HYDROGEOLOGICAL RISK ASSESSMENT FOR THE RESTORATION OF THE WESTERN QUARRY USING INERT FILL AT LA GIGOULANDE QUARRY, JERSEY

Report reference: BGL/JE/PF/5699/01/HRA
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1. Introduction

Report context

1.1 MJCA are commissioned by Granite Products (C.I.) Limited (Granite Products) to prepare a hydrogeological risk assessment (HRA) in support of an application for a Waste Management Licence (WML) for the restoration of the deeper western quarry by landfilling using inert fill at La Gigoulande Quarry, Jersey. A generic quantitative HRA reference BGL/JE/SPS/1589/01/HRA2[1] was submitted to and in consultation with the Department of the Environment at the States of Jersey in January 2013 to inform their decision on the planning application number P/2012/0121 for the installation and operation of an inert waste recycling facility for the production of secondary aggregate and soils and the restoration of the western quarry using inert fill. The generic quantitative HRA was used to determine the waste acceptance criteria which would result in acceptable concentrations of substances in the groundwater and surface water systems at the site. The generic quantitative HRA was approved by the Department of the Environment at the States of Jersey and, following further consultation, planning permission P/2012/0121 was granted in September 2016.

1.2 This HRA report prepared in support of the application for a WML for the restoration of the western quarry using inert fill at La Gigoulande Quarry comprises an update to the generic quantitative HRA dated January 2013. The HRA has been prepared based on the conceptual site model presented in the environmental setting and installation design report (ESID) reference BGL/JE/PF/5699/01/ESID dated November 2023[2]. This HRA should be read in conjunction with the ESID report.

1.3 In the absence of guidance specific to Jersey the structure of the HRA is based on guidance produced by the Environment Agency for England and Wales on HRAs in support of applications for an Environmental Permits presented on the www.gov.uk[3] website. In England and Wales an Environmental Permit is the equivalent

1 MJCA. 2013. Hydrogeological risk assessment for the restoration of the western quarry using inert fill at La Gigoulande Quarry, Jersey. Report reference BGL/JE/SPS/1589/01/HRA2.

2 MJCA. 2023. Environmental setting and installation design report (ESID) for the restoration of the western quarry using inert fill at La Gigoulande Quarry, Jersey. Report reference BGL/JE/PF/5699/01/ESID.

3 https://www.gov.uk/guidance/landfill-operators-environmental-permits/what-to-include-in-your-hydrogeological-risk-assessment

authorisation mechanism to the WML which is used in Jersey. As the site will accept inert waste materials only there are sections of the guidance which are not relevant although the general structure has been followed.

1.4 Details of the environmental setting of the site, the geology, the hydrogeology, the history of the site, potential contaminant migration pathways and receptors are described in the ESID report. Details of the waste acceptance procedures to confirm that inert waste materials only will be placed in the western quarry are presented in Section 6 of the Working Plan which comprises Appendix D to the Application Report. The restoration design is presented in the ESID report. This HRA should be read in conjunction with the ESID report. Additional information in respect of the site waste handling and inspection procedures is presented also in the Working Plan.

1.5 It is concluded in the HRA that there is no significant risk from the proposed restoration of the western quarry using inert fill to groundwater and surface water quality in the vicinity of the site over the whole life cycle of the site.

2. Hydrogeological risk assessment – Qualitative risk screening (Tier 1)

2.1 The hydrogeological risk assessment is undertaken in accordance with EA guidance[3] above and follows a tiered approach to risk assessment[4] with the level of risk assessment proportional to the risks to groundwater and surface water from the landfill operation. Information on the geology, hydrology and hydrogeology of the site is presented in the ESID report. The information in the ESID report is used to identify the relationships between the source, pathways and the identified potential receptors.

The nature of the hydrogeological risk assessment

Potential risks presented by the site

2.2 The materials that will be deposited at the landfill site will be inert materials comprising residues from the inert waste recycling facility at the site the subject of WML WML026 or inert waste for which treatment is technically not possible. Although the EU Landfill Directive 1999[5] is not relevant to Jersey it does include a definition of inert waste. Inert waste is defined in the EU Landfill Directive 1999 as:

> *"…waste that does not undergo any significant physical, chemical or biological transformations. Inert waste will not dissolve, burn or otherwise physically or chemically react, biodegrade or adversely affect other matter with which it comes into contact in a way likely to give rise to environmental pollution or harm to health. The total leachability and pollutant content of the waste and the ecotoxicity of the leachate must be insignificant, and in particular not endanger the quality of surface water and/or groundwater;"*

2.3 The waste types that it is proposed may be accepted at the site are presented in Table WP 1 of the Working Plan. The waste acceptance procedures to confirm that inert waste materials only are deposited in the western quarry are also presented in the Working Plan. Detailed waste acceptance procedures will be in place to minimise the risk that unacceptable waste materials are accepted at the site. Procedures will

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4 https://www.gov.uk/guidance/groundwater-risk-assessment-for-your-environmental-permit#use-a-tiered-approach-to-your-risk-assessment

5 Official Journal of the European Communities. 1999. Council Directive 1999/31/EC of 26 April 1999 on the landfill of waste.

be in place for the rejection of non-conforming loads. The receipt, handling and storage of materials are the subject of procedures in the company management system which is accredited to the ISO 14001 standard. A summary of the management system is presented at Appendix F to the application report.

2.4 As set out in the ESID, it is considered that the waste does not comprise a contaminant source with the potential to have a significant detrimental effect on groundwater quality. As the materials that will be deposited at the landfill site will comprise inert waste only there will be no significant concentrations of hazardous substances and no significant concentrations of non-hazardous pollutants in water that has percolated through the waste mass. Based on the proposed placement of inert materials only it is considered that there will be no significant risks to human health or to the environment from the inert wastes deposited in the landfill.

Sensitivity of surrounding water environment

2.5 As set out in the ESID, the site is excavated through Quaternary loess deposits into underlying Ordovician coarse grained granite. The granite is water bearing and has a low primary permeability and a high secondary permeability imparted by fractures in the rock with groundwater storage and flow principally through the fracture network. Groundwater flow in the fractured granite aquifer at the site is towards the La Gigoulande Mill Stream to the north west, west and south west of the site. La Gigoulande Mill Stream flows from north east to south west generally parallel to the northern boundary of the quarry between approximately 10m and 150m from the site boundary before turning south into St Peter's Valley approximately 60m west of the quarry. It is likely that the groundwater in the granite provides base flow to the stream where the level of the groundwater is higher than the stream to the west and south west of the site. La Gigoulande Mill Stream flows into the La Hague Reservoir approximately 150m south west of the site. A bypass channel for La Gigoulande Mill Stream is in place to divert the stream round La Hague Reservoir when needed. The La Hague Reservoir is an unlined manmade reservoir used for public water supply. In addition, there are 73 licensed and unlicensed groundwater abstractions within 500m of the site potentially used to abstract water for domestic use or limited commercial use in hotels, gardens and spas with the closest located approximately 55m from the site boundary.

2.6 During mineral extraction and landfilling operations in the western quarry the void is and will continue to be dewatered to facilitate dry working of the granite and the placement of the inert waste materials. Groundwater and incident rainfall pumped from the sump in the quarry are conveyed to a settlement facility to the south west of the quarry prior to their consented discharge to La Gigoulande Mill Stream (Discharge Permit DP(B)2000/11/03. Following completion of landfilling of the site dewatering operations will cease and the groundwater levels will recover. Further details on the surface water and groundwater management in place are presented in the ESID. Based on the Conceptual Site Model the site is in a sensitive setting as the site is located in a fractured granite aquifer used for licensed and unlicensed water supply. The site is sub-water table hence groundwater provides a direct pathway to surface water receptors from the site comprising the La Gigoulande Mill Stream thence the La Hague Reservoir which is used for public water supply.

Hazards posed and likelihood of the risk happening

2.7 Notwithstanding that it is concluded based on the proposed use of inert waste only that there will be no significant risks to human health or to the environment from the proposed inert landfill and that waste acceptance procedures will be in place to minimise the risk that unacceptable waste materials are accepted consideration has been given to the mitigation of residual risk given the sensitivity of the site setting. For the purpose of the risk assessment it is considered that any flow from the landfill to the aquifer is within the fractured granite the base of which at the site is approximately 34m above mean sea level (AMSL). The fractured granite is the strata from which the most significant groundwater inflows through fractures and fissures have been recorded based on the data collected at the site (Appendix ESID C). It is assumed for the purpose of the assessment that the granite is effectively impermeable below 34mAMSL. Above an elevation of 34mAMSL there is the potential for discharge of substances to receptors in the unlikely scenario where water percolating through the waste mass includes discernible[6] concentrations of hazardous substances or significant concentrations of non-hazardous pollutants. Substances will be attenuated by processes of partitioning and degradation relevant

6 https://www.gov.uk/government/publications/groundwater-protection-technical-guidance/groundwater-protection-technical-guidance#discernibility

to the nature of the contaminants and the physical and chemical properties of the granite and will be diluted in the groundwater.

Qualitative risk screening (Tier 1)

2.8 A qualitative risk screening (Tier 1) is presented above with the Source - pathway - receptor linkages throughout the lifecycle of the site summarised in Table HRA 1 and the schematic cross sections presented on Figure HRA 1. Based on this qualitative risk screening it is considered that there is no significant risk from the proposed deposition of inert waste materials at the site to groundwater quality in the fractured granite aquifer or the surface water quality in the La Gigoulande Mill Stream and the La Hague Reservoir as it is considered that the waste does not comprise a contaminant source with the potential to have a significant detrimental effect on water quality.

Consideration of further tiers of risk assessment

2.9 While it is considered that the Tier 1 qualitative risk screening demonstrates that there is no significant risk from the proposed deposition of inert waste materials at the site to surrounding groundwater and surface water quality, a further Tier 2 generic quantitative risk assessment (GQRA) has been undertaken to support these conclusions and is presented at Section 3 to this report. While the Tier 1 qualitative risk screening does not suggest there is an unacceptable risk, it is considered that due to the sensitive setting of the site a further Tier 2 GQRA will be expected.

3. Hydrogeological risk assessment – Generic quantitative risk assessment (GQRA) (Tier 2)

3.1 Although it is determined in the qualitative risk screening (Tier 1) presented in the HRA that there is no significant risk posed to groundwater and surface water quality by the deposition of inert waste materials at the site, a generic quantitative risk assessment (GQRA) (Tier 2) has been undertaken for the proposed infilling in the western quarry at La Gigoulande Quarry by way of a simple mass balance equation to demonstrate that there is no significant risk to groundwater quality and surface water quality.

The priority contaminants modelled

3.2 Consistent with EA guidance[3] above the modelled substances have been selected by way of a risk screening exercise. The proposed waste acceptance criteria have been screened against relevant screening assessment criteria. For hazardous substances the relevant screening criterion is the minimum reporting value (MRV) where available or otherwise the limit of quantification provided in the UKTAG Technical report on Groundwater Hazardous Substances. For non hazardous pollutants the screening assessment criterion is the minimum of the relevant Drinking Water Standard (DWS) or the background groundwater concentrations. For the purpose of the screening assessment groundwater quality monitoring data for the up hydraulic gradient boreholes BH1, BH2, BH3 and BH10 have been reviewed for the period November 2015 to October 2022. The locations of the boreholes are shown on Figure HRA 2 and the monitoring data collected at the boreholes is presented at Appendix ESID E to the ESID report. The screening assessment spreadsheet is presented at Appendix HRA 1.

3.3 As part of the risk screening exercise a risk characterisation ratio (RCR) has been calculated as the assumed source concentration divided by the relevant screening criterion. Based on the risk screening exercise the hazardous substances arsenic, chromium VI (conservatively it is assumed that all of the chromium is chromium VI), lead and mercury and the non-hazardous pollutants cadmium, copper, nickel and zinc have a RCR greater than 5 and are substances included in the source term for the GQRA and for which Environmental Assessment Levels (EALs) have been set. Further to the above the substances chloride, fluoride, sulphate, fluoranthene and toluene are included also in the GQRA. Chloride and sulphate are ubiquitous in groundwater, naturally occurring materials and waste materials. Fluoride minerals occur generally within granite complexes . Fluoranthene and toluene are hazardous substances considered representative of a range of organic compounds.

3.4 EALs proposed for this HRA are set out in Table HRA 2. EALs are the concentrations of substances above which it is considered that there may be a discernible discharge of hazardous substances to groundwater or pollution of groundwater by non-hazardous pollutants at the relevant receptors. The EALs for the selected substances have been set as either the maximum concentration plus 10% in groundwater up hydraulic gradient of the site or the mean recorded concentration plus three times the standard deviation in groundwater up hydraulic gradient of the site as determined from groundwater quality monitoring carried out at boreholes BH1, BH2, BH3 and BH10 (Figure HRA 2) for the period November 2015 to October 2022.

3.5 In the absence of a specific definition of inert waste in Jersey for use in the HRA and as a conservative assumption the source term concentrations for the selected determinands in the western quarry used in the GQRA comprise the liquid to solid ratio 10 l/kg leaching limit values presented in the EU Commission document for inert Waste Acceptance Criteria (WAC)[7] expressed in mg/l. The liquid to solid ratio 10 l/kg leaching limit values for inert waste are those with which waste leaching test results are compared prior to acceptance at an inert waste landfill as necessary.

3.6 The source term concentration for toluene is based on the solid composition WAC for BTEX converted into mg/l. For the purpose of the GQRA toluene is used as a worst case compound for BTEX concentrations. Toluene has been selected as one sample of inert waste tested by Granite Products from La Collette Recycling and Landfilling facility included BTEX above the method detection limit and the BTEX in the sample primarily was toluene and xylene. Toluene gives the most conservative results in respect of the GQRA. It should be noted that the modelling of toluene is a conservative approach as BTEX was not recorded above the method detection limit in a further nine samples of inert waste tested by Granite Products from La Collette. The source term concentration for fluoranthene is based on the solid composition

[7] Council Decision of 19 December 2002 establishing criteria and procedures for the acceptance of waste at landfills pursuant to Article 16 of and Annex II to Directive 1999/31/EC. Official Journal of the European Communities. 2003/33/EC

WAC for PAHs converted into mg/l. For the purpose of the GQRA fluoranthene is used as a worst case compound for PAH concentrations. Fluoranthene has been selected as a number of samples of inert waste tested by Granite Products from La Collette Recycling and Landfilling facility included PAHs above the method detection limit and fluoranthene comprised the PAH with the highest concentration in the samples. The WAC testing results are presented at Appendix HRA 2. The source term is presented in Table HRA 2.

3.7 10 sets of WAC testing results are available for April 2016, November 2016 and December 2021 for samples tested by Granite Products of wastes received at the La Collette Recycling and Landfilling facility. BTEX compounds were recorded as present above their respective analytical detection limits in one out of the 10 samples in which the toluene concentration comprises approximately 23.5% of the total BTEX concentration. PAH compounds were recorded as present in 9 out of the 10 samples analysed. The concentration of fluoranthene as a percentage of the total PAH compounds recorded above their respective analytical detection limit ranges between 6.4% and 24.5% with a mean of 9.8%. It is therefore assumed in deriving the leachate concentrations of toluene and fluoranthene that these compounds make up 23.5% and 24.5% of the total BTEX and PAH concentrations respectively comprising, as a conservative assumption, the maximum recorded in the samples tested by Granite Products of the wastes received at the La Collette Recycling and Landfilling facility.

Review of technical precautions

3.8 As set out in the qualitative risk screening in Section 2 of the HRA, notwithstanding that it is concluded based on the proposed use of inert waste only that there will be no significant risks to the environment from the proposed development consideration has been given to the mitigation of residual risk given the sensitivity of the site setting. The site setting is assessed as part of the GQRA to show whether there will be a discernible discharge of hazardous substances to receptors in the unlikely scenario where water percolating through the waste mass includes discernible concentrations of hazardous substances or significant concentrations of non-hazardous pollutants. Substances will be attenuated by processes of partitioning and degradation relevant to the nature of the contaminants and the physical and chemical properties of the granite and will be diluted in the groundwater.

Modelling approach

3.9 During placement of inert waste materials at the site the void will be dewatered to facilitate the dry placement of restoration materials. Pumped groundwater will be discharged to the consented discharge location on La Gigoulande Mill Stream. It is assumed that substances in the inert waste transported in water percolating through the waste mass will migrate to the outside edge of the waste mass and enter groundwater in the water management system comprising the quarry sump in the fractured granite aquifer. Once groundwater pumping has ceased it is assumed that groundwater will infiltrate the waste and will equilibrate with the groundwater in the surrounding fractured granite aquifer. It is assumed that substances in the inert waste transported in water percolating through the waste mass will migrate to the down hydraulic gradient edge of the waste and enter groundwater in the fractured granite aquifer thence flow to the down hydraulic gradient edge of the site. It is assumed conservatively that the compliance point for hazardous substances and for non-hazardous pollutants is in the groundwater at the edge of the landfill following immediate dilution in the fractured granite aquifer.

3.10 Based on the conceptual site model presented in the ESID report the principal receptor for contaminants migrating from the waste is the groundwater in the fractured granite aquifer adjacent to the western quarry. For the purpose of this assessment it is considered that the groundwater directly adjacent to the north western and western boundaries of the western quarry or the down hydraulic gradient edge of the western quarry is the receptor. The potential migration of contaminants from the site will continue laterally in the groundwater in the saturated zone of the fractured granite aquifer. The secondary receptors comprise the La Gigoulande Mill Stream and La Hague Reservoir down hydraulic gradient of and to the west and south west of the site. As a conservative assumption the effects of dilution only are modelled. Attenuation, dispersion and degradation are not relied on in the saturated pathway for the purpose of calculating the concentration of substances at the receptors. A summary of the source-pathway-receptor linkages is presented in Table HRA 1 and the cross section presented on Figure HRA 1.

3.11 For the purpose of this GQRA, for the reasons outlined above, dilution in the fractured granite aquifer is considered only. Dilution in the secondary receptors of La

Gigoulande Mill Stream and La Hague Reservoir is not included. Other than immediate dilution in the fractured granite aquifer no attenuation of hazardous substances or of non-hazardous pollutants in the waste and the fractured granite aquifer is taken into consideration in the modelling. Because attenuation processes will act to reduce the concentrations of hazardous substances or of non-hazardous pollutants in the waste and the concentrations of non-hazardous pollutants along the groundwater flow path prior to the groundwater reaching La Gigoulande Mill Stream and La Hague Reservoir, it is considered that this assumption is conservative. No allowance is made for the fact that groundwater pumping in the water management system will be at a higher rate than flow in the fractured granite aquifer adjacent to La Gigoulande Mill Stream and La Hague Reservoir and that the same model is used to represent both the operational and post operational scenarios. It is therefore considered that there will be dilution of substances within the groundwater management system during the operational phase which is not taken account of in the model due to groundwater being drawn into the groundwater management system from the down hydraulic gradient edge of the landfill. It is considered also that during the post operational scenario some runoff draining towards the edge of the restored landfill may infiltrate round the sides of the landfill thereby resulting in the dilution of substances migrating from the waste mass which is not taken account of in the model.

3.12 As a conservative assumption it is assumed that all of the modelled substances are present at the relevant inert WAC concentrations at the edge of the site boundary. Accordingly these concentration values are used as model input parameters in a spreadsheet based model which predicts the concentration of contaminants in the fractured granite aquifer at the compliance point taking into account immediate dilution in the aquifer. For each of the substances EALs are proposed as described above. To assess the magnitude of the potential impact on groundwater quality of the acceptance of inert waste at the WAC leaching limit values, the predicted concentration of contaminants in the fractured granite aquifer at the compliance point are compared with the EALs.

3.13 The GQRA has been undertaken using a simple deterministic dilution model constructed using Microsoft Excel™. The model uses Darcy's Law to determine the flow out of the sidewall of the landfill and the flow in the surrounding granite aquifer.

To determine the predicted concentration of substances in the groundwater immediately down hydraulic gradient of the source area the flow rates are multiplied by the concentration of each substance percolating from the waste and background concentrations of substances in the fractured granite aquifer. The calculations have been carried out using the as follows:

$$C_x = \frac{Q_{cs}C_{cs} + Q_{aq}C_{aq}}{Q_{cs} + Q_{aq}}$$

Where:

C_x is the predicted concentration immediately down hydraulic gradient of the discharge area in the fractured granite aquifer (mg/l).

Q_{cs} is the flow rate out of the discharge area (m^3/s) which is calculated based on the hydraulic conductivity of the waste multiplied by the assumed hydraulic gradient across the waste.

C_{cs} is the concentration in the source comprising the inert WAC liquid to solid ratio 10 l/kg leaching limit value assumed at the edge of the site (expressed as mg/l).

Q_{aq} is the flow rate in the fractured granite aquifer adjacent to the discharge area (m^3/s) which is calculated based on the assumed hydraulic conductivity of the fractured granite aquifer multiplied by the calculated hydraulic gradient in the fractured granite aquifer.

C_{aq} is the background concentration in the fractured granite aquifer (mg/l).

Model parameterisation

3.14 The principal assumptions used in the dilution model and the assessment are:

- The concentrations of contaminants at the source are in a steady state and therefore not declining.
- The hydraulic conductivity of the waste comprises a single value. This assumption is also the subject of sensitivity analysis.
- The calculated flux occurs throughout the whole surface area over an assumed length of the sidewall of the landfill.

- No retardation, dispersion or oxidation/reduction of the determinands modelled occurs in the waste or in the aquifer.

3.15 Granite Products have carried out testing on the hydraulic conductivity of two samples of waste from La Collette reclamation site where partial recycling of aggregate takes place before the residual material is disposed of to marine landfill. The samples are comparable with likely recycling residue at the La Gigoulande recycling site and good examples of future landfill input in the western quarry at La Gigoulande Quarry. In addition, Granite Products have carried out testing on the hydraulic conductivity of three samples of waste from La Collette that were not suitable for recycling and were awaiting disposal in the landfill facility. The hydraulic conductivities of the wastes ranged from 9.00×10^{-10}m/s to 2.42×10^{-8}m/s with a geometric mean of 4.12×10^{-9}m/s (samples W1, W4 and W5). As a conservative assumption the dilution model has been run with three different hydraulic conductivities of the waste comprising 1×10^{-9}m/s, 1×10^{-8}m/s and 1×10^{-7}m/s. The results of the hydraulic conductivity testing from La Gigoulande and La Collette are presented at Appendix HRA 2.

3.16 Where possible the input parameters are based on site specific data or other relevant sources. Where no site specific data are available professional judgement has been used to select appropriate parameter values based on relevant scientific literature. The values for the parameters used in the model and the justifications for their use are presented at Appendix HRA 3. An electronic copy of the dilution model is presented at Appendix HRA 4.

Model results – Emissions to groundwater or surface water

3.17 A summary of the results of the dilution model is presented in Table HRA 3.

Hazardous substances and non-hazardous pollutants

3.18 While the inert WAC used as the source term in the HRA model includes concentrations of hazardous substances above the minimum reporting values the results of the model show that there will be no discernible discharge of hazardous substances or non-hazardous pollutants from the placement of inert restoration materials at the site. While the inert WAC used as the source term in the HRA model includes concentrations of non-hazardous pollutants with the potential to cause pollution the results of the model show that there will be no pollution of groundwater from the placement of inert waste materials at the site.

3.19 The source term used for BTEX and PAH has been reviewed to confirm that there will be no discernible discharge of hazardous substances from the placement of inert waste materials at the site assuming a waste hydraulic conductivity of 1 x 10^{-8}m/s (Tables HRA 3 and 4). Based on the information presented in Section 3.15 of this report and at Appendix HRA 2 it is considered likely that the hydraulic conductivity of the waste placed within the quarry void will be approximately equal to or significantly lower than 1 x 10^{-8}m/s.

3.20 The model results show that the calculated concentrations of the hazardous substances and non-hazardous pollutants in the groundwater at the edge of the site following immediate dilution in the fractured granite aquifer are lower than the respective EALs. Consequently, there is no significant risk to down hydraulic gradient receptors such as areas of groundwater discharge to the surface watercourses.

3.21 Due to the inert nature of the waste no artificial barriers or surface capping system including a surface water drainage layer is necessary. Based on the results of the generic quantitative HRA it is considered that a basal lining system comprising an artificially established attenuation layer at the base and sides of the landfill is not necessary for the purpose of groundwater protection.

Sensitivity analysis

3.22 A sensitivity analysis has been undertaken to assess the sensitivity of the model to:

- the hydraulic gradient in the waste,
- the thickness of the fractured granite aquifer, and
- the hydraulic conductivity of the fractured granite aquifer.

The sensitivity analyses have been carried out on the model where the hydraulic conductivity of the waste is 1 x 10^{-8}m/s. The results of the sensitivity analyses are presented in Table HRA 4 and the models are presented at Appendix HRA 5.

Hydraulic gradient in the waste

3.23 The hydraulic gradient in the waste may be greater than in the surrounding fractured granite aquifer due to the lower hydraulic conductivity of the waste compared with the fractured granite aquifer. If it is assumed that the hydraulic gradient in the waste is double that in the aquifer, the results of the dilution model show that there will be no discernible discharge of hazardous substances or pollution of groundwater by non-hazardous pollutants from the placement of inert waste at the site.

Thickness of the fractured granite aquifer

3.24 If the thickness of the fractured granite aquifer is reduced to 5m the results of the dilution model show that there will be no discernible discharge of hazardous substances or pollution of groundwater by non-hazardous pollutants from the placement of inert waste at the site. There is no difference in the results of the dilution model whether the aquifer thickness is assumed to be 19.84m as presented in the GQRA or 5.00m as presented in the sensitivity analysis model. This is due to the proportional change in the depth of sidewall of the landfill in contact with groundwater comprising the discharge zone from the landfill and the thickness of the fractured granite aquifer in which groundwater flow takes place adjacent to the outside edge of the landfill.

Hydraulic conductivity of the fractured granite aquifer

3.25 In one of the sensitivity scenarios the hydraulic conductivity in the fractured granite aquifer has been reduced to that at the lower end of the range of testing at the site in 2005 of 9.2×10^{-7}m/s. It is considered that the testing carried out in 2021 either was below the base of the fractured granite aquifer with limited groundwater movement or owing to the limited time and quantities removed from the boreholes, was not representative of the aquifer as a whole. The hydraulic conductivity value of 9.2×10^{-7}m/s is within the range of values derived from the testing in 2021. If it is assumed that the hydraulic conductivity in the fractured granite aquifer is 9.2×10^{-7}m/s, with the exception of marginal increases in the BTEX and PAH concentrations within the aquifer, the results of the dilution model show that there will be no discernible discharge of hazardous substances or pollution of groundwater by non-hazardous pollutants from the placement of inert waste at the site. The mean hydraulic conductivity in the granite complexes across the island shown on the British Geological Survey 1:25,000 scale map entitled "Hydrogeological map of Jersey" dated 1992 is 1 x 10^{-4}m/s. On this basis it is reasonable any assumed hydraulic conductivity within the granite aquifer which is several orders of magnitude below this value will not reflect the regional scale transmissivity of the granite aquifer through which the aquifer hydraulic conductivity within the dilution calculation models is derived. It is therefore likely that the dilution factor with respect to leachate from the waste within the granite aquifer will be significantly greater than that assumed as part of this sensitivity analysis.

Accidents and their consequences

3.26 While it is considered that using the inert waste WAC liquid to solid ratio 10 l/kg leaching limit values is a conservative approach as this assumes that all substances are at the maximum allowable limit, a further sensitivity analysis has been undertaken with respect to the source term concentration used in the model. In effect the sensitivity analysis allows for the unlikely situation where a significant portion of waste loads are accepted above the WAC. The inert waste acceptance criteria have been increased to the concentration in the first eluate from a percolation test (C_0) on inert wastes specified in the EU Council Decision of 2002 in accordance with the Landfill Directive 1999[7] above. The results of the sensitivity analysis model are presented in Table HRA 4 and the model is presented at Appendix HRA 5. Based on the results of the dilution model if the waste has a source term at the C_0 concentration for inert wastes it is considered that there will be no discernible discharge of hazardous substances or pollution of groundwater by non-hazardous pollutants from the placement of inert waste at the site.

Conclusions of GQRA

3.27 Based on this GQRA it is considered that there is no significant risk from the proposed deposition of inert waste materials at the site to groundwater quality in the fractured granite aquifer or the surface water quality in the La Gigoulande Mill Steam or the La Hague Reservoir.

4. Hydrogeological risk assessment – Verification monitoring

Hydrogeological leachate completion criteria

4.1 No biodegradable waste materials will be deposited at the site which could result in the generation of leachate. Only inert wastes will be deposited at the site which have a limited potential for the leaching of contaminants. As such, leachate completion criteria and leachate monitoring are not relevant to inert landfill sites.

Monitoring

4.2 An ongoing scheme of water quality monitoring prior to and during restoration by infilling in the western quarry is presented in applicant's Quality, Health, Environment, Safety Sustainably Together Management System (QHEST) Procedure JSY07 Management and Monitoring of Site Water Effluent and Discharges. A copy of Procedure JSY07 is presented at Appendix ESID E to the ESID. The monitoring locations are shown on Figure HRA 2. Water quality monitoring is necessary prior to and during restoration by infilling to confirm that there is no significant effect on the quality of the groundwater in the granite or surface water in La Gigoulande Mill Stream as a result of the placement of restoration materials. The scheme of water quality monitoring includes the determinands modelled in the GQRA.

4.3 Interim water quality compliance limits and assessment levels are set at the quarry sump during the period of active groundwater control as presented in Table HRA 5 for select substances included in the GQRA. The substances selected are representative of the range of substances modelled, are identified in the WAC testing results for samples of wastes received at the La Collette Recycling and Landfilling facility and/or have the highest risk characterisation ratio in the GQRA. It is proposed that water quality compliance and assessment limits are applied to groundwater at the down hydraulic gradient boreholes BH6 and BH7 following cessation of active groundwater control. Prior to the cessation of groundwater control the groundwater quality data at boreholes BH6 and BH7 will be reviewed and appropriate compliance limits and assessment levels will be proposed for approval by the Government of Jersey. The compliance limits for the quarry sump proposed in Table HRA 5 comprise the EALs used in the HRA calculated based on the groundwater quality monitoring from up hydraulic gradient boreholes BH1, BH2, BH3 and BH10 between November 2015 and October 2022. An electronic copy of the derivation of the compliance limits (EALs) and assessment levels are provided at Appendix HRA 4. It is proposed that the compliance limits for the quarry sump are reviewed and, where necessary, updated and agreed with the Government of Jersey prior to acceptance of waste at the site.

4.4 As stated above there is a pathway between the inert fill material placed in the western quarry and La Gigoulande Mill Stream by groundwater potentially discharging to the La Gigoulande Mill Stream to the north west, west and south west of the site. As groundwater quality will be monitored at groundwater monitoring boreholes between the western quarry and La Gigoulande Mill Stream it is considered unnecessary to monitor surface water quality to confirm that there is no significant effect on the quality of surface water as a result of the placement of the inert waste materials. However, in order to provide additional confidence surface water quality monitoring will continue in La Gigoulande Mill Stream. The scheme of surface water monitoring proposed is presented in Procedure JSY07 (Appendix ESID E of the ESID) and the monitoring locations are shown on Figure HRA 2. Water is and will continue to be discharged to La Gigoulande Mill Stream under the current Discharge Permit DP(B)2000/11/03. The surface water quality monitoring proposed in Table HRA 5 fulfils also the requirements of monitoring the quarry discharge under the discharge permit for the site.

5. Conclusions

5.1 Based on the results of the risk assessment it is considered that an artificially established attenuation layer or other artificial barrier in the western quarry is not necessary to protect soil and groundwater.

5.2 It is concluded based on the results of the deterministic dilution model that there is no significant risk that the predicted concentration of contaminants which may reach controlled waters will result in pollution of groundwater or harm to human health if the waste deposited in the landfill is at the liquid to solid ratio 10 l/kg leaching and solid concentration limit values for inert wastes specified in the EU Council Decision of 2002 in accordance with the Landfill Directive 1999.

TABLES

Table HRA 1
Source - pathway - receptor linkages throughout the lifecycle of the site

Phase of landfill	Source	Pathway	Receptor
Operational	***Water percolating through the inert waste materials*** Given the inert nature of the waste that will be deposited in the site the potential for the presence of discernible concentrations of hazardous substances or significant concentrations of non-hazardous pollutants is negligible. During quarrying and landfilling the groundwater table is depressed by groundwater pumping. The inert wastes will be placed above the depressed groundwater level.	Water management system	Water management system La Gigoulande Mill Stream
Post operational/ Completion	***Water percolating through the inert restoration materials*** Given the inert nature of the waste that will be deposited in the site the potential for the presence of discernible concentrations of hazardous substances or significant concentrations of non-hazardous pollutants is negligible. The groundwater level will recover following cessation of groundwater pumping upon completion of infilling.	Groundwater in the fractured granite aquifer	Groundwater in the fractured granite aquifer Secondary receptors: La Gigoulande Mill Stream thence La Hague Reservoir Private groundwater abstractions

Table HRA 2
Source term and background quality concentrations used in the dilution model

Determinand	Drinking Water Standard[1]	Background groundwater quality[2]	Environmental assessment level[3]	Source term concentration[4]
Chloride (mg/l)	250	52.7	114	80
Sulphate (mg/l)	250	74.7	191	100
Lead (mg/l)	0.01	0.005	0.0071	0.05
Copper (mg/l)	2.0	0.008	0.038	0.2
Fluoride (mg/l)	1.5	0.32	0.70	1.0
Zinc (mg/l)		0.05	0.139	0.4
Arsenic (mg/l)	0.01	0.0031	0.01	0.05
Cadmium (mg/l)	0.005	0.00052	0.00087	0.004
Chromium (mg/l)	0.05	0.0016	0.0068	0.05
Mercury (mg/l)	0.001	0.00002	0.001	0.001
Nickel (mg/l)	0.02	0.0027	0.006	0.04
Toluene (mg/l)	0.001	0.005	0.005	0.2046
Fluoranthene (mg/l)	0.0001	0.000243	0.000568	0.0334

Notes

1 Standards for wholesome water as defined in Water (Jersey) Law 1972 (consolidated version showing the law from September 2021 to Current). The standard for toluene is for benzene in Water (Jersey) Law 1972. The standard for fluoranthene is for total PAHs.

2 The background groundwater quality has been set as the mean concentration in groundwater up hydraulic gradient of the site as determined from groundwater quality monitoring carried out at boreholes BH1, BH2, BH3 and BH10 between November 2015 and October 2022. The background water quality for mercury is the concentration recorded in the groundwater at borehole BH1 in October 2022. The background water quality for fluoranthene is for total PAHs. Where concentrations in the groundwater are recorded as less than the laboratory detection limit it is assumed that the determinands are present at the laboratory detection limit of the analytical method used.

3 The Environmental Assessment Levels (EALs) for the hazardous substances arsenic, chromium and fluoranthene have been set as the maximum concentrations plus 10% and for the hazardous substance lead and for the non-hazardous pollutants have been set as the mean concentrations plus three times the standard deviation in groundwater up hydraulic gradient of the site as determined from groundwater quality monitoring carried out at boreholes BH1, BH2, BH3 and BH10 between November 2015 and October 2022. The approach for arsenic, chromium and fluoranthene has been taken as the substances are recorded above detection limits (DL) in the groundwater round the site on numerous occasions over the monitoring review period. The EALs for mercury and toluene comprise the DL of the analytical methods used as the determinands have not been recorded in the groundwater at the site above the DL with the exception of one concentration of mercury of 0.00002mg/l recorded in the groundwater at borehole BH1 in October 2022. The EAL for fluoranthene is for total PAHs.

4 The source term concentrations comprise the liquid to solid ratio 10 l/kg leaching limit values for inert Waste Acceptance Criteria presented in the EU Council Decision of 2002 in accordance with the Landfill Directive 1999 expressed in mg/l. The source term concentration for toluene is based on the solid composition WAC for BTEX converted into mg/l. It is

conservatively assumed that 23.5% of the total BTEX concentration comprises toluene. The source term concentration for fluoranthene is based on the solid composition WAC for Total PAHs converted into mg/l. It is conservatively assumed that 24.5% of the total PAH concentration comprises fluoranthene.

Table HRA 3

Summary of the results of the deterministic dilution model

Determinand	Drinking Water Standard[1]	Environmental assessment level[2]	Predicted concentrations of determinands in the groundwater immediately down hydraulic gradient of the landfill		
			Hydraulic conductivity of the waste (m/s)		
			$1x10^{-7}$	$1x10^{-8}$	$1x10^{-9}$
Chloride (mg/l)	250	114	52.9	52.7	52.7
Sulphate (mg/l)	250	191	74.9	74.7	74.7
Lead (mg/l)	0.01	0.0071	0.00536	0.00504	0.00500
Copper (mg/l)	2.0	0.038	0.0095	0.0082	0.0080
Fluoride (mg/l)	1.5	0.70	0.33	0.32	0.32
Zinc (mg/l)		0.139	0.0528	0.0503	0.0500
Arsenic (mg/l)	0.01	0.01	0.00347	0.00314	0.00310
Cadmium (mg/l)	0.005	0.00087	0.00055	0.00052	0.00052
Chromium (mg/l)	0.05	0.0068	0.00198	0.00164	0.00160
Mercury (mg/l)	0.001	0.001	0.00003	0.00002	0.00002
Nickel (mg/l)	0.02	0.006	0.0030	0.0027	0.0027
Toluene (mg/l)	0.001	0.005	0.007	0.005	0.005
Fluoranthene (mg/l)	0.0001	0.000568	0.000506	0.000269	0.000245

Notes

Highlighted Denotes an exceedance of an Environmental Assessment Level

[1] Standards for wholesome water as defined in Water (Jersey) Law 1972 (consolidated version showing the law from September 2021 to Current). The standard for toluene is for benzene in Water (Jersey) Law 1972. The standard for fluoranthene is for total PAHs.

[2] See Table HRA 2 for the derivation of the Environmental Assessment Levels

Table HRA 4

Assessment of the sensitivity analyses on the results of the dilution model

Determinand	Drinking Water Standard[1]	Environmental assessment level[2]	Predicted concentrations of determinands in the groundwater immediately down hydraulic gradient of the landfill			
			Source term C_0	Hydraulic gradient in waste double that in the aquifer	Fractured aquifer thickness reduced to 5m	Reduced aquifer hydraulic conductivity to 9.2×10^{-7}m/s
Chloride (mg/l)	250	114	53.0	52.7	52.7	53.2
Sulphate (mg/l)	250	191	75.8	74.4	74.7	75.2
Lead (mg/l)	0.01	0.0071	0.00512	0.00507	0.00504	0.00585
Copper (mg/l)	2.0	0.038	0.0085	0.0083	0.0082	0.0116
Fluoride (mg/l)	1.5	0.70	0.32	0.32	0.32	0.33
Zinc (mg/l)		0.139	0.0509	0.0506	0.0503	0.05659
Arsenic (mg/l)	0.01	0.01	0.00315	0.00317	0.00314	0.00398
Cadmium (mg/l)	0.005	0.00087	0.00054	0.00053	0.00052	0.00059
Chromium (mg/l)	0.05	0.0068	0.00168	0.00168	0.00164	0.00251
Mercury (mg/l)	0.001	0.001	0.00002	0.00002	0.00002	0.00004
Nickel (mg/l)	0.02	0.006	0.00279	0.00276	0.00273	0.00340
Toluene (mg/l)	0.001	0.005	0.005	0.005	0.005	0.009
Fluoranthene (mg/l)	0.0001	0.000568	0.000269	0.000296	0.000269	0.000867

Notes

1 Standards for wholesome water as defined in Water (Jersey) Law 1972 (consolidated version showing the law from September 2021 to Current). The standard for toluene is for benzene in Water (Jersey) Law 1972. The standard for fluoranthene is for total PAHs.

2 See Table HRA 2 for the derivation of the Environmental Assessment Levels.

Table HRA 5

Interim groundwater quality compliance limits and assessment levels

<table>
<tr><td colspan="3">Criterion Objective
To confirm that the deposition of inert waste at the site has no adverse effect on groundwater quality</td></tr>
<tr><td>Measurement</td><td colspan="2">Arsenic, cadmium, chloride, chromium, copper, fluoride, lead, mercury, toluene and total PAH</td></tr>
<tr><td>Frequency</td><td colspan="2">Quarterly. To be reviewed annually.</td></tr>
<tr><td>Monitoring points the subject of compliance</td><td colspan="2">In the quarry sump during the period of groundwater control[1]
Groundwater monitoring boreholes BH6 and BH7 down hydraulic gradient of the site following cessation of pumping[2]</td></tr>
<tr><td rowspan="2">Compliance limits[3]</td><td colspan="2">HAZARDOUS SUBSTANCES
Arsenic 0.01mg/l
Chromium 0.0068mg/l
Lead 0.0071mg/l
Toluene 0.005mg/l
Total PAH 0.000568mg/l</td></tr>
<tr><td colspan="2">NON-HAZARDOUS POLLUTANTS
Cadmium 0.00087mg/l
Chloride 114mg/l
Copper 0.038mg/l
Fluoride 0.7mg/l</td></tr>
<tr><td rowspan="2">Assessment levels[4]</td><td colspan="2">HAZARDOUS SUBSTANCES
Arsenic 0.0097mg/l
Chromium 0.0062mg/l
Lead 0.0065mg/l
Total PAH 0.000516mg/l
Not applicable for toluene as the compliance limit is set at the detection limits (DL) of the analytical method used.</td></tr>
<tr><td colspan="2">NON-HAZARDOUS POLLUTANTS
Cadmium 0.00075mg/l
Chloride 93mg/l
Copper 0.028mg/l
Fluoride 0.57mg/l</td></tr>
<tr><td>Assessment test</td><td colspan="2">Concentrations exceed the assessment level on three consecutive occasions.</td></tr>
<tr><td colspan="2">Contingency action</td><td>Response Time</td></tr>
<tr><td colspan="2">Advise the Department of the Environment at the Government of Jersey.</td><td>1 month</td></tr>
<tr><td colspan="2">Increase the sampling frequency to monthly.</td><td>1 month</td></tr>
<tr><td colspan="2">Undertake investigation work to identify the source of the contaminants.</td><td>6 months</td></tr>
<tr><td colspan="2">Report to the Government of Jersey on the re-appraisal of risks and options for corrective measures.</td><td>12 months</td></tr>
<tr><td colspan="2">If the risks are acceptable re-evaluate the assessment criteria.
If the risks are unacceptable implement agreed corrective measures.</td><td>18 months
18 months</td></tr>
</table>

Notes:

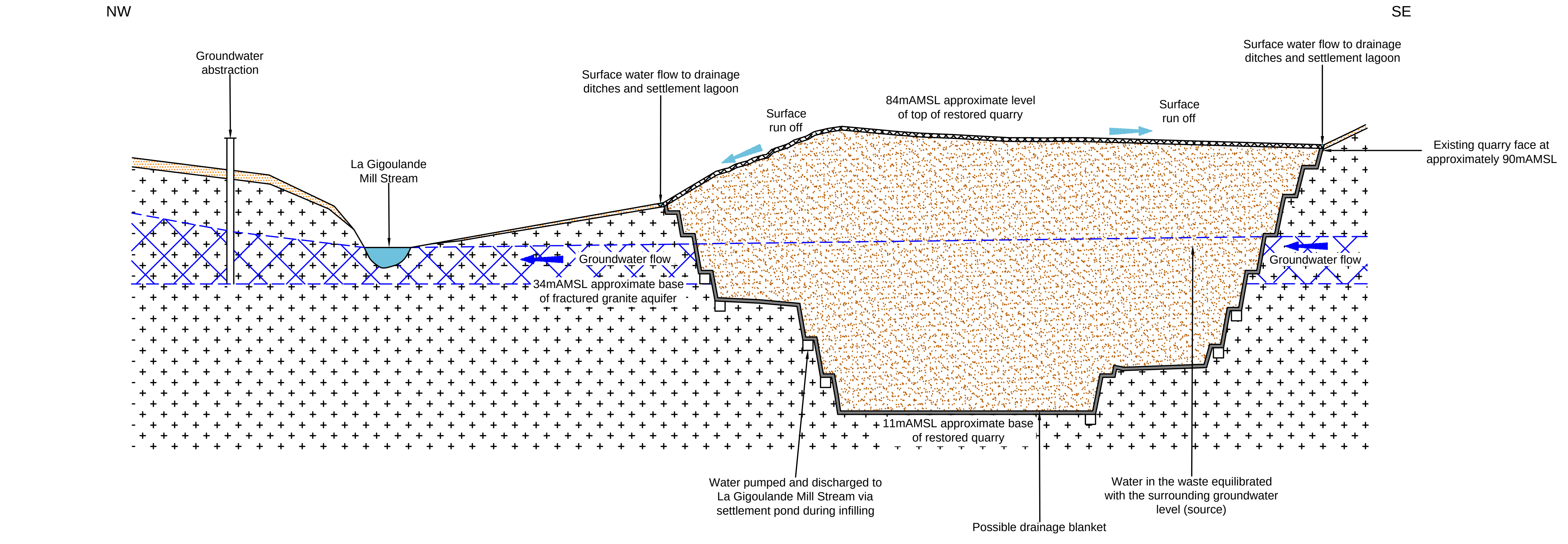
[1] It is proposed that the monitoring data is reviewed prior to the acceptance of waste at the site and that, where necessary, the compliance limits and assessment levels for the quarry sump are updated for use during the period of groundwater control.

[2] It is proposed that the monitoring data is reviewed prior to the cessation of groundwater control and that compliance limits and assessment levels are set for use following the cessation of groundwater control.

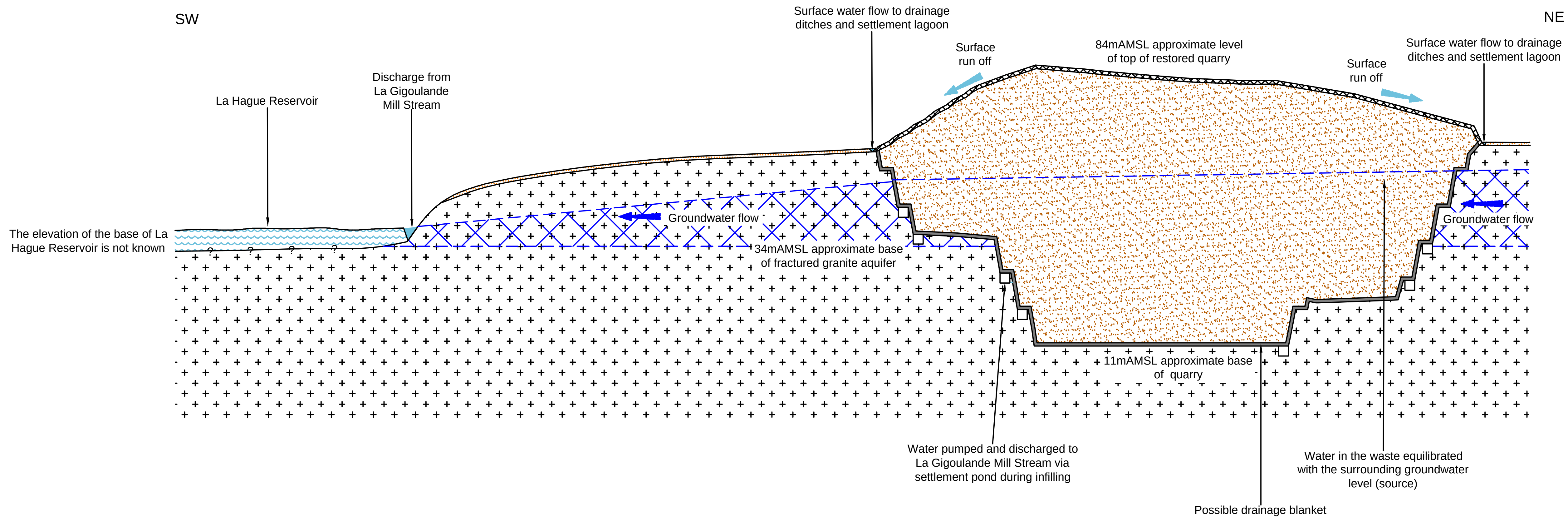
[3] The compliance limits are set at the Environmental Assessment Levels (EAL) used in the HRA (See Table HRA 2).

[4] No assessment levels are proposed for the hazardous substance toluene as the compliance limit is set at the detection limits (DL) of the analytical methods used. The assessment levels for the remaining hazardous substances are set as the maximum concentration recorded in the groundwater up hydraulic gradient of the site as determined from groundwater quality monitoring carried out at boreholes BH1, BH2, BH3 and BH10 between November 2015 and October 2022 with the exception of lead. The assessment levels for lead and the non-hazardous pollutants are set as the mean concentration plus two times the standard deviation in groundwater up hydraulic gradient of the site as determined from groundwater quality monitoring carried out at boreholes BH1, BH2, BH3 and BH10 between November 2015 and October 2022. As with the EALs, where concentrations in the groundwater are recorded as less than the laboratory detection limit it is assumed that the determinands are present at the laboratory detection limit of the analytical method used.

FIGURES



Not to scale



Not to scale

Key / Notes

- Surface waterbody
- Reservoir
- Groundwater
- Quaternary deposits
- Granite bedrock
- Inert Waste
- Restoration soils

Note:
mAMSL metres above mean sea level

Rev	Status	Drn	App	Chk	Date
A	Minor amends	KR	CJG	GT	03/11/23
	Final	KR	JRC	CJC	06/10/23

Site
LA GIGOULANDE QUARRY

Client
GraniteProducts

Title
Conceptual site model

Figure HRA 1

Scale
As shown

Drawing Ref
BGL/JE/04-23/23686revA

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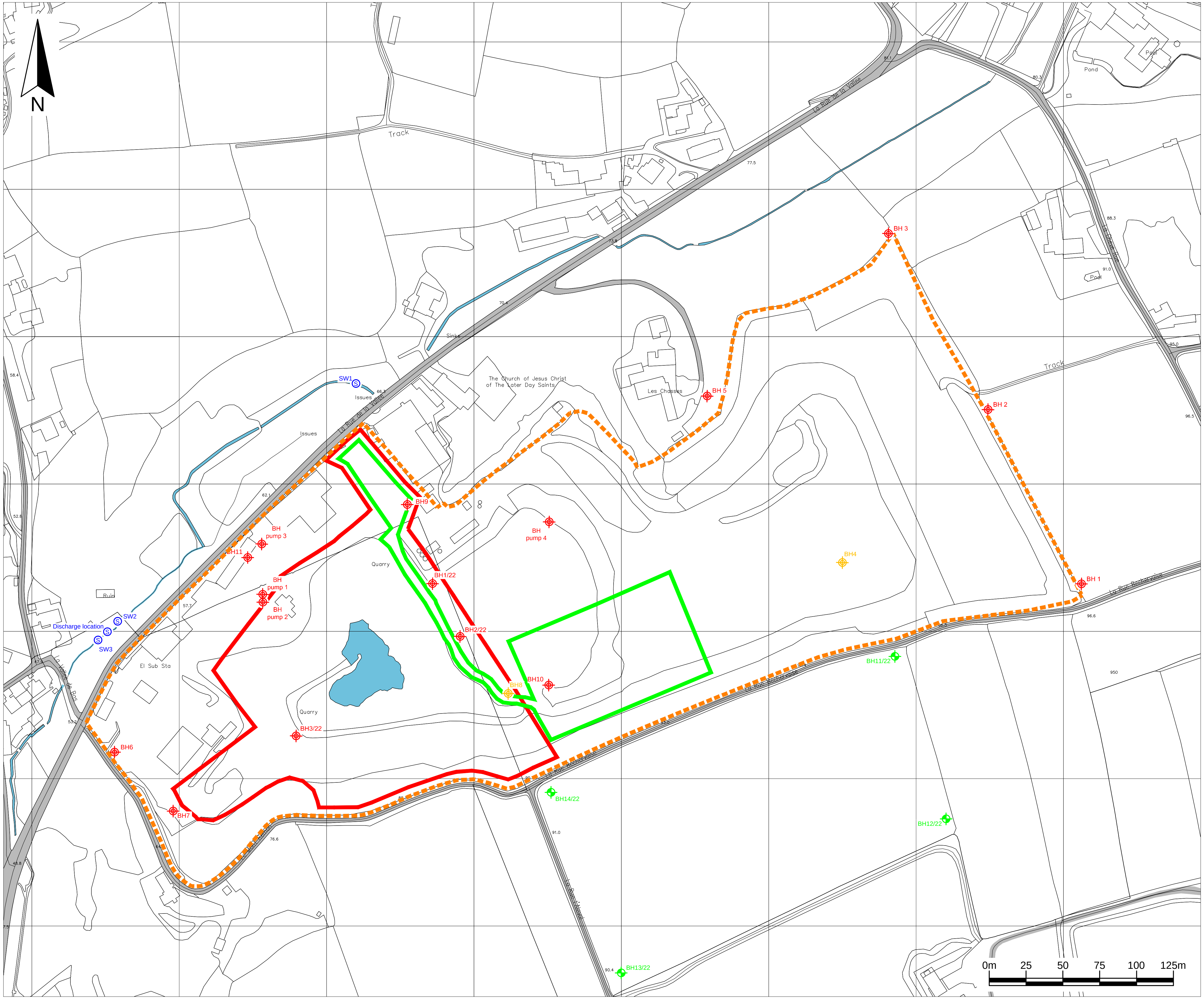

Key / Notes

- Boundary of the area the subject of the Waste Management Licence application
- Boundary of Waste Management Licence WML026
- Approximate boundary of La Gigoulande Quarry
- La Gigoulande Mill Stream
- Culverted watercourse
- BH1 Approximate location of a borehole in the granite
- SW1 Approximate location of a surface water monitoring point
- BH4 Approximate location of a borehole that has been lost
- BH11/22 Approximate location of a groundwater monitoring borehole
- 101 Contours (mAOD)

Rev	Status	Drn	App	Chk	Date
A	Minor amends	KR	CJG	GT	03/11/23
	Final	KR	CT	JRC	06/10/23

Site
LA GIGOULANDE QUARRY

Client
GraniteProducts
QUALITY LOCAL STONE SINCE 1946

Title
The locations of groundwater and surface water monitoring points

Figure HRA 2

Scale
1:2,500@A3

Drawing Ref
BGL/JE/04-23/23687revA

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APPENDICES

APPENDIX HRA1

GENERIC QUANTITATIVE RISK ASSESSMENT - RISK SCREENING EXERCISE

			Inert waste leaching limit values [A]						La Gigoulande Quarry		
Parameter	**Symbol and notes**	**Category [B, C]**	**L/S = 10l/kg**	**L/S = 10l/kg eluate concentratation**	**Jersey Wholesome Water Standard [H]**	**Minimum reporting value (MRV) [F, G]**	**Minimum of MRV and DWS**	**Risk characterisation ratio** (ignoring background groundwater quality)	**Mean background concentration**	**Screening assessment criterion**	**Risk characterisation ratio (RCR)**
Units			**mg/kg**	**mg/l**	**mg/l**	**mg/l**	**mg/l**		**mg/l**		
Antimony	Sb	Non hazardous	0.06	0.006	0.005		0.005	1.2		Minimum quality standard	1.2
Arsenic	As	Hazardous	0.5	0.05	0.01	0.005	0.005	10.0	0.00311	MRV	10
Barium	Ba	Non hazardous	20	2							
Cadmium	Cd	Non hazardous	0.04	0.004	0.005		0.005	0.8	0.00052	Mean background	7.7
Chromium	Cr	Hazardous [D]	0.5	0.05	0.05	0.001	0.001	50.0	0.00156	MRV	50.0
Copper	Cu	Non hazardous	2	0.2	2		2	0.1	0.0080	Mean background	25.1
Lead	Pb	Hazardous	0.5	0.05	0.01	0.0002	0.0002	250.0	0.0051	MRV	250.0
Mercury	Hg	Hazardous [E]	0.01	0.001	0.001	0.00001	0.00001	100.0	0.00002	MRV	100.0
Molybdenum	Mo	Non hazardous	0.5	0.05							
Nickel	Ni	Non hazardous	0.4	0.04	0.02		0.02	2.0	0.0027	Mean background	14.8
Selenium	Se	Non hazardous	0.1	0.01	0.01		0.01	1.0	0.003	Mean background	3.3
Zinc	Zn	Non hazardous	4	0.4					0.0523	Mean background	7.6
Chloride	Cl^-	Non hazardous	800	80	250		250	0.3	52.66	Mean background	1.5
Fluoride	F^-	Non hazardous	10	1	1.5		1.5	0.7	0.32	Mean background	3.1
Sulphate	SO_4^{2-}	Non hazardous	1000	100	250		250	0.4	74.73	Mean background	1.3
Phenol index		Non hazardous	1	0.1							
Dissolved organic carbon		Non hazardous	500	50							
Total dissolved solids		Non hazardous	4000	400							

Selection of screening assessment criterion:

Hazardous substances — Screening criterion is the MRV.

Non hazardous substance — Screening criterion is the DWS unless the mean background concentration is lower in which case the mean background concentration is used.

Risk characterisation ratio — The risk characterisation ratio (RCR) is the assumed source concentration divided by the relevant screening criterion.

Key

Substance that it is proposed is modelled.

Notes

[A] Council decision of 19 December 2002 establishing criteria and procedures for the acceptance of waste at landfills pursuant to Article 16 of and Annex II to Directive 1999/31/EC. Official Journal of the European Communities. 2003/33/EC.

[B] "2018 01 31 Confirmed hazardous substances list" http://www.wfduk.org/sites/default/files/Media/JAGDAG/2018%2001%2031%20Confirmed%20hazardous%20substances%20list_0.pdf accessed 18 April 2023

[C] Where a substance has not been determined as a hazardous substance or non hazardous pollutant it is assumed that it is a non hazardous pollutant.

[D] Conservatively it is assumed that all of the chromium is chromium VI which is designated as a hazardous substance.

[E] Conservatively it is assumed that all of the mercury is mercury II which is designated as a hazardous substance.

[F] https://www.gov.uk/government/publications/values-for-groundwater-risk-assessments/hazardous-substances-to-groundwater-minimum-reporting-values accessed 13 April 2023

[G] MRV for arsenic, chromium and lead based on http://wfduk.org/sites/default/files/Media/UKTAG_Technical%20report_GW_Haz-Subs_ForWebfinal.pdf

[H] "Wholesome Water" as defined in the Schedule to the Water (Jersey) Law 1972 (the official consolidated version showing the law from September 2021 to Current) https://www.jerseylaw.je/laws/current/Pages/27.700.aspx accessed 12 April 2023

Substances for which there is no MRV or relevant environmental quality standards are not considered in detail.

APPENDIX HRA2

RESULTS OF THE WASTE ACCEPTANCE CRITERIA TESTING UNDERTAKEN ON SAMPLES FROM LA GIGOULANDE QUARRY AND LA COLLETTE RECYCLING AND LANDFILLING FACILITY AND OF HYDRAULIC CONDUCTIVITY TESTING UNDERTAKEN ON SAMPLES AT LA COLLETTE RECYCLING AND LANDFILLING FACILITY

Jersey WAC Sample Results

		Off -site waste samples					Off-site waste samples								Off-site waste samples						Quarry material				
Client Sample No	Inert Landfill Waste Acceptance Criteria Limits	SAMPLE 1	SAMPLE 2	SAMPLE 3	SAMPLE 4	SAMPLE 5	SAMPLE 1	SAMPLE 2	SAMPLE 3	SAMPLE 4	SAMPLE 5	SAMPLE 6	SAMPLE 7	SAMPLE 8	W1	W2	W3	W4	W5	W6	S1- Top of Pile	S4- Side of Bank	Topsoil	S2B	
JEFL Job No		16/8113	16/8113	16/8113	16/8113	16/8113	16/17967	16/17967	16/17967	16/17967	16/17967	16/17967	16/17967	16/17967	21/19726	21/19726	21/19726	21/19726	21/19726	21/19726	21/19726	21/19726	21/19726	21/19726	
Sample Date		20/04/2016 14:00	21/04/2016 10:00	21/04/2016 10:30	21/04/2016 11:00	21/04/2016 11:30	29/11/2016	29/11/2016	29/11/2016	29/11/2016	29/11/2016	29/11/2016	29/11/2016	30/11/2016	02/12/2021	02/12/2021	02/12/2021	02/12/2021	02/12/2021	02/12/2021	02/12/2021	02/12/2021	02/12/2021	02/12/2021	
Solid Waste Analysis																									
Total Organic Carbon (%)	3	1.55	0.88	0.67	0.4	0.53	0.89	0.96	0.33	0.05	NDP	1.14	0.26	0.66	0.59	0.58	0.73	0.32	0.88	0.13	0.05	0.21	0.66	0.12	0
Sum of BTEX (mg/kg)	6	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	0.442	<0.025	<0.025	<0.025	<0.025	<0.025	0
Sum of 7 PCBs (mg/kg)	1	<0.035	<0.035	<0.035	<0.035	<0.035	<0.035	<0.035	<0.035	<0.035	<0.035	<0.035	<0.035	<0.035	<0.035	<0.035	<0.035	<0.035	<0.035	<0.035	<0.035	<0.035	<0.035	<0.035	0
Mineral Oil (mg/kg)	500	34	<30	<30	<30	<30	37	<30	92	<30	130	<30	<30	<30	<30	<30	110	<30	327	<30	<30	<30	<30	<30	0
PAH Sum of 17 (mg/kg)	100	<0.64	1.9	<0.64	1.33	0.74	2.98	1.12	1.13	<0.64	1.32	<0.64	0.85	4.37	0.87	0.65	1.28	<0.64	2.39	<0.64	<0.64	<0.64	<0.64	<0.64	0
Eluate Analysis (mg/kg)																									
Arsenic	0.5	0.048	0.034	0.123	0.085	0.078	0.051	0.075	0.066	0.056	0.031	0.08	<0.025	0.087	0.041	0.052	0.054	<0.025	0.074	0.047	<0.025	<0.025	0.029	<0.025	0
Barium	20	<0.03	<0.03	0.05	<0.03	<0.03	0.05	0.05	<0.03	<0.03	0.05	0.06	<0.03	<0.03	0.15	0.1	0.41	0.05	0.12	0.14	0.05	<0.03	<0.03	<0.03	0
Cadmium	0.04	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0
Chromium	0.5	<0.015	0.019	<0.015	0.015	<0.015	<0.015	0.021	<0.015	0.145	0.175	<0.015	<0.015	0.048	0.017	0.018	0.138	<0.015	0.034	0.155	<0.015	<0.015	<0.015	0.016	0
Copper	2	0.15	<0.07	<0.07	<0.07	<0.07	<0.07	0.12	<0.07	<0.07	0.1	<0.07	<0.07	0.26	<0.07	<0.07	<0.07	<0.07	0.1	<0.07	<0.07	<0.07	<0.07	<0.07	0
Mercury	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0
Molybdenum	0.5	<0.02	0.05	0.07	<0.02	0.03	<0.02	0.03	<0.02	0.03	<0.02	<0.02	<0.02	0.06	0.05	0.06	0.06	<0.02	0.09	0.06	<0.02	<0.02	<0.02	<0.02	0
Nickel	0.4	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.03	<0.02	<0.02	<0.02	<0.02	<0.02	0
Lead	0.5	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0
Antimony	0.06	<0.02	<0.02	<0.02	0.05	<0.02	<0.02	0.12	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.02	<0.02	0.09	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	2
Selenium	0.1	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	0
Zinc	4	0.04	<0.03	<0.03	<0.03	0.03	<0.03	<0.03	<0.03	<0.03	<0.03	0.04	<0.03	<0.03	0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	0.04	<0.03	0.04	0
Chloride	800	36	14	55	11	11	147	289	13	22	40	27	13	30	62	91	49	14	50	129	7	8	10	9	0
Fluoride	10	5	<3	<3	<3	7	<3	4	<3	4	<3	4	4	7	5	4	<3	<3	<3	<3	<3	<3	4	<3	0
Sulphate as SO4	1000	215.7	246.4	989	362.1	296	1432.8	702.3	392.2	211.9	1217.3	307.9	68.2	430.4	4762	2324	14408	131	3465	3592	35	26	<5	57	7
Total Dissolved Solids	4000	2281	2061	<350	2961	2320	2731	1859	860	1690	2888	1320	2080	2851	9484	4408	19909	970	6401	6689	<350	<350	<350	<350	5
Phenol	1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0
Dissolved Organic Carbon	500	80	40	60	40	50	30	80	30	<20	30	100	200	110	70	70	50	60	140	40	<20	20	50	<20	0

Key

	Above inert WAC limit
	Above inert WAC limit but considered compliant in accordance with The Landfill Directive Council Decision of 19/12/02 (2003/33/EC) that states that "the value for TDS can be used alternatively to the value for sulphate and chloride"
	Above 6000mg/kg absolute default standard
	Above inert WAC limit but in accordance with The Landfill Directive Council Decision of 19/12/02 (2003/33/EC), value for DOC <500mg/kg at L/S10, either at the soil's own pH or at a pH value between 7.5 and 8.0
	Above inert WAC limit, but a non-primary parameter

	Samples obtained from La Collect recycling or landfill facility

Jersey Organic Test Breakdown (Totals in WAC Compliance sheet)

	Sample ID	SAMPLE 1	SAMPLE 2	SAMPLE 3	SAMPLE 4	SAMPLE 5	SAMPLE 1	SAMPLE 2	SAMPLE 3	SAMPLE 4	SAMPLE 5	SAMPLE 6	SAMPLE 7	SAMPLE 8	W1	W2	W3	W4	W5	W6	S1 - TOP OF PILE	S4 - SIDE OF BANK	TOPSOIL	S2B
	Sample Date	20/04/2016 14:00	21/04/2016 10:00	21/04/2016 10:30	21/04/2016 11:00	21/04/2016 11:30	29/11/2016	29/11/2016	29/11/2016	29/11/2016	29/11/2016	29/11/2016	29/11/2016	30/11/2016	02/12/2021	02/12/2021	02/12/2021	02/12/2021	02/12/2021	02/12/2021	02/12/2021	02/12/2021	02/12/2021	02/12/2021
Naphthalene	mg/kg	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Acenaphthylene	mg/kg	<0.03	<0.03	<0.03	<0.03	<0.03	0.07	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	0.05	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Acenaphthene	mg/kg	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Fluorene	mg/kg	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Phenanthrene	mg/kg	0.05	0.06	<0.03	0.11	0.05	0.19	0.08	0.05	<0.03	0.09	0.08	0.25	0.2	0.06	0.05	0.14	<0.03	0.26	0.11	<0.03	<0.03	<0.03	<0.03
Anthracene	mg/kg	<0.04	<0.04	<0.04	<0.04	<0.04	0.07	<0.04	<0.04	<0.04	<0.04	<0.04	0.07	0.07	<0.04	<0.04	<0.04	<0.04	0.08	<0.04	<0.04	<0.04	<0.04	<0.04
Fluoranthene	mg/kg	0.08	0.2	0.04	0.25	0.13	0.46	0.2	0.18	<0.03	0.29	0.12	0.18	0.74	0.13	0.09	0.24	<0.03	0.41	0.12	<0.03	<0.03	<0.03	<0.03
Pyrene	mg/kg	0.06	0.19	0.04	0.21	0.11	0.44	0.17	0.17	<0.03	0.23	0.11	0.15	0.72	0.11	0.09	0.21	<0.03	0.36	0.09	<0.03	<0.03	<0.03	<0.03
Benzo(a)anthracene	mg/kg	0.07	0.21	<0.06	0.15	0.07	0.37	0.12	0.14	<0.06	0.14	<0.06	0.12	0.43	0.11	0.09	0.14	<0.06	0.21	0.08	<0.06	<0.06	<0.06	<0.06
Chrysene	mg/kg	0.06	0.23	<0.02	0.12	0.07	0.31	0.12	0.14	<0.02	0.13	0.06	0.08	0.45	0.09	0.06	0.11	<0.02	0.19	0.05	<0.02	<0.02	<0.02	<0.02
Benzo(bk)fluoranthene	mg/kg	0.11	0.43	<0.07	0.2	0.13	0.49	0.19	0.19	<0.07	0.2	0.08	<0.07	0.74	0.15	0.11	0.19	<0.07	0.35	<0.07	<0.07	<0.07	<0.07	<0.07
Benzo(a)pyrene	mg/kg	0.06	0.2	<0.04	0.11	0.07	0.3	0.09	0.09	<0.04	0.09	<0.04	<0.04	0.36	0.08	0.06	0.09	<0.04	0.19	0.04	<0.04	<0.04	<0.04	<0.04
Indeno(123cd)pyrene	mg/kg	0.05	0.19	<0.04	0.1	0.06	0.13	0.08	0.09	<0.04	0.08	<0.04	<0.04	0.26	0.07	0.05	0.08	<0.04	0.17	<0.04	<0.04	<0.04	<0.04	<0.04
Dibenzo(ah)anthracene	mg/kg	<0.04	0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	0.08	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Benzo(ghi)perylene	mg/kg	0.05	0.15	<0.04	0.08	0.05	0.15	0.07	0.08	<0.04	0.07	<0.04	<0.04	0.21	0.07	0.05	0.08	<0.04	0.17	<0.04	<0.04	<0.04	<0.04	<0.04
Coronene	mg/kg	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	0.06	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
PAH 17 Total	mg/kg	<0.64	1.9	<0.64	1.33	0.74	2.98	1.12	1.13	<0.64	1.32	<0.64	0.85	4.37	0.87	0.65	1.28	<0.64	2.39	<0.64	<0.64	<0.64	<0.64	<0.64
Benzo(b)fluoranthene	mg/kg	0.08	0.31	<0.05	0.14	0.09	0.35	0.14	0.14	<0.05	0.14	0.06	<0.05	0.53	0.11	0.08	0.14	<0.05	0.25	<0.05	<0.05	<0.05	<0.05	<0.05
Benzo(k)fluoranthene	mg/kg	0.03	0.12	<0.02	0.06	0.04	0.14	0.05	0.05	<0.02	0.06	0.02	<0.02	0.21	0.04	0.03	0.05	<0.02	0.1	<0.02	<0.02	<0.02	<0.02	<0.02
PAH Surrogate % Recovery	%	103	102	96	113	99	99	105	96	91	97	104	114	101	92	90	94	75	92	96	94	95	96	96
Mineral Oil (C10-C40)	mg/kg	34	<30	<30	<30	<30	37	<30	92	<30	130	<30	<30	<30	<30	<30	110	<30	327	<30	<30	<30	<30	<30
MTBE	ug/kg	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	25	<5	<5	<5	<5	<5
Benzene	ug/kg	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Toluene	ug/kg	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	104	<5	<5	<5	<5	<5
Ethylbenzene	ug/kg	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	41	<5	<5	<5	<5	<5
m/p-Xylene	ug/kg	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	141	<5	<5	<5	<5	<5
o-Xylene	ug/kg	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	156	<5	<5	<5	<5	<5
PCB 28	ug/kg	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
PCB 52	ug/kg	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
PCB 101	ug/kg	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
PCB 118	ug/kg	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
PCB 138	ug/kg	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
PCB 153	ug/kg	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
PCB 180	ug/kg	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Total 7 PCBs	ug/kg	<35	<35	<35	<35	<35	<35	<35	<35	<35	<35	<35	<35	<35	<35	<35	<35	<35	<35	<35	<35	<35	<35	<35
% Toluene of BTEX total																			0.235294					
% Fuoranthene of PAH total		0.114286					0.071318	0.082305	0.073469						0.068783	0.06383	0.087273		0.079922	0.244898				

Samples obtained from La Collect recycling or landfill facility

Max % toluene of BTEX total	0.235	% Expressed as decimal
Max % fluoranthene of PAH total	0.245	% Expressed as decimal
Min % fluoranthene of PAH total	0.064	% Expressed as decimal
Average	0.098	% Expressed as decimal
SD	0.057	% Expressed as decimal
Mean plus 2sd	0.212	
Mean plus 3sd	0.269	
Count	9.00	

Percentage used in HRA models

Jersey Asbestos Results

Client Sample No	SAMPLE 1	SAMPLE 2	SAMPLE 3	SAMPLE 4	SAMPLE 5	SAMPLE 1	SAMPLE 2	SAMPLE 3	SAMPLE 4	SAMPLE 5	SAMPLE 6	SAMPLE 7	SAMPLE 8
JEFL Job No	16/8113	16/8113	16/8113	16/8113	16/8113	16/17967	16/17967	16/17967	16/17967	16/17967	16/17967	16/17967	16/17967
Date of Analysis	**04/05/2016**	**04/05/2016**	**04/05/2016**	**04/05/2016**	**04/05/2016**	**09/12/2016**	**09/12/2016**	**09/12/2016**	**09/12/2016**	**09/12/2016**	**09/12/2016**	**09/12/2016**	**09/12/2016**
General Description	soil/stones	soil/stones	soil/stones	soil/stones	soil/stones	soil-stones	soil-stones	soil-stones	soil-stones	soil-stones	soil-stones	soil-stones	soil-stones
Asbestos Fibres	NAD	NAD	NAD	NAD	NAD	NAD	NAD	NAD	NAD	Fibre Bundles	NAD	NAD	NAD
Asbestos Fibres (2)	NAD	NAD	NAD	NAD	NAD	NAD	NAD	NAD	NAD		NAD	NAD	NAD
Asbestos ACM	NAD	NAD	NAD	NAD	NAD	NAD	NAD	NAD	NAD	Insulation Debris	NAD	NAD	NAD
Asbestos ACM (2)	NAD	NAD	NAD	NAD	NAD	NAD	NAD	NAD	NAD		NAD	NAD	NAD
Asbestos Type	NAD	NAD	NAD	NAD	NAD	NAD	NAD	NAD	NAD	Amosite	NAD	NAD	NAD
Asbestos Type (2)	NAD	NAD	NAD	NAD	NAD	NAD	NAD	NAD	NAD		NAD	NAD	NAD
Asbestos Level Screen	NAD	NAD	NAD	NAD	NAD	NAD	NAD	NAD	NAD	Asbestos level cannot be determined at this stage of analysis	NAD	NAD	NAD

NAD - No Asbestos Detected

No asbestos analysis carried out on 2021 samples

TESTING OF JERSEY WASTE ARISINGS AND QUARRY MATERTIALS

Waste sample reference and date (relating to excel IWAC results file)	**SAMPLE 2** 16/17967 **09/12/2016**
Sampled by	Graham Holland (GP), Glen Spash (SLR), Karen Myers (KM)
Location / Description	Sample 2. Wet rejects stockpile at recycling yard. Brown very clayey slightly gravelly SAND. Gravel is subangular to subrounded fine to coarse brick, concrete, granite, tiles, glass and occasional metal.
Photos	
Comment re waste acceptance	Comparable with recycling residue at future GP recycling site. WAC results ok apart from antimony.
Physical testing reference and date	PBA report 0930/17 dated 06/08/17: Permeability 2.42E-08 m/s 2% clay, 23% silt

BS EN ISO 17892-11 : 2019

PERMEABILITY IN A TRIAXIAL CELL

Location	W1
Sample Type	B

Description:
Brown slightly sandy, gravelly SILT. Gravel is fine to medium.

SPECIMEN DETAILS

Depth within original sample	n/a
Orientation within original	n/a
Specimen preparation	Remoulded to medium dense

TEST DETAILS		**INITIAL**	**FINAL**
Diameter	*mm*	103.75	103.66
Height	*mm*	115.28	115.18
Water Content	*%*	15.5	17.5
Bulk Density	*Mg/m³*	2.06	2.11
Dry Density	*Mg/m³*	1.79	1.79
Average Laboratory Temperature	*°C*	20	
Source of Permeant Water		De-aired tap water	

SATURATION STAGE

Saturation initially by constant water content, followed by back-pressure assistance.

Pore pressure coefficient ('B' value)	0.52	0.95

CONSOLIDATION STAGE

Effective pressure	*kPa*	50
Volume change	*mL*	2.6

PERMEABILITY STAGE — Measured under constant head conditions in a triaxial cell

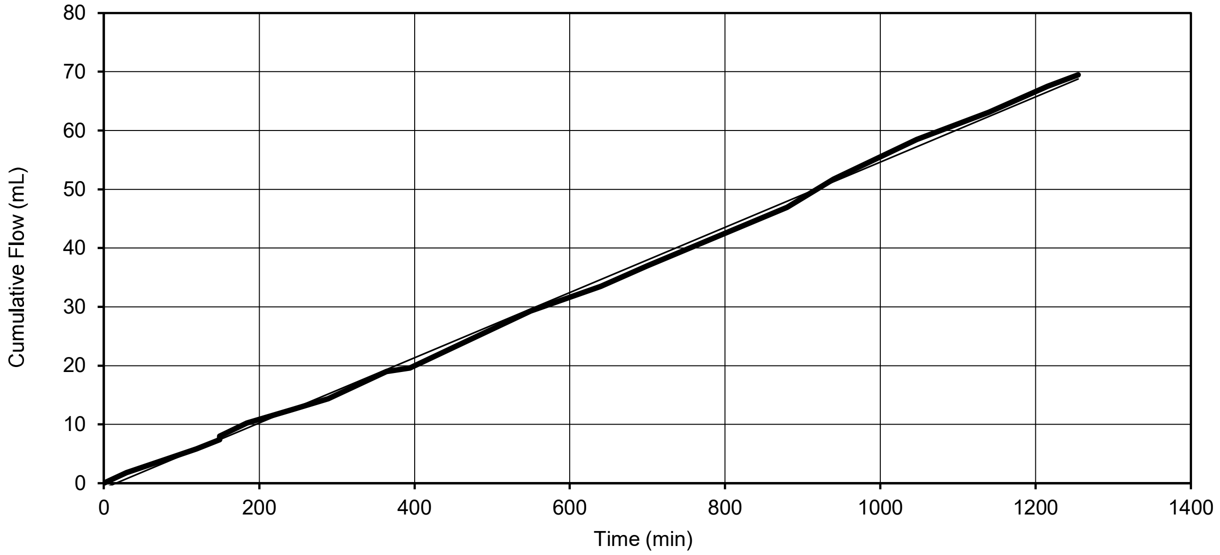
Pressure difference across specimen	*kPa*	10
Hydraulic gradient		8.9
Mean effective stress	*kPa*	50
Correction for head loss	*kPa*	0

TEST DURATIONS

Saturation	*days*	3
Consolidation	*days*	1
Flow	*days*	1

Coefficient of Permeability

k_v at 20 °C = 1.2×10^{-8} m/s



Tested by AC
Checked and Approved by
[redacted]
P Heritage - Project Manager
18/05/2022

Project Number:
GEO / 35350

Project Name:
LA GIGOULANDE QUARRY, JERSEY
416.07923.00002

GEOLABS
UKAS TESTING 1982

BS EN ISO 17892-11 : 2019

PERMEABILITY IN A TRIAXIAL CELL

Location	W4
Sample Type	B

Description:
Light brown slightly sandy gravelly CLAY. Gravel is fine to medium.

SPECIMEN DETAILS

Depth within original sample	n/a
Orientation within original	n/a
Specimen preparation	Remoulded to medium dense.

TEST DETAILS		**INITIAL**	**FINAL**
Diameter	*mm*	104.24	103.62
Height	*mm*	115.64	114.95
Water Content	*%*	21.3	21.6
Bulk Density	*Mg/m³*	2.04	2.08
Dry Density	*Mg/m³*	1.68	1.71
Average Laboratory Temperature	*°C*	20	
Source of Permeant Water		De-aired tap water	

SATURATION STAGE

Saturation initially by constant water content, followed by back-pressure assistance.

Pore pressure coefficient ('B' value)		0.76	0.98

CONSOLIDATION STAGE

Effective pressure	*kPa*	50
Volume change	*mL*	17.5

PERMEABILITY STAGE — Measured under constant head conditions in a triaxial cell

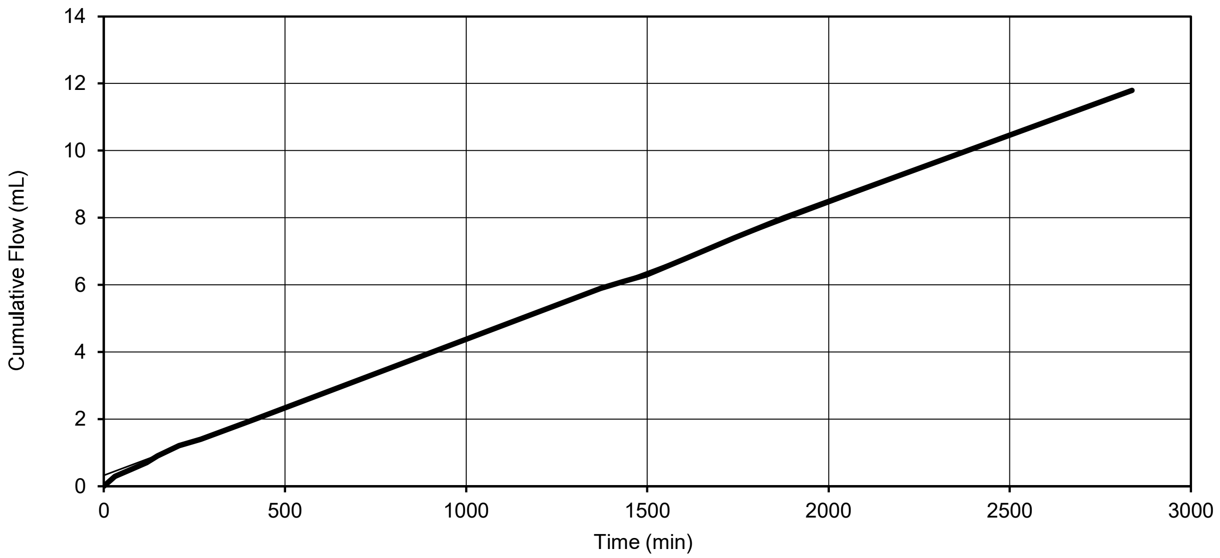
Pressure difference across specimen	*kPa*	10
Hydraulic gradient		8.9
Mean effective stress	*kPa*	50
Correction for head loss	*kPa*	0

TEST DURATIONS

Saturation	*days*	2
Consolidation	*days*	2
Flow	*days*	2

Coefficient of Permeability

k_v at 20 °C = 9.0×10^{-10} m/s



Tested by AC
Checked and Approved by

[redacted]

P Heritage - Project Manager
16/05/2022

Project Number:

GEO / 35350

Project Name:

LA GIGOULANDE QUARRY, JERSEY
416.07923.00002

GEOLABS® UKAS TESTING 1982

BS EN ISO 17892-11 : 2019

PERMEABILITY IN A TRIAXIAL CELL

Location	W5
Sample Type	B

Description:
Brown sandy gravelly clayey SILT. Gravel is fine to medium.

SPECIMEN DETAILS

Depth within original sample	n/a
Orientation within original	n/a
Specimen preparation	Remoulded to medium dense.

TEST DETAILS		**INITIAL**	**FINAL**
Diameter	*mm*	103.76	103.51
Height	*mm*	113.89	113.61
Water Content	*%*	15.0	15.3
Bulk Density	*Mg/m³*	2.21	2.23
Dry Density	*Mg/m³*	1.92	1.93
Average Laboratory Temperature	*°C*	20	
Source of Permeant Water		De-aired tap water	

SATURATION STAGE

Saturation initially by constant water content, followed by back-pressure assistance.

Pore pressure coefficient ('B' value)	0.82	0.96

CONSOLIDATION STAGE

Effective pressure	*kPa*	50
Volume change	*mL*	7.0

PERMEABILITY STAGE Measured under constant head conditions in a triaxial cell

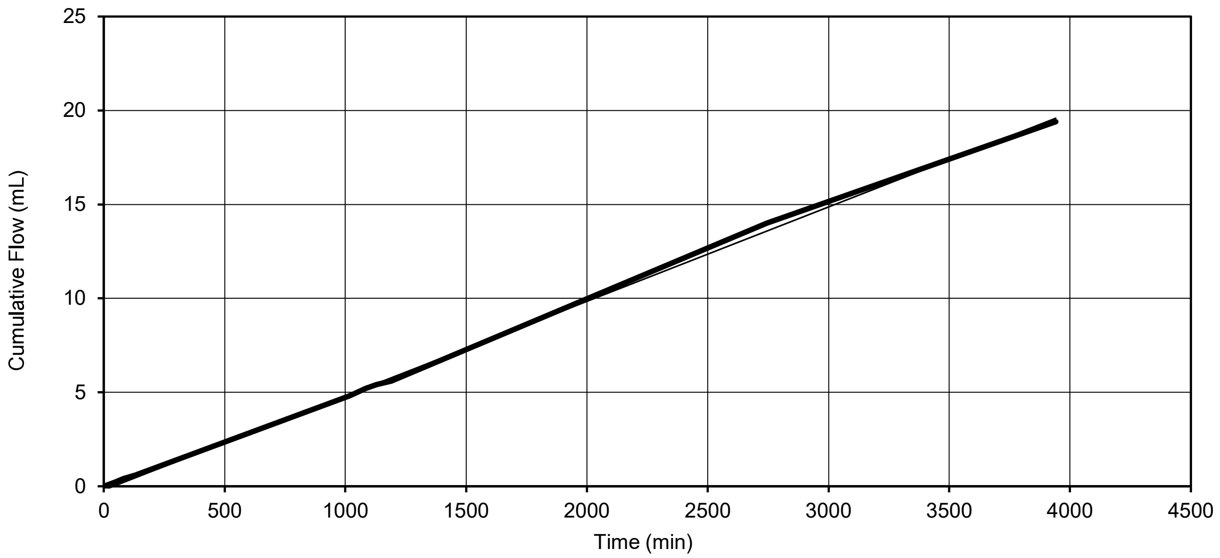
Pressure difference across specimen	*kPa*	10
Hydraulic gradient		9.0
Mean effective stress	*kPa*	50
Correction for head loss	*kPa*	0

TEST DURATIONS

Saturation	*days*	2
Consolidation	*days*	1
Flow	*days*	2

Coefficient of Permeability

k_v at 20 °C = 1.1 x 10^{-9} m/s



Tested by AC
Checked and Approved by

[redacted]

P Heritage - Project Manager
18/05/2022

Project Number:
GEO / 35350

Project Name:
LA GIGOULANDE QUARRY, JERSEY
416.07923.00002

APPENDIX HRA3

HARD COPY OF THE GENERIC QUANTITATIVE RISK ASSESSMENT MODEL

Calculation 1

Deterministic dilution model to calculate the predicted concentrations of determinands migrating from the waste in the western quarry into the fractured granite aquifer immediately down hydraulic gradient of the landfill - Hydraulic conductivity of the waste of 1x10^{-7}m/s and source term concentration of inert WAC

Determinands	Chloride	Sulphate	Lead	Copper	Flouride	Zinc	Arsenic	Cadmium	Chromium	Mercury	Nickel	Toluene	Fluoranthene	Justification / Source
Units	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	
Source term concentration	80	100	0.05	0.2	1.0	0.4	0.05	0.004	0.05	0.001	0.04	0.2043	0.0334	See Table HRA2.
Background groundwater concentration	52.7	74.7	0.005	0.008	0.32	0.05	0.0031	0.00052	0.0016	0.00002	0.0027	0.005	0.000243	See Table HRA2.

Flow out of the sidewall

Parameter	Value	Units	Justification / Source
Hydraulic gradient	5.10E-02	None	For the purpose of this assessment it is assumed that groundwater infiltrating the waste has equilibrated with the groundwater in the surrounding fractured granite aquifer hence the hydraulic gradient is the same as that in the surrounding aquifer. The hydraulic gradient is calculated from the range of head differences between up hydraulic gradient borehole BH5 in the west of the site and down hydraulic gradient boreholes BH6 and BH7.
Hydraulic conductivity of the waste	1.00E-07	m/s	Hydraulic conductivity based on values for fine grained soils.
Length of sidewall perpendicular to groundwater flow	300	m	Length of sidewall perpendicular to groundwater flow to the north west, west and south west of the site.
Depth of sidewall in contact with groundwater	19.84	m	Average saturated thickness of the fractured granite aquifer calculated from an effective base of the fractured granite aquifer of 34mAMSL and the range of groundwater levels recorded round the western quarry in boreholes BH6 to BH10.
Flow out of the sidewall	3.03E-05	m³/s	Calculated

Flow in the aquifer in contact with the sidewall

Parameter	Value	Units	Justification / Source
Hydraulic gradient in the aquifer	5.10E-02	None	Calculated from the range of head differences between up hydraulic gradient borehole BH5 in the west of the site and down hydraulic gradient boreholes BH6 and BH7.
Aquifer hydraulic conductivity	2.21E-05	m/s	Geometric mean of the hydraulic conductivity values for the fractured granite aquifer calculated from borehole testing at the site in 2005
Width of mixing zone	170	m	Width of the landfill perpendicular to groundwater flow.
Aquifer depth in contact with sidewall	19.84	m	Average saturated thickness of the fractured granite aquifer calculated from an effective base of the fractured granite aquifer of 34mAMSL and the range of groundwater levels recorded round the western quarry in boreholes BH6 to BH10.
Flow rate in the aquifer past the sidewall	3.80E-03	m³/s	Calculated

Results

Determinand	Chloride	Sulphate	Lead	Copper	Flouride	Zinc	Arsenic	Cadmium	Chromium	Mercury	Nickel	Toluene	Fluoranthene
Units	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
DWS	250	250	0.01	2.0	1.5		0.01	0.005	0.05	0.001	0.02	0.001	0.000100
EAL	114	191	0.0071	0.038	0.7	0.139	0.01	0.00087	0.0068		0.006	0.005	0.000568
Predicted concentration in the aquifer immediately down hydraulic gradient of the landfill	52.9	74.9	0.00536	0.0095	0.33	0.05277	0.00347	0.00055	0.00198	0.00003	0.00300	0.007	0.000506

Notes

Highlighted — Denotes an exceedance of an environmental assessment limit

Calculation 2

Deterministic dilution model to calculate the predicted concentrations of determinands migrating from the waste in the western quarry into the fractured granite aquifer immediately down hydraulic gradient of the landfill - Hydraulic conductivity of the waste of 1x10^{-8}m/s and source term concentration of inert WAC

Determinands	Chloride	Sulphate	Lead	Copper	Flouride	Zinc	Arsenic	Cadmium	Chromium	Mercury	Nickel	Toluene	Fluoranthene	Justification / Source
Units	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	
Source term concentration	80	100	0.05	0.2	1.0	0.4	0.05	0.004	0.05	0.001	0.04	0.2043	0.0334	See Table HRA2.
Background groundwater concentration	52.7	74.7	0.005	0.008	0.32	0.05	0.0031	0.00052	0.0016	0.00002	0.0027	0.005	0.000243	See Table HRA2.

Flow out of the sidewall

Parameter	Value	Units	Justification / Source
Hydraulic gradient	5.10E-02	None	For the purpose of this assessment it is assumed that groundwater infiltrating the waste has equilibrated with the groundwater in the surrounding fractured granite aquifer hence the hydraulic gradient is the same as that in the surrounding aquifer. The hydraulic gradient is calculated from the range of head differences between up hydraulic gradient borehole BH5 in the west of the site and down hydraulic gradient boreholes BH6 and BH7.
Hydraulic conductivity of the waste	1.00E-08	m/s	Hydraulic conductivity based on values for fine grained soils.
Length of sidewall perpendicular to groundwater flow	300	m	Length of sidewall perpendicular to groundwater flow to the north west, west and south west of the site.
Depth of sidewall in contact with groundwater	19.84	m	Average saturated thickness of the fractured granite aquifer calculated from an effective base of the fractured granite aquifer of 34mAMSL and the range of groundwater levels recorded round the western quarry in boreholes BH6 to BH10.
Flow out of the sidewall	3.03E-06	m³/s	Calculated

Flow in the aquifer in contact with the sidewall

Parameter	Value	Units	Justification / Source
Hydraulic gradient in the aquifer	5.10E-02	None	Calculated from the range of head differences between up hydraulic gradient borehole BH5 in the west of the site and down hydraulic gradient boreholes BH6 and BH7.
Aquifer hydraulic conductivity	2.21E-05	m/s	Geometric mean of the hydraulic conductivity values for the fractured granite aquifer calculated from borehole testing at the site in 2005
Width of mixing zone	170	m	Width of the landfill perpendicular to groundwater flow.
Aquifer depth in contact with sidewall	19.84	m	Average saturated thickness of the fractured granite aquifer calculated from an effective base of the fractured granite aquifer of 34mAMSL and the range of groundwater levels recorded round the western quarry in boreholes BH6 to BH10.
Flow rate in the aquifer past the sidewall	3.80E-03	m³/s	Calculated

Results

Determinand	Chloride	Sulphate	Lead	Copper	Flouride	Zinc	Arsenic	Cadmium	Chromium	Mercury	Nickel	Toluene	Fluoranthene
Units	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
DWS	250	250	0.01	2.0	1.5		0.01	0.005	0.05	0.001	0.02	0.001	0.000100
EAL	114	191	0.0071	0.038	0.7	0.139	0.01	0.00087	0.0068	0.001	0.006	0.005	0.000568
Predicted concentration in the aquifer immediately down hydraulic gradient of the landfill	52.7	74.7	0.00504	0.0082	0.32	0.05028	0.00314	0.00052	0.00164	0.00002	0.0027	0.005	0.000269

Notes

Highlighted — Denotes an exceedance of an environmental assessment limit

Calculation 3

Deterministic dilution model to calculate the predicted concentrations of determinands migrating from the waste in the western quarry into the fractured granite aquifer immediately down hydraulic gradient of the landfill - Hydraulic conductivity of the waste of 1x10^{-9}m/s and source term concentration of inert WAC

Determinands	Chloride	Sulphate	Lead	Copper	Flouride	Zinc	Arsenic	Cadmium	Chromium	Mercury	Nickel	Toluene	Fluoranthene	Justification / Source
Units	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	
Source term concentration	80	100	0.05	0.2	1.0	0.4	0.05	0.004	0.05	0.001	0.04	0.2043	0.0334	See Table HRA2.
Background groundwater concentration	52.7	74.7	0.005	0.008	0.32	0.05	0.0031	0.00052	0.0016	0.00002	0.0027	0.005	0.000243	See Table HRA2.

Flow out of the sidewall

Parameter	Value	Units	Justification / Source
Hydraulic gradient	5.10E-02	None	For the purpose of this assessment it is assumed that groundwater infiltrating the waste has equilibrated with the groundwater in the surrounding fractured granite aquifer hence the hydraulic gradient is the same as that in the surrounding aquifer. The hydraulic gradient is calculated from the range of head differences between up hydraulic gradient borehole BH5 in the west of the site and down hydraulic gradient boreholes BH6 and BH7.
Hydraulic conductivity of the waste	1.00E-09	m/s	Hydraulic conductivity based on values for fine grained soils.
Length of sidewall perpendicular to groundwater flow	300	m	Length of sidewall perpendicular to groundwater flow to the north west, west and south west of the site.
Depth of sidewall in contact with groundwater	19.84	m	Average saturated thickness of the fractured granite aquifer calculated from an effective base of the fractured granite aquifer of 34mAMSL and the range of groundwater levels recorded round the western quarry in boreholes BH6 to BH10.
Flow out of the sidewall	3.03E-07	m³/s	Calculated

Flow in the aquifer in contact with the sidewall

Parameter	Value	Units	Justification / Source
Hydraulic gradient in the aquifer	5.10E-02	None	Calculated from the range of head differences between up hydraulic gradient borehole BH5 in the west of the site and down hydraulic gradient boreholes BH6 and BH7.
Aquifer hydraulic conductivity	2.21E-05	m/s	Geometric mean of the hydraulic conductivity values for the fractured granite aquifer calculated from borehole testing at the site in 2005
Width of mixing zone	170	m	Width of the landfill perpendicular to groundwater flow.
Aquifer depth in contact with sidewall	19.84	m	Average saturated thickness of the fractured granite aquifer calculated from an effective base of the fractured granite aquifer of 34mAMSL and the range of groundwater levels recorded round the western quarry in boreholes BH6 to BH10.
Flow rate in the aquifer past the sidewall	3.80E-03	m³/s	Calculated

Results

Determinand	Chloride	Sulphate	Lead	Copper	Flouride	Zinc	Arsenic	Cadmium	Chromium	Mercury	Nickel	Toluene	Fluoranthene
Units	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
DWS	250	250	0.01	2.0	1.5		0.01	0.005	0.05	0.001	0.02	0.001	0.000100
EAL	114	191	0.0071	0.038	0.7	0.139	0.01	0.00087	0.0068	0.001	0.006	0.005	0.000568
Predicted concentration in the aquifer immediately down hydraulic gradient of the landfill	52.7	74.7	0.00500	0.0080	0.32	0.05003	0.00310	0.00052	0.00160	0.00002	0.00270	0.005	0.000245

Notes

Highlighted	Denotes an exceedance of an environmental assessment limit

APPENDIX HRA4

ELECTRONIC COPY OF THE GENERIC QUANTITATIVE RISK ASSESSMENT MODELS INCLUDING THE SENSITIVITY ANALYSES TOGETHER WITH THE CALCULATIONS OF BACKGROUND, EAL/ COMPLIANCE LIMIT AND ASSESSMENT LEVEL CONCENTRATIONS

APPENDIX HRA5

HARD COPY OF GENERIC QUANTITATIVE RISK ASSESSMENT SENSITIVITY ANALYSES

Sensitivity analysis 1

Deterministic dilution model to calculate the predicted concentrations of determinands migrating from the waste in the western quarry into the fractured granite aquifer immediately down hydraulic gradient of the landfill - Hydraulic conductivity of the waste of 1x10^{-8}m/s and source term concentration of inert WAC C0

Determinands	Chloride	Sulphate	Lead	Copper	Flouride	Zinc	Arsenic	Cadmium	Chromium	Mercury	Nickel	Toluene	Fluoranthene	Justification / Source
Units	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	
Source term concentration	460	100	0.15	0.6	2.5	0.4	0.06	0.02	0.10	0.002	0.12	0.2043	0.0334	C0
Background groundwater concentration	52.7	74.7	0.005	0.008	0.32	0.05	0.0031	0.00052	0.0016	0.00002	0.0027	0.005	0.000243	See Table HRA2.

Flow out of the sidewall

Parameter	Value	Units	Justification / Source
Hydraulic gradient	5.10E-02	None	For the purpose of this assessment it is assumed that groundwater infiltrating the waste has equilibrated with the groundwater in the surrounding fractured granite aquifer hence the hydraulic gradient is the same as that in the surrounding aquifer. The hydraulic gradient is calculated from the range of head differences between up hydraulic gradient borehole BH5 in the west of the site and down hydraulic gradient boreholes BH6 and BH7.
Hydraulic conductivity of the waste	1.00E-08	m/s	Hydraulic conductivity based on values for fine grained soils.
Length of sidewall perpendicular to groundwater flow	300	m	Length of sidewall perpendicular to groundwater flow to the north west, west and south west of the site.
Depth of sidewall in contact with groundwater	19.84	m	Average saturated thickness of the fractured granite aquifer calculated from an effective base of the fractured granite aquifer of 34mAMSL and the range of groundwater levels recorded round the western quarry in boreholes BH6 to BH10.
Flow out of the sidewall	3.03E-06	m³/s	Calculated

Flow in the aquifer in contact with the sidewall

Parameter	Value	Units	Justification / Source
Hydraulic gradient in the aquifer	5.10E-02	None	Calculated from the range of head differences between up hydraulic gradient borehole BH5 in the west of the site and down hydraulic gradient boreholes BH6 and BH7.
Aquifer hydraulic conductivity	2.21E-05	m/s	Geometric mean of the hydraulic conductivity values for the fractured granite aquifer calculated from borehole testing at the site in 2005
Width of mixing zone	170	m	Width of the landfill perpendicular to groundwater flow.
Aquifer depth in contact with sidewall	19.84	m	Average saturated thickness of the fractured granite aquifer calculated from an effective base of the fractured granite aquifer of 34mAMSL and the range of groundwater levels recorded round the western quarry in boreholes BH6 to BH10.
Flow rate in the aquifer past the sidewall	3.80E-03	m³/s	Calculated

Results

Determinand	Chloride	Sulphate	Lead	Copper	Flouride	Zinc	Arsenic	Cadmium	Chromium	Mercury	Nickel	Toluene	Fluoranthene
Units	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
DWS	250	250	0.01	2.0	1.5		0.01	0.005	0.05	0.001	0.02	0.001	0.000100
EAL	114	191	0.0071	0.038	0.7	0.139	0.01	0.00087	0.0068	0.001	0.006	0.005	0.000568
Predicted concentration in the aquifer immediately down hydraulic gradient of the landfill	53.0	74.7	0.00512	0.0085	0.32	0.05028	0.00315	0.00054	0.00168	0.00002	0.00279	0.005	0.000269

Notes

Highlighted — Denotes an exceedance of an environmental assessment limit

Sensitivity analysis 2

Deterministic dilution model to calculate the predicted concentrations of determinands migrating from the waste in the western quarry into the fractured granite aquifer immediately down hydraulic gradient of the landfill - Hydraulic conductivity of the waste of 1x10^{-8}m/s and source term concentration of inert WAC - Hydraulic gradient in the waste double that in the fractured granite aquifer

Determinands	Chloride	Sulphate	Lead	Copper	Flouride	Zinc	Arsenic	Cadmium	Chromium	Mercury	Nickel	Toluene	Fluoranthene	Justification / Source
Units	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	
Source term concentration	80	100	0.05	0.2	1.0	0.4	0.05	0.004	0.05	0.001	0.04	0.2043	0.0334	See Table HRA2.
Background groundwater concentration	52.7	74.7	0.005	0.008	0.32	0.05	0.0031	0.00052	0.0016	0.00002	0.0027	0.005	0.000243	See Table HRA2.

Flow out of the sidewall

Parameter	Value	Units	Justification / Source
Hydraulic gradient	1.02E-01	None	To account for the possibility that the hydraulic gradient in the waste mass may be greater than in the aquifer, conservatively a hydraulic gradient of twice that in the aquifer has been used.
Hydraulic conductivity of the waste	1.00E-08	m/s	Hydraulic conductivity based on values for fine grained soils.
Length of sidewall perpendicular to groundwater flow	300	m	Length of sidewall perpendicular to groundwater flow to the north west, west and south west of the site.
Depth of sidewall in contact with groundwater	19.84	m	Average saturated thickness of the fractured granite aquifer calculated from an effective base of the fractured granite aquifer of 34mAMSL and the range of groundwater levels recorded round the western quarry in boreholes BH6 to BH10.
Flow out of the sidewall	6.07E-06	m³/s	Calculated

Flow in the aquifer in contact with the sidewall

Parameter	Value	Units	Justification / Source
Hydraulic gradient in the aquifer	5.10E-02	None	Calculated from the range of head differences between up hydraulic gradient borehole BH5 in the west of the site and down hydraulic gradient boreholes BH6 and BH7.
Aquifer hydraulic conductivity	2.21E-05	m/s	Geometric mean of the hydraulic conductivity values for the fractured granite aquifer calculated from borehole testing at the site in 2005
Width of mixing zone	170	m	Width of the landfill perpendicular to groundwater flow.
Aquifer depth in contact with sidewall	19.84	m	Average saturated thickness of the fractured granite aquifer calculated from an effective base of the fractured granite aquifer of 34mAMSL and the range of groundwater levels recorded round the western quarry in boreholes BH6 to BH10.
Flow rate in the aquifer past the sidewall	3.80E-03	m³/s	Calculated

Results

Determinand	Chloride	Sulphate	Lead	Copper	Flouride	Zinc	Arsenic	Cadmium	Chromium	Mercury	Nickel	Toluene	Fluoranthene
Units	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
DWS	250	250	0.01	2.0	1.5		0.01	0.005	0.05	0.001	0.02	0.001	0.000100
EAL	114	191	0.0071	0.038	0.7	0.139	0.01	0.00087	0.0068	0.001	0.006	0.005	0.000568
Predicted concentration in the aquifer immediately down hydraulic gradient of the landfill	52.7	74.7	0.00507	0.0083	0.32	0.05056	0.00317	0.00053	0.00168	0.00002	0.00276	0.005	0.000296

Notes

Highlighted — Denotes an exceedance of an environmental assessment limit

Sensitivity analysis 3

Deterministic dilution model to calculate the predicted concentrations of determinands migrating from the waste in the western quarry into the fractured granite aquifer immediately down hydraulic gradient of the landfill - Hydraulic conductivity of the waste of $1x10^{-8}$m/s and source term concentration of inert WAC- Reduced thickness of fractured granite aquifer (5m)

Determinands	Chloride	Sulphate	Lead	Copper	Flouride	Zinc	Arsenic	Cadmium	Chromium	Mercury	Nickel	Toluene	Fluoranthene	Justification / Source
Units	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	
Source term concentration	80	100	0.05	0.2	1.0	0.4	0.05	0.004	0.05	0.001	0.04	0.2043	0.0334	See Table HRA2.
Background groundwater concentration	52.7	74.7	0.005	0.008	0.32	0.05	0.0031	0.00052	0.0016	0.00002	0.0027	0.005	0.000243	See Table HRA2.

Flow out of the sidewall

Parameter	Value	Units	Justification / Source
Hydraulic gradient	5.10E-02	None	For the purpose of this assessment it is assumed that groundwater infiltrating the waste has equilibrated with the groundwater in the surrounding fractured granite aquifer hence the hydraulic gradient is the same as that in the surrounding aquifer. The hydraulic gradient is calculated from the range of head differences between up hydraulic gradient borehole BH5 in the west of the site and down hydraulic gradient boreholes BH6 and BH7.
Hydraulic conductivity of the waste	1.00E-08	m/s	Hydraulic conductivity based on values for fine grained soils.
Length of sidewall perpendicular to groundwater flow	300	m	Length of sidewall perpendicular to groundwater flow to the north west, west and south west of the site.
Depth of sidewall in contact with groundwater	5.00	m	Assumed thickness for sensitivity analysis.
Flow out of the sidewall	7.65E-07	m³/s	Calculated

Flow in the aquifer in contact with the sidewall

Parameter	Value	Units	Justification / Source
Hydraulic gradient in the aquifer	5.10E-02	None	Calculated from the range of head differences between up hydraulic gradient borehole BH5 in the west of the site and down hydraulic gradient boreholes BH6 and BH7.
Aquifer hydraulic conductivity	2.21E-05	m/s	Geometric mean of the hydraulic conductivity values for the fractured granite aquifer calculated from borehole testing at the site in 2005
Width of mixing zone	170	m	Width of the landfill perpendicular to groundwater flow.
Aquifer depth in contact with sidewall	5.00	m	Assumed thickness for sensitivity analysis.
Flow rate in the aquifer past the sidewall	9.58E-04	m³/s	Calculated

Results

Determinand	Chloride	Sulphate	Lead	Copper	Flouride	Zinc	Arsenic	Cadmium	Chromium	Mercury	Nickel	Toluene	Fluoranthene
Units	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
DWS	250	250	0.01	2.0	1.5		0.01	0.005	0.05	0.001	0.02	0.001	0.000100
EAL	114	191	0.0071	0.038	0.7	0.139	0.01	0.00087	0.0068	0.001	0.006	0.005	0.000568
Predicted concentration in the aquifer immediately down hydraulic gradient of the landfill	52.7	74.7	0.00504	0.0082	0.32	0.05028	0.00314	0.00052	0.00164	0.00002	0.00273	0.005	0.000269

Notes

Highlighted — Denotes an exceedance of an environmental assessment limit

Sensitivity analysis 4a

Deterministic dilution model to calculate the predicted concentrations of determinands migrating from the waste in the western quarry into the fractured granite aquifer immediately down hydraulic gradient of the landfill - Hydraulic conductivity of the waste of 1x10^{-8}m/s and source term concentration of inert WAC - Reduced hydraulic conductivity of fractured granite aquifer

Determinands	Chloride	Sulphate	Lead	Copper	Flouride	Zinc	Arsenic	Cadmium	Chromium	Mercury	Nickel	Toluene	Fluoranthene	Justification / Source
Units	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	
Source term concentration	80	100	0.05	0.2	1.0	0.4	0.05	0.004	0.05	0.001	0.04	0.2043	0.0334	See Table HRA2.
Background groundwater concentration	52.7	74.7	0.005	0.008	0.32	0.05	0.0031	0.00052	0.0016	0.00002	0.0027	0.005	0.000243	See Table HRA2.

Flow out of the sidewall

Parameter	Value	Units	Justification / Source
Hydraulic gradient	5.10E-02	None	For the purpose of this assessment it is assumed that groundwater infiltrating the waste has equilibrated with the groundwater in the surrounding fractured granite aquifer hence the hydraulic gradient is the same as that in the surrounding aquifer. The hydraulic gradient is calculated from the range of head differences between up hydraulic gradient borehole BH5 in the west of the site and down hydraulic gradient boreholes BH6 and BH7.
Hydraulic conductivity of the waste	1.00E-08	m/s	Hydraulic conductivity based on values for fine grained soils.
Length of sidewall perpendicular to groundwater flow	300	m	Length of sidewall perpendicular to groundwater flow to the north west, west and south west of the site.
Depth of sidewall in contact with groundwater	19.84	m	Average saturated thickness of the fractured granite aquifer calculated from an effective base of the fractured granite aquifer of 34mAMSL and the range of groundwater levels recorded round the western quarry in boreholes BH6 to BH10.
Flow out of the sidewall	3.03E-06	m³/s	Calculated

Flow in the aquifer in contact with the sidewall

Parameter	Value	Units	Justification / Source
Hydraulic gradient in the aquifer	5.10E-02	None	Calculated from the range of head differences between up hydraulic gradient borehole BH5 in the west of the site and down hydraulic gradient boreholes BH6 and BH7.
Aquifer hydraulic conductivity	9.20E-07	m/s	Lowest of the hydraulic conductivity values for the fractured granite aquifer calculated from borehole testing at the site in 2005
Width of mixing zone	170	m	Width of the landfill perpendicular to groundwater flow.
Aquifer depth in contact with sidewall	19.84	m	Average saturated thickness of the fractured granite aquifer calculated from an effective base of the fractured granite aquifer of 34mAMSL and the range of groundwater levels recorded round the western quarry in boreholes BH6 to BH10.
Flow rate in the aquifer past the sidewall	1.58E-04	m³/s	Calculated

Results

Determinand	Chloride	Sulphate	Lead	Copper	Flouride	Zinc	Arsenic	Cadmium	Chromium	Mercury	Nickel	Toluene	Fluoranthene
Units	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
DWS	250	250	0.01	2.0	1.5		0.01	0.005	0.05	0.001	0.02	0.001	0.000100
EAL	114	191	0.0071	0.038	0.7	0.139	0.01	0.00087	0.0068	0.001	0.006	0.005	0.000568
Predicted concentration in the aquifer immediately down hydraulic gradient of the landfill	53.2	75.2	0.00585	0.0116	0.33	0.05659	0.00398	0.00059	0.00251	0.00004	0.00340	0.009	0.000867

Notes

Highlighted — Denotes an exceedance of an environmental assessment limit