage blanket installed beneath the base and sides of Cells 1 and 2 to allow dewatering of these two cells during filling
Construction Quality Assurance	All construction works are subject to independent CQA.

2.2.2 Leachate Management

Leachate levels will be actively managed through abstraction to maintain leachate heads of no more than 2m in all cells during the period of active waste placement and the active management period of the site. However, following the cessation of groundwater control leachate heads in Cells 1 and 2 will be maintained at a maximum elevation of 2m below the rest groundwater level, to maintain hydraulic containment. Abstracted leachate will be taken off-site to a suitable leachate treatment facility.

2.2.3 Leachate Generation

The potential volumes of leachate that will be generated by New England Quarry Landfill have been estimated using water balance methods and the results are presented within Appendix HRA9. Two scenarios have been analysed for the site at New England Quarry:

- Scenario 1 - A most likely future waste input of 33,000tpa results in filling being completed by the end of 2043 and restoration thereafter based on a commissioning date of 2014.
- Scenario 2 - A maximum future waste input of 60,000tpa results in filling being completed by the end of 2030 and restoration thereafter based on a commissioning date of 2014.

These estimations indicate the following:

- Due to the low rate of filling and estimated density of the waste (1 tonne per m³) a low annual absorptive capacity is indicated which is exceeded on an annual basis by the rainfall or infiltration inputs to the waste. This has been estimated assuming the density to absorptive capacity relationship of Municipal Solid Waste (MSW);
- In Scenario 1, at an input rate of 33,000tpa, leachate production would peak at approximately 16,845m³/year (c.46m³/day) between 2022 and 2024. Following the complete restoration of the site, a steady-state free leachate production of approximately 2,550m³/year (c.7m³/day) is achieved in 2044; and
- In Scenario 2, at an input rate of 60,000tpa, leachate production would peak at approximately 16,150m³/year (c.44m³/day) in 2018 and 2019. Following the complete restoration of the site, a steady-state free leachate production of approximately 2,550m³/year (c.7m³/day) is achieved in 2032.

2.2.4 Leachate Quality and Priority Contaminants

The proposed landfill will accept a mixed waste stream consisting of 60% rejected or un-burnable municipal solid waste (MSW), 26% commercial and industrial waste and 14% incinerator bottom ash (IBA)

The application site is a new landfill and there are no site specific leachate source values available. A literature review has been undertaken to identify which species are likely to be present in the leachate and at what concentration.

The source terms to be used within the modelling have been determined based on the available literature to best represent likely source terms for the proposed waste stream. The following two sources have been used:

- Environment Agency, 2004b³ – leaching Tests undertaken by the Environment Agency on MSW Bottom Ash; and
- Golder Associates (2000) *LandSim default values*.

Details of the species and the typical concentrations reported in the literature are given in Table 2-2.

³ Environment Agency (2004b): *Testing of residues from incineration of municipal solid waste, Science Report P1-494/SR2*

**Table 2-2
 Leachate Concentrations from Literature Review**

Determinand	Environmental Quality Standards (EQS) ⁴	MSW from LandSim (mg/l)			IBA from Environment Agency ³ (mg/l)			Max Risk Factor
		Min	Mean	Max	Min	Mean	Max	
Ammoniacal Nitrogen (as N)	0.39 ^b	4.37	723	3640	3	15	20	9333
Chloride	250	36.6	2270	7760	360	1800	2700	31.04
Copper	0.001 – 0.028	0.00489	0.0243	1.13	1.2	6	17	607.1
Lead	0.004 – 0.25	0.00957	0.13	1.02	0.06	0.3	5	250
Zinc	0.008 – 0.5	0.00225	0.165	208	0.01	0.05	1.3	1664
Molybdenum	0.07 ^a				0.064	0.32	0.44	6.29
Arsenic	0.05	0.000673	0.00484	1.31	0.0002	0.001	0.001	26.2
Nickel	0.05 – 0.2	0.00883	0.12	2.21	0.016	0.08	0.18	44.2
Selenium	0.01 ^a				<0.001	<0.001	<0.001	-
Chromium	0.005 – 0.25	0.00856	0.0647	1.75	0.002	0.007	0.025	7-350
Cadmium	0.005	0.0019	0.0101	0.105	0.0002	0.001	0.001	21
Mercury	0.001	0.00004	0.00009	0.00195	0.000002	0.00001	0.00002	1.95

Notes: where EQS standards are not available the most relevant alternative has been used

a- WHO values used

b- UK DWS values used

Based on this literature review, several key determinands have been identified with high risk factors. These include ammoniacal nitrogen and some heavy metals. Chloride has also been included as a key determinand due to its conservative nature.

The priority non-hazardous pollutants are:

- chloride – owing to high concentrations generally recorded in both MSW and IBA waste, and because it is a conservative substance (i.e. it is not degraded or retarded);
- ammoniacal nitrogen - a key contaminant within MSW waste, although generally significantly lower concentrations in bottom ash;
- copper – often recorded at a concentration in IBA leachate, in excess of 10x greater than in MSW leachate;
- lead – recorded in bottom ash leachate at concentrations in excess of 5x greater than in MSW leachate; and
- zinc - high leachate concentrations in IBA leachate often in excess of those recorded in MSW leachate.

⁴ Environment Agency (2003): *Hydrogeological Risk Assessments for Landfills*, ref LFTGN01, Appendix 8

Source concentration for non-hazardous pollutants have been estimated by calculating the weighted mean concentration based on the proportion of the waste in the total waste stream and the concentrations given in Table 2.2. The inputs to the weighted average calculation are summarised in Table 2-3.

**Table 2-3
 Inputs to Weighted Mean Calculation**

Waste Stream	Proportion of Total Waste Inputs (%)	Source of Leachate Concentrations
Un-burnable MSW	60	LandSim default values divided by 2
IBA	14	Values from EA report ³
Commercial and industrial wastes	26	LandSim default values

A summary of the non-hazardous pollutant concentrations in the leachate, based on the above, is given in Table 2-4.

**Table 2-4
 Leachate Source Term Weighted Means**

Determinand	Weighted Means (mg/l)		
	Min	Mean	Max
Chloride	71	1,523	4,724
Ammoniacal Nitrogen	3	407	2,041
Copper	0.17	0.85	3.01
Lead	0.014	0.11	1.27
Zinc	0.0027	0.10	116.66
Cadmium	0.029	0.146	0.199
Mercury	0.0003	0.0015	0.0039

Available literature provides little information regarding hazardous pollutants within IBA or non-combustibles; therefore the following hazardous substances have been included at concentrations typically found in leachate from MSW waste:

- cadmium – frequently recorded in IBA and MSW at concentrations above its Minimum Reporting Value MRV⁵;
- mercury – frequently recorded in IBA and MSW at concentrations above its MRV;
- mecoprop – no specific IBA information but common within MSW leachate;
- xylene – no specific IBA information but common within MSW leachate; and
- naphthalene – no specific IBA information but common within MSW leachate;

⁵ Minimum Reporting Value (MRV) is the lowest possible concentration at which a substance is detectable with laboratory analysis

2.3 Hydrogeological Setting

Aquifer Characteristics

The Environment Agency Groundwater Vulnerability Map⁶ shows that the dolerite intrusion and Devonian slates beneath the application site and the surrounding area are classified as a Secondary Aquifer (formerly known as a Minor Aquifer):

- the groundwater potential of the slates and dolerite is limited as it has a negligible primary hydraulic conductivity and low secondary hydraulic conductivity associated with discontinuities (fissures, fractures, joints, bedding planes) ;
- groundwater flow is therefore restricted to open discontinuities within the slate and dolerite; and
- the groundwater is in hydraulic continuity with the River Yealm; however the groundwater contribution to the river is not significant as groundwater flow rates are low compared to the high river discharge rate.

A series of hydraulic conductivity tests were undertaken by Carnon Contracting⁷ (Carnon) in nine of the ten groundwater monitoring boreholes in May to June 2005, while a further series of hydraulic conductivity tests were undertaken by SLR in September 2009 in eight of the groundwater monitoring boreholes.

Both tests used the Hvorslev method of analysis for calculating hydraulic conductivity, as per guidance in BS 5930:1999⁸. The full depth of the saturated strata below the static water level within each monitoring borehole was included within these calculations. Using this approach the calculated hydraulic conductivity values are low in both the slates and the dolerite, and range from 3.1×10^{-6} m/sec to 3.7×10^{-8} m/sec, as detailed in Table 2-5 below.

**Table 2-5
 Hydraulic Conductivity Test Results**

BHID	Main Strata	SLR Hydraulic Conductivity Tests		Carnon Hydraulic Conductivity Tests
		General Approach (m/sec)		Constant Head (m/sec)
NE/101	Slate	5.07×10^{-8}		5.94×10^{-7}
NE/102	Dolerite	1.40×10^{-7}		1.45×10^{-6}
NE/104	Dolerite	1.50×10^{-7}		3.05×10^{-6}
NE/105	Slate	1.09×10^{-6}		1.85×10^{-6}
NE/106	Dolerite	-		3.13×10^{-6}
NE/107	Slate	9.65×10^{-8}		2.65×10^{-6}
NE/108	Slate	6.29×10^{-8}		6.42×10^{-7}
NE/109	Slate	3.71×10^{-8}		6.30×10^{-8}
NE/110	Dolerite	1.83×10^{-7}		1.18×10^{-7}

It is noted that groundwater flow in aquifers developed within these types of strata typically decreases with depth, due to a decrease in the number and openness of the discontinuities associated with weathering, fractures, joints and bedding planes.

⁶ EA, Groundwater Vulnerability Map, Sheet 49, South Devon.

⁷ Carnon Contracting (2005) *Factual Report on New England Quarry Ground Investigation*

⁸ BSI (1999) *BS5930:1999 Code of Practice for Site Investigations, Section 4: Field Tests*

Groundwater flow within these strata is therefore concentrated within the relatively thin upper bedrock horizons of the bedrock, as well as within the 'blast-fracture' zone that will be present immediately adjacent to the quarry base and walls as a result of the quarrying activities at the development site.

The hydraulic conductivity of this relatively thin active groundwater flow zone has been determined by calculating the aquifer transmissivity based on the full saturated thickness of the test zone in the borehole, and then recalculating the hydraulic conductivity of this active zone assuming an aquifer thickness of 3m. The results of the calculations are given in Table 2-6 and details in Appendix HRA10.

**Table 2-6
 Calculated Hydraulic Conductivities Based on Aquifer Thickness of 3m**

Value	Hydraulic Conductivity (m/s)
Minimum	3.69×10^{-7}
Mean	8.46×10^{-6}
Maximum	3.21×10^{-5}

Groundwater Elevations

Groundwater levels have been monitored on a quarterly basis in ten monitoring boreholes. Groundwater level hydrographs are included in Appendix HRA1. The groundwater level data are summarised below in Table 2-7.

Table 2-7 Summary of Groundwater Monitoring Data

Monitoring Borehole	Datum level (mOD)	Groundwater level (mOD)				Range (m)
		Count	Min	Average	Max	
NE/101	36.33	7	33.82	34.05	34.19	0.37
NE/102	44.17	7	36.05	36.35	37.09	1.04
NE/103	49.87	4	41.2	42.96	47.28	6.08
NE/104	48.42	7	39.3	39.58	40.04	0.74
NE/105	61.57	11	51.95	52.98	55.01	3.06
NE/106	73.13	2	54.73	56.48	58.23	3.50
NE/107	75.38	7	64.56	65.96	67.94	3.38
NE/108	58.66	7	52.26	52.55	52.94	0.68
NE/109	75.19	11	61.52	65.15	68.26	6.74
NE/110	57.0	7	47.17	47.52	47.71	0.54

This information indicates the following:

- groundwater levels in the immediate vicinity of the quarry lie between c.2 and c.13 metres below original ground level (mbgl);
- groundwater level fluctuations range from 0.37m to 3.50m, excluding NE/103 and 109 which are anomalous;
- the current floor of the quarry lies at c.35mOD at its lowest point, and is therefore located below the groundwater levels within the dolerite and shale;
- groundwater flow direction is easterly to north-easterly, towards the River Yealm and its tributary along the northern boundary of the application site, as shown on Drawing HRA2. The groundwater hydraulic gradient ranges from 0.062 to 0.123; and

- the groundwater and the rivers are in hydraulic continuity, although flow rate across the proposed site to the Yealm is low.

2.3.2 Groundwater Abstractions and Source Protection Zones

There are five groundwater abstractions within 3km of the site boundary, as summarised in Table 2-8, below.

Table 2-8
Groundwater Abstractions within 3km of the Site Boundary

Reference Number (locations shown in Drawing HRA3)	National Grid Reference (Distance from Site Boundary)	Licence Holder	Abstraction Details Daily Rate (m ³) Annual Rate (m ³)	Licence Number
1	A. SX 6080 5520 B. SX 6010 5510 C. SX 6080 5510	Mr D M Harvey Strashleigh Farm	Agricultural use 27m ³ /day 9855m ³ /year	15/47/001/G/002
2	SX 6210 5565	Endsleigh Garden & Leisure Ltd	Horticultural use 23m ³ /day 2675m ³ /year	14/46/006/0115
3	SX 573 563	Unknown	unknown	Private Borehole

Note: Information provided by Environment Agency and South Hams District Council

There are no Source Protection Zones within 3km of the site boundary.

Groundwater Quality

Groundwater quality data have been provided by Viridor for the ten on-site monitoring boreholes, NE/101 to NE/110. Based on the projected groundwater flow direction, boreholes NE/106, NE/107, NE/109 and NE/110 have been used to determine background groundwater quality, while boreholes NE/102 and NE/104 will be used to monitor down-gradient quality. Available groundwater quality data for all monitoring wells are included within Appendix HRA2 and the locations of the wells are shown on Drawing HRA2.

Groundwater quality is typically good, with low levels of all key metals and major ionic species. The results indicate some variation between groundwater within the slates and the dolerite, typified by marginally higher concentrations of calcium, chloride and conductivity within the slate in comparison to the dolerite.

Background groundwater quality for key parameters is summarised in Table 2-9 below.

**Table 2-9
 Background Groundwater Quality of Key parameters**

Determinand		NE/106	NE/107	NE/109	NE/110	Maximum (all background boreholes)
Chloride (mg/l)	Count	1.00	6.00	9.00	6.00	22.00
	Min	10.00	10.00	10.00	13.00	10.00
	Mean	10.00	12.33	12.89	16.17	13.50
	Max	10.00	15.00	21.00	21.00	21.00
Ammoniacal Nitrogen (mg/l)	Count	1.00	6.00	9.00	6.00	22.00
	Min	0.03	0.02	0.02	0.02	0.02
	Mean	0.03	0.03	0.04	0.02	0.03
	Max	0.03	0.06	0.09	0.02	0.09
Cadmium Dissolved (ug/l)	Count	1.00	6.00	9.00	6.00	22.00
	Min	0.28	0.15	0.15	0.15	0.15
	Mean	0.28	0.26	0.23	0.20	0.23
	Max	0.28	0.50	0.28	0.25	0.50
Lead Dissolved (ug/l)	Count	1.00	6.00	9.00	6.00	22.00
	Min	3.00	1.00	1.00	1.00	1.00
	Mean	3.00	2.08	2.56	1.75	2.23
	Max	3.00	3.00	6.52	2.50	6.52
Zinc (ug/l) Dissolved	Count	1.00	6.00	9.00	6.00	22.00
	Min	5.50	1.00	1.00	2.50	1.00
	Mean	5.50	4.33	16.28	4.33	9.27
	Max	5.50	11.00	112.00	8.00	112.00
Copper Dissolved (ug/l)	Count	1.00	6.00	9.00	6.00	22.00
	Min	24.20	0.50	0.50	0.50	0.50
	Mean	24.20	2.58	3.08	1.75	3.54
	Max	24.20	6.00	15.20	2.50	24.20

The results in Table 2-9, above, indicate that none of the parameters have exceeded their respective Drinking Water Standards (DWS) or Environmental Quality Standards (EQS).

2.4 Hydrological Setting

Recharge Characteristics

The application site lies within MAFF Agroclimate⁹ Area 43 south, which indicates that the annual total rainfall varies from 820 to 1,200 mm/year, with the average rainfall of 1,048mm/year. The effective rainfall reported by MAFF (excess winter rain) is 530mm per annum. Data supplied by the Meteorological Office from the MORECS database indicate an annual rainfall total of 1,471mm and an effective rainfall value of 727mm/yr (1961 to 1990).

Near site monitoring data have also been provided by the Environment Agency for two sites up-stream of the application site as follows:

- Lutton located 5.6km north-west of the quarry at an elevation of 160mOD along the Piall River, a tributary of the Yealm; and
- adjacent to the River Yealm at Cornwood, 8km north of the site at an elevation of 100mOD.

Both these rainfall gauges indicate similar annual rainfall levels, as summarised in Table 2-10 below.

Table 2-10
Summary of Daily Rainfall Statistics

Gauging Station	Reference Number (Drawing HRA3)	Annual Rainfall (mm)			
		Monitoring Period	Annual Min (Year)	Annual Average	Annual Max (Year)
Lutton	4	1974-2009	1,063 (1975)	1,410	1,748 (2000)
Cornwood	5	1998 - 2009	1,071 (1999)	1,486	1,773 (2002)

Surface Water Features

Several key hydrological features are near to the site. Key amongst these is the River Yealm which flows from north to south along the sites eastern boundary. Parts of the application site are located within the Environment Agency Flood Zones 2 and 3; however the proposed landfill is located on significantly higher ground and as such is not located within either of these flood zones.

The Yealm is a typically flashy river with flows at both up-stream (Cornwood) and down-stream monitoring locations (Puslinch) recording flows ranging from a Q_{95} of 0.206 m³/sec to a peak flow of 24.2m³/sec. Estimates of the flow in the Yealm at Popples Bridge have been made using Low Flows 2000; the Q_{10} , Q_{50} and Q_{95} are 3.192, 0.862 and 0.192 m³/sec respectively.

In addition to the main river, several tributaries are located within 1km of the site including a small stream which flows along the northern boundary, and a second stream which joins the Yealm from the east, approximately half way along the site boundary.

⁹ MAFF, 1976. Climate and Drainage. Technical Bulletin 34. HMSO, London.

Surface Water Quality

The Environment Agency monitors the quality of the River Yealm at Popples Bridge immediately down gradient from the application site. The results of the monitoring are summarised in Table 2-11 below.

Table 2-11
Surface Water Quality in the River Yealm at Popples Bridge (1990 - 2009)

Determinand	Count	River Yealm Quality				EQS / DWS
		Min	Mean	95%ile	Max	
pH	741	5.6	7.48	7.94	8.3	
Conductivity (μ S/cm)	202	47	132.2	200	284	
BOD (mg/l)	640	<1	1.18	2.405	10.9	
Ammoniacal Nitrogen (mg/l as N)	775	<0.01	0.025	0.07	0.25	0.39
T.O.N (mg/l)	459	<0.2	1.59	2.99	4.6	
Nitrate (mg/l)	755	0.19	1.67	2.92	4.58	50
Nitrite (mg/l)	756	<0.004	0.0076	0.021	0.1	0.1
Suspended Solids (mg/l)	475	<0.4	10.05	32.11	333	
Alkalinity (mg/l)	446	<10	30.54	53	116	
Chloride (mg/l)	184	8	16.67	22	35	250
Ortho Phosphate (mg/l)	756	<0.01	0.033	0.1	0.28	2.2
Sulphate (mg/l)	184	<5	8.78	12.73	15	400
Sodium (mg/l)	125	5	10.2	13.96	21.1	170
Potassium (mg/l)	296	<0.2	1.86	3.04	4.36	
Magnesium (mg/l)	415	0.79	3.12	4.8	25	50
Calcium (mg/l)	415	<1	12.56	22.16	49.7	250
Chromium (μ g/l)	92	<1	0.77	1	3	5 - 250
Arsenic (μ g/l)	64	<10	5.2	7.44	20	50
Manganese (μ g/l)	92	2	19.64	67.15	187	50
Iron (μ g/l)	74	<50	272.8	1125.5	3520	1000
Copper (μ g/l)	386	<1	1.83	4	12	1 - 28
Zinc (μ g/l)	466	<1	6.81	18.675	57.2	8 - 500
Nickel (μ g/l)	94	<1	1.06	2.675	7	50 - 200
Dissolved Oxygen (mg/l)	642	7.3	10.58	12.28	14.9	

The surface water quality data indicate that the quality of the River Yealm is good and has remained so throughout the last 19 years with no sign of degradation. There are occasional exceedences of the EQS or DWS for iron, manganese and some heavy metals. These probably relate to high suspended solids when the river is in flood.

The River Basin Management Plan for the South-West, which helps deliver the European Water Framework Directive, was published for in December 2009 and June 2009. A summary of the quality of the River Yealm from the plan is given below:

- Current ecological quality Moderate
- Current chemical quality Pass
- 2015 ecological quality Moderate
- 2015 predicted chemical quality Pass
- Overall risk At risk

The plan indicates that the chemical quality of the Yealm is good, the ecological quality is moderate and that the water body is at risk of not achieving good ecological status by 2015.

Discharge Consents

There are four discharge consent s located within 1km of the site boundary, as summarised in Table 2-12, below.

Table 2-12
Discharge Consents to Surface Water within 1km of the Site Boundary

Reference Number (Drawing HRA3)	National Grid Reference (Distance from Site Boundary)	Licence Holder	Discharge Details	Consent Number
6	SX 58931 54588 (500m)	Wales & West Utilities	Trade Waste to a tributary of the River Yealm	303861
7	SX 59660 54770 (0m)	Viridor Waste (Somerset) Ltd	Trade Waste to River Yealm	NRA-SW-3426
8	SX 59660 54770 (0m)	Viridor Waste (Somerset) Ltd	Trade Waste to a tributary of the River Yealm	NRA-SW-6422
9	SX 59937 55698 (1km)	South West Water (Lee mill Pumping Station)	Sewage effluent to River Yealm	301626

Note:

1. Information provided by Environment Agency, April 2009

3.0 CONCEPTUAL HYDROGEOLOGICAL MODEL

The conceptual hydrogeological site model is based on the source-pathway-receptor linkages and is focussed on the proposed development. The conceptual model is shown in Drawing HRA4 and is summarised in Table 3-1 below:

**Table 3-1
Summary of Conceptual Hydrogeological Model**

Source

The quarry void created by extraction of the dolerite at New England Quarry will be restored as a fully engineered containment landfill site, with a mixed waste stream consisting of:

- 60% rejected or un-burnable municipal solid waste (MSW)
- 26% commercial and industrial waste
- 14% Incinerator Bottom Ash (IBA)

The landfill will be filled at a most likely rate of 33,000 tonnes per annum, creating a 30 year filling time. In order to provide operational flexibility a maximum annual rate of 60,000 tonnes per annum will be applied for. If the site was filled at this rate, which is unlikely, the filling time of would be 16 years. The site will be filled in 10 cells.

The landfill will be constructed with a 1.0m thick mineral base and side liner and a HDPE geomembrane. The clay liner (or equivalent) will have a hydraulic conductivity of no more than 1×10^{-9} m/s.

A leachate collection system will be installed within the base of each of the cells to allow for active management of leachate heads via leachate extraction.

The base of the landfill in Cells 1 and 2 will be located below the current groundwater table. The groundwater will be maintained below the base of the landfill to prevent heave, until filled with waste to an elevation of 56.6mOD at which point groundwater levels will return to normal creating an inward hydraulic gradient into Cells 1 and 2

Following cessation of active leachate management at the site the leachate levels will be allowed to rise, creating an outward hydraulic gradient.

The landfill will be capped using suitable materials as to limit infiltration to 50 ± 10 mm per year. Proposed final restoration contours will be similar to the topography prior to quarrying and in keeping with the topography of the surrounding hillsides.

Pathways The potential contaminant pathways throughout the lifecycle of the site can be conceptualised as follows:

Early Operational Phase – a groundwater drainage blanket installed beneath the base and sides of Cells 1 and 2 will allow dewatering of the underlying bedrock in order to keep groundwater levels below the base of the landfill and so prevent basal stability concerns. During this period, an outward hydraulic gradient will be established across the basal liner of Cell 1 and 2 as leachate elevations will be higher than the groundwater elevations within the underlying drainage blanket.

Late Operational Phase and Post Closure – when sufficient waste is in place to prevent heave, groundwater levels will be allowed to rebound to new equilibrium levels below Cells 1 and 2, while leachate management continues from all cells, creating two separate potential contaminant pathways:

- diffusion of contaminants across the sidewall and basal liners will occur within Cells 1 and 2, where leachate heads elevations are located below adjacent groundwater elevations; and
- advective migration of contaminants through the liners for all other completed landfill cells will take place given that groundwater elevations will lie below leachate elevations, resulting in outward hydraulic gradients across the basal lining system.

This phase will start after cessation of dewatering between year 4 (16 year scenario) and year 7 (30 year scenario).

Long Term Post Closure Phase – once active leachate management has ended and leachate heads are able to rise above the adjacent groundwater levels, outward hydraulic gradients will be established, resulting in potential advective contaminant migration from all cells.

Attenuation (including degradation and retardation) of potential contaminants will take place within the clay mineral liner (geological barrier) component of the lining system, and also within the unsaturated and saturated pathways in lifecycle Phases 2 and 3 of the site.

Receptors The Environmental Permitting Regulations, 2010 require that the entry of hazardous substances into groundwater must be prevented and that the entry of non-hazardous pollutants into groundwater must be minimised so as to prevent pollution. In order to comply with the Regulations, the following are considered the appropriate receptors:

Hazardous substances:

- Pore water at the base of mineral liner, prior to dilution.

Non-hazardous pollutants:

- Groundwater under-drainage discharge (when dewatering active); and
 - Groundwater at the downstream installation boundary, immediately adjacent to the River Yealm (post dewatering).
-

The compliance point for both hazardous substances and non-hazardous pollutants is the point of discharge of groundwater from within the under-drainage during active groundwater control. Following cessation of active groundwater control the compliance point for non hazardous pollutants is the groundwater at the downstream site boundary, immediately adjacent to the River Yealm. For hazardous substances the compliance point in the revised 2010 guidelines⁴ is directly below the site and so allows for the immediate dilution in groundwater. As a conservative approach this assessment uses the base of the unsaturated zone as the compliance point.

It is noted that there may be other, physical receptors further away from the above points; however, compliance with the Regulations at the point defined above will ensure that other receptors are adequately protected.

4.0 HYDROGEOLOGICAL RISK ASSESSMENT

4.1 The Nature of the Hydrogeological Risk Assessment

As set out within the Environment Agency's technical guidance¹, the appropriate complexity of assessment for a proposed development should be determined from the potential risks, which are linked to the nature of potential hazards, the sensitivity of the surrounding environment, degree of uncertainty and likelihood of a risk being realised. There are essentially two levels of complexity:

Simple risk assessments should be carried out where feasible source-pathway-receptor linkages are identified, or in preparation for conducting a more complex assessment, and where either:

- it is clear from the conceptual model and the risk screening that the hazards are relatively low and the environmental setting is sufficiently insensitive to negate the possibility of significant impacts (e.g. sites on low hydraulic conductivity strata remote from abstractions and surface waters); or
- the potential source, pathway and receptor terms can all be defined with sufficient certainty so as to be confidently represented by conservative inputs, models and assumptions, e.g. a single homogenous source of in-house waste, well-defined flow characteristics and directions, etc.

Complex risk assessments should be carried out where complete source-pathway-receptor terms are present and where either:

- the site setting is sufficiently sensitive to warrant detailed assessment e.g. on permeable strata (e.g. Major Aquifer); within a Source Protection Zone; or close to surface water bodies; or
- there is uncertainty relating to any of the source, pathway or receptor terms e.g. variable leachate quality, or an undefined groundwater flow pattern that cannot be overcome by the adoption of conservative inputs or assumptions.

Given the site's setting beneath the water table and within close vicinity to an important surface water body it is considered appropriate to undertake a complex risk assessment.

4.2 The Proposed Modelling Scenarios

4.2.1 Lifecycle Phases

It is recognised that the hydrogeological risk assessment must assess the proposed developments compliance with the requirements of the Environmental Permitting (England and Wales) Regulations, 2010 throughout the lifecycle of the landfill i.e. from the start of the operational phases until the point at which the landfill no longer is capable of posing an unacceptable environmental risk.

Current Environment Agency guidance states that "the risk assessment must take account of future failure and degradation of the active controls (e.g. artificial sealing liner and leachate drainage systems, and operational/management controls) as well as the likely contaminant concentrations in the landfill when failure/degradation occurs". Details of the scenarios are given in Table 4-1.

LandSim 2.5 has been developed so that account can be taken of leachate quality variations and unavoidable degradation of active controls (e.g. engineering and management measures) over time.

Two models have been used to assess the full lifecycle of the landfill site:

- LandSim (2.5.17) Model – to model the impact of the landfill during the periods when potential advective leachate migration can take place from the site. Two versions of this model have been run to represent the most likely (30 years) and worst case (16 years) filling times; and
- Environment Agency Diffusion Spreadsheet¹⁰ – to model the impact of diffusion from Cells 1 and 2 when inward gradients are established, as discussed above.

This approach is considered to be worst case as it assumes that outward hydraulic gradients are established for all cells throughout the full lifetime of the site. This is conservative as in reality there will be inward gradients into Cells 1 and 2 when groundwater levels are allowed to recover following cessation of groundwater management.

The LandSim model has been interrogated to assess the impact of leachate seepage on the quality of the under drainage when active dewatering is in place. This has been done by looking at the concentration of contaminants at the base of the unsaturated zone at year 7 when dewatering will cease. This is a conservative approach as it does not take into account dilution in the under-drainage.

¹⁰ Environment Agency, 2004, *Contaminant Fluxes from Hydraulic Containment Landfills Spreadsheet*, Science Report SC0310/SR

**Table 4-1
 Hydrogeological Risk Assessment Scenarios**

Scenario	Landfill Source Assumed Function & Parameter	Landfill Cap¹¹ Assumed Operation & Parameter	Drainage System Assumed Operation & Parameter	Engineered Liner¹² Assumed Operation & Parameter
Operational	Weighted averages calculated based on relevant literature and proposed waste stream, see section 2.2.4	Infiltration assumed to be equal to average annual rainfall: Min: 500mm Max: 1200mm (Uniform Distribution)	Active leachate management. Leachate Head: All Phases: 0.5m, 2.0m (Uniform Distribution) Inward diffusion	Lining system comprising minimum 1m engineered clay and HDPE membrane Clay hydraulic conductivity: Min: 1.0×10^{-11} m/s Mode: 1.0×10^{-10} Max: 1.0×10^{-9} m/s (Log Triangular) HDPE with LandSim default defects for placement with CQA and leak detection.
Post Closure	Declining source term. (Log Triangular)	Site capped and restored with membrane . Infiltration specified as: 50 +/- 5mm (Normal Distribution)	Active leachate management. Leachate head - all phases: 0.5m, 2.0m (Uniform Distribution)	As above. HDPE liner degradation rate as per LandSim defaults.
Long Term Post Closure		Landfill cap membrane assumed to have completely degraded. Infiltration assumed to equal effective rainfall: 265 +/- 26.5mm (Normal Distribution).	No leachate management. Leachate heads at ground surface.	As above. HDPE liner completely degraded.

¹¹ Assumed that the landfill cap will function as designed up until approximately 250 years. Following that period it has been assumed that it degrades until approximately 1000 years, when final infiltration is equal to effective rainfall.

¹² Assumed that the HDPE basal liner will function as designed until approximately 150 years. Number of defects in the basal liner set to double every 100 years thereafter.

4.2.2 Accidents and their Consequences

The potential degradation of engineered and management systems is considered within this assessment by the use of LandSim 2.5 in modelling the site. However, this does not allow for the consideration of the potential impacts associated with accidents.

Accidents are considered to be the unintentional incidents that could reasonably occur, which are unforeseeable in terms of their time of occurrence. The process of evaluating environmental risks should therefore include the consideration of the potential impact of accidents as well as the resulting harm.

A qualitative risk assessment of the potential impacts of accidents and resulting damage to engineered and management systems is presented, overleaf, within Table 4-2¹³. This also considers the likelihood of the accidents occurring and the magnitude of the consequences of such accidents and failures¹⁴. This assessment indicates that:

- it has been determined to be either “fairly probable” or “probable” that the consequence of any potential accident would be the site’s non-compliance with the requirements of the Environmental Permitting Regulations, 2010, owing to the potentially increased discharge of hazardous substances and non-hazardous pollutants into the environment; and
- the prevention of the accidents from occurring is key to the management of New England Landfill. Consequently, this places the emphasis on having robust and workable procedures and actions in place in order to prevent them from occurring and by ensuring a comprehensive CQA system is in place during construction.

Given that the likelihood of an accident resulting in non-compliance is “unlikely to very unlikely” additional quantitative assessment of the potential events is not considered necessary.

¹³ This qualitative assessment has been carried out using the terms and methodology set out within “Environment Agency, November 2002, Guidance on the Management of Landfill Gas”.

¹⁴ Given that this risk assessment tests the compliance of the proposed development with the requirements of the Environmental Permitting Regulations, 2010, it is considered appropriate that the magnitude of the consequences should be related to the potential for non-compliance.

Table 4-2
Qualitative Assessment of Accidents and their Consequences

Potential Accidents	Likelihood of Occurrence	Implications of Occurrence	Consequence of Occurrence	Likelihood of Non-compliance with the Environmental Permitting Regulations, 2010.
Flooding	Extremely Unlikely	Site inundated High leachate heads with increased leakage through liner Potential over-topping of control systems Reduced attenuation potential	Severe	Probable
Subsidence	Very Unlikely	Potential breach of the engineered containment Increased leachate leakage Reduced attenuation potential	Severe	Probable
Landslides	Extremely Unlikely	Possible breach of the engineered containment, although this would depend upon the location of the landslide Increased leachate leakage Reduced attenuation potential	Significant	Fairly Probable
Fires	Very Unlikely	Potential breach of the geomembrane and degradation of the leachate management system Increased leachate leakage	Significant	Fairly Probable
Explosions	Very Unlikely	Potential breach of the engineered containment and degradation of the leachate management system Increased leachate leakage Reduced attenuation potential	Severe	Probable
Major Breach of Installation Liner	Unlikely	Increased leachate leakage Reduced attenuation potential	Significant	Probable

4.3 Determination of Environmental Assessment Limits (EALS)¹⁵

Compliance with the Environmental Permitting (England and Wales) Regulations, 2010, requires that the proposed development will not result in discernible discharges of hazardous substances entering the groundwater and will not cause pollution of groundwater by non-hazardous pollutants.

The setting of Environmental assessment Limits (EAL's) is therefore necessary in order to assess whether the Environmental Permitting (England and Wales) Regulations, 2010 are being met at the proposed landfill site.

With regard to the proposed development, the following EAL's are considered appropriate:

- for hazardous substances, the EAL's shall be the minimum reporting values as defined in Environment Agency's guidance¹ or where background groundwater quality exceeds the specified standards; and
- for non-hazardous pollutants the EAL's shall be the freshwater EQS¹⁶¹⁷, or the DWS where no EQS standards are available, except where background groundwater quality exceeds the specified standards.

Where background water quality exceeds the specified standards the EAL's will be set at the maximum recorded concentration in background groundwater.

The selected EAL's for hazardous substances and non-hazardous pollutants are shown below in Table 4-3.

¹⁵ An EAL can be defined as a water quality standard that is defined by either UK Regulations (e.g. Water Supply (Water Quality) Regulations 1989), EU Directives (e.g. Drinking Water Directive (80/778/EEC)) or another relevant source (e.g. non-statutory Environmental Quality Standards)

¹⁶ These were determined to be appropriate after considering Figure 3.1, Determination of Target Concentrations in Groundwater. Environment Agency (October 1999): *Methodology for the Derivation of Remedial Targets for Soil and Groundwater to Protect Water Resources*, R&D P20.

¹⁷ Note: EQS standards for metals have been chosen based on the alkalinity of the river

**Table 4-3
 Derivation of Environmental Assessment Limits**

Determinand	UK Drinking Water Standard	Environmental Quality Standard¹⁸	Environment Agency Minimum Reporting Values¹⁹ for Hazardous Substances	Maximum Concentration in Background Groundwater in Bedrock	Proposed Resultant EAL
Amm-N (mg/l as N)	0.39	-	-	0.09	0.39
Chloride (mg/l)	250	250	-	21	250
Copper (mg/l)		0.005	-	0.024	0.024
Lead (mg/l)		0.003	-	0.0065	0.0065
Zinc (mg/l)	5.0	0.030	-	0.112	0.112
Cadmium (mg/l)	0.005	0.005	0.0001	0.0005	0.0005
Mercury (mg/l)	0.001	0.001	0.00001	-	0.00001
Mecoprop (mg/l)	0.0001	0.02	0.00004	-	0.00004
Naphthalene (mg/l)	0.0001	0.01	-	-	0.0001
Toluene (mg/l)	-	0.05	0.004	-	0.004
Xylene (mg/l)	-	0.03	0.003	-	0.03

¹⁸ Maximum admissible 95-percentile concentration for hardness of 0-50mg/l.

¹⁹ As proposed in Appendix 7: Assessing discharges of List I substances to groundwater: Minimum Reporting Values for selected substances in clean water. In Environment Agency (2003) *Hydrogeological Risk Assessments for Landfills and the Derivation of Groundwater Control and Compliance Limits*;

4.4 Numerical Modelling

4.4.1 Justification for Modelling Approach and Software

The hydrogeological risk assessment has been carried out using conservative assumptions regarding the source, pathways and receptors.

The Environment Agency's LandSim software (version 2.5.17) and the Environment Agency's Contaminant Fluxes from Hydraulic Containment Landfills Worksheet Version 1.0 have been used to provide an estimate of the potential risks associated with the proposed site as they both use audited and verified model code that is widely accessible.

The LandSim software was used for the following reasons:

- it uses Monte Carlo (stochastic) techniques and so allows a probabilistic appreciation of the site's performance;
- it provides a consistent approach to the estimation of hydrogeological risks; and
- it aids comprehensive reporting of input values, assumptions and results.

The LandSim model has been assessed in a stochastic fashion and throughout this assessment the acceptable probability of an undesirable outcome occurring has been set at the 95%ile confidence level. In addition, the 95%ile is commonly selected as a reasonable worst case, against which it is acceptable to make decisions taking into account the assumptions and limitations of the modelling process.

4.4.2 Model Parameterisation

The nature of all of the input parameters used, together with the appropriate probability distributions used to describe them are presented in the following:

Appendix HRA3 parameterisation table for LandSim model; and

Appendix HRA4 parameterisation table for diffusion model;

Parameter values were determined from information directly measured at site wherever possible. If no site data were available, conservative parameter values were taken from authoritative sources or after previous SLR experience at similar sites. Unless certain alternative distributions were apparent (such as uniform, normal, lognormal), triangular distributions were used throughout the modelling process. Log triangular distributions were also used to parameterise leachate concentrations.

With regards to the potential leakage of leachate from the development and the potential dilution of this leachate within groundwater, there are two key elements: the hydraulic conductivity of the mineral element of the lining system, the unsaturated pathway and groundwater flow.

With regards to the **hydraulic conductivity of the mineral liner**, the input probability distribution for (1×10^{-11} m/s, 1×10^{-10} m/s and 1×10^{-9} m/s log triangular distribution) is based on the design specification which states the material will be placed with a maximum hydraulic conductivity of 1.0E-9m/s.

The **unsaturated pathway** has been modelled as a porous medium because the dolerite and shale do not possess significant dual porosity,. The LandSim user manual stipulates that:

“The dual porosity model involves several simplifications for use with Chalk and in this release of LandSim the option is not appropriate for other lithologies”

The unsaturated pathway has been modelled with a thickness range of 0.01m to 15m. This represents the range of unsaturated zone beneath the three landfilled terraces.

With regards to **groundwater flow** within the bedrock, the flow direction and gradient across the site, together with the hydraulic conductivity has been determined from site specific monitoring and *in situ* test data.

4.5 Emissions to Groundwater

This section of the assessment considers whether the predicted discharge from the proposed development complies with the requirements of the Environmental Permitting (England and Wales) Regulations, 2010. Also considered is the potential impact of the discharge of non-hazardous pollutants on the surface water quality of the River Yealm. Electronic and hard copies of all of the models and results are presented within Appendices HRA5, HRA6 and HRA7.

The impact of the site is considered in two parts; during active dewatering and post dewatering/ long term post closure phase.

4.5.1 Dewatering Phase

During the construction and filling of Cells 1 and 2 outward advective contaminant migration will be able to take place across the basal liner. because groundwater is being collected in the under-drainage to prevent basal heave. This will occur up to year 4 (in the 16 year scenario) and year 7 (in the 30 year scenario).

The impact of potential leachate seepage on the quality of the under-drainage during this period, excluding dilution within the under-drainage system, has been assessed based on the predicted concentrations of the hazardous substances at the base of the mineral liner, and the predicted concentrations of the non-hazardous pollutants at the base of the unsaturated zone. A summary of results for non hazardous pollutants is included within

Table 4-4 and hazardous substances in Table 4-5.

**Table 4-4
 Maximum Concentration of Non-Hazardous Pollutants at the Base of the Unsaturated
 Zone at Years 4 and 7**

Determinand	Maximum Concentration at 95%ile (mg/l)		EAL (mg/l)
	LandSim Model – Year 4	LandSim Model – Year 7	
Ammoniacal-N	<1x10 ⁻¹⁰	<1x10 ⁻¹⁰	0.39
Chloride	<1x10 ⁻¹⁰	101.70	250
Copper	<1x10 ⁻¹⁰	<1x10 ⁻¹⁰	0.024
Lead	<1x10 ⁻¹⁰	<1x10 ⁻¹⁰	0.0065
Zinc	<1x10 ⁻¹⁰	<1x10 ⁻¹⁰	0.112

**Table 4-5
 Maximum Concentration of Hazardous Substances at the Base of the Unsaturated
 Zone at Years 4 and 7**

Determinand	Max Concentration at 95%ile (mg/l)		EAL (mg/l)
	LandSim Model – Year 4	LandSim Model – Year 7	
Cadmium	<1x10 ⁻¹⁰	<1x10 ⁻¹⁰	0.0005
Mercury	<1x10 ⁻¹⁰	<1x10 ⁻¹⁰	0.00001
Mecoprop	<1x10 ⁻¹⁰	<1x10 ⁻¹⁰	0.00004
Naphthalene	<1x10 ⁻¹⁰	<1x10 ⁻¹⁰	0.0001
Toluene	<1x10 ⁻¹⁰	<1x10 ⁻¹⁰	0.004
Xylene	<1x10 ⁻¹⁰	<1x10 ⁻¹⁰	0.03

Table 4-4 and Table 4-5 demonstrate that the resultant concentrations for both hazardous substances and non-hazardous pollutants are lower than the Environmentally Acceptable Limits (EAL) as set out in Table 4-3. The modelling shows that there would be no unacceptable discharges of Hazardous pollutants to groundwater.

4.5.2 Post Dewatering and Long-Term Post Closure Phase

Once groundwater management below Cells 1 and 2 has ceased and inward hydraulic gradients have developed, non-hazardous pollutants and hazardous substances will potentially be able to migrate through the liner via diffusion from cells 1 and 2. Advective migration will continue from the other cells (cells 3-6) as the bases of these cells are above adjacent groundwater levels. This scenario will continue until the cessation of active leachate management.

With the cessation of active leachate management and the recovery of leachate elevations above the adjacent groundwater elevations, outward hydraulic gradients will become established across the whole site and potential outward advective contaminant migration will take place across the lining system.

The resultant concentrations for hazardous substances under these conditions have been assessed at the outside edge of the mineral liner (prior to any dilution occurring) for both the 16 year and 30 year scenarios. Results for Hazardous substances are presented in Table 4-6. This is a conservative approach as the 2010 guidance allows the dilution of Hazardous Substances in the groundwater immediately below the site.

**Table 4-6
 Hazardous Substance Concentrations at Outside Edge of Liner (Prior to Dilution)**

Determinand	Max Concentration at 95%ile (mg/l)			EAL (mg/l)
	LandSim Model - 16 Years Scenario	LandSim Model - 30 Years Scenario	Diffusion Model	
Cadmium	1.94×10^{-8}	5.21×10^{-6}	3.86×10^{-4}	0.0005
Mercury	$<1 \times 10^{-10}$	$<1 \times 10^{-10}$	3.28×10^{-7}	0.00001
Mecoprop	8.28×10^{-8}	3.743×10^{-8}	$<1 \times 10^{-10}$	0.00004
Naphthalene	3.03×10^{-6}	1.697×10^{-6}	$<1 \times 10^{-10}$	0.0001
Toluene	7.0×10^{-4}	4.25×10^{-4}	$<1 \times 10^{-10}$	0.004
Xylene	9.75×10^{-4}	7.88×10^{-4}	$<1 \times 10^{-10}$	0.03

Note 1: Maximum cadmium concentrations at the outer edge of the liner do not exceed 0.0005mg/l during the initial 1000 years, during which time inward diffusive gradients should have been replaced by outward advective flux of contaminants following cessation of active leachate management. These results also assume that the HDPE artificial sealing liner does not degrade over this period, which is a worst case assumption.

Table 4-6 demonstrates that the resultant concentrations are lower than the concentrations that have been determined to be discernible. The modelling shows that there would be no unacceptable discharges of Hazardous pollutants to groundwater.

Non-hazardous pollutants have been assessed at the compliance point i.e. the groundwater within the bedrock at down-gradient site boundary immediately adjacent to the River Yealm. Maximum 95th percentile concentrations are presented in Table 4-7.

**Table 4-7
 Non-Hazardous Pollutant Concentrations at Down-Gradient Compliance Point**

Determinand	Maximum Concentration (mg/l)			EAL (mg/l)
	LandSim Model - 16 Years Scenario	LandSim Model - 30 Years Scenario	Diffusion Model ^a	
Ammoniacal-N	0.203	0.142	6.33×10^{-3}	0.39
Chloride	102.79	84.40	0.407	250
Copper	0.013	0.013	4.39×10^{-7}	0.024
Lead	0.0055	0.0055	9.40×10^{-14}	0.0065
Zinc	0.052	0.051	5.23×10^{-5}	0.112

Note: The diffusion spreadsheet results do not take into consideration background water quality.

Table 4-7 demonstrates that the predicted resultant concentrations are lower than the appropriate EALs. The modelling has shown that the discharge of non-hazardous pollutants would be sufficiently limited so as to avoid pollution.

4.5.3 Conclusions

The modelling has demonstrated that based on the proposed development and waste streams, there should be no significant release of hazardous substances or non-hazardous pollutants throughout the whole lifecycle of the landfill site. Therefore, the installation should not result in any discernible discharge of hazardous substances to groundwater or result in groundwater or surface water pollution by non-hazardous pollutants.

The modelling also represents worst case conditions, for the following reasons:

- the LandSim model assumes an outward hydraulic gradients from all Cells 1 to 6, throughout the entire lifecycle of the landfill. In reality, inward hydraulic gradients will be present for Cells 1 and 2 following cessation of groundwater management while active leachate management takes place;
- the model results also exclude the additional dilution of non-hazardous pollutants within the River Yealm, which will be over 1,700 times at Q_{95} flow rate in the river ($0.192 \text{ m}^3/\text{sec}$);
 - the 95%ile LandSim model results demonstrate that the leakage rate through the EBS reaches a peak of $0.00011 \text{ m}^3/\text{sec}$ ($9,783 \text{ l/day}$) from year 5,000 onwards while combined leakage and aquifer flow will reach a peak of $0.00092 \text{ m}^3/\text{sec}$ ($29,071 \text{ m}^3/\text{year}$) from year 4,500 onwards. Therefore the worst case dilution rate of the leachate in the aquifer is 7 times and the worst case additional dilution rate of the leachate in the river (at Q_{95} flow rates) is 1,745 times. Leakage rates at earlier time slices in the life cycle of the site will be lower and the dilution will therefore be higher than the values given above. The values quoted above have all been taken from the results files of the 30 year model run;
 - new guidance published by the EA in 2010 allows for the dilution of Hazardous Substances in the groundwater beneath the site. This has not been allowed for in this assessment; and
- the Agency's diffusion spreadsheet does not take into consideration background water quality. This is a worst case scenario, given that if a contaminant is present in background groundwater the concentration gradient across the landfill liner for that species would be less, and therefore the diffusion across the liner would be also reduced.

4.6 Essential and Technical Precautions

Essential and technical precautions are those measures required to ensure that the proposed development complies with the Environmental Permitting (England and Wales) Regulations, 2010 (i.e. that hazardous substances are not discharged to groundwater in discernible concentrations and that non-hazardous pollutants are not discharged so as to cause pollution).

In order to ensure compliance with the Environmental Permitting (England and Wales) Regulations, 2010, the following technical precautions will be required.

4.6.1 Capping

The site should be capped with a low hydraulic conductivity cap to reduce infiltration and to control leachate generation once the site has finished accepting waste.

4.6.2 Lining Design

The risk assessment has demonstrated that in order to comply with the groundwater and landfill regulations the following needs to be incorporated within the lining design:

- 1.0m clay liner (or equivalent) with a maximum hydraulic conductivity of 1×10^{-9} m/sec; and
- a HDPE liner needs to be installed to CQA standard.

4.6.3 Leachate Control

It is essential that leachate heads in all cells are maintained below 2m, except in Cells 1 and 2 following the cessation of groundwater control, when heads will be maintained at a maximum elevation of 2m below the rest groundwater level.

4.6.4 Groundwater Management

Groundwater levels will be managed during construction and filling of Cells 1 and 2, so as to maintain groundwater levels below the base of the site and therefore remove any potential concerns with regard to liner stability. A drainage blanket will be installed to CQA standards and to a suitable specification given in the landfill design report and groundwater discharged to the River Yealm.

4.6.5 Leak Detection System

A leak detection survey will be completed on the HDPE liner, repairs made and the liner retested, prior to the deposition of waste in each phase.

4.7 Hydrogeological Completion Criteria

With regards to the conditions when Permit Completion will be attained, it is proposed that these would be satisfied when the site no longer has the potential to cause damage to or deterioration of the environment and risk to human health i.e. it no longer poses a potential risk to the environment or human health.

The Environment Agency's LandSim 2.5.17 model results include all phases of the landfill lifecycle, including when the active management has ceased during the long term post closure scenario. The hydrogeological risk assessment has therefore demonstrated the site's compliance with the Environmental Permitting Regulations, 2010, throughout the life of the site, including the long-term post closure scenario, when leachate heads are modelled on the assumption that there is no active management of leachate and the landfill cap and liner HDPE have fully degraded.

4.8 Sensitivity Analysis and Model Calibration

4.8.1 Sensitivity Analysis

A quantitative analysis has been undertaken to determine the sensitivity of the LandSim model to a number of key input parameters. The input parameters selected for inclusion within the sensitivity analysis were chosen either due to a lack of certainty in the initial assigned values (i.e. no site specific data), or due to the likely high sensitivity of the parameter based on SLR experience.

The sensitivity analysis was based on the LandSim model as included within Appendix HRA7. Each parameter included within the analysis was reduced from the initial assigned

value or range by 50%, the model was re-run and the results analysed. Subsequently, each parameter was increased from the initial input range by 100% and the model re-run. The model was run in 'expected values' mode to obtain the equivalent of a deterministic calculation and the 50%ile (most likely) model output. The 30 year model was used as this represents the 'most likely' situation. The input parameters are summarised in Table 4-8 below:

Table 4-8
Sensitivity Analysis Input Parameters

Input Parameter	Original Value / Range	Value/Range for Sensitivity Analysis	
		Model 1 (-50%)	Model 2 (+100%)
Leachate Head (m)	Min: 0.5 Max: 2.0 Uniform	Min: 0.25 Max: 1.0 Uniform	Min: 1.0 Max: 4.0 Uniform
Aquifer Hydraulic conductivity (m/s)	Min: 3.69×10^{-7} Mode: 8.46×10^{-6} Max: 3.21×10^{-5} Log Triangular	Min: 1.845×10^{-7} Mode: 4.23×10^{-6} Max: 1.605×10^{-5} Log Triangular	Min: 7.38×10^{-7} Mode: 1.69×10^{-5} Max: 6.42×10^{-5} Log Triangular
Aquifer porosity	Min: 0.01 Max: 0.03 Uniform	Min: 0.005 Max: 0.015 Uniform	Min: 0.02 Max: 0.06 Uniform
Liner Hydraulic Conductivity (m/s)	Min: 1.0×10^{-11} Mode: 1.0×10^{-10} Max: 1.0×10^{-9} Log Triangular	Min: 5.0×10^{-12} Mode: 5.0×10^{-11} Max: 5.0×10^{-10} Log Triangular	Min: 2.0×10^{-11} Mode: 2.0×10^{-10} Max: 2.0×10^{-9} Log Triangular
Liner Thickness (m)	1.0 Single value	0.5 Single value	2.0 Single value
Chloride Source Term (mg/l)	Min: 71 Mode: 1523 Max: 4724 Log Triangular	Min: 35.5 Mode: 761.5 Max: 2362 Log Triangular	Min: 142 Mode: 3046 Max: 9448 Log Triangular

It was considered appropriate to review the concentration of chloride downstream of the site as the modelling has determined that this is the substance with the highest risk of exceeding its EQS.

Chloride was considered appropriate as it is a conservative contaminant, is commonly found in landfill leachate at very high concentrations and its resultant concentrations are purely a function of the leakage rate and dilution.

The results of the sensitivity analysis are presented graphically within Appendix HRA8. The resultant concentrations of chloride at the downstream boundary are plotted for each parameter considered, for the original value of the parameter, the original value +100% and the original value -50%. Therefore, the sensitivity of the model to each parameter is reflected in the gradient of a best-fit line drawn through the three resultant concentrations. In simple terms, the greater the variation in the three results, the more sensitive the model is to that parameter.

Review of the resultant chloride concentrations confirms that the model is not sensitive to leachate heads or aquifer porosity. The model is shown to be more sensitive to the aquifer hydraulic conductivity, which influences the dilution of non-hazardous pollutants beneath the site. The model is also shown to be sensitive to changes in the engineered liner hydraulic conductivity, which influences the rate of leakage, and the chloride source term.

The sensitivity analysis suggests that the model is most sensitive to aquifer hydraulic conductivity and the engineered liner hydraulic conductivity, which are parameterised with a high level of confidence. It should be noted that the engineered liner will be placed under CQA and it will be ensured that the liner hydraulic conductivity falls within the range specified in the risk assessment model.

The relatively high sensitivity of the chloride source term is not considered of major concern because the model results are significantly below the EAL of 250mg/l and the chloride source term used within the modelling represents a worst case scenario and is therefore considered unlikely for leachate concentrations to be higher than those used within the LandSim model. There is also a high level of confidence in the model results given the parameterisation of the LandSim model, which is based on site specific and relevant published information where available.

4.8.2 Model Calibration

As the landfill is not yet operational it is not possible to calibrate the model.

5.0 REQUISITE SURVEILLANCE

5.1 The Risk Based Monitoring Scheme

The Environmental Permitting (England and Wales) Regulations, 2010, require that “*requisite surveillance*” is undertaken where disposal of substances potentially giving rise to hazardous substances or non-hazardous pollutants have been authorised by the Environment Agency. The site will be a non-hazardous landfill; therefore there is potential for pollution of groundwater and surface water.

Appropriate requisite surveillance will take place within leachate, groundwater and surface water to ensure the site continues to meet with the Environmental Permitting Regulations, 2010, throughout its life. Proposed groundwater, surface water and leachate monitoring locations are indicated on Drawing HRA5.

5.2 Leachate Monitoring

Leachate quality monitoring will be undertaken from all collection sumps installed within the waste. In addition leachate levels will be monitored away from the sumps in at least one monitoring borehole in each cell which has a basal liner.

The proposed leachate monitoring schedule and compliance limits are detailed in Table 5-1 below.

**Table 5-1
 Proposed Leachate Monitoring Schedule**

Monitoring Point	Frequency	Measurement and Analytical Suite	Compliance Limit
LMP(s) cell 1 LMP(s) cell 2 LMP(s) cell 3a LMP(s) cell 3b LMP(s) cell 3c LMP(s) cell 5a LMP(s) cell 5b All leachate sumps	Monthly	Leachate level, volume removed	Leachate head: 2m above cell base
Leachate sampled from the collection sump of each hydraulically separate cell	Quarterly	pH, electrical conductivity, temperature, alkalinity, ammoniacal nitrogen, chloride, sulphate, magnesium, potassium, calcium, sodium, BOD, COD, TOC, TON, iron, zinc, lead, chromium, manganese, nickel, cadmium, copper, phenols	-
	Annual	Hazardous Substances Screen ²⁰ , monitoring point base	-

²⁰ Given the uncertainty about the possible range of List I Substances that may be present within the landfill leachate, a combination of six different analytical methods is required for the List I Substance screening exercise as follows: (i) GCMS scan for volatiles; (ii) GCMS scan for semi-volatiles; (iii) derivitised GCMS scan for semi-volatiles; (iv) extraction of organotin compounds; (v) reduction of mercury compounds; and (vi) solution of cadmium compounds.

5.3 Groundwater Monitoring

Unretarded travel times have been assessed using the results for chloride, which does not degrade. Based on the LandSim modelling the travel time through the clay liner, ignoring the HDPE liner is 1 year (95-percentile value). The travel time to the down-gradient compliance point is 6.5 years based on the 30 year filling time scenario. These travel times have been taken into account when setting the proposed frequency of monitoring for hazardous substances in the groundwater under-drainage discharge and in the groundwater monitoring boreholes.

The requirements of the Environmental Permitting (England and Wales) Regulations, 2010, indicate that there should be requisite surveillance of groundwater. The current configuration of monitoring wells around the perimeter of the quarry is considered appropriate for monitoring of up-gradient groundwater levels and quality using boreholes NE107 and NE109. For the monitoring of down-gradient water levels and quality, boreholes NE102 and NE104 will be used; however an additional borehole will be drilled on the installation boundary between these two to intercept groundwater from directly beneath the centre of the site prior to reaching the river.

In addition regular monitoring of groundwater discharge from the groundwater under-drainage (location SW5) during the first four to seven years of waste disposal (subject to input rates) will be required.

The proposed groundwater monitoring schedules are detailed in Table 5-2.

**Table 5-2
 Proposed Groundwater Monitoring Schedule**

Locations	Frequency	Measurement and Analytical Suite
NE/101, NE/102, NE/104, NE/107, NE/109, NE/110, New down-gradient borehole(s)	Monthly	Groundwater level (mOD)
Discharge from groundwater under-drainage (SW5)	Monthly	Ammoniacal nitrogen, chloride, electrical conductivity, pH, discharge flow rate (m ³ /day)
	Quarterly	As monthly plus; total alkalinity (CaCO ³), magnesium, potassium, calcium, sodium, sulphate COD, TON, TOC iron, zinc, lead, chromium, manganese, nickel, cadmium, copper
	Annually	Hazardous substances screen
NE/107, NE/109(up-gradient boreholes	Quarterly	Ammoniacal nitrogen, chloride, electrical conductivity, pH, total alkalinity (CaCO ³), magnesium, potassium, calcium, sodium, sulphate COD, TON, TOC iron, zinc, lead, chromium, manganese, nickel, cadmium, copper
NE/102, NE/104 (down gradient boreholes)	Annually	Xylene, toluene Plus additional Hazardous Substances above the MRV screening limits in the annual leachate monitoring review unless agree otherwise by EA
New down-gradient borehole	Every 2 years	Hazardous substances screen, monitoring point base

5.4 Surface Water Monitoring

The main receptor from the quarry has been assessed as the River Yealm; therefore regular monitoring upstream and downstream of the landfill will be required with the same frequency as that for the monitoring of groundwater. Surface water monitoring will be undertaken regularly at two locations along the Yealm:

- SW3: River Yealm up-stream of the site
- SW4: River Yealm down-stream of the site at Popples Bridge

In addition surface water monitoring will be undertaken at the outflow from the two attenuation ponds designed to attenuate clean surface water runoff (SW1 and SW2). Monitoring of the outflow from the under-drainage has been specified in the groundwater monitoring section of this report. A Surface Water Management Plan has been produced as part of this EP Application submission. The proposed monitoring schedule is detailed in Table 5-3

**Table 5-3
 Proposed Surface Water Monitoring Schedule**

Monitoring Location	Frequency	Measurement and Analytical Suite
SW1, SW2, SW3, and SW4	Monthly	Ammoniacal nitrogen, chloride, electrical conductivity, pH, suspended solids, visible oils or greases
SW3, SW4	Quarterly	As monthly plus; total alkalinity (CaCO ₃), sulphate, magnesium, potassium, calcium, sodium, COD, BOD, TON, TOC, iron, zinc, lead, chromium, manganese, nickel, copper

5.5 Control and compliance limits

The Landfill Regulations require the derivation of control and compliance limits as defined in Paragraph 4(C) of Annex III of the Landfill Directive.

It is proposed that control and compliance limits are set for both existing and the one additional down-gradient groundwater monitoring boreholes. Control and compliance limits have been set for all non-hazardous pollutants identified within this report, while compliance limits have also been set for hazardous substances toluene, xylene and naphthalene as these have been identified as the most likely to be present in the leachate.

It is not practicable to derive control levels for hazardous substances in groundwater that can be measured by normal analytical methods. It is proposed that control levels for non-hazardous pollutants should comprise an increasing trend in concentrations of the identified non-hazardous pollutants for four consecutive sampling events.

The proposed compliance limits for hazardous substances are set at the discernable concentrations for that substance (MRV). For non-hazardous pollutants compliance limits are set at the appropriate EAL, while the control level has been set half way between the 'worst case' predicted resultant groundwater concentration (95%ile) and the relevant EAL. Table 5-4 presents trigger and control levels for non-hazardous pollutants and compliance limits for hazardous substances.

**Table 5-4
 Groundwater Control and compliance limits for Hazardous Substances and Non-Hazardous Pollutants**

Location	Determinand	Control Level (mg/l)	Compliance Limit (mg/l)
Borehole NE/102, NE/104, new down-gradient borehole* ¹	Ammoniacal Nitrogen	0.37	0.4
	Chloride	100	250
	Copper	0.021	0.024
	Zinc	0.091	0.112
Discharge from groundwater under-drainage (SW5)	Lead	0.0127	0.02
	Cadmium	-	0.0006* ²
	Toluene	-	0.004
	Xylene	-	0.03
	Naphthalene	-	0.0001

Notes:

*1 *Compliance Limit only applies after groundwater under-drainage has ceased*

*2 *Maximum concentration detected in groundwater plus 20% to account for natural variation in background*

The compliance limits outlined in Table 5-4 satisfy the requirements of the Landfill Directive in that they allow assessment of the performance of the existing and proposed landfill and ensure that the installation is not causing pollution of groundwater. The compliance limits are based on a relatively limited dataset and will be reviewed in the light of additional data on background water quality from sampling undertaken between the submission of the EP application and the first disposal of waste in the site.

compliance limits will be reviewed on a regular basis in accordance with the permit requirements for supplementary HRA submissions and following additional quality monitoring data and amendments agreed with the Agency.

6.0 CONCLUSIONS

6.1 Compliance with Schedule 10 (Landfill) of the Environmental Permitting Regulations, 2010

The results of this risk assessment have established that the site complies with the requirements of Schedule 10 of the Environmental Permitting Regulations, 2010.

The installation will potentially pose a hazard to ground and surface water quality. Consequently arrangements must be made to collect contaminated leachate and any contaminated water that is generated by the site.

The installation will require a geological barrier and artificial sealing liner of sufficient thickness and attenuating properties to avoid the release of hazardous pollutants and minimise the release of non-hazardous pollutants.

Groundwater compliance limits have been outlined that would allow the performance of the proposed development to be judged against the conclusions of this risk assessment as required by the Regulations.

6.2 Compliance with Schedule 22 (Groundwater Activities) of the Environmental Permitting Regulations, 2010

The risk assessment has demonstrated that the proposed development will remain compliant with Schedule 10 of the Environmental Permitting Regulations, 2010.

The proposed development will not result in hazardous substances entering groundwater nor in the introduction of non-hazardous pollutants so as to cause pollution. Essential and technical precautions to ensure have been set out to ensure the sites future compliance with the groundwater regulations. The following essential and technical precautions have been identified as part of the hydrogeological risk assessment:

- maintenance of leachate elevations within all proposed cells, to within the heads assumed for this assessment;
- construction of a geological barrier and artificial liner constructed to CQA standards with a maximum hydraulic conductivity of 1×10^{-9} m/s, minimum porosity of 1% and a clay barrier of at least 1.0m thickness;
- a landfill cap must be installed to a sufficient standard as to limit infiltration and leachate generation within the landfill;
- a risk-based programme of leachate, groundwater and surface water monitoring must be undertaken to ensure the sites continued compliance with the stated control and compliance limits.

The site therefore complies with these relevant requirements of the Environmental Permitting Regulations, 2010.

7.0 CLOSURE

This report has been prepared by SLR Consulting Limited with all reasonable skill, care and diligence, and taking account of the manpower and resources devoted to it by agreement with the client. Information reported herein is based on the interpretation of data collected and has been accepted in good faith as being accurate and valid.

This report is for the exclusive use of Viridor; no warranties or guarantees are expressed or should be inferred by any third parties. This report may not be relied upon by other parties without written consent from SLR.

SLR disclaims any responsibility to the client and others in respect of any matters outside the agreed scope of the work.