LANDFILL ENVIRONMENTAL PERMIT APPLICATION

HYDROGEOLOGICAL RISK ASSESSMENT (HRA)

FOR THE DEVELOPMENT CONSENT ORDER APPLICATION FOR THE ALTERATION AND CONSTRUCTION OF HAZARDOUS WASTE AND LOW LEVEL RADIOACTIVE WASTE FACILITIES AT THE EAST NORTHANTS RESOURCE MANAGEMENT FACILITY, STAMFORD ROAD, NORTHAMPTONSHIRE

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AN APPLICATION TO VARY ENVIRONMENTAL PERMIT NUMBER EPR/TP3430GW FOR THE HAZARDOUS WASTE LANDFILL SITE OPERATED BY AUGEAN SOUTH LIMITED AT EAST NORTHANTS RESOURCE MANAGEMENT FACILITY

REVIEW OF THE HYDROGEOLOGICAL RISK ASSESSMENT FOR EAST NORTHANTS RESOURCE MANAGEMENT FACILITY AND HYDROGEOLOGICAL RISK ASSESSMENT FOR THE PROPOSED WESTERN EXTENSION

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1. Introduction

1.1 MJCA is commissioned by Augean South Limited (Augean) to undertake a review of the hydrogeological risk assessment (HRA) for the landfill at the East Northants Resource Management Facility (reference 1). The review of the HRA has been undertaken in accordance with condition 3.1.5 of Environmental Permit (EP) variation number EPR/TP3430GW/V005 for the hazardous waste landfill issued in October 2015 (reference 2).

1.2 In addition to the review, the HRA has been updated to support an application to vary EP EPR/TP3430GW to authorise the development of a hazardous waste landfill in Phases 12 to 21 (the western extension area) adjacent to the west, north west and south west of the current operational hazardous waste landfill at East Northants Resource Management Facility (ENRMF landfill). The location of the currently permitted site and the location of the proposed western extension are shown on Figure HRA 1.

HRA review

1.3 Prior to 2002 the site was the subject of a Waste Management Licence (WML 73068) with the original EP (formerly referred to as a Pollution Prevention and Control Permit) issued on 16 July 2002 (reference BK 2259). The EP was issued based on documentation and risk assessments submitted with the EP application and on responses to queries raised by the Environment Agency during the application process. Since the original EP was issued in 2002 a number of variations to the EP have been issued and additional documentation and risk assessments have been submitted with the applications to vary the EP. The supporting documentation and risk assessments include the most recent HRA (reference 1) and the most recent Environmental Setting and Installation Design Report (ESID) (reference 3) dated September 2014. The current EP variation reference EPR/TP3430GW/V005 issued in October 2015 (reference 2) comprises a consolidated version of the EP including all current EP conditions.

1.4 The 2014 HRA (reference 1) was prepared to support the application to vary the EP for the construction of new landfill void comprising the Western Landfill Area (WLA Phases 6 to 11) to the west of the previously permitted hazardous waste landfill site. The 2014 HRA was based on a preliminary HRA prepared in 2011 (reference 4) in support of a Development Consent Order (DCO) for the WLA. In the 2011 preliminary HRA information from an HRA review prepared in August 2008 (reference 5) and the original EP application HRA prepared in December 2004 (reference 6) together with updated monitoring data were used to develop a LandSim model to assess the potential impact of the preliminary design of the WLA. The 2014 HRA took into consideration changes to the design of the WLA since the 2011 preliminary HRA was prepared together with changes to the conceptual site model based on information collected during a site investigation in the WLA in 2013 (reference 7) and environmental monitoring carried out at the site since the preparation of the 2011 preliminary HRA.

1.5 It is stated in condition 3.1.5 of EP variation number EPR/TP3430GW/V005 for ENRMF that:

> *"The operator shall submit to the Environment Agency a review of the Hydrogeological Risk Assessment:*
>
> *(a) between nine and six months prior to the fourth anniversary of the granting of the permit; and*
>
> *(b) between nine and six months prior to every subsequent six years after the fourth anniversary of the granting of the permit."*

If it is assumed that the 2008 HRA review was the first HRA review and that the 2014 HRA comprised the second HRA review then this report comprises the third HRA review for the site since the original EP was issued. This report comprises the first HRA review for the site following the issue of EP variation reference EPR/DP3639LM/V005 in October 2015 with future HRA reviews due every six years.

1.6 Leachate level and groundwater level and quality monitoring data for the period May 2014 to March 2021 and leachate quality monitoring data for the period May 2014 to February 2021 have been reviewed. The CQA validation reports for the construction since 2014 of Phase 6 (cells 6A, 6B and 6C) and Phase 10 have been reviewed to confirm that the values for the engineering containment parameters used in the 2014 HRA are consistent with the phases constructed at the site. The data and information have been compared with the assumptions made in the conceptual model presented in the 2014 ESID (reference 3) on which the 2014 HRA is based together with the values for the parameters used in the modelling in the 2014 HRA. The positions of the monitoring locations together with the key features of the site are shown on Figure HRA 2.

1.7 Where necessary the HRA models have been updated to demonstrate that the impact of the site on groundwater is compliant with Schedule 22 of the Environmental Permitting (England and Wales) Regulations 2016 which have replaced the 2010 regulations referred to in the 2014 HRA. The results of the HRA review are presented in this report.

Revised HRA (2021 HRA) to support the application to vary the EP to extend the area of the landfill site

1.8 A site investigation in the proposed western extension area was undertaken between November 2019 and March 2020. A total of twenty six boreholes were drilled round the perimeter of and within the proposed western extension. The results of the site investigation have been used to update the conceptual site model to include the western extension area and are presented in the ESID report submitted with the application to vary the EP (reference 8). The site investigation report is presented as an Appendix to the ESID report. The scope of the site investigation was agreed with the Environment Agency. The results of the site investigation have been used to inform the design of the western extension area presented in the application to vary the EP. The principles of the thickness of the geological barrier to be left in situ beneath the western extension area have been the subject of consultation with the Environment Agency including a meeting held on 17 July 2020 for the purpose of receiving pre-application advice prior to the preparation of the landfill design and the application to vary the EP. A record of the pre-application advice is provided at Appendix HRA A.

1.9 The conceptual site model is presented in the ESID (reference 8) including a description of the geology, hydrogeology and hydrology of the site. Geological cross sections through the currently permitted landfill and the western extension area are presented in the ESID report. A schematic cross section as a summary of the conceptual site model for the western extension area is presented on Figure HRA 3.

1.10 Following completion of the HRA review, the HRA model has been revised to include the proposed western extension to the west, north west and south west of the currently permitted site. The results of the revised models are presented in this report. This report includes the revised HRA in support of the application to vary the EP for the hazardous waste landfill to include the western extension. The revised HRA is included in the same report as the HRA review document as agreed with the Environment Agency (Appendix HRA A). The revised HRA is referred to as the 2021 HRA for the purpose of this report.

1.11 For ease of reference for the Environment Agency in determining the application to include the western extension, a sign posting document is included at Appendix HRA B in respect of the template for HRAs. The document identifies where the information for each section of the template for HRAs relevant to the western extension can be located in this document which includes both the review of the 2014 HRA and the 2021 HRA for the proposed western extension.

1.12 EP EPR/FB3598DD for the disposal of Low Level Radioactive Waste (LLW) in Phase 4B onwards and up to Phase 11 of the landfill site was issued in 2015 superseding the permit issued in 2011 for the disposal of LLW in phases 4B, 5A and 5B. It is intended that the disposal of LLW will continue in future phases in the western extension area. The assessment of potential radiological impacts from the disposal of LLW on water resources is the subject of a separate assessment as part of a variation to be made to the LLW Permit and is not considered in this HRA.

2. Review of the conceptual site model

Sources

2.1 In the HRA the lifecycle of the landfill is divided into three stages. The first stage comprises the operational phase of the landfill up to the completion of filling with waste where active leachate management is undertaken during active waste deposition. The second stage comprises the post closure managed phase of the landfill where all areas of the site are restored and active leachate management continues. The third stage comprises the point beyond which active management is necessary. During the third stage there will be no active leachate management.

2.2 Since the issue in 2015 of EP variation reference EPR/TP3430GW/V005 there have been no significant changes to the permitted site operations. Since the preparation of the 2014 HRA (reference 1) the main changes at the site with respect to the development of the landfill comprise the construction of phases 6 and 10, the completion of the capping of phases 1, 2, 4A, 5A, 6A and 6B and the temporary capping of phase 5B. Landfilling is currently ongoing in phases 6C and 10. Phase 7 is currently being constructed. Phases 3 and 4B remain unchanged since 2014 with phase 3 being fully capped and phase 4B covered with temporary capping. ENRMF hazardous waste landfill is in the first or operational stage of the landfill life cycle considered in the HRA.

2.3 Leachate levels at the site are reviewed in the section on the review of essential and technical precautions (Section 3) of this HRA review.

Leachate quality

2.4 There have been changes to the classification of some substances as hazardous substances or non-hazardous pollutants since the 2014 HRA was carried out for the site with some hazardous substances for groundwater modelled in the 2014 HRA being reclassified as non-hazardous pollutants. Cadmium and naphthalene which are included in the hazardous substance leachate source term for the previous HRAs, have been reclassified as non-hazardous pollutants.

2.5 Leachate concentrations for each determinand modelled in the 2014 HRA have been reviewed over the monitoring period May 2014 to February 2021 comprising the period of monitoring following that reviewed in the 2014 HRA. The leachate concentrations have been compared with the values used in the 2014 HRA. The results of the comparison of the leachate quality data with the 2014 HRA source term are presented in Table HRA 1. The re-classification of substances as non-hazardous pollutants has been included in the table. An electronic copy of the leachate quality monitoring data reviewed is presented at Appendix HRA C.

2.6 In the 2014 HRA the currently permitted landfill comprised phases 1 to 5 and the WLA comprised the future landfill phases 6 to 11. Phases 1 and 2A comprise co-disposal areas with hazardous and non-hazardous wastes deposited in the phases. Phase 2B is predominantly filled with hazardous waste with a limited amount of co-disposal. In the 2014 HRA the source term for the future phases in the WLA generally were consistent with those used for Phases 1 to 5 except for ammoniacal nitrogen and chloride. The ammoniacal nitrogen concentrations recorded in the leachate in the co-disposal phases of the current landfill were greater than the concentrations recorded in the hazardous waste phases hence the ammoniacal nitrogen source term concentration for Phases 1 to 5 were based on the combined quality of the hazardous waste phases and the co-disposal phases and the source term for the WLA was based on the ammoniacal nitrogen concentrations recorded in the hazardous waste phases only.

2.7 At the time of the 2014 HRA the current site was permitted to accept wastes with levels of chloride which derogate from the hazardous Waste Acceptance Criteria by up to 3 times until December 2015. It was assumed that the cells in the WLA would not accept waste during 2015 as filling would continue in Phases 1 to 5 hence the source term for the WLA was adjusted to reflect the change in the Waste Acceptance Criteria for chloride at the site. The current landfill was included in the model presented in the 2014 HRA so that the cumulative impact of aqueous contaminants from the current and future landfill areas at the site at the receptor was modelled where appropriate. In fact, as a result of changes in government policy, the derogation of chloride from the hazardous Waste Acceptance Criteria by up to 3 times did not cease in December 2015 and has not yet been removed. For this HRA review the chloride leachate quality data for Phases 1 to 5 have been compared with the 2014 HRA leachate source term for those phases and the leachate quality data recorded in the hazardous waste phases only of Phases 1 to 5 and in Phase 6 have been compared with the 2014 HRA leachate source term for the WLA consistent with ammoniacal nitrogen concentrations.

2.8 Where concentrations recorded in the leachate over the review period exceed the concentrations in the source term used in the 2014 HRA the source term has been updated. While some of the updated source terms are not significantly different to the 2014 source term concentrations, due to the re-classification of some substances as hazardous substances or non-hazardous pollutants, a comprehensive update of the source term has been carried out to include all revisions identified. The classification of substances has an impact on the location at which compliance is assessed as set out in Section 2.25 and 2.26 below. With the reclassification of cadmium and naphthalene as non-hazardous pollutants, to redress the balance of hazardous substances and non-hazardous pollutants used in the source term of the LandSim models arsenic has been added to the hazardous substances included in the source term. The relevant chemical and attenuation properties for arsenic used in the updated LandSim model are presented in Table HRA 2.

2.9 With the exception of the addition of arsenic, the concentrations of hazardous substances recorded in the leachate since the preparation of the 2014 HRA are within the range of concentrations used in the source term of the 2014 HRA in all of the landfill cells or phases and no revisions to the source term concentrations are necessary. With the exception of naphthalene and zinc there have been revisions to the concentrations of all non-hazardous pollutants used in the source term of the 2014 HRA in some or all of the landfill phases. The results of the LandSim modelling run with the updated source terms are presented in Section 4.

Waste porosity

2.10 The *waste porosity* input parameter in LandSim is not clearly defined as total porosity and as such effective porosity or drainable porosity of waste values have been used in the 2014 LandSim models for ENRMF. It does not state in the LandSim manual how *waste porosity* is used in the model calculations. Based on comments from the Environment Agency on other sites where this approach has been taken, the LandSim manual has been reviewed and it is assumed that *waste porosity* is used along with field capacity to calculate the “Free draining volume of leachate present in the waste mass (Vfd)” parameter presented in equation 4 of the LandSim 2.5 manual update (page XI) calculating leachate levels. It is assumed that the volume, Vfd, is calculated using a *drainable porosity* parameter calculated from (total) *waste porosity* minus *field capacity* which implies that the *waste porosity* used in LandSim is the total porosity of the waste rather than the effective porosity or drainable porosity assumed in the 2014 LandSim models. On this basis and as summarised in Table HRA 3 revised *waste porosity* values have been calculated and comprise the effective porosity or drainable porosity of waste values used as *waste porosity* in the 2014 LandSim models added to the *field capacity* values in the models. This approach has been accepted by the Environment Agency on other sites.

Western extension

2.11 The source term used for the 2021 HRA are presented in Table HRA 4. The dimensions of the landfill in the western extension used in the 2021 HRA are presented in Table HRA 5.

Pathways

2.12 In respect of the pathway through the basal liner, the CQA validation reports for engineering carried out at the site since the 2014 HRA are reviewed in the section in this report on the review of essential and technical precautions (Section 3) as part of the HRA review.

2.13 The conceptual site model (CSM) for the site on which the 2014 HRA is based is described in the 2014 ESID (reference 3) and the geology at and in the vicinity of the proposed western extension area is presented in the 2021 ESID report submitted with the application to vary the EP (reference 8). In summary, the geology comprises glacial till (formerly boulder clay) where present, overlying the Blisworth Limestone Formation in the south eastern corner of the currently permitted site and northern part of the proposed western extension area. In the remainder of the site the glacial till where present overlies the Rutland Formation which comprises mainly clays and silty clays. The Rutland Formation underlies the Blisworth Limestone Formation (where present) and is underlain in turn by the Lincolnshire Limestone Formation, the Grantham Formation, the Northampton Sand Formation and the Whitby Mudstone Formation. In part of the proposed western extension area the glacial till directly overlies the Lincolnshire Limestone Formation with both the Rutland Formation and Blisworth Limestone Formation absent. The Lincolnshire Limestone Formation comprises mainly limestones, sandy limestones and sandstones. The Grantham Formation and Northampton Sand Formation are not easily differentiated at the site and comprise mainly silt, clay, sand and sandstones. The Whitby Mudstone Formation comprises mudstone and clay.

2.14 The Grantham Formation includes a thin laminated clay unit observed in the majority of boreholes round the perimeter of the currently permitted site and the proposed western extension area. This clay unit is of variable thickness between 0.1m and 1.5m thick where recorded and considered to be laterally discontinuous as the unit is absent at a number of locations across the currently permitted site. Beneath the proposed western extension area this clay unit is generally laterally extensive but thinner typically ranging from 0.1m to 0.8m in thickness and pinching out near to the southern boundary of the proposed western extension area. Given the often thin and locally discontinuous nature of this clay unit in the Grantham Formation generally, the Lincolnshire Limestone Formation and Northampton Sand Formation are considered to be in hydraulic continuity at the site and are considered to form a single aquifer unit.

2.15 The Blisworth Limestone Formation and Lincolnshire Limestone Formation are designated as Principal aquifers by the Environment Agency. The glacial till is designated as a Secondary undifferentiated aquifer and the Rutland Formation is designated a Secondary B aquifer. The Grantham Formation is designated a Secondary undifferentiated aquifer and the Northampton Sand Formation is designated a Secondary A Aquifer.

2.16 The Blisworth Limestone Formation where present at the site occurs close to ground level and is thin and of insignificant resource value. The Lincolnshire Limestone Formation and Northampton Sand Formation are considered to be in hydraulic continuity at the site and are considered to form a single aquifer unit. The pathway for the migration of leachate from the site will be through the basal liner of the landfill, vertically through the unsaturated zone of the Lincolnshire Limestone Formation and to the groundwater in the Lincolnshire Limestone Formation. For the WLA (Phases 6 to 11) approximately 2m of the Rutland Formation has been and is being left in situ between the base of the liner and the top of the Lincolnshire Limestone Formation to act as part of the natural geological barrier. The 2m thickness was informed by sensitivity analysis of the LandSim models presented in the 2014 HRA (reference 1). However, for the purposes of the modelling carried out in the 2014 HRA it is assumed conservatively that the 2m of in situ Rutland Formation beneath the WLA is not present.

2.17 Groundwater levels recorded at boreholes round the perimeter of the currently permitted site recorded between November 2003 and March 2021 are presented on Figure HRA 4A. As can be seen on Figure HRA 4A groundwater levels at the currently permitted site fluctuate within similar ranges between May 2014 and March 2021 compared with between November 2003 and April 2014. The unsaturated zone thicknesses calculated for Phases 1 to 5 and the WLA (Phases 6 to 11) based on groundwater levels recorded between May 2014 and March 2021 are similar to albeit slightly less than the values used in the 2014 HRA (Table HRA 2).

2.18 It is assumed in the 2014 HRA that groundwater flow in the Lincolnshire Limestone Formation/ Northampton Sand Formation is to the south and south east with the deregulated/ private groundwater abstraction approximately 1.1km south east of the site at Law's Lawn comprising the closest sensitive receptor. The pathway length used in the models comprises the distance to the site boundary of a minimum 40m from the southern edge of the landfill. Based on the groundwater levels presented on Figure HRA 4A it is considered that there has been no significant change in the groundwater regime at the site since 2014 hence the assumptions made in the 2014 HRA with respect to the saturated pathways and groundwater flow direction remain valid.

2.19 Indicative groundwater level contours are presented on Figure HRA 5 for the groundwater in the Lincolnshire Limestone Formation/ Northampton Sand Formation. The groundwater level contours have been interpolated from the groundwater levels recorded in June 2020 at the monitoring boreholes at and in the vicinity of the currently permitted site and the proposed western extension. Hydraulic gradients across the currently permitted site including the WLA generally are within the range of gradients used in the 2014 HRA.

Western extension

2.20 Consistent with the WLA and as agreed with the Environment Agency during pre-application consultation, it is proposed that 2m of the Rutland Formation or glacial clay will be left in situ between the base of the liner and the top of the Lincolnshire Limestone Formation in the western extension to act as part of the natural geological barrier (Figure HRA 3). For the purposes of the modelling carried out in the 2021 HRA it is assumed conservatively that the 2m of in situ Rutland Formation beneath the western extension is not present.

2.21 Groundwater levels recorded at boreholes round the perimeter of the proposed western extension recorded between January 2014 and March 2021 are presented on Figure HRA 4B. The groundwater levels recorded in the boreholes installed in 2019/ 2020 are within the range recorded in the boreholes round the current ENRMF site with the exception of the boreholes K34 to K37 along the southern boundary of the western extension where groundwater levels are lower. The lower groundwater levels recorded at boreholes K34 to K37 are consistent with groundwater flow towards the south as expected and the levels are between those recorded at the current ENRMF site and those recorded at borehole K09 located approximately 700m south east of the site. The thickness of the unsaturated zone is calculated based on groundwater levels recorded between November 2003 and March 2021 and the level of the top of the Lincolnshire Limestone Formation for use in the 2021 HRA to include the western extension (Table HRA 5).

2.22 The Lincolnshire Limestone Formation/ Northampton Sand Formation aquifer was locally confined by the Rutland Formation at boreholes K30 and K31 located along the eastern boundary of the northern area of the western extension between December 2019 and March 2020 and over a similar period in 2020/ 2021. Since monitoring records began at the site in November 2003, the highest recorded groundwater levels were recorded at the majority of boreholes over the winter/spring of 2019/ 2020 or 2020/ 2021 (Figure 4A) including at borehole K01 comprising the closest borehole to K30 and K31 with a long-term monitoring record. The maximum groundwater levels at K01 in the winter/spring of 2019/ 2020 and 2020/ 2021 were 76.02mAOD and 74.74mAOD respectively. Groundwater levels above 74mAOD have been recorded on one other occasion only over the monitoring record at borehole K01 in 2007. Over the period of elevated groundwater levels at K30 and K31 levels at K01 down to approximately 71mAOD were recorded. As a conservative maximum it could be inferred that groundwater in the vicinity of boreholes K30 and K31 may have been locally confined during the monitoring period November 2003 to March 2021 when groundwater levels at borehole K01 exceed 71mAOD comprising 10% of monitoring occasions. The impact of the highest groundwater levels recorded at boreholes during the period December 2019 to March 2020 and December 2020 to March 2021 is assessed by sensitivity analysis of the revised HRA Landsim model presented at Section 5 with respect to the unsaturated zone thickness of the northern area of the western extension. The elevated groundwater levels are recorded at boreholes K30 and K31 are below the proposed basal levels of Phases 13 and 14 of the western extension adjacent to the boreholes.

2.23 The groundwater contours presented on Figure HRA 5 show that in general groundwater flows from north to south across the western extension area consistent with the current ENRMF site with an element of flow towards the west in the central area of the western extension. The closest sensitive receptor to the western extension area comprises the issue to the south where the tributary of the Willow Brook emerges approximately 0.8km south south east of the western extension. Consistent with the 2014 HRA the pathway length used in the models comprises the distance to the site boundary of a minimum 40m from the southern edge of the landfill.

2.24 Saturated pathway thicknesses calculated based on groundwater levels recorded between November 2003 and March 2021 and the level of the top of the clay layer within the Grantham Formation as a conservative assumption where present or the top of the Whitby Mudstone Formation for use in the 2021 HRA to include the western extension are presented in Table HRA 5. Hydraulic gradients across the western extension generally are within the range of gradients used in the 2014 HRA with the exception of the southern area where gradients are shallower. Hydraulic gradients calculated based on groundwater levels recorded between November 2003 and March 2021 for use in the 2021 HRA to include the western extension are presented in Table HRA 5.

Receptors

2.25 Details of all licensed, deregulated and private water abstractions located within 2km of the site are presented in the 2021 ESID report (reference 8). Based on the records provided there are no additional abstractions located down hydraulic gradient and within 2km of the site to those reported in 2014.

2.26 As described in the 2014 HRA, the compliance point for hazardous substances in groundwater will be at one or more boreholes down hydraulic gradient and directly adjacent to the landfill. No contaminant attenuation is assumed for hazardous substances in the groundwater pathways so that only the effect of immediate dilution after the discharge enters the groundwater is modelled. For the purpose of the HRAs the receptor for hazardous substances is at a monitoring borehole down hydraulic gradient of the phase boundary.

2.27 As described in the 2014 HRA, the compliance point for non-hazardous pollutants in groundwater will be at one or more boreholes down hydraulic gradient and adjacent to the landfill. For the purpose of the HRAs the receptor and compliance point for non-hazardous pollutants is at a monitoring borehole 40m down hydraulic gradient of the landfill and adjacent to the EP boundary.

2.28 The secondary receptors closest to the site for non-hazardous pollutants migrating from the landfill is an abstraction borehole located approximately 1.1km down hydraulic gradient of the current ENRMF site.

2.29 Environmental Assessment Levels (EALs) were proposed in the 2014 HRA (reference 1) based on laboratory detection limits, background groundwater quality data or the Drinking Water Standard (DWS) depending on which is more appropriate. EALs are the concentrations of substances above which there may be a discernible discharge of hazardous substances to groundwater and pollution of groundwater by non-hazardous pollutants at the respective receptors. The EALs are presented in Table HRA 1. The EALs have been reviewed as part of the review of the impacts on groundwater quality section (Section 5) of this HRA review.

Western extension

2.30 The compliance point for hazardous substances and non-hazardous pollutants for the western extension are consistent with the current ENRMF site. For the purpose of the 2021 HRA the receptor and compliance point for hazardous substances is at a monitoring borehole down hydraulic gradient of the phase boundary and the receptor and compliance point for non-hazardous pollutants is at a monitoring borehole 40m down hydraulic gradient of the landfill and adjacent to the EP boundary.

2.31 The secondary receptor closest to the site for non-hazardous pollutants migrating from the landfill is the issue to the south where the tributary of the Willow Brook emerges approximately 0.8km south south east of the western extension.

2.32 The EALs for the 2021 HRA are consistent with those used in the HRA review presented in Table HRA 1 and are reproduced in Table HRA 4.

Summary of changes to the sources, pathways or receptors

2.33 In summary the changes to the conceptual site model since the 2014 HRA was carried out are:

- reclassification of cadmium and naphthalene as non-hazardous pollutants and the addition of arsenic to the source term as a hazardous substance (Table HRA 1),
- updates to the source term used in the 2014 HRA based on the leachate quality recorded over the review period and the reclassification of substances (Table HRA 1)
- waste porosity revisions (Table HRA 2)

2.34 The results of the HRA review re-run models are presented in Section 4 and Table HRA 6.

2021 HRA for the western extension

2.35 The input parameters for the revised Landsim models to include the western extension are presented in Table HRA 4 and Table HRA 5. All input parameters are included in the tables including those for the currently permitted ENRMF landfill for completeness.

2.36 The thicknesses used as input values for the Landsim models in the 2014 HRA for the unsaturated zone have been updated for the currently permitted landfill and western landfill areas based on the groundwater level monitoring data recorded between November 2003 and March 2021. While these values are not significantly different to those used in the 2014 HRA (Table HRA 2) they have been updated for completeness and to correct an error in the ground level used to calculated the groundwater level hence the unsaturated zone thickness at borehole K12 in the 2014 HRA.

2.37 The results of the 2021 HRA to assess the western extension are presented in Section 5 and Table HRA 7.

3. Review of the essential and technical precautions

3.1 For the purpose of reviewing the essential and technical precautions the leachate level monitoring data and the available CQA reports for the construction of Phase 6 and Phase 10 have been reviewed and compared with the assumptions and values for the parameters used in the 2014 HRA (reference 1).

CQA data

3.2 The results of the comparison of landfill liner data from the CQA reports for Cells 6A to 6C of Phase 6 (references 9 to 11) and Phase 10 (reference 12) with the values for the parameters used in the 2014 HRA (reference 1) are presented in Table HRA 2. Based on a review of the available landfill liner data from the CQA reports the data are within the range of values for the parameters used in the 2014 HRA or show that the values for the parameters used in the 2014 HRA are conservative.

3.3 Phases 6 and 10 comprising the constructed phases of the WLA have been separated out in the HRA review re-run model with the hydraulic conductivity of the liner presented in a log triangular distribution using the lower quartile, geometric mean and 90th percentile of the data for Phases 6 and 10 (values in brackets in Table HRA 2) consistent with the approach taken for Phases 1 to 5 in the model.

3.4 There is a significant amount of data for testing of the hydraulic conductivity of the clay materials excavated from ENRMF and used to construct clay liners to a CQA criterion of 1 x 10^{-9}m/s at ENRMF and the nearby Augean Thornhaugh Landfill Site. A total of 270 samples of clay liner material from the construction of Phases 6 and 10 at ENRMF and Phases 3 to 7A at Thornhaugh Landfill have undergone laboratory hydraulic conductivity testing for the purpose of CQA verification. The data are presented at Appendix HRA D. As can be seen from the graphs presented at Appendix HRA D the data spans orders of magnitude and appears to be skewed to the lower end of the range. When the log values of the hydraulic conductivity are presented graphically the distribution appears normal hence the distribution of the data is log normal. Consistent with Environment Agency guidance on the selection of model input parameters (reference 13) a log normal distribution is typically used to describe the variation in hydraulic conductivity values.

3.5 The values for the hydraulic conductivity of the liner in Phases 7 to 9 and Phase 11 of the WLA have been updated to the log normal distribution of the significant amount of data for the hydraulic conductivity of the clay materials excavated from ENRMF and used to construct clay liners to a CQA criterion of 1 x 10^{-9}m/s (Table HRA 2).

Leachate level

3.6 A leachate level compliance limit of 5m above the top of the basal landfill liner is set in Table S3.1 'Leachate level limits and monitoring requirements' of the EP for the site (reference 2). The leachate level limit of 5m is set for both operational cells and non operational cells for the period from the issue date of the current EP in October 2015 to 30 December 2026. The increase in leachate level limit was to allow for the storage of an increased quantity of leachate so that it is available for use in the waste treatment plant operations at the site. Based on the current EP, after 31 December 2026 the leachate limit for all cells will be set at 1m above the top of the basal landfill liner. It is proposed as part of the EP variation application to extend the period of the 5m leachate limit in the currently permitted ENRMF landfill (i.e. Phases 1 to 11 of the landfill site) from 2026 to 2046 (2021 HRA). Leachate levels recorded at the site between January 2014 and March 2021 are shown on Figure HRA 6. Generally leachate levels are below the leachate level limit of 5m with exceedances of the leachate level limit recorded on a number of occasions in leachate wells KCLW2A2, KCLW2A3, KCLW3B1, KCLW4A1, KCL5A1 and KCLW5B1 over the monitoring period reviewed. It is considered that in general the leachate levels are managed and maintained below the compliance limit.

3.7 It is understood that leachate wells KCLW1A1, KCLW2A3 and KCLW2B3 have become blocked and are not in use currently. It is understood that leachate well KCLW1A1 became unblocked during engineering works in the area at the end of 2020 to the extent that leachate levels can now be monitored in the well. During the current period when leachate levels are permitted to be up to 5m above the cell base there are more than sufficient remaining leachate monitoring/extraction wells in the Phase 1 and 2 area to provide leachate control and monitoring in accordance with Environment Agency guidance. At the time when leachate levels are required to be returned to 1m above the base it will be necessary to review the suitability of the leachate monitoring, extraction and control infrastructure within Phases 1A, 1B, 2A and 2B.

3.8 Consistent with the long term compliance limit the leachate level in the re-run HRA review LandSim model and the LandSim model in support of the 2021 HRA for the proposed western extension are set at 1m. The LandSim models have been run with a leachate level of 5m in the currently permitted landfill with results from the first 100year time slice presented in this report to represent the potential impacts from the short term compliance limit of 5m. There are no proposals for a short term leachate level compliance limit of 5m in the western extension.

Cap material/ infiltration

3.9 As presented in section 3 of the ESID (reference 8) the rainfall data for the meteorological station at Wittering Airfield has been updated. As detailed in section 2 above, the capping works in Phases 1, 2, 3, 4A, 5A, 6A and 6B is complete with Phases 4B and 5B covered with temporary capping. It is understood that capping of all phases has been completed with clay with the exception of sections along the northern slope of Phases 1 and 2A, Phase 2B and Phase 3. It is understood that a combination of a Geosynthetic Clay Liner (GCL) with a geomembrane have been used to cap the northern slope of Phases 1 and 2A, Phase 2B and Phase 3. As such, all capped phases of the site have a component of clay capping. It is proposed that future capping works will be completed using clay. On the basis that clay has been and will be used to cap the site, infiltration parameters used for the landfill have been reviewed. Calculations for potential infiltration through a 1m clay cap are presented at Appendix HRA E.

3.10 The infiltration parameters used in the revised HRA review model models have been updated to reflect the updated rainfall data and the use of a clay cap. The updated parameters are used in the 2021 HRA (Table HRA 5). The currently permitted design includes for either a clay cap or a geomembrane cap. The EP variation application includes for either a clay cap or a geomembrane cap. As there are geomembrane elements to limited areas of cap over the restored areas of the currently permitted landfill and in the future the cap could comprise a geomembrane, sensitivity analyses have been run for both the revised HRA review model and the 2021 HRA with geomembrane caps.

4. HRA review modelling

4.1 As set out in Section 2, the source term concentrations have been updated where the concentrations recorded in the leachate over the review period exceed the concentrations in the source term used in the 2014 HRA model. The updated model has been run in LandSim version 2.5.17. The reclassification of substances as hazardous substances or non-hazardous pollutants has an impact on the location at which compliance is assessed. The reclassification of substances as non-hazardous pollutants has been addressed as part of the updated model runs in this HRA review. There have been revisions to the concentrations for the non-hazardous pollutants chloride and manganese and arsenic has been added to the hazardous substance source term.

4.2 The updated model incorporates changes to the conceptual site model with changes to the waste porosity. The model phase boundaries have been updated such that the currently permitted landfill area from the 2014 HRA comprising Phases 1 to 5 is labelled as the permitted eastern area, Phase 6 and the current operational Phase 10 have been separated out from the WLA and are labelled P6 & 10 permitted western area, and the WLA comprising the future Phases 7 to 9 and 11 are labelled P7-9 & 11 permitted western area. The hydraulic conductivity values of the clay liner for P6 & 10 permitted western area comprise values derived from the CQA data for these phases consistent with those for the permitted eastern area. The hydraulic conductivity values of the clay liner for P7-9 & 11 permitted western area comprise a log normal distribution using the mean and standard deviation from the results of hydraulic conductivity tests of 270 samples from Phases 6 and 10 at ENRMF and Phases 3 to 7A at the nearby Augean Thornhaugh Landfill site which have been constructed with the same clay materials excavated at ENRMF and proposed for use in the future cells with a CQA criterion for the construction of the compacted clay landfill liner of 1×10^{-9}m/s.

4.3 Consistent with the 2014 HRA, for the purposes of this HRA review the receptor for hazardous substances in the LandSim model is the assumed down hydraulic gradient monitoring point adjacent to the landfill phases. The receptor for non-hazardous substances is the groundwater at a monitoring borehole down hydraulic gradient of the landfill and adjacent to the EP boundary. The compliance point in the model has been moved such that it is located on the boundary between the constructed phases of the WLA and the future phases of the WLA to assess the maximum cumulative impact from the landfill phases.

Emissions to groundwater

4.4 The results of the updated LandSim model are summarised in Table HRA 6. An electronic copy of the LandSim model and result file are presented at Appendix HRA C. A hard copy of the LandSim model is presented at Appendix HRA F.

Hazardous substances

4.5 The results of the LandSim model show that there will be no discernible discharge of hazardous substances above the relevant EALs at the 50th percentile or the 95th percentile results to the groundwater at the assumed monitoring point adjacent to the boundary of the landfill phases during the operational or post closure managed phases of the landfill.

Non-hazardous pollutants

4.6 The results of the LandSim model show that there will be no exceedances of the groundwater EALs by non-hazardous pollutants at the 50th percentile or 95th percentile results at the non-hazardous pollutant receptor during the operational or the post closure managed phases of the landfill.

Warning messages

4.7 Consistent with the 2014 HRA model following completion of the model run an on-screen warning is displayed stating that '*leakage rate decreasing'* during the current simulation. The leachate level is fixed at 1m hence leakage should be consistent throughout the life of the model. From the hydraulics results of the model for the leakage from the landfill there is no detectable decrease in leakage rate shown during the life of the model. It is considered that any period over which the leakage rate decreases must be very short and very slight only hence will not have a significant impact on the overall results of the model and that the input parameters used are appropriate.

Sensitivity analysis

4.8 A leachate level limit of 1m is set for all phases in the re-run of the HRA review LandSim model the results for which are presented in Table HRA 6. As discussed in Section 3 a leachate level compliance limit of 5m above the top of the basal landfill liner is set in the EP for the site to allow for a greater volume of leachate storage for use in the waste treatment plant operations at the site. The leachate level limit of 5m applies for all phases at the currently consented site and is a temporary limit for the period up to 31 December 2026. After 31 December 2026 the leachate limit for all cells will be specified at 1m above the top of the basal landfill liner. The proposal to extend the period of the 5m leachate limit from 31 December 2026 to 31 December 2046 for Phases 1 to 11 as part of the EP variation application is assessed in the 2021 HRA (Section 5).

4.9 To assess the risk to groundwater from leachate levels above 1m the re-run HRA review model has been run with a leachate head input value of 5m in the permitted phases. The results from the first 100year time slice are provided below.

The results of the model for a temporary 5m leachate head compliance limit during the period of operation of the waste treatment plant included in the model time slice period 0 to 100 years

Substance	Environmental Assessment Level (EAL) (mg/l)	Maximum concentration at the 95th percentile	Maximum concentration at the 50th percentile
Hazardous substances			
Arsenic	0.035	-	-
Dichlorprop	0.00005	-	-
Toluene	0.001	-	-
Trichloroethene	0.001	-	-
Non-hazardous pollutants			
Ammoniacal N	0.39	-	-
Cadmium	0.0007	-	-
Chloride	250	**306**	43
Manganese	0.46	-	-
Naphthalene	0.00001	-	-
Zinc	0.11	-	-

The results of the sensitivity analysis show that there will be no exceedances of the groundwater EALs by hazardous substances or non-hazardous pollutants at the 50th percentile or 95th percentile results at the relevant receptors during the operational or the post operational phases of the landfill with the exception of chloride. The results of the sensitivity analysis show that the concentration of chloride at the 95th percentile results of 306mg/l exceeds the EAL of 250mg/l with a leachate head of 5m. The time to exceedance of the EAL for chloride at the 95th percentile results is 87 years. The increased leachate levels are permitted for a period of 11 years only. The model predicts that in these time scales the breakthrough of chloride at the base of the clay liner at the 50th percentile and 95th percentile results are below the EAL. Based on the sensitivity analysis there is no significant increased risk to groundwater resulting from temporary leachate levels above 1m and up to 5m for the period up to 31 December 2026 in the permitted landfill.

4.10 The results after the period of operation of the waste treatment plant are not valid as leachate levels will be controlled at 1m in all phases after this period. Irrespective of this, the results show at the 50th percentile (most likely) there would be no exceedance of the EALs at the relevant receptors even if the leachate head was maintained at 5m in the permitted phases of the landfill in perpetuity. The only exceedance of the EALs at the 95th percentile is an exceedance of the non-hazardous pollutant chloride (results: 325mg/l, EAL: 250mg/l).

4.11 Consistent with the sensitivity analysis carried out of the period of management control provided to the Environment Agency in response to a Schedule 5 notice during the determination of the 2014 EP variation application (reference 14), the re-run HRA review model has been run deterministically with a management control period of 60 years to assess the change in the "Expected Values" (50^{th} percentile or most likely concentration).

4.12 The results of the sensitivity analysis of the management control period for the re-run HRA review model are comparable with the results of the sensitivity analysis undertaken on the 2014 HRA model in 2015. The results show that with a duration of management control of 60 years the predicted "expected" or "most likely" concentrations do not exceed the groundwater EALs for hazardous substances or non-hazardous pollutants at the relevant receptors during the operational or the post closure managed phases of the landfill.

4.13 As set out in section 3, as the currently permitted design includes for either a clay cap or a geomembrane cap and as there are geomembrane elements to limited areas of cap over the restored areas of the currently permitted landfill a sensitivity analysis has been carried out on the cap design infiltration incorporating a geomembrane caps. The re-run HRA review model has been run with the cap design infiltration from the 2014 HRA. The results are provided below.

The results of the model with a geomembrane cap

Substance	Environmental Assessment Level (EAL) (mg/l)	Maximum concentration at the 95th percentile	Maximum concentration at the 50th percentile
Hazardous substances			
Arsenic	0.035	6.1E-04	-
Dichlorprop	0.00005	1.5E-10	-
Toluene	0.001	-	-
Trichloroethene	0.001	-	-
Non-hazardous pollutants			
Ammoniacal N	0.39	8.1E-03	2.9E-07
Cadmium	0.0007	-	-
Chloride	250	184	38
Manganese	0.46	1.4E-03	-
Naphthalene	0.00001	-	-
Zinc	0.11	4.2E-06	-

The results of the sensitivity analysis show that there will be no exceedances of the groundwater EALs by hazardous substances or non-hazardous pollutants at the 50th percentile or 95th percentile results at the relevant receptors during the operational or the post closure managed phases of the landfill where a geomembrane cap is used.

4.14 An electronic copy of the sensitivity analysis LandSim models and result files is presented at Appendix HRA C.

4.15 Based on the re-runs of the LandSim model undertaken using the updated source term concentrations, waste porosity and clay liner hydraulic conductivity values it is considered that the results are similar to those presented in the 2014 HRA and do not change the conclusions of the HRA. The site remains compliant with Schedule 22 of the Environmental Permitting (England and Wales) Regulations 2016.

5. 2021 HRA in support of the application to vary the EP

5.1 The LandSim model updated as part of this HRA review has been revised to include the proposed western extension. The source term for the revised model is presented in Table HRA 4. All site input parameters are presented in Table HRA 5 including references and justifications for the values selected where these differ from the 2014 HRA. The input parameters for the chemical and attenuation properties are consistent with the 2014 HRA with the parameters for the added hazardous substance arsenic presented in Table HRA 3 of this HRA review. A copy of Table HRA 3 of the input parameters for the chemical and attenuation properties from the 2014 HRA is provided at Appendix HRA G for reference and completeness.

Emissions to groundwater

5.2 The results of the 2021 HRA LandSim model are summarised in Table HRA 7. An electronic copy of the LandSim model and result file is presented at Appendix HRA C. A hard copy of the LandSim model is presented at Appendix HRA H.

Hazardous substances

5.3 Consistent with the results of the HRA review model, the results of the 2021 HRA LandSim model with the proposed western extension show that there will be no discernible discharge of hazardous substances above the relevant EALs at the 50th percentile or 95th percentile predicted results to groundwater at the assumed monitoring point adjacent to the boundary of the landfill phases during the operational or post closure managed phases of the landfill.

Non-hazardous pollutants

5.4 The results of the 2021 HRA LandSim model show that there will be no exceedances of the groundwater EALs by non-hazardous pollutants at the 50th percentile or 95th percentile predicted results at the non-hazardous pollutant receptor during the operational or the post closure managed phases of the landfill.

Warning messages

5.5 Consistent with the 2014 HRA models and the re-run HRA review models, following completion of the model run an on-screen warning is displayed stating that '*leakage* *rate decreasing'* during the current simulation. The leachate level is fixed at 1m hence leakage should be consistent throughout the life of the model. From the hydraulics results of the model for the leakage from the landfill there is no detectable decrease in leakage rate shown during the life of the model. It is considered that any period over which the leakage rate decreases must be very short and very slight only hence will not have a significant impact on the overall results of the model and that the input parameters used are appropriate.

Sensitivity analysis

5.6 Consistent with the re-run HRA review model, a leachate level limit of 1m is set for all phases in the 2021 HRA LandSim model the results for which are presented in Table HRA 7. To assess the risk to groundwater from leachate levels above 1m the 2021 HRA model has been run with a leachate head input value of 5m in the currently permitted phases (Phases 1 to 11). The leachate level limit of 5m applies for all currently permitted phases at the site and will be a temporary limit for the period up to 31 December 2046. After 31 December 2046 the leachate limit for all cells will be set at 1m above the top of the basal landfill liner. There are no proposals for a 5m leachate level limit in the western extension hence leachate levels remain at 1m in these phases. The results from the first 100year time slice are provided below.

The results of the model for a temporary 5m leachate head compliance limit during the period of operation of the waste treatment plant included in the model time slice period 0 to 100 years

Substance	Environmental Assessment Level (EAL) (mg/l)	Maximum concentration at the 95th percentile	Maximum concentration at the 50th percentile
Hazardous substances			
Arsenic	0.035	-	-
Dichlorprop	0.00005	-	-
Toluene	0.001	-	-
Trichloroethene	0.001	-	-
Non-hazardous pollutants			
Ammoniacal N	0.39	8.0E-08	-
Cadmium	0.0007	-	-
Chloride	250	172	27
Manganese	0.46	-	-
Naphthalene	0.00001	-	-
Zinc	0.11	-	-

The results of the sensitivity analysis show that there will be no exceedances of the groundwater EALs by hazardous substances or non-hazardous pollutants at the 50th percentile or 95th percentile results at the relevant receptors during the operational or the post closure managed phases of the landfill.

5.7 The results after the period of operation of the waste treatment plant are not valid as leachate levels will be controlled at 1m in all phases after this period. Irrespective of this, the results show at the 50th percentile (most likely) there would be no exceedance of the EALs at the relevant receptors even if leachate head was maintained at 5m in the permitted phases of the landfill in perpetuity. The only exceedance of the EALs at the 95th percentile is a marginal exceedance of the non-hazardous pollutant chloride (results: 254mg/l, EAL: 250mg/l).

5.8 Consistent with the sensitivity analysis of the period of management control carried out for the re-run HRA review model, the 2021 HRA model has been run deterministically with a management control period of 60 years to assess the change in the "Expected Values" (50th percentile or most likely concentration). The results of the sensitivity analysis of the management control period for the 2021 HRA model are comparable to the results of the sensitivity analysis for the re-run HRA review model. The results show that with a duration of management control of 60 years the predicted "expected" or "most likely" concentrations do not exceed the groundwater

EALs for hazardous substances or non-hazardous pollutants at the relevant receptors during the operational or the post closure managed phases of the landfill.

5.9 To assess the impact of the highest groundwater levels recorded during the period December 2019 to March 2020 and December 2020 to March 2021 the 2021 model has been run with an unsaturated zone thickness in the northern area of the western extension of 4.1m based on groundwater levels recorded at boreholes K01 and K25 to K32 round the northern area between February 2020 and February 2021. The results of the sensitivity analysis show that there will be no exceedances of the groundwater EALs by hazardous substances or non-hazardous pollutants at the 50th percentile or 95th percentile results at the relevant receptors.

5.10 As set out in section 3, as the EP variation application includes for either a clay cap or a geomembrane cap and as there are geomembrane elements to limited areas of cap over the restored areas of the currently permitted landfill a sensitivity analysis has been carried out on the cap design infiltration incorporating a geomembrane cap. The 2021 HRA model has been run with the cap design infiltration from the 2014 HRA. The results are provided below.

The results of the model for with a geomembrane cap

Substance	Environmental Assessment Level (EAL) (mg/l)	Maximum concentration at the 95th percentile	Maximum concentration at the 50th percentile
Hazardous substances			
Arsenic	0.035	1.7E-03	-
Dichlorprop	0.00005	1.6E-08	-
Toluene	0.001	-	-
Trichloroethene	0.001	-	-
Non-hazardous pollutants			
Ammoniacal N	0.39	0.0365	9.0E-06
Cadmium	0.0007	-	-
Chloride	250	229	66
Manganese	0.46	4.6E-03	4.1E-06
Naphthalene	0.00001	-	-
Zinc	0.11	2.1E-04	-

The results of the sensitivity analysis show that there will be no exceedances of the groundwater EALs by hazardous substances or non-hazardous pollutants at the 50th percentile or 95th percentile results at the relevant receptors during the operational or the post closure managed phases of the landfill where a geomembrane cap is used.

5.11 An electronic copy of the sensitivity analysis LandSim models and result files is presented at Appendix HRA C.

Conclusion of the 2021 HRA in support of the application to vary the EP

5.12 Based on the 2021 HRA model there are no significant adverse impacts as a result of the inclusion of the western extension area. It is proposed that 2m of glacial clay or Rutland Formation will be retained in situ beneath the engineered basal liner of the western extension consistent with the permitted western landfill area. The presence of this insitu clay has not been taken into account in the models hence the predicted impacts presented in this 2021 HRA are conservative and the insitu clay provides a level of additional precaution within the site design. It is concluded that the site including the proposed western extension will remain compliant with Schedule 22 of the Environmental Permitting (England and Wales) Regulations 2016.

6. Review of the impact on groundwater quality for the current landfill site

Groundwater compliance limits

6.1 The groundwater compliance limits and control levels for the site are set out in Table HRA 8 of the 2014 HRA and Table S3.4 Groundwater emissions limits and monitoring requirements of EP variation number EPR/TP3430GW/V005 for ENRMF landfill. The compliance limits are set at the Environmental Assessment Limits (EAL) from the 2014 HRA. The monitoring points at which the compliance limits and control levels should be applied for Phases 1 to 5 are the downgradient boreholes K04, K05, K06A, K12, K13A, K14A, K15A and K16 and for Phases 6 to 11 are the downgradient boreholes K07, K08, K11 and K21. The groundwater quality monitoring data collected between May 2014 and March 2021 have been reviewed and compared with the compliance limits set in 2014. An electronic copy of the groundwater quality monitoring data reviewed is presented at Appendix HRA C. A comparison of groundwater quality data collected between May 2014 and March 2021 with the compliance limits set in 2014 is presented on the chemographs presented at Appendix HRA I. Revisions to the compliance limits are proposed where appropriate.

Hazardous substances

6.2 The hazardous substance arsenic is now included in the LandSim models for the site. As arsenic was not included in the 2014 HRA, groundwater quality monitoring data since 2003 has been reviewed to identify the trends in arsenic concentrations in the groundwater at the site over time. The data shows that arsenic concentrations are similar up and down hydraulic gradient of the site. High limits of detection were used on numerous dates in 2020 with all results recorded below the limits of detection on these occasions. The high limit of detection data is not included in the following review. Concentrations range from <0.00016mg/l to 0.035mg/l in the boreholes up hydraulic gradient to the north of the site and to the west of the WLA and from <0.00016mg/l to 0.042mg/l in the boreholes down hydraulic gradient to the south of the site and to the east of the site. The majority of concentrations recorded from 2003 to 2015 are above the limit of quantification of 0.005mg/l specified in the UK Technical Advisory Group report on Groundwater Hazardous Substances (reference 15) and approximately half of all concentrations are above the UK drinking water standard (UK DWS) of 0.01mg/l. No concentrations of arsenic recorded in the groundwater are above the freshwater Environmental Quality Standard (EQS) of 0.05mg/l. The proposed EAL for arsenic comprises the maximum concentration recorded in the groundwater up hydraulic gradient of the site of 0.035mg/l recorded at borehole K02a in May 2015. The proposed EAL has been exceeded on one occasion over the review period at boreholes K07 and K21 to the south and down hydraulic gradient of the WLA in May 2015.

6.3 Dichloroprop concentrations in the groundwater at the down hydraulic gradient boreholes have occasionally exceeded the compliance limit of 0.00005mg/l over the review period as shown on the chemographs at Appendix HRA I. The exceedance of the compliance limit in all boreholes round the perimeter of the currently permitted site in the groundwater sampled in May 2016 is due to a higher limit of detection of the analytical method used for these samples. The compliance limit was exceeded at a number of boreholes both up and down hydraulic gradient of the site in May 2018 indicating a laboratory error or a source up hydraulic gradient of the site. Dichloroprop has been recorded intermittently above the limit of detection of the analytical method used since August 2017 at borehole K14a located to the south east and down hydraulic gradient of the landfill with the compliance limit exceeded in February and May 2018 and in May and August 2019.

6.4 The limit of detection of the analytical method used for toluene over the review period is at the compliance limit of 0.001mg/l. The compliance limit was exceeded at boreholes K05 and K09 located to the south east and down hydraulic gradient of the landfill and at borehole K03a located to the north east and up hydraulic gradient of the landfill in March 2020 only. The analytical method detection limit used for trichloroethene over the review period is at the compliance limit of 0.001mg/l. There are no trichloroethene concentrations recorded in the groundwater round the site above the analytical method detection limit over the review period.

Non-hazardous pollutants

6.5 Ammoniacal nitrogen concentrations in the groundwater at the down hydraulic gradient boreholes occasionally exceed the compliance limit of 0.39mg/l with exceedances at borehole K04 in November 2018, boreholes K11 and K12 in February 2020, borehole K12 in March and April 2020 and boreholes K04, K12, K14a and K16 in July 2020. Ammoniacal nitrogen concentrations greater than the compliance limit are recorded in the groundwater at locations up hydraulic gradient of the site as well as at the select down hydraulic gradient boreholes on these dates indicating a source up hydraulic gradient of the landfill.

6.6 Cadmium concentrations in the groundwater at boreholes round the perimeter of the currently permitted site are recorded at concentrations below the compliance limit of 0.0007mg/l on all occasions with the exception of August 2016 and select dates in March, June and December 2020. Concentrations of cadmium an order of magnitude higher than the compliance limit were recorded in August 2016 and March, June and December 2020 in the groundwater at boreholes K02a, K17 and/ or K18 located to the north and up hydraulic gradient of the landfill and in June 2020 at boreholes K11 located down hydraulic gradient of the landfill. The analytical method detection limit used for cadmium concentrations recorded in the groundwater on selected dates in March 2020 was higher than the compliance limit.

6.7 Chloride concentrations in the groundwater at the down hydraulic gradient borehole K04 located to the east of the landfill have frequently exceeded the compliance limit of 250mg/l during the review period as shown on the chemographs at Appendix HRA I. A rising trend in chloride concentrations is recorded at the borehole with concentrations above the compliance limit from March 2014 rising to a high of 1,600mg/l in May 2017. Since May 2017 concentrations of chloride recorded in the groundwater at borehole K04 generally have fluctuated between approximately 600mg/l and 1,000mg/l with a maximum of 1,700mg/l recorded in July 2020. Chloride concentrations were recorded below the compliance limit in the groundwater at borehole K04 in November 2018, May 2019, March 2020 and February 2021. Similar concentrations of chloride are recorded in the groundwater at boreholes K03a and K10 to the north of borehole K04. Generally, the chloride concentrations recorded in the groundwater at borehole K03a are higher than those recorded at boreholes K04 and K10. Borehole K03a is located up hydraulic gradient of the landfill indicating that the source of elevated chloride concentrations is entering the groundwater up hydraulic gradient of the landfill. It is understood that the Environment Agency are aware of the potential up hydraulic gradient sources of chloride to the north of this area of ENRMF including an old landfill in the woodland to the east of Stamford Road, a pond to the west of Stamford Road and the Ministry of Defence site in the woodland.

6.8 Chloride concentrations were recorded above the compliance limit in the groundwater at down hydraulic gradient borehole K14a between July 2014 and November 2015 with a maximum of 500mg/l recorded in October and December 2014. Chloride concentrations in the groundwater at the down hydraulic gradient boreholes K07, K11, K12 and K21 have frequently exceeded the compliance limit of 250mg/l during February to April 2020. Maximum concentrations of 1,415mg/l, 2,321mg/l, 3,545mg/l and 1,026mg/l were recorded in the groundwater at boreholes K07, K11, K12 and K21 respectively in March 2020. Since April 2020 chloride concentrations at the boreholes generally have been recorded below the compliance limit of 250mg/l with exceedances at borehole K11 in November 2020, January 2021 and February 2021. Chloride concentrations at borehole K12 have remained above the compliance limit of 250mg/l throughout the remainder of the review period with concentrations fluctuating around approximately 700mg/l.

6.9 Chloride concentrations at up hydraulic gradient boreholes K02a and K17 located to the north of the landfill frequently exceeded the compliance limit of 250mg/l between May 2014 and November 2019 and generally fluctuate between concentrations of 150mg/l and 410mg/l. In February and March 2020 the concentrations of chloride recorded in the groundwater at boreholes K02a and K17 together with borehole K18 rose by an order of magnitude with maximum concentrations of 3,711mg/l, 3,800mg/l and 5,700mg/l recorded at the boreholes respectively in March 2020. Concentrations at boreholes K17 and K18 rose to a second peak of 1,874mg/l at K17 and 5,700mg/l at K18 in April 2020 following an initial fall in concentrations. Since April 2020 chloride concentrations have remained relatively stable in K02a generally fluctuating between approximately 280mg/l and 480mg/l between April 2020 and December 2020 with higher values of between approximately 400mg/l and 740mg/l between January 2021 and March 2021 with a high of 2100mg/l in February 2021. Chloride concentrations in the groundwater at boreholes K17 and K18 have generally fallen to a low of approximately 500mg/l in December 2020 and of approximately 120mg/l in November 2020 respectively. Further peaks in chloride concentrations in the groundwater at boreholes K17 and K18 were recorded in July 2020 of 1,100mg/l and 1,176mg/l respectively and in December 2020 of 1,200mg/l and 1,354mg/l respectively. Between December 2020 and March 2021 chloride concentrations have generally remained above 1,110mg/l at borehole K17 with a peak of 1,497mg/l recorded in February 2021. Chloride concentrations in the groundwater at borehole K18 were at or below 250mg/l in 2021 with concentrations rising in the second half of February 2021 from 691mg/l to a high of 1,248mg/l in March 2021.

6.10 It is clear that an incident occurred up hydraulic gradient of the site in 2020 causing the rise in chloride concentrations both up and down hydraulic gradient of the site throughout 2020 and into 2021. It is understood that extreme persistent rainfall over the autumn and winter of 2019/ 2020 together with extreme storm events in February 2020 culminated in an incident at the site whereby surface water runoff laden with suspended solids from the waste treatment plant flowed off site into scrub and grassland north of the site cumulating in flooded doline features. Given the limited thickness of Rutland Formation above the Lincolnshire Limestone Formation in the doline features it is considered that contaminated water migrated into the Lincolnshire Limestone Formation from the doline features up hydraulic gradient of the site. There is no evidence that the runoff reached the swallow hole to the north west of the site. As the elevated chloride concentrations are the results of a single incident following extreme weather conditions the chloride concentrations in the groundwater have fallen since the incident. Although chloride concentrations in the boreholes are generally declining it is possible that residual contamination in the soil profile and flushing due to rainfall may result in temporary increases in concentrations in the groundwater. It is anticipated any flushes will be significantly less than the concentrations recorded in March and April 2020. The incident was reported to the Environment Agency and investigations are still ongoing.

6.11 Manganese concentrations in the groundwater at the down hydraulic gradient boreholes occasionally exceed the compliance limit of 0.37mg/l with exceedances at borehole K21 in May 2019, borehole K12 in February 2020 and borehole K04 in May 2020. Manganese concentrations in the groundwater at borehole K03a located to the north east and up hydraulic gradient of the landfill were recorded at concentrations above the compliance limit between October 2015 and February 2015. Manganese concentrations in the groundwater at boreholes K17 and K18 located to the north and up hydraulic gradient of the landfill were recorded at concentrations above the compliance limit between February and May 2020. A manganese concentration was recorded above the compliance limit at borehole K19 located to the west and up hydraulic gradient of the landfill in March 2021. .

6.12 The limit of detection of the analytical method used for naphthalene concentrations recorded in the groundwater in all boreholes round the perimeter of the currently permitted site exceed the compliance limit of 0.00001mg/l on all sampling dates over the review period. There are no naphthalene concentrations recorded in the groundwater round the site above the analytical method detection limit used of 0.001mg/l over the review period.

6.13 Zinc concentrations in the groundwater at the down hydraulic gradient boreholes occasionally exceed the compliance limit of 0.11mg/l with exceedances at borehole K15A in November 2017, at boreholes K04, K07, K11, K12, K16 and K21 in February 2020, at borehole K12 in April 2020, at boreholes K10 and K11 in August 2020 and at borehole K21 in September 2020. The analytical method detection limit of 0.248mg/l used for zinc concentrations recorded in the groundwater in March 2020 was higher than the compliance limit. Zinc concentrations above the compliance limit were recorded in the groundwater at boreholes K01, K02a, K03a, K17 and K18 north and up hydraulic gradient of the landfill in August 2019, at borehole K18 in February 2020, at K17 in April 2020, at boreholes K01 and K02a in May 2020 and at borehole K02a in September 2020. It is considered that the exceedances of the zinc compliance limit in February and April 2020 are associated with the pollution event in 2020.

General groundwater quality

6.14 In general the electrical conductivity (EC) values in the groundwater at the site reflect the concentrations of chloride recorded in the groundwater with elevated EC recorded up hydraulic gradient and to the east of the eastern half of the permitted site. Elevated EC is recorded in the groundwater at all locations with elevated chloride in 2020. This pattern is also seen in concentrations of potassium and sodium in the groundwater. The pH of the groundwater at the site ranges from approximately 6.7 to 8.6 over the review period.

Western extension

6.15 Groundwater quality data is available for a limited number of groundwater samples from a selection of boreholes located round the western extension for dates in March 2020 and January, February and March 2021. It is proposed that compliance limits are set for boreholes in the western extension area following the collection of a minimum of 12 months of monitoring data and prior to landfilling in the western extension to facilitate the assessment of potential seasonal variations in groundwater quality round the western extension. For this initial assessment of groundwater quality at and in the vicinity of the western extension the available groundwater quality data from a number of boreholes located round the western extension have been compared with the compliance limits for the currently permitted site which comprise the Environmental Assessment Limit (EAL) against which the 2021 HRA is assessed for the western extension.

6.16 The hazardous substance arsenic is recorded at concentrations below the proposed EAL of 0.035mg/l in the groundwater round the western extension with the exception of a total arsenic concentration of 0.3135mg/l recorded at borehole K37 at the south western corner of the western extension in March 2021. The dissolved arsenic concentration recorded in the groundwater at borehole K37 on the same date was below the EAL at 0.0032mg/l. There are no concentrations of hazardous substances dichlorprop and trichloroethene recorded in the groundwater round the western extension above the respective analytical method detection limits. There are no concentrations of the hazardous substance toluene recorded in the groundwater round the western extension above the analytical method detection limit with the exception of at borehole K35A along the southern boundary in February 2021 when a concentration of 0.002mg/l was recorded which is above the EAL of 0.001mg/l.

6.17 The non-hazardous pollutant ammoniacal nitrogen is generally recorded at concentrations below the EAL of 0.39mg/l in the groundwater round the western extension with the exception of samples from boreholes K22 and K23 along the western boundary of the southern area in in February 2021 when concentrations of 1.2mg/l and 0.82mg/l respectively were recorded. The non-hazardous pollutants cadmium and chloride are recorded at concentrations below the EALs of 0.007mg/l and 250mg/l respectively in the groundwater round the western extension. Chloride concentrations of between 18mg/l and 87mg/l are recorded in the groundwater round the western extension.

6.18 Dissolved manganese is recorded at concentrations below the EAL of 0.37mg/l in the groundwater round the western extension. Total manganese is recorded at concentrations above the EAL at borehole K37 in the south in January and March 2021 and at boreholes K25, K27, K29 and K31 round the northern area in March 2021 with a maximum concentration of 26mg/l recorded at borehole K37. The dissolved manganese concentration recorded in the groundwater at borehole K37 on the same date was 0.26mg/l. There are no concentrations of the non-hazardous pollutant naphthalene recorded in the groundwater round the western extension above the analytical method detection limits of 0.001mg/l or 0.005mg/l. Dissolved zinc is recorded at concentrations below the EAL of 0.11mg/l in the groundwater round the western extension. Total zinc is recorded at concentrations below the compliance limit in the groundwater round the western extension with the exception of at borehole K37 in January 2021 when a concentration of 0.52mg/l was recorded.

6.19 EC values in the groundwater round the western extension range from 702µS/cm to 1070µS/cm. The pH of the groundwater ranges from 6.8 to 7.2. Potassium concentrations range from 1.1mg/l to 11mg/l, sodium concentrations range from 3.8mg/l to 53mg/l and sulphate concentrations range from 26mg/ to 140mg/l in the groundwater round the western extension.

Environmental Assessment Levels (EALs)

6.20 The EALs used in the 2014 HRA are presented in Table HRA 1 with the exception of the EAL for naphthalene. All EALs were set based on laboratory detection limits, background groundwater quality data or the DWS depending on which was more appropriate at the time that the 2014 HRA was prepared. There are no proposed changes to the EALs as a result of the groundwater quality reviewed in the HRA review with the exception of including arsenic and naphthalene. The EAL for naphthalene has been updated to the general quality for a groundwater body threshold from the Water Framework Directive Directions (reference 16). The same EALs have been applied to the 2021 HRA.

Surface water quality

6.21 The regular discharge of surface water from the site at the permitted discharge point has not yet commenced with the exception of some discharges in January 2021. The surface water quality monitoring results for the discharge location SWSEOFALL in January 2021 are presented at Appendix HRA J. The results of the surface water quality monitoring at the discharge location SWSEOFALL are below the discharge limits set out in Table S3.3 Point source emission to water (other than sewer) emissions limits. Further surface water monitoring will be the subject of the monitoring requirements of and discharge limits set in EP variation number EPR/TP3430GW/V005 for ENRMF landfill when the discharge of surface water from the site recommences. Should further permitted discharge locations be needed for the management of surface water in the western extension these will be the subject of discharge limits set in the permit. No discharge of surface water from the site will take place other than at a permitted discharge point without the relevant permissions from the Environment Agency.

Conclusions of the review of impacts on groundwater quality

6.22 In general groundwater quality down hydraulic gradient of the currently permitted site is below the groundwater quality compliance limits. Any exceedances are intermittent with no sustained upward trends in concentrations recorded. Where compliance limits are exceeded there are elevated concentrations recorded up hydraulic gradient of the site indicating a source up hydraulic gradient of the landfill site.

6.23 Groundwater quality compliance limits for the groundwater monitoring boreholes located down hydraulic gradient of the western extension will be derived following the collection of a minimum 12 months of monitoring data to assess potential seasonal variations in groundwater quality round the western extension and prior to landfilling in the western extension.

6.24 A pollution incident associated with surface water runoff from the waste treatment plant occurred at the site in February/ March 2020 and was reported to the Environment Agency. This incident has had an effect on groundwater quality both up and down gradient of the landfill site but the recorded effect is reducing over time. Investigations are still on going.

6.25 The quality of the surface water discharged from the site at the permitted discharge point in January 2021 was below the discharge limits set out in Table S3.3 Point source emission to water (other than sewer) emissions limits.

6.26 The requisite surveillance tables from the 2014 HRA are reproduced as Table HRA 8 to Table HRA 12. The tables have been amended to include the western extension.

7. Conclusions

7.1 Based on the results of the review of the HRA for ENRMF landfill it is considered that generally the information reviewed since the 2014 HRA was carried out is within the ranges used in the 2014 HRA or, where the values are outside the ranges used in the 2014 HRA, it does not change significantly the results of the 2014 HRA. The LandSim models which form part of the 2014 HRA have been re-run to include the increase in concentrations of the non-hazardous pollutants chloride and manganese in the source term. The re-classification of cadmium and naphthalene as non-hazardous pollutants has been addressed as part of the updated model. The hazardous substance arsenic has been added to the source term determinands included in the model. The re-run LandSim model includes waste porosity revisions, updated hydraulic conductivity values of the clay liner in the WLA and updated infiltration parameters.

7.2 Based on the results of the re-run LandSim model, as discussed in Section 4, it is considered that the increase in concentrations of substances in the leachate and updates to the model do not alter significantly the results of the models and do not change the conclusions of the 2014 HRA. Consequently it is considered that the modelled impact of the site on groundwater as demonstrated in the 2014 HRA complies with Schedule 22 of the Environmental Permitting (England and Wales) Regulations 2016. Schedule 22 of the Environmental Permitting (England and Wales) Regulations 2016 supersedes Schedule 22 of the Environmental Permitting (England and Wales) Regulations 2010 which superseded and revoked the Groundwater Regulations.

7.3 The groundwater compliance limits set in 2014 have been compared with the concentrations of determinands recorded in the groundwater at the site. In general groundwater quality down hydraulic gradient of the currently permitted site is below the groundwater quality compliance limits. Any exceedances are intermittent with no sustained upward trends in concentrations recorded. Where compliance limits are exceeded there are elevated concentrations also recorded up hydraulic gradient of the site indicating a source up hydraulic gradient of the site. A pollution incident occurred at the site in February/ March 2020 and was reported to the Environment Agency. Investigations are still ongoing. It is clear that the incident occurred up hydraulic gradient of the landfill site in 2020 and was not as a result of failure of landfill engineering or leachate level management at the site.

7.4 Based on the results of the review of the 2014 HRA including the monitoring data presented in this report it is considered that ENRMF Landfill Site remains compliant with Schedule 22 to the Environmental Permitting (England and Wales) Regulations 2016.

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7.5 The LandSim model updated as part of this HRA review has been revised to include the proposed western extension. It is proposed that 2m of glacial clay or Rutland Formation will be retained in situ beneath the engineered basal liner of the western extension consistent with the design principles for the permitted western landfill area. The benefits provided by this insitu clay has not been incorporated in the models hence the predicted impacts presented in this 2021 HRA are conservative and the insitu clay provides an additional level of protection within the site design. The results of the revised Landsim model, as discussed in Section 5, show that the site will remain compliant with Schedule 22 of the Environmental Permitting (England and Wales) Regulations 2016 with the addition of the proposed western extension to the currently permitted site.

7.6 Consistent with the currently permitted site, the essential and technical precautions that will be put in place in future waste phases at the site to protect the groundwater from hazardous substances and non-hazardous pollutants include the placement of a basal and perimeter liner system together with a low permeability cap. The leachate level at the site will be managed and maintained below the compliance limit until the concentrations of substances in the leachate have reduced to a level where there will be no significant risk of discernible discharge of hazardous substances and no significant risk of pollution of groundwater by non-hazardous pollutants hence the landfill has reached completion. Completion of the landfill will be determined from the results of the monitoring of leachate quality and in agreement with the Environment Agency.

7.7 It is proposed that the requisite surveillance is extended to include the future phases of the western extension including leachate quality, leachate levels, groundwater quality and surface water quality as set out in the 2021 HRA and/ or the ESID (reference 8). The proposed requisite surveillance is presented in Table HRA 8 to Table HRA 12. Groundwater quality compliance limits for groundwater at the monitoring boreholes located down hydraulic gradient of the western extension will be derived following the collection of a minimum of 12 months of monitoring data and prior to landfilling in the western extension such that potential seasonal variations in groundwater quality round the western extension can be assessed.

8. References

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4. MJCA, 2011. Preliminary hydrogeological risk assessment for the proposed extension to the existing hazardous waste landfill site at East Northants Resource Management Facility. Report reference AU/KCE/CN/2719/01.

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14. MJCA, 2015. East Northants Resource Management Facility - Response to the notice of request for further information dated 11 March 2015. Schedule 1 to the letter to M Townshend of the Environment Agency dated 22 April 2015. Report reference AU/KCE/AW/5469/01.

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16. The Water Framework Directive (Standards and Classification) Directions (England and Wales) 2015.

17. Ellis J.C., Turrell J.A. and Blackmore K.M. 2002. Techniques for the interpretation of Landfill Monitoring Data. Guidance Notes. Final R & D Technical Report P1-471. Environment Agency Research Contractor: WRc plc.

18. Golder Associates. ConSim 2 help file.

TABLES

Table HRA 1

Comparison of the leachate source term used in the 2014 HRA with the results of the leachate quality monitoring carried out between May 2014 and November 2020

Determinand	Landfill phases	Environmental assessment level (EAL) in 2014 HRA	2014 HRA source term concentration (mg/l)			Leachate concentration recorded between May 2014 and February 2021 (mg/l)		
			Minimum	Most Likely	Maximum	Minimum	Mean	Maximum
Hazardous substances								
Arsenic	CP and WLA	0.035[A]	***0.02***	*0.52*	*15.1*	0.003	**0.87**	14.38 (14.38 x1.2 = **17.3**)
Dichloroprop	CP and WLA	0.00005	0.009	1.3	16	0.00002	0.024	0.70
Toluene	CP and WLA	0.001	0.030	4.2	180	0.001	0.001	0.043
Trichloroethene	CP and WLA	0.001	0.12	0.79	18	0.001	0.010	0.1
Non-hazardous pollutants								
Ammoniacal nitrogen	CP	0.39	112	325	1700	2.2	286	**2460**
	WLA (haz only)		92	181	1142	0.4	**193**	**2460**
Cadmium	CP and WLA	0.0007	0.00021	0.014	1.7	0.00003	**0.0776**	0.3
Chloride	CP *(Phases 1 to 5)*	250	5,330	12,550	73,200	4.2	**25,358**	***89,000***
	WLA (haz only)		5,330	12,550	15,000	4.2	**30,693**	**120,000**
Manganese	CP and WLA	0.46	0.4	3.3	71	0.001	**5.51**	**310**
Naphthalene	CP and WLA	0.000075	0.0042	0.67	19	0.001	0.159	9.9
Zinc	CP and WLA	0.11	0.023	1	60	0.004	1	**76**

Notes:

In the 2014 HRA the currently permitted landfill (CP) comprised Phases 1 to 5 and the Western Landfill Area (WLA) comprised the future landfill Phases 6 to 11. Values used for the source term for both the CP and WLA derived from the concentrations of determinands recorded in the hazardous waste (Phase 2B onwards) and in the co-disposal waste phases (Phases 1 to 2A) at the site where they are elevated relative to the respective value from the hazardous waste phases alone. The leachate quality data for all phases from May 2014 to February 2021 have been compared with these source term values. For the determinands ammoniacal nitrogen and chloride the leachate quality data for Phases 1 to 5 have been compared with the CP 2014 HRA source term and the leachate quality data for Phases 2b to 6 have been compared with the WLA 2014 HRA source term. Arsenic was not modelled in 2014. The values in the table for 2014 HRA source term concentration are derived from leachate quality monitoring carried out in the landfill between 2004 and February 2014 for comparative purposes. Consistent with the other source term values, the minimum arsenic concentration comprises the 25th percentile of the data, the most likely comprise the average value of the data and the maximum comprises the maximum values from the data plus 20%.

The leachate concentrations are the minimum, mean and maximum from the data for May 2014 to February 2021. Outliers have been removed using the methodology from the Environment Agency guidance notes (reference 17).

BOLD denotes the concentration recorded in the leachate that exceed those used in the LandSim models in the 2014 HRA and are used in the 2021 HRA review updated model run.

[A] The EAL for arsenic comprises the maximum concentration recorded in the groundwater up hydraulic gradient of the permitted landfill. The EAL for naphthalene has been updated to the general quality for a groundwater body threshold from the Water Framework Directive Directions (reference 16)

[B]

Table HRA 2

Input parameters for the LandSim hydrogeological model – chemical and attenuation properties for arsenic

Parameter	Pathway	K_d (l/kg)		
		Minimum	Most likely	Maximum
Hazardous substances				
Arsenic	Clay liner	25		250
	Lincolnshire Limestone	25		31

Notes:

Probability density functions key:

- Unshaded: single value
- Solid shading: uniform distribution

Derivation of parameter values:

The K_d values are from reference 18

Table HRA 3

A comparison of the values of the parameters used in the 2014 HRA with the information for the site collected since the 2014 HRA was prepared

Parameter	Unit	Phase	Values used in the 2014 HRA model			Values based on information collected since the 2014 HRA was prepared			
			Minimum	Most likely	Maximum	Minimum	Mean	Maximum	Source/justification
Landfill parameters									
Waste porosity	Fraction	All	0.01		0.2	**0.37**		**0.56**	Effective porosity or drainable porosity of waste values used as *waste porosity* in the 2014 LandSim models added to the *field capacity* values in the models (see section 2.10 of report).
Engineered barrier properties – Clay liner									
Clay liner thickness	m	WLA		**1.0**		1.05		1.48	The thickness is based on the surveyed thickness of the mineral liner presented in the CQA reports for the construction of Phases 6A, 6B, 6C and 10.
Hydraulic conductivity	m/s	WLA – Phases 6 and 10	6.9E-11	3.0E-10	1.0E-09	1.3E-11 **(5.6E-11)**	1.5E-10 **(9.3E-11)**	9.8E-10 **(2.7E-10)**	Based on clay liner permeability values in the CQA reports for the construction of Phases 6A, 6B, 6C and 10. Value in brackets comprises the lower quartile, the geometric mean and the 90th percentile of the values used for Phases 6 and 10 in the updated HRA review model.

Table HRA 3

A comparison of the values of the parameters used in the 2014 HRA with the information for the site collected since the 2014 HRA was prepared

Parameter	Unit	Phase	Values used in the 2014 HRA model			Values based on information collected since the 2014 HRA was prepared			
			Minimum	Most likely	Maximum	Minimum	Mean	Maximum	Source/justification
		WLA – Phases 7 to 9 and 11					**1.4E-10**	**Log normal with a standard deviation of 1.7E-10**	Calculated from the results of hydraulic conductivity tests of 270 samples from phases 6 and 10 at ENRMF and phases 3 to 7A at Thornhaugh which have been constructed with the same clay materials proposed for the future cells with a CQA criteria for the construction of compacted clay landfill liner of 1 x 10^{-9}m/s.
Dry bulk density	g/cm³	All	**1.49**	**1.64**	**1.78**	1.55	1.68	1.80	Based on the dry density values in the CQA reports for Phases 6A, 6B, 6C and 10.
Moisture content	Fraction	All	**0.14**		**0.25**	0.14		0.27	Based on the moisture content values in the CQA reports for the Phases 6A, 6B, 6C and 10.

Table HRA 3

A comparison of the values of the parameters used in the 2014 HRA with the information for the site collected since the 2014 HRA was prepared

Parameter	Unit	Phase	Values used in the 2014 HRA model			Values based on information collected since the 2014 HRA was prepared			
			Minimum	Most likely	Maximum	Minimum	Mean	Maximum	Source/justification
Unsaturated zone – Unsaturated Lincolnshire Limestone									
Unsaturated zone thickness	m	Current permitted landfill		**8.68**	Normal, with a standard deviation of 1.26		8.03	Normal, with a standard deviation of 1.35	Based on groundwater level monitoring data from May 2014 to March 2021.
		Western landfill area		**9.49**	Normal, with a standard deviation of 1.66		9.15	Normal, with a standard deviation of 1.70	Based on groundwater level monitoring data from May 2014 to March 2021.
Aquifer pathway –Lincolnshire Limestone									
Saturated zone thickness	m	Both		**7.42**	Normal, with a standard deviation of 1.44		7.77	Normal, with a standard deviation of 1.45	Based on groundwater level monitoring data from May 2014 to March 2021.

Notes
BOLD denotes the values used in the 2021 HRA review updated LandSim model run.

Table HRA 4
Leachate source term for the 2021 HRA including the western extension

Determinand	Landfill phases	Environmental assessment level (EAL) (mg/l)	2021 HRA source term concentration (mg/l)			Comments
			Minimum	Most Likely	Maximum	
Hazardous substances						
Arsenic	All	0.035	0.02	0.87	17.3	See Table HRA 1
Dichloroprop	All	0.00005	0.009	1.3	16	From 2014 HRA
Toluene	All	0.001	0.030	4.2	180	From 2014 HRA
Trichloroethene	All	0.001	0.12	0.79	18	From 2014 HRA
Non-hazardous pollutants						
Ammoniacal nitrogen	Phases 1 to 5	0.39	112	325	2952	Minimum and most likely from 2014 HRA. See footnote for maximum value.
	Phase 6 onwards		92	193	2952	Minimum from 2014 HRA. See Table HRA 1 for updated most likely value and footnote for maximum value.
Cadmium	All	0.0007	0.00021	0.0776	1.7	From 2014 HRA. See Table HRA 1 for updated most likely value.
Chloride	Phases 1 to 5	250	9150	23,600	106,800	See footnote
	Phase 6 onwards		10,000	28,500	144,000	See footnote
Manganese	All	0.46	0.4	5.51	372	Minimum from 2014 HRA. See Table HRA 1 for updated most likely value. See footnote for maximum.
Naphthalene	All	0.000075	0.0042	0.67	19	From 2014 HRA
Zinc	All	0.11	0.023	1	91.2	Minimum and most likely from 2014 HRA. See footnote for maximum.

NOTE: Values are derived from the 2014 HRA where appropriate and as indicated or the minimum comprises the 25th percentile of the data, the most likely comprise the average value of the data and the maximum comprises the maximum values from the data plus 20% of the leachate data from 2010 to 2020. Outliers have been removed using the methodology from the Environment Agency guidance notes (reference 18).

Table HRA 5

Input parameters for the 2021 LandSim hydrogeological risk assessment model to include the western extension - site parameters

Parameter	Units	Part of site	Minimum	Most likely	Maximum	Probability density function	Reference / justification
Landfill parameters							
Infiltration to waste	mm/year	All		609		Normal with a 10% standard deviation	Based on the annual average precipitation for the period 1981 to 2010 for the Wittering Airfield rainfall monitoring station (reference 8)
Cap design infiltration – clay cap	mm/year	All		1.6		Single	Appendix HRA E
Duration of management control	years	All		20,000		Single	The management control period set in the 2021 HRA LandSim model is 20,000 years. Management control will continue until such a time when the site no longer presents a significant risk to groundwater. This period will be determined from the results of leachate quality monitoring and in agreement with the Environment Agency. A management control period of 60 years is included in the sensitivity analyses consistent with that carried out as part of post submission consultation on the 2014 HRA.

Table HRA 5

Input parameters for the 2021 LandSim hydrogeological risk assessment model to include the western extension - site parameters

Parameter	Units	Phase	Minimum	Most likely	Maximum	Probability density function	Reference/justification
Basal area of the landfill	ha	Permitted eastern landfill area		10.62		Single	From 2014 HRA
		Permitted western landfill area (Phase 6 & 10)		2.3		Single	Apportionment from 2014 HRA total for WLA of 8.3 approximated from CQA as built drawings (references X to Y)
		Permitted western landfill area (Phase 7 to 9 & 11)		6.0		Single	Apportionment from 2014 HRA total for WLA of 8.3 (see above)
		Northern area of western extension		4.70		Single	From material movement calculations for Scenario 1B Area 1N (approximated to fit dimensions)
		Southern area of western extension		9.49		Single	From material movement calculations for Scenario 1B Area 1S, 2 & 3 (approximated to fit dimensions)
Surface area of the landfill	ha	Permitted eastern landfill area		12.75		Single	From 2014 HRA
		Permitted western landfill area (Phase 6 & 10)		4.3		Single	Apportionment from 2014 HRA total for WLA of 11.2 approximated from CQA as built drawings (references 11 to 14)

Table HRA 5

Input parameters for the 2021 LandSim hydrogeological risk assessment model to include the western extension - site parameters

Parameter	Units	Phase	Minimum	Most likely	Maximum	Probability density function	Reference/justification
		Permitted western landfill area (Phase 7 to 9 & 11)		6.9		Single	Apportionment from 2014 HRA total for WLA of 11.2 (see above)
		Northern area of western extension		6.51		Single	From material movement calculations for Scenario 1B Area 1N (approximated to fit dimensions)
		Southern area of western extension		14.45		Single	From material movement calculations for Scenario 1B Area 1S, 2 & 3 (approximated to fit dimensions)
Waste thickness	m	Permitted eastern landfill area		19.0		Single	Average thickness of waste estimated based on the volume of waste (2,215,590m^3) divided by the mid-point between the surface area of the landfill and the area the base of the landfill.
		Permitted western landfill area (Phases 6 & 10)		15.2		Single	Average thickness of waste estimated based on the volume of waste (501,995m^3) divided by the mid-point between the surface area of the landfill and the area the base of the landfill.
		Permitted western landfill area (Phases 7 to 9 & 11)		14.1		Single	Average thickness of waste estimated based on the volume of waste (914,120m^3) divided by the mid-point between the surface area of the landfill and the area the base of the landfill.

Table HRA 5

Input parameters for the 2021 LandSim hydrogeological risk assessment model to include the western extension - site parameters

Parameter	Units	Phase	Minimum	Most likely	Maximum	Probability density function	Reference/justification
		Northern area of western extension		13.8			Average thickness of waste estimated based on the volume of waste (774,060m^3) divided by the mid-point between the surface area of the landfill and the area the base of the landfill.
		Southern area of western extension		14.7		Single	Average thickness of waste estimated based on the volume of waste (1,759,460m^3) divided by the mid-point between the surface area of the landfill and the area of the base of the landfill.
Waste porosity	fraction	All	0.37		0.56	Uniform	See Table HRA 3
Waste density	kg/l	All		1.53		Single	From 2014 HRA
Waste field capacity	fraction	All		0.36		Single	From 2014 HRA
Head of leachate when surface breakout occurs	m	Permitted eastern landfill area		6.5			From 2014 HRA
		Permitted western landfill area		3.7			From 2014 HRA
		Northern area of western extension		4.0			Minimum depth to top of clay basal liner below top of constructed bunds on southern boundary of phase (Figure SRA 5 drawing reference AU/KCW12-20/22129)

Table HRA 5

Input parameters for the 2021 LandSim hydrogeological risk assessment model to include the western extension - site parameters

Parameter	Units	Phase	Minimum	Most likely	Maximum	Probability density function	Reference/justification
		Southern area of western extension		4.0			Minimum depth to top of clay basal liner below top of constructed bunds on northern boundary of phase 21 (Figure SRA 5 drawing reference AU/KCW/12-20/22129)
Specified head of leachate on liner	m	All		1		Single	The compliance limit has been modelled as 1m above the top of the basal liner. Sensitivity analysis for short term 5m limit in currently permitted ENRMF
Flexible membrane liner							
Pin holes	ha^{-1}	All	0		25	Triangular	From 2014 HRA
Holes	ha^{-1}	All	0		5	Triangular	
Tears	ha^{-1}	All	0	0.1	2	Triangular	
Onset of degradation	years	All		150		Single	
Time for defects to double	years	All		100		Single	
Clay liner							
Clay liner thickness	m	Permitted eastern landfill area	1.0	1.5	2.5	Triangular	From 2014 HRA

Table HRA 5

Input parameters for the 2021 LandSim hydrogeological risk assessment model to include the western extension - site parameters

Parameter	Units	Phase	Minimum	Most likely	Maximum	Probability density function	Reference/justification
		Permitted western landfill area and western extension		1.0		Single	Design thickness.
Hydraulic conductivity	m/s	Permitted eastern landfill area	4.1×10^{-11}	6.0×10^{-11}	1.5×10^{-10}	Log Triangular	From 2014 HRA
		Permitted western landfill area (Phases 6 and 10)	5.6×10^{-11}	9.3×10^{-11}	2.7×10^{-10}	Log Triangular	Based on CQA data for the clay used for liner material in the constructed phases 6 and 10 in the WLA. The minimum comprises the lower quartile, the most likely comprises the geometric mean and the maximum comprises the 90th percentile
		Permitted western landfill area (Phase 7 to 9 & 11) and western extension		1.4×10^{-10}		Log normal with a standard deviation of 1.7×10^{-10}	Calculated from the results of hydraulic conductivity tests of 270 samples from phases 6 and 10 at ENRMF and phases 3 to 7A at Thornhaugh which have been constructed with the same clay materials proposed for the future cells with a CQA criteria for the construction of compacted clay landfill liner of 1×10^{-9}m/s.

Table HRA 5

Input parameters for the 2021 LandSim hydrogeological risk assessment model to include the western extension - site parameters

Parameter	Units	Phase	Minimum	Most likely	Maximum	Probability density function	Reference/justification
Fraction of organic carbon	Fraction	All	0.002	0.004	0.01	Triangular	From 2014 HRA
Dry bulk density	g/cm^3	All	1.49	1.64	1.78	Triangular	From 2014 HRA
Moisture content	Fraction	All	0.14		0.25	Log Triangular	From 2014 HRA
Longitudinal pathway dispersivity	m	Permitted eastern landfill area	0.1	0.15	0.25	Triangular	From 2014 HRA
		All others		0.1		Single value	
Unsaturated zone – Unsaturated Lincolnshire Limestone[1]							
Unsaturated zone thickness	m	Permitted eastern landfill area		7.97		Normal, with a standard deviation of 1.24	Updated as error in respect of borehole K12 levels in 2014 HRA. Based on groundwater level monitoring data from November 2003 to March 2021.
		Permitted western landfill area		9.29		Normal with a standard deviation of 1.70	
		Northern area of western extension		6.47		Normal with a standard deviation of 1.48	Based on groundwater level monitoring data from November 2003 to March 2021.

Table HRA 5

Input parameters for the 2021 LandSim hydrogeological risk assessment model to include the western extension - site parameters

Parameter	Units	Phase	Minimum	Most likely	Maximum	Probability density function	Reference/justification
		Southern area of western extension		10.66		Normal with a standard deviation of 0.76	
Hydraulic conductivity	m/s	All	1.16×10^{-5}	5.0×10^{-5}	1.16×10^{-4}	Log Triangular	From 2014 HRA
Moisture content	Fraction	All	0.004		0.01	Uniform	From 2014 HRA
Fraction of organic carbon	Fraction	All	0.0007		0.0009	Uniform	From 2014 HRA
Bulk density	kg/l	All		2.0		Single value	From 2014 HRA
Longitudinal pathway dispersivity	m	Permitted eastern landfill area		0.797		Normal, with a standard deviation of 0.124	10% of pathway length (reference 18 of 2014 HRA).
		Permitted western landfill area		0.929		Normal, with a standard deviation of 0.170	
		Northern area of western extension		0.647		Normal, with a standard deviation of 0.148	

Table HRA 5

Input parameters for the 2021 LandSim hydrogeological risk assessment model to include the western extension - site parameters

Parameter	Units	Phase	Minimum	Most likely	Maximum	Probability density function	Reference/justification
		Southern area of western extension		1.066		Normal, with a standard deviation of 0.076	
Aquifer pathway – Lincolnshire Limestone							
Saturated zone thickness	m	All		8.16		Normal, with a standard deviation of 1.25	Based on groundwater level monitoring data from November 2003 to March 2021.
Hydraulic conductivity	m/s	All	1.16×10^{-5}	5.0×10^{-5}	1.16×10^{-4}	Log Triangular	From 2014 HRA
Aquifer pathway length	m	Permitted eastern landfill area	355		655	Uniform	The range of distances to the down hydraulic gradient compliance point (site boundary).
		Permitted western landfill area (Phase 6 & 10)	355		685	Uniform	
		Permitted western landfill area (Phase 7 to 9 & 11)	355		695	Uniform	
		Northern area of western extension	695		1135	Uniform	

Table HRA 5

Input parameters for the 2021 LandSim hydrogeological risk assessment model to include the western extension - site parameters

Parameter	Units	Phase	Minimum	Most likely	Maximum	Probability density function	Reference/justification
		Southern area of western extension	40		695	Uniform	
Hydraulic gradient	None	All	0.0083	0.0120	0.0136	Triangular	Based on the mean and interquartile range of gradients calculated between pairs of up and down hydraulic gradient boreholes at the site from groundwater level monitoring data from November 2003 to March 2021. The use of an interquartile range eliminates values which are sporadic and unrepresentative of the hydraulic gradient beneath the majority of the site.
Aquifer pathway width	m	Permitted eastern landfill area		425		Single	Updated from the 2014 HRA
		Permitted western landfill area (Phase 6 & 10)		130		Single	Apportionment from 2014 HRA total for WLA. Approximated from CQA as built drawings (references 11 to 14) and areas.
		Permitted western landfill area (Phase 7 to 9 & 11)		202		Single	

Table HRA 5

Input parameters for the 2021 LandSim hydrogeological risk assessment model to include the western extension - site parameters

Parameter	Units	Phase	Minimum	Most likely	Maximum	Probability density function	Reference/justification
		Northern area of western extension		148		Single	Approximate average width of the base of the western landfill area perpendicular to groundwater flow direction.
		Southern area of western extension		221		Single	
Pathway porosity	Fraction	All	0.004		0.01	Uniform	From the 2014 HRA
Longitudinal pathway dispersivity	m	All	4.0		113.5	Uniform	10% of minimum and maximum pathway length (reference 18 of 2014 HRA).
Transverse dispersivity	m	All	0.4		11.35	Uniform	1% of minimum and maximum pathway length (reference 18 of 2014 HRA).

Notes

1 For the purpose of assessing the risk from the western permitted landfill and the western extension it is assumed conservatively that the glacial till and/ or Rutland Formation beneath the site is not present.

Table HRA 6

Results of the re-run HRA review LandSim model for hazardous substances and non-hazardous pollutants at ENRMF Landfill Site

	Phases contributing to the predicted receptor concentration	Environmental Assessment Level (EAL) (mg/l)	UK Drinking Water Standard (mg/l)[1]	Time taken for breakthrough of the contaminant at the 95th percentile (years)[2]	Time taken to exceed the EAL at the 95th percentile (years)[3]	Maximum concentration of the contaminant at the 95th percentile [4]	Time taken for breakthrough at the 50th percentile (years)[2]	Time taken to exceed the EAL at the 50th percentile (years)[3]	Maximum concentration at the 50th percentile [4]
Hazardous substances									
Arsenic	Phases 1 to 5	0.035 UKTAG2016 LOQ 0.005	0.01	-	-	-	-	-	-
	Phases 6 and 10			15,600	-	6.7E-08	-	-	-
	Phases 7 to 9 and 11			15,200		5.3E-06			
Dichlorprop	Phases 1 to 5	0.00005	0.0001Pesticides	-	-	-	-	-	-
	Phases 6 and 10			-	-	-	-	-	-
	Phases 7 to 9 and 11			-	-	-	-	-	-
Toluene	Phases 1 to 5	0.001	0.001Benzene	-	-	-	-	-	-
	Phases 6 and 10			-	-	-	-	-	-
	Phases 7 to 9 and 11			-	-	-	-	-	-
Trichloroethene	Phases 1 to 5	0.001	0.0001	-	-	-	-	-	-
	Phases 6 and 10			-	-	-	-	-	-
	Phases 7 to 9 and 11			-	-	-	-	-	-
Non-hazardous pollutants									
Ammoniacal N	Both	0.39	0.39	120	-	2.5E-04	340	-	1.9E-08
Cadmium	Both	0.0007	0.005	-	-	-	-	-	-
Chloride	Both	250	250	35	-	159	45	-	55
Manganese	Both	0.46	0.05	11,650	-	7.2E-04	-	-	-
Naphthalene	Both	0.000075	0.0001PAHs	-	-	-	-	-	-
Zinc	Both	0.11	3	15,650	-	7.8E-09	-	-	-

Notes

The concentrations for hazardous substances are those predicted at the monitoring point adjacent to the boundary of the respective phases in LandSim.

The concentrations for non-hazardous pollutants are those predicted at the site boundary from the cumulative impact of all phases

The derivations of the EALs are explained in the 2014 HRA

1. For indicative purposes where no drinking water standards exist for a determinand with the exception of zinc, a value for a similar determinand is presented and the name of the similar determinand is shown in superscript to the right of the standard. The standard for zinc is derived from the Surface Waters (Abstraction for Drinking Water) (Classification) Regulations 1996.
2. Where the time taken for the breakthrough of a contaminant is not shown there is no breakthrough of the contaminant over the 20,000 years modelled.
3. Where the time taken to exceed the EAL is not shown there is no exceedance of the EAL over the 20,000 years modelled.
4. Where the maximum concentration is not shown there is no concentration reported above 1×10^{-10}mg/l

Table HRA 7

Results of the 2021 HRA LandSim model for hazardous substances and non-hazardous pollutants at ENRMF Landfill Site to include the western extension

	Phases contributing to the predicted receptor concentration	Environmental Assessment Level (EAL) (mg/l)	UK Drinking Water Standard (mg/l)[1]	Time taken for breakthrough of the contaminant at the 95th percentile (years)[2]	Time taken to exceed the EAL at the 95th percentile (years)[3]	Maximum concentration of the contaminant at the 95th percentile [4]	Time taken for breakthrough at the 50th percentile (years)[2]	Time taken to exceed the EAL at the 50th percentile (years)[3]	Maximum concentration at the 50th percentile [4]
Hazardous substances									
Arsenic	Permitted eastern landfill area	0.035 UKTAG2016 LOQ 0.005	0.01	-		-	-	-	-
	Permitted western landfill area (Phases 6 & 10)			14,100	-	1.9E-06	-	-	-
	Permitted western landfill area (Phases 7 to 9 & 11)			14,100		1.8E-05	-	-	-
	Northern area of western extension			10,000		2.9E-04	-	-	-
	Southern area of western extension			13,700		8.6E-06	-	-	-
Dichlorprop	Permitted eastern landfill area	0.00005	0.0001Pesticides	-	-	-	-	-	-
	Permitted western landfill area (Phases 6 & 10)			-	-	-	-	-	-
	Permitted western landfill area (Phases 7 to 9 & 11)			-	-	-	-	-	-
	Northern area of western extension			-	-	-	-	-	-
	Southern area of western extension			-	-	-	-	-	-
Toluene	Permitted eastern landfill area	0.001	0.001Benzene	-	-	-	-	-	-
	Permitted western landfill area (Phases 6 & 10)			-	-	-	-	-	-
	Permitted western landfill area (Phases 7 to 9 & 11)			-	-	-	-	-	-
	Northern area of western extension			-		-	-	-	-
	Southern area of western extension			-	-	-	-	-	-
Trichloroethene	Permitted eastern landfill area	0.001	0.0001	-	-	-	-	-	-
	Permitted western landfill area (Phases 6 & 10)			-	-	-	-	-	-
	Permitted western landfill area (Phases 7 to 9 & 11)			-	-	-	-	-	-
	Northern area of western extension			-	-	-	-	-	-
	Southern area of western extension			-	-	-	-	-	-
Non-hazardous pollutants									
Ammoniacal N	Both	0.39	0.39	100	-	1.7E-03	250	-	1.6E-07
Cadmium	Both	0.0007	0.005	-	-	-	-	-	-
Chloride	Both	250	250	39	-	250	53	-	89
Manganese	Both	0.46	0.05	7,100	-	0.01	-	-	-
Naphthalene	Both	0.000075	0.0001PAHs	-	-	-	-	-	-
Zinc	Both	0.11	3	10,000	-	4.0E-04	-	-	-

Notes

The concentrations for hazardous substances are those predicted at the monitoring point adjacent to the boundary of the respective phases in LandSim.

The concentrations for non-hazardous pollutants are those predicted at the site boundary from the cumulative impact of the all phases.

The derivations of the EALs are explained in the 2014 HRA

1. For indicative purposes where no drinking water standards exist for a determinand with the exception of zinc, a value for a similar determinand is presented and the name of the similar determinand is shown in superscript to the right of the standard. The standard for zinc is derived from the Surface Waters (Abstraction for Drinking Water) (Classification) Regulations 1996.
2 Where the time taken for the breakthrough of a contaminant is not shown there is no breakthrough of the contaminant over the 20,000 years modelled.
3 Where the time taken to exceed the EAL is not shown there is no exceedance of the EAL over the 20,000 years modelled.
4 Where the maximum concentration is not shown there is no concentration reported above 1 x 10^{-10}mg/l

Table HRA 8
The proposals for the monitoring of leachate, groundwater and surface water at ENRMF

	Monitoring point	Frequency	Determinands
Leachate	Operational and future Phases		
	MEPP - one sampling point per phase	Monthly	Leachate level.
		Quarterly	Ammoniacal nitrogen, chloride, pH, electrical conductivity, calcium, chromium, copper, lead, iron, nickel, arsenic, magnesium, total sulphates, potassium, toluene, dichlorprop, naphthalene, trichloroethene, chemical oxygen demand, biochemical oxygen demand, total alkalinity, cadmium, manganese and zinc.
		Annually	Antimony, selenium, fluoride, molybdenum, barium, DOC and a screen for hazardous substances. Depth to base of monitoring well.
	Non Operational Phases[1]		
	MEPP - one sampling point per phase	Quarterly	Leachate level
		Annually	Ammoniacal nitrogen, chloride, pH, electrical conductivity, nickel, toluene, dichlorprop, naphthalene, trichloroethene, chemical oxygen demand, biochemical oxygen demand, cadmium, manganese, zinc, total sulphates, total alkalinity ($CaCO_3$), sodium, arsenic, potassium, calcium, magnesium, chromium, iron, lead, copper. Depth to base of monitoring well.
		Once every 4 years	Antimony, barium, molybdenum, selenium, fluoride, DOC and a screen for hazardous substances.
Groundwater	Boreholes: K01, K02A, K03A, K04, K05, K06A, K07, K08, K10, K11, K12, K13A, K14A, K15A, K16, K17, K18, K19, K20, K21, K22, K23, K24, K25, K26, K27, K28, K29, K30, K31, K32, K34, K35A, K36, K37 and future borehole K33.	Quarterly	Water level, pH, electrical conductivity, ammoniacal nitrogen, chloride, manganese, zinc Cadmium, dichlorprop, naphthalene, toluene and trichloroethene
		Annually	Depth to base of monitoring well, total alkalinity, magnesium, potassium, total sulphates, calcium, sodium, chromium, copper, iron, lead and nickel
		Annually for first six years of operation	Hazardous substances detected in the leachate plus barium, molybdenum, antimony, selenium, fluoride, DOC. After the initial 6 year monitoring period for hazardous substances, if the results of quarterly or annual monitoring suggest increasing trends in hazardous substances, the operator shall undertake a full leachate hazardous substances screen also.
Surface water	Monitoring location SWSEOFALL and future permitted discharge locations	Monthly	pH, electrical conductivity, total suspended solids, ammoniacal nitrogen, chloride and visual oil and grease.

Notes:
The locations of the monitoring points are shown on Figure ESID 10 (drawing reference AU/KCW/02-21/22247)
[1] Non Operational Phases are defined in Variation number EPR/TP3430GW/V005 as phases that have a final engineered cap.

Table HRA 9

The risk based monitoring scheme and proposed compliance limits and control levels for leachate levels at ENRMF during the operational phase and post closure managed phase of the landfill

Criterion Objective **To identify an unacceptable increase in leakage of leachate over that calculated in the HRA**	
Measurement	Leachate level in m depth above the top of the mineral liner
Frequency	Monthly (quarterly in non operational phases see Table HRA 8)
Monitoring points	Leachate level monitoring borehole - KCLW1A1, KCLW1B1, KCLW2A1, KCLW2B1, KCLW2B3, KCLW3A2, KCLW3A3, KCLW3B2, KCLW3B3, KCLW4A2, KCLW4A3, KCLW4B2, KCLW4B3, KCLW5A2, KCLW5A3, KCLW5B2, KCLW5B3, KCLW6A2, KCLW6B2, KCLW6C2, KCLW6C3, KCLW10A2, KCLW10A3 and all future leachate monitoring locations in the currently permitted landfill and in the western extension. Leachate extraction wells – KCLW1A2, KCLW1B2, KCLW2A2, KCLW2B2, KCLW3A1, KCLW3B1, KCLW4A1, KCLW4B1, KCLW5A1, KCLW5B1, KCLW6A1, KCLW6B1, KCLW6C1, KCLW10A1 and all future leachate extraction locations in the currently permitted landfill and in the western extension.
Compliance limit	**Currently permitted landfill** During the period of operation of the soil treatment plant Leachate level shall not exceed 5m depth of leachate above the top of the mineral liner in the leachate monitoring boreholes and 6m depth of leachate above the top of the mineral liner in the leachate extraction wells Once the soil treatment plant becomes non operational the leachate level shall not exceed 1m depth of leachate above the top of the mineral liner in the leachate monitoring boreholes and 2m depth of leachate above the top of the mineral liner in the leachate extraction wells **Western extension** Leachate level shall not exceed 1m depth of leachate above the top of the mineral liner in the leachate monitoring boreholes and 2m depth of leachate above the top of the mineral liner in the leachate extraction wells
Control level	**Currently permitted landfill** During the period of operation of the soil treatment plant Leachate level shall not exceed 4.5m depth of leachate above the top of the mineral liner in the leachate monitoring boreholes and 5.5m depth of leachate above the top of the mineral liner in the leachate extraction wells Once the soil treatment plant becomes non operational the leachate level shall not exceed 0.75m depth of leachate above the top of the mineral liner in the leachate monitoring boreholes and 1.75m depth of leachate above the top of the mineral liner in the leachate extraction wells **Western extension** Leachate level shall not exceed 0.75m depth of leachate above the top of the mineral liner in the leachate monitoring boreholes and 1.75m depth of leachate above the top of the mineral liner in the leachate extraction wells
Control level test	Leachate level exceeds the control level by 0.75m on more than three consecutive occasions

Contingency action	**Response time**
Advise the Environment Agency in response to an exceedance of the compliance limit	1 month
Increase the monitoring frequency to weekly	1 month
Undertake investigation work to identify the cause of the rise in leachate levels	3 months
Report to the Environment Agency on the re-appraisal of risks and options for corrective measures	6 months
If the risks are acceptable re-evaluate the assessment criteria	6 months
If the risks are unacceptable implement corrective measures	12 months

Notes:
The locations of the monitoring wells and leachate extraction wells are shown on Figure HRA 2 and Figure ESID 10.

Table HRA 10

The risk based monitoring scheme and proposed compliance limits and control levels for leachate quality at ENRMF during the operational phase and post closure managed phase of the landfill

Criterion Objective			
To identify an unacceptable increase in the concentration of a component in the leachate over that calculated in the HRA			
Measurement	Leachate quality		
Frequency	See Table HRA 8		
Monitoring points	Leachate level monitoring borehole - KCLW1A1, KCLW1B1, KCLW2A1, KCLW2A3, KCLW2B1, KCLW2B3, KCLW3A2, KCLW3A3, KCLW3B2, KCLW3B3, KCLW4A2, KCLW4A3, KCLW4B2, KCLW4B3, KCLW5A2, KCLW5A3, KCLW5B2, KCLW5B3, KCLW6A2, KCLW6B2, KCLW6C2, KCLW6C3, KCLW10A2, KCLW10A3 and all future leachate monitoring locations in the currently permitted landfill and in the western extension. Leachate extraction wells – KCLW1A2, KCLW1B2, KCLW2A2, KCLW2B2, KCLW3A1, KCLW3B1, KCLW4A1, KCLW4B1, KCLW5A1, KCLW5B1, KCLW6A1, KCLW6B1, KCLW6C1, KCLW10A1 and all future leachate extraction locations in the currently permitted landfill and in the western extension.		
Compliance limit	Not relevant		
Control level [a]	**Determinand**	**Concentration that shall not be exceeded (mg/l)**	
		Phases 1 to 5 in the currently permitted landfill	Remainder of currently permitted site and western extension
	Arsenic	17.3	
	Dichlorprop	16	
	Toluene	180	
	Trichloroethene	18	
	Ammoniacal nitrogen	2952	
	Cadmium	1.7	
	Chloride	106,800	144,000
	Manganese	372	
	Naphthalene	19	
	Zinc	91.2	
Control level test	Concentration exceeds the control level on three consecutive occasions		

Contingency action	**Response time**
Advise the Environment Agency in response to failure of the control test	1 month
Increase the monitoring frequency as appropriate (monthly increases to weekly and quarterly increases to monthly)	1 month
Undertake investigation work to identify the cause of the rise in concentrations	3 months
Report to the Environment Agency on the re-appraisal of risks and options for corrective measures	6 months
If the risks are acceptable re-evaluate the assessment criteria	6 months
If the risks are unacceptable implement corrective measures	12 months

Notes:

[a] Control levels are set at the maximum source term concentration from the 2021 HRA model.

Table HRA 11

The risk based monitoring scheme and proposed compliance limits and control levels for groundwater quality at ENRMF during the operational phase and post closure managed phase of the landfill

Criterion Objective To identify an unacceptable increase in the concentration of a component in the groundwater over that calculated in the HRA		
Measurement	Groundwater quality	
Frequency	See Table HRA 8	
Monitoring points	K01, K02A, K03A, K04, K05, K06A, K07, K08, K11, K12, K13A, K14A, K15A, K16, K21, K22, K23, K24, K25, K26, K27, K28, K29, K30, K31, K32, K34, K35A, K36, K37 and future borehole K33	
Monitoring points at which the compliance limits and control levels should be applied	Down hydraulic gradient groundwater monitoring boreholes Currently Permitted site – K04, K05, K06A, K07, K08, K11, K12, K13A, K14A, K15A K16, & K21. Western extension following the commencement of landfilling in this area of the site [c] – K34, K35A. K36 & K37 (additional locations to be determined following further monitoring)	
Compliance limit [a]	**Determinand**	**Concentration (mg/l)**
	Arsenic	0.035
	Dichlorprop	0.00005
	Toluene	0.001
	Trichloroethene	0.001
	Ammoniacal nitrogen	0.39
	Cadmium	0.0007
	Chloride	250
	Manganese	0.46
	Naphthalene	0.000075
	Zinc	0.11
Control level [b]	**Determinand**	**Concentration (mg/l)**
	Arsenic in the leachate	17.3
	Dichlorprop in the leachate	16
	Toluene in the leachate	180
	Trichloroethene in the leachate	18
	Ammoniacal nitrogen	0.31
	Cadmium	0.00056
	Chloride	200
	Manganese	0.37
	Naphthalene	0.00006
	Zinc	0.09
Control test	Concentration exceeds the control level on three consecutive occasions	

Contingency action	**Response time**
Advise the Environment Agency in response to failure of the control test	1 month
Increase the monitoring frequency to monthly	1 month
Undertake investigation work to identify the cause of the rise in concentrations	3 months
Report to the Environment Agency on the re-appraisal of risks and options for corrective measures	6 months
If the risks are acceptable re-evaluate the assessment criteria	6 months
If the risks are unacceptable implement corrective measures	12 months

Notes:

(green shading) Control level is relevant to leachate quality

[a] The compliance limits are set at the Environmental Assessment Limits.

[b] The control levels for hazardous substances are set at the maximum source term concentrations in the leachate from the HRA model. The control levels for non-hazardous pollutants are set at the eighty percent of the Environmental Assessment Limits.

[c] Limited groundwater quality data is available for boreholes located round the western extension. It is proposed that compliance limits are set for groundwater at boreholes in the western extension area following the collection of a minimum of 12 months of monitoring data and prior to landfilling in the western extension to facilitate the assessment of potential seasonal variations in groundwater quality round the western extension.

Table HRA 12

The monitoring scheme and compliance limits and control levels for surface water quality at ENRMF

Criterion Objective To identify an unacceptable increase in the concentration of a component in the surface water		
Measurement	Surface water quality	
Frequency	See Table HRA 8	
Monitoring point at which the compliance limits and control levels should be applied	SWSEOFALL and future permitted discharge locations	
Compliance limit [A]	**Determinand**	**Concentration (mg/l)**
	Suspended Solids	40
	pH	<6 and >9 (pH units)
	Ammoniacal nitrogen	1
	Chloride	250
	Oil or grease	Visible discharge
Control level [B]	Suspended Solids	32
	pH	<6.6 and >8.4 (pH units)
	Ammoniacal nitrogen	0.8
	Chloride	200
	Oil or grease	-
Control test	Concentration exceeds the compliance limit on three consecutive occasions	

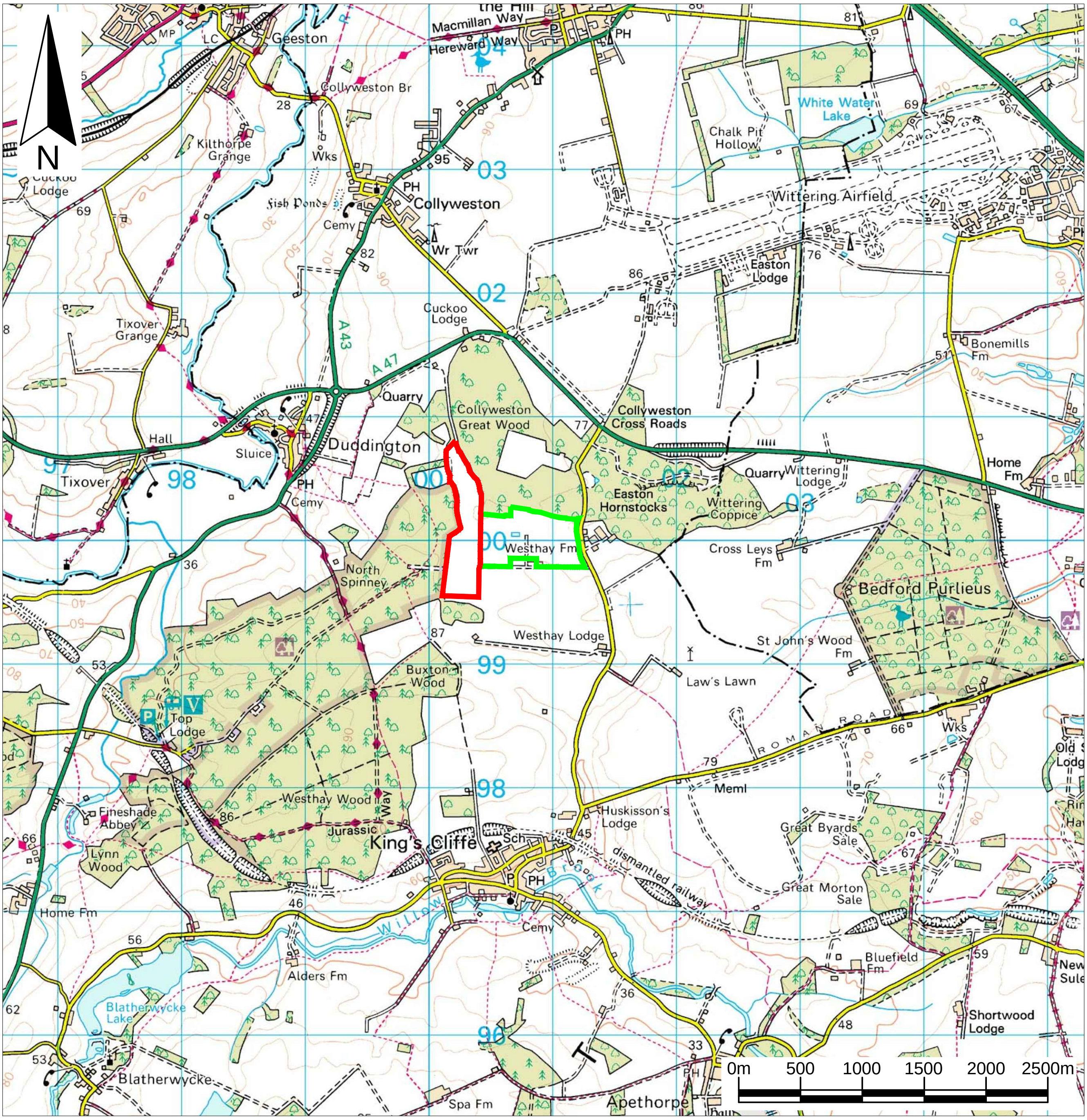
Contingency action	**Response time**
Advise the Environment Agency in response to failure of the control test	1 month
Increase the monitoring frequency to weekly	1 month
Undertake investigation work to identify the cause of the rise in concentrations	3 months
Report to the Environment Agency on the re-appraisal of risks and options for corrective measures	6 months
If the risks are acceptable re-evaluate the assessment criteria	6 months
If the risks are unacceptable implement corrective measures	12 months

Notes:

A The compliance limits are based on the limits presented in Table S3.3 of the current Environmental Permit for the current landfill operations (EP number EPR/TP3430GW).

B The control levels are set at approximately 90% of the compliance limits.

FIGURES



Key / Notes

Approximate current boundary of Environmental Permit number EPR/TP3430GW/V005 for the ENRMF hazardous waste landfill

Proposed western extension to the ENRMF hazardous waste landfill Environmental Permit

Rev	Status	Drn	App	Chk	Date
	Final	KR	ML	LH	23/04/21

Site
EAST NORTHANTS RESOURCE MANAGEMENT FACILITY

Client
Augean SOUTH LTD

Title
The site location

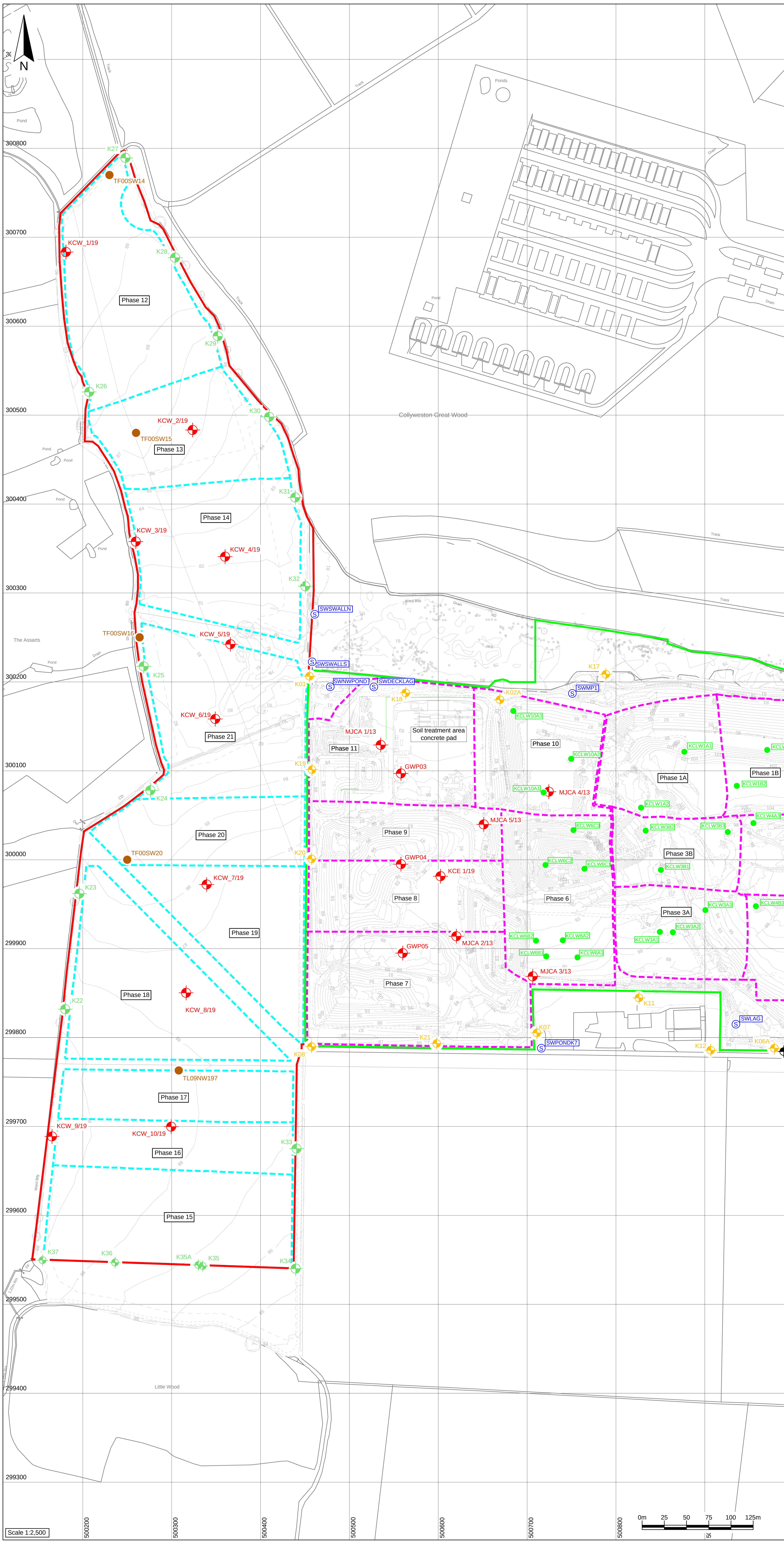
Figure HRA 1

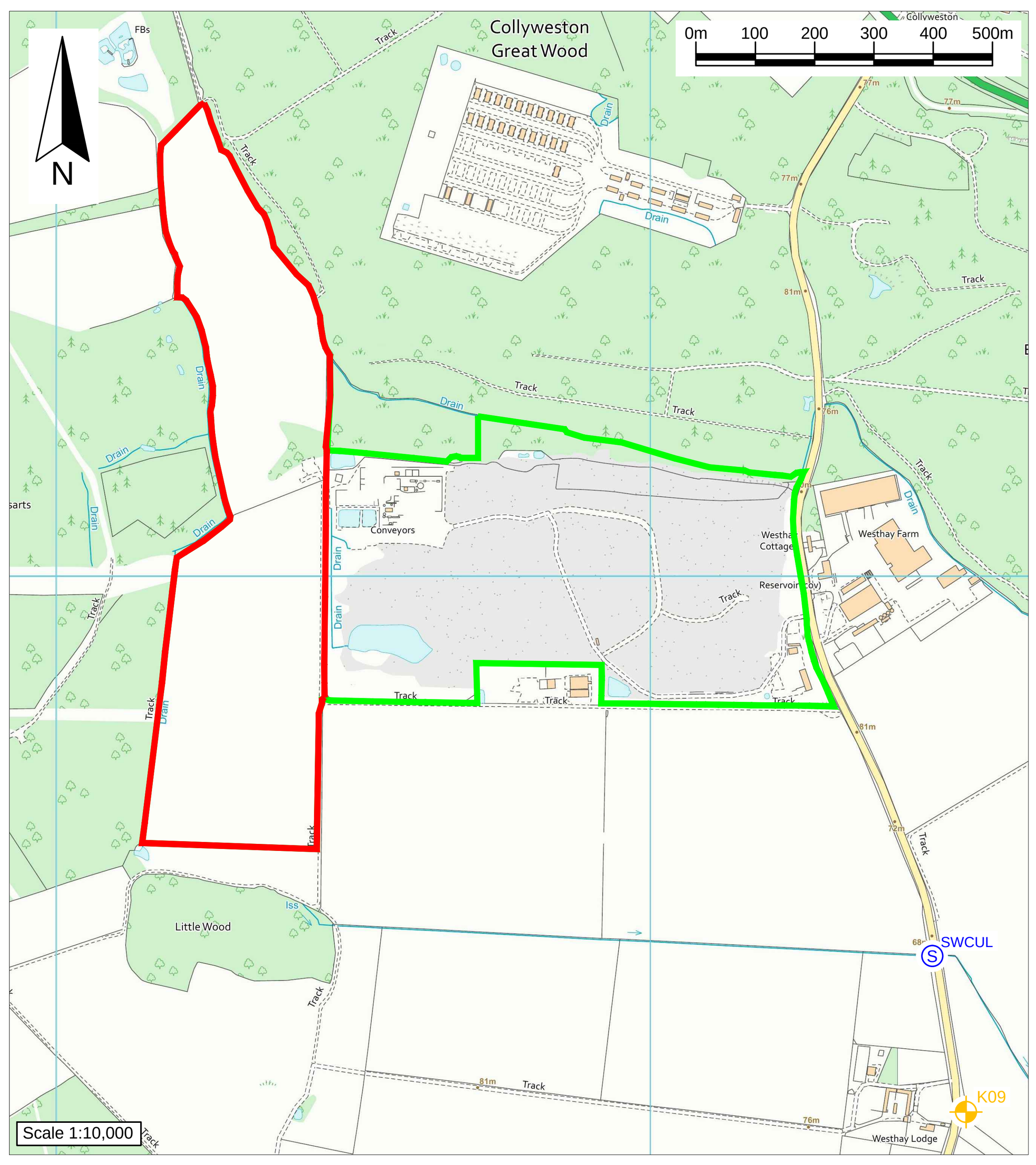
Scale
1:50,000@A4

Drawing Ref
AU/KCW/09-20/21952

MJCA
Technical advisers on environmental issues

Baddesley Colliery Offices,
Main Road, Baxterley, Atherstone,
Warwickshire, CV9 2LE.
Telephone : 01827 717891
Fax : 01827 718507



Key / Notes

- Proposed western extension to the ENRMF hazardous waste landfill Environmental Permit
- Approximate current boundary of Environmental Permit number EPR/TP3430GW/V005 for the ENRMF hazardous waste landfill
- Approximate location of the phase boundaries in the current permitted landfill
- Approximate phase boundaries in the Western Extension
- Leachate monitoring location
- Lincolnshire Limestone Formation/Northampton Sand Formation groundwater monitoring location
- Location of a decommissioned Lincolnshire Limestone Formation/Northampton Sand Formation groundwater monitoring borehole
- Location of a new Lincolnshire Limestone Formation/ Northampton Sand Formation groundwater and landfill gas monitoring borehole
- Approximate location of a British Geological Survey (BGS) borehole
- Location of a site investigation borehole
- Surface water monitoring location

Note:
Drawing based on LSS model reference 'AU-KCW-15668.LSS' and 'FULL SITE SURVEY UPDATE 24.05.2005.lss' provided by Egniol in 2005

Rev	Status	Drn	App	Chk	Date
	Final	KR	ML	LH	23/04/21

Site: EAST NORTHANTS RESOURCE MANAGEMENT FACILITY

Client: Augean SOUTH LTD

Title: Locations of the groundwater, surface water and leachate monitoring points

Figure HRA 2

Scale: As shown@A1

Drawing Ref: AU/KCW/09-20/21953

MJCA
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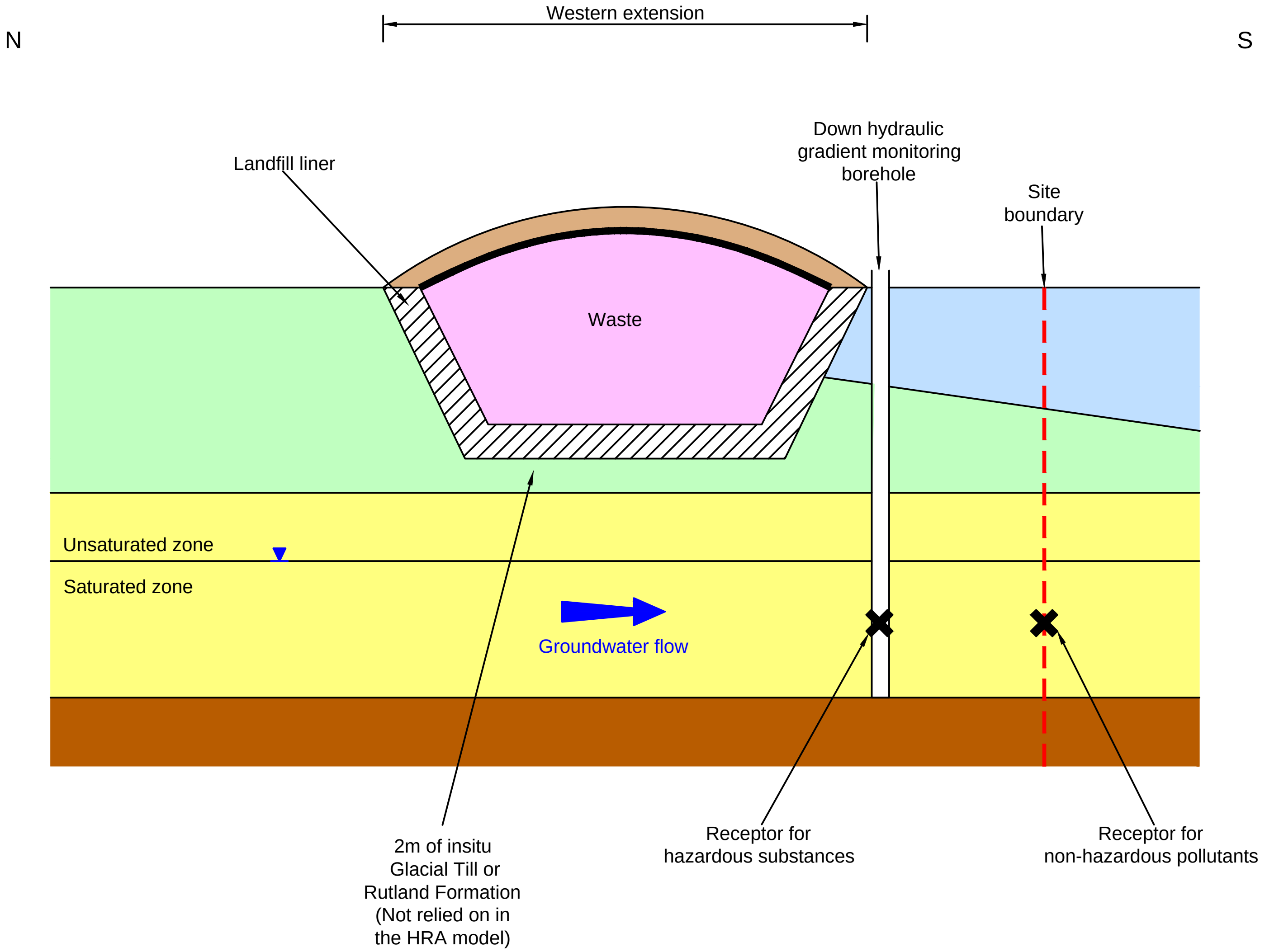


Key / Notes

GEOLOGY

- Glacial Till
- Rutland Formation
- Lincolnshire LimestoneFormation, Grantham Formation and Northampton Sand Formation
- Whitby Mudstone Formation

LANDFILL

- Landfill cap with a drainage layer and cover soils
- Composite HDPE flexible membrane liner and a 1m thick compacted clay liner

Rev	Status	Drn	App	Chk	Date
	Final	KR	JRC	LH	23/04/21

Site
EAST NORTHANTS RESOURCE MANAGEMENT FACILITY

Client
Augean SOUTH LTD

Title
Conceptual site model - western extension

Figure HRA 3

Scale
Not to scale

Drawing Ref
AU/KCW/01-21/22196

MJCA
Technical advisers on environmental issues
Baddesley Colliery Offices,
Main Road, Baxterley, Atherstone,
Warwickshire, CV9 2LE.
Telephone : 01827 717891
Fax : 01827 718507

Figure HRA 4A - Groundwater levels recorded in the Lincolnshire Limestone Formation/ Northampton Sand Formation at the monitoring boreholes in the vicinity of the currently permitted ENRMF landfill between November 2003 and March 2021

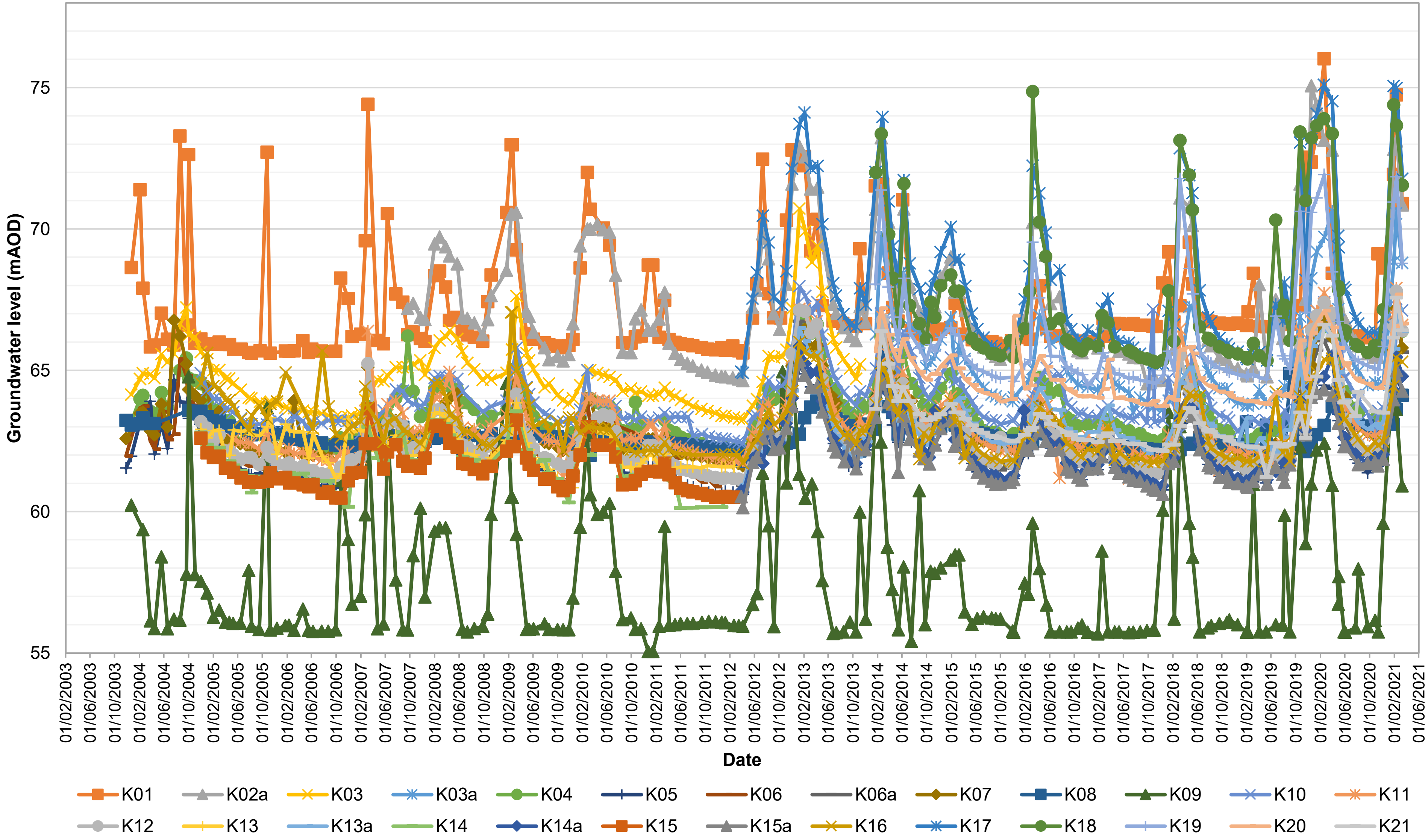
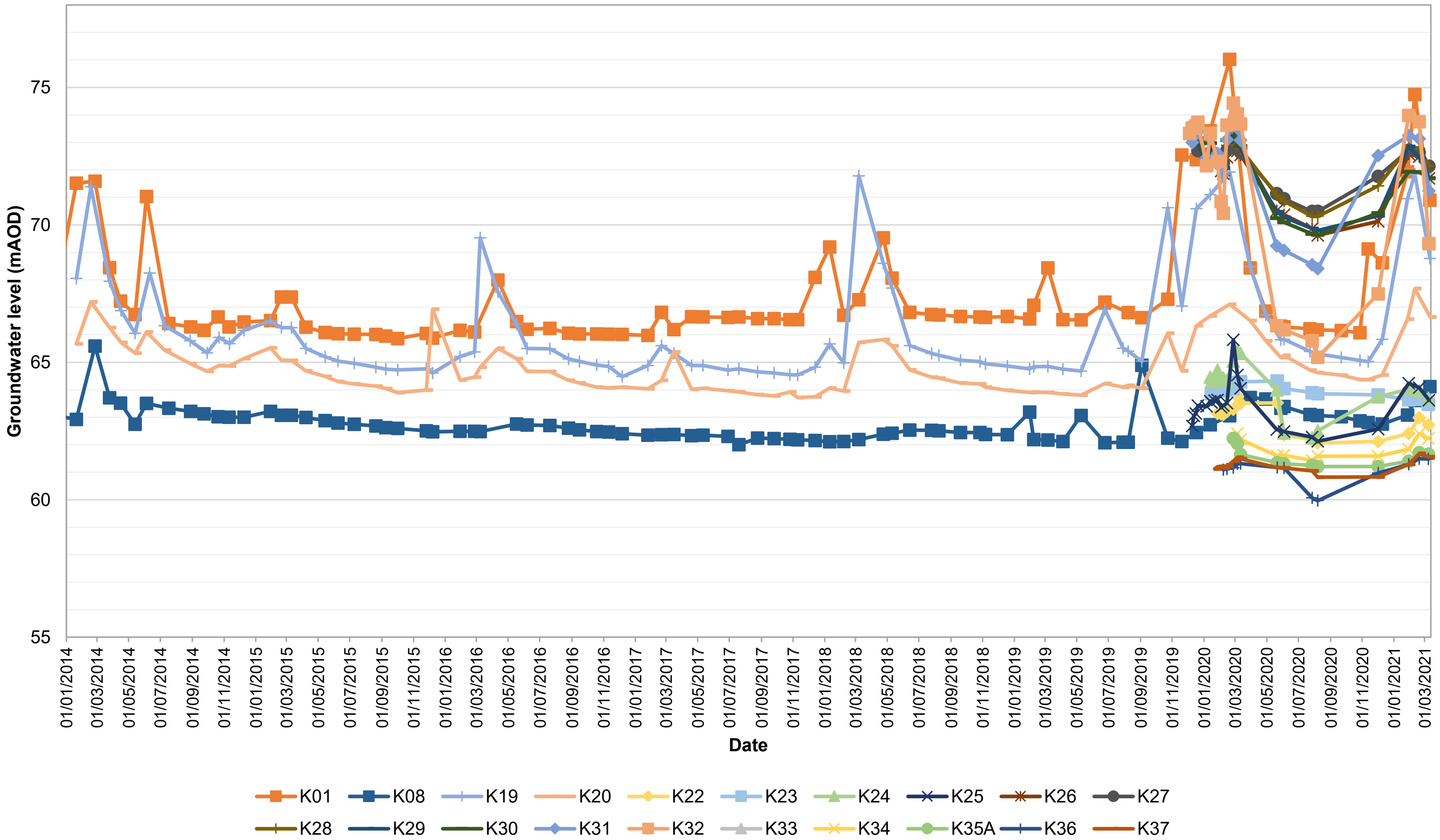
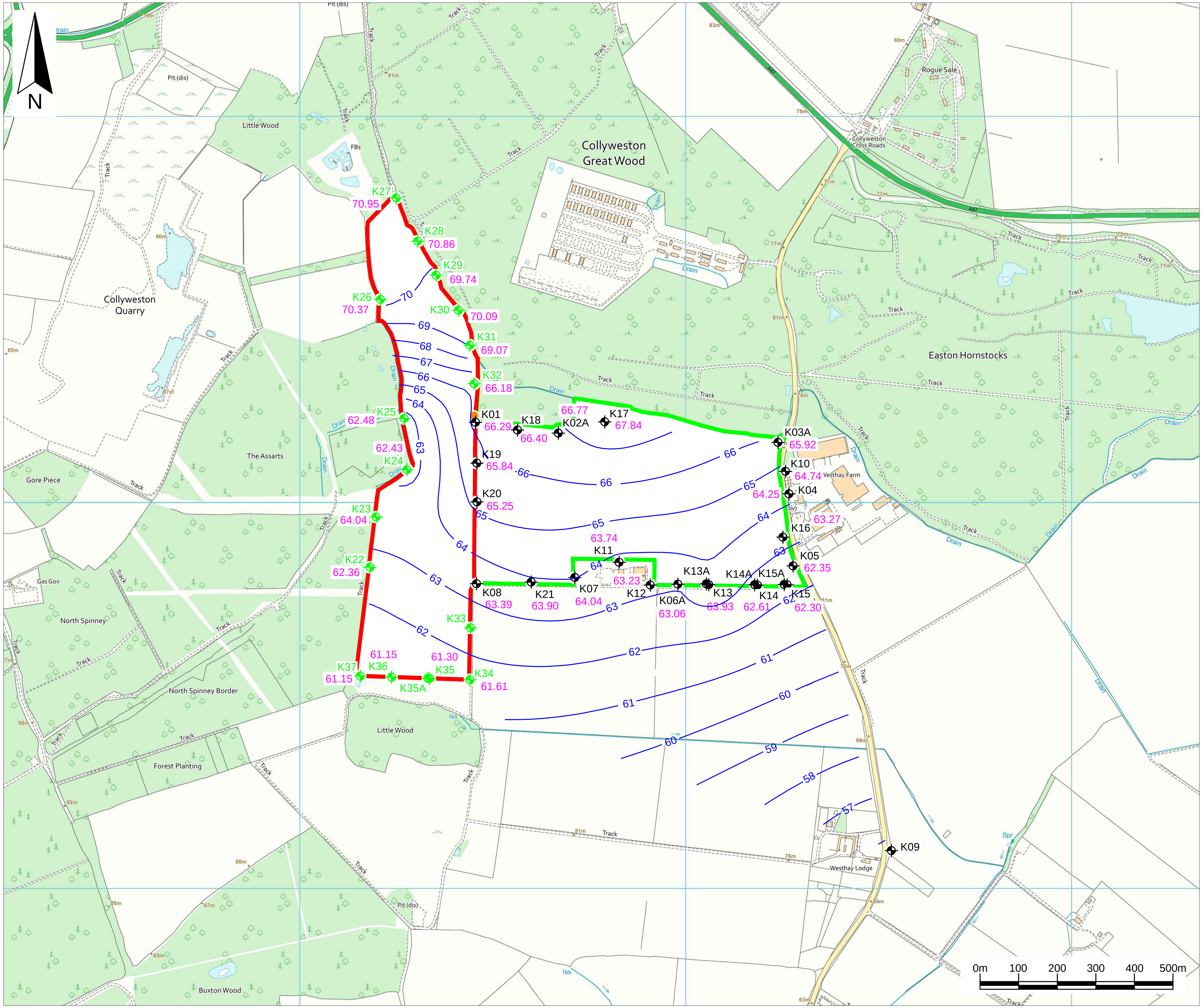


Figure HRA 4B - Groundwater levels recorded in the Lincolnshire Limestone Formation/ Northampton Sand Formation at the monitoring boreholes in the vicinity of the proposed western extension to ENRMF landfill between January 2014 and March 2021





Key / Notes

- Proposed western extension to the ENRMF hazardous waste landfill Environmental Permit
- Approximate current boundary of Environmental Permit number EPR/TP3430GW/V005 for the ENRMF hazardous waste landfill
- Approximate location of a swallow hole
- K01 Location of a monitoring borehole
- K22 Location of a new groundwater and landfill gas monitoring borehole
- 65.92 Groundwater level (mAOD) recorded at boreholes on 3 June 2020
- —64— Groundwater contours (mAOD) interpolated from groundwater levels recorded at boreholes at and in vicinity of the proposed western extension and the currently permitted site in June 2020

Rev	Status	Drn	App	Chk	Date
	Final	KR	ML	LH	23/04/21

Site
EAST NORTHANTS RESOURCE MANAGEMENT FACILITY

Client
Augean SOUTH LTD

Title
Groundwater level contours interpolated from groundwater levels recorded at and in the vicinity of ENRMF in June 2020

Figure HRA 5

Scale
1:10,000@A3

Drawing Ref
AU/KCW/09-20/21954

MJCA
Technical advisers on environmental issues
Baddesley Colliery Offices, Main Road, Baxterley, Atherstone, Warwickshire, CV9 2LE.
Telephone : 01827 717891
Fax : 01827 718507

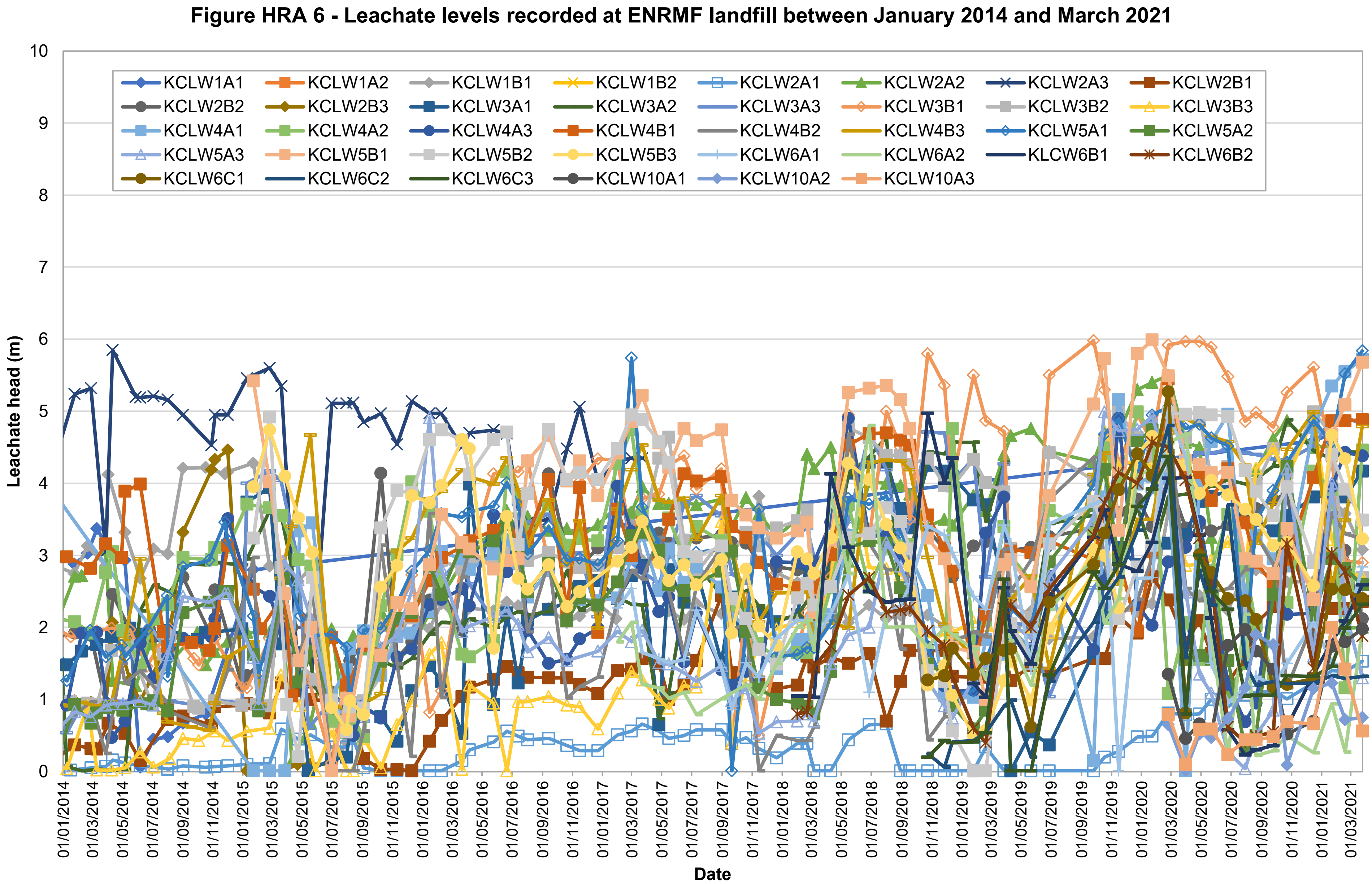


Figure HRA 6 - Leachate levels recorded at ENRMF landfill between January 2014 and March 2021
Leachate head (m)
Date
0
1
2
3
4
5
6
7
8
9
10
KCLW1A1
KCLW1A2
KCLW1B1
KCLW1B2
KCLW2A1
KCLW2A2
KCLW2A3
KCLW2B1
KCLW2B2
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01/01/2021
01/03/2021

APPENDICES

APPENDIX HRA A

ENVIRONMENT AGENCY PRE-APPLICATION CORRESPONDENCE AND ADVICE

[redacted]

From: [redacted]
Sent: 28 July 2020 15:18
To: [redacted]
Cc: [redacted]
Subject: East Northants Resource Management Facility - pre operational conditions

Hi [redacted]

Following on from our pre-application discussions for East Northants Resource Management Facility on 17/07/20, I can now provide some more information for you on the issue of the pre-operational condition for the site investigation into the swallow hole.

You asked if it would be possible to issue the variation for the extension area, including the swallow hole and its immediate surroundings, and have a pre-operational condition to allow infilling of these areas once the pre-operational condition for the site investigation has been signed off.

I can confirm that we can use pre-operational conditions in situations where we need more detail on how the proposal can be carried out, provided that we are already confident that the activity would not cause pollution or other unacceptable impacts. But for situations where there are more unknowns that could lead to unacceptable impacts, we would need to take the approach of a variation.

Based on what we know so far for this situation, we think the highest risk option would be to completely cover up the swallow hole and this might be the most difficult option to justify. Therefore this scenario would most likely need a variation if we get to the point of agreeing that it can take place.

The other options with stand-off zones to the swallow hole might lend themselves more to a pre-operational condition. However all of this will ultimately depend on the findings of your site investigations, and no final decisions can be made until then.

I hope this clarifies the principles of our approach, but if you have any questions then please get back to me.

Regards

[redacted]

[redacted] CSci FGS
Geoscience Operations Team (part of National Permitting Service)
Environment Agency
Mob. [redacted]

[redacted]

From: [redacted]
Sent: 10 August 2020 12:29
To: [redacted]
Cc: [redacted]
Subject: Pre-Application: EA/EPR/TP3430GW/V007 - Augean South Limited

10 August 2020

Dear All

Pre-Application: EA/EPR/TP3430GW/V007 - Augean South Limited

We provide below a summary of the items agreed during our video conference meeting held on 17 July 2020. The meeting was held in response to the request dated 1 July 2020 for pre-application advice in respect of a proposed application to vary the Environmental Permit for the East Northants Resource Management Facility (ENRMF) hazardous waste landfill. The proposed application is to vary the permit to include the deposition of hazardous waste to the north west, west and south west of the currently permitted site. The meeting attendees were Roland Evans, Jim Branson and Andrew Wright from the Environment Agency (EA), Peter Oldfield from Augean and Jo Congo and Dan Riding from MJCA. Andrew Wright set up the meeting and left before the main discussion.

The meeting was held in order to discuss the results of the site investigation in the potential extension area undertaken between November 2019 and March 2020 and the principles of the design of the potential extension. The agenda for the meeting comprised:

1. The results of the site investigation
2. The thickness of the Rutland Formation that should be left in-situ during construction of a potential extension to ENRMF consistent with the approach taken for the Western Landfill Area of the current landfill at the site
3. The principles of a potential extension in the vicinity of the swallow hole
4. Next steps

Agenda items 1 and 2

The results of the site investigation show that the thickness of the Rutland Formation and glacial till deposits, where present, in the potential extension area is consistent generally with the area of the current permitted site. The results of laboratory tests on core samples taken from the Rutland Formation and glacial till showed hydraulic conductivities are within the range of values recorded for the Rutland Formation beneath the Western Landfill Area (WLA) of the current permitted site. The principles agreed for design of the currently permitted WLA in respect of the thickness of the Rutland Formation which is left in situ were informed by sensitivity analysis of the LandSim models presented in the Hydrogeological Risk Assessment (HRA) for the current site. The LandSim model results for the currently permitted WLA show that if the thickness of Rutland Formation left in situ is greater than 2m the model results show limited additional benefit.

Given the similar geology beneath the potential extension area and the WLA it was agreed that it would be acceptable for the same approach to be used in the potential extension area. It was agreed that the thickness of Rutland Formation and glacial till retained in situ for the extension area would not be less than the 2m agreed for the currently permitted WLA. It was agreed that following further work if it is proposed that the principles of the design of the potential extension will deviate significantly from that agreed for the WLA, further pre-application discussions should be held with the EA.

Agenda item 3

Regarding the principles of a potential landfill extension in the vicinity of the swallow hole it is proposed that the application will be progressed based on the principle that the detail of the development in the area of the swallow hole will be agreed following issue of the Development Consent Order and Environmental Permit variation. It is proposed that three options are presented in the DCO and Environmental Permit variation applications comprising:

1. Continuous landfill with a stand off from the swallow hole.
2. Retention of a 20m corridor (10m either side of the swallow hole area) linking the land to the west of the potential extension to the swallow hole for surface water drainage.
3. Retention of a 150m corridor (75m either side of the swallow hole area) linking the land to the west of the potential extension to the swallow hole for surface water drainage.

It is proposed that the detail of the development in the area of the swallow hole would be agreed through a Pre-operational condition (POC) for the potential extension area which is the approach preferred by Augean. It is understood that the approach of agreeing the detail of the development in the vicinity of the swallow hole area through a POC will be discussed internally by the EA who would then provide further advice (see below).

Regarding the area of the potential extension in the vicinity of the swallow hole area there are three main considerations from a design perspective that will need to be assessed as part of any further work and investigations. These main considerations comprise:

1. It will be necessary to investigate if the anomalies identified by a geophysical survey of this area of the site are cavities/ solution features. If they are it will be necessary to investigate whether they are small, hence can be grouted in a similar way to the agreed approach for the currently permitted site. If they are significant it may be necessary to stand off from them for any landfill construction works.
2. Based on the hydrogeology of this area of the site, it will need to be assessed whether grouting is likely to cause restrictions that are significantly detrimental to the hydrogeological regime.
3. It will be necessary to assess the consequences if the surface water drainage pathway to the swallow hole is blocked off and identify surface water management and mitigation solutions.

It was agreed that modelling and or monitoring would need to verify that the hydrogeological and hydrological regime could be managed and would not be significantly detrimentally affected by the potential extension in the vicinity of the shallow hole. The approach would depend on the results of further investigations, assessments and the selected design. The EA agreed that the options and considerations proposed are reasonable.

Agenda item 4

It was agreed that MJCA would undertake an HRA review of the current site and then add the potential extension area to the HRA which would then be submitted in support of the Environmental Permit variation application. The cumulative impact of the current permitted landfill site and the potential extension area will be assessed albeit that the cumulative impacts may be limited as the extension is adjacent to the currently permitted site in respect of the groundwater flow direction which is towards the south generally. The principles and approach agreed for the currently permitted WLA will be followed for the potential extension area. As stated above, if the principles and approach deviate significantly from that agreed for the currently permitted WLA then further pre-application discussions will be held with the EA.

Further advice

Thank you for the email from Roland Evans of 28 July 2020 providing further advice in respect of the approach to agreeing the detail of the development in the vicinity of the swallow hole through a POC (agenda item 3 above). The e-mail provides clarification that a POC can be used in situations where the EA need more detail on how the proposal can be carried out, provided that the EA are already confident that the activity would not cause pollution or other unacceptable impacts. For situations where there are more unknowns that could lead to unacceptable impacts, the EA would need to take the approach of a variation. As a result it may be possible that a POC can be employed for the development in the vicinity of the swallow hole subject to the results of the permit variation assessments. In addition as all three of the options above have stand-offs from the swallow hole to a differing degree they may all lend themselves to a POC.

We trust that the information provided in this e-mail is to your satisfaction. We should be grateful to receive confirmation that our record of our meeting and the agreements reached are consistent with your records. Should you have any queries or need any further information please do not hesitate to contact us.

Regards

[redacted]

[redacted]
Our ref: AU/KCW/JRC/2991/01/25452
AU_KCWg25452 FV

Technical advisers on environmental issues

Baddesley Colliery Offices
Main Road
Baxterley
Atherstone
Warwickshire
CV9 2LE
Telephone: (01827) [redacted]
Fax: (01827) [redacted]

Established in 1983
Over 35 years of reliability in a changing environment

[redacted]

[redacted]

From: [redacted]
Sent: 13 August 2020 16:34
To: [redacted]
[redacted]
Subject: RE: Pre-Application: EA/EPR/TP3430GW/V007 - Augean South Limited

[redacted],

I have reviewed the summary below and can confirm that it represents a satisfactory description of what was discussed in the video conference.

However, having further considered the implications of potential impeding any surface water flow to the swallow hole I think we would look more favourably on a solution that maintains this element. This will obviously be determined by the outcome of your proposed investigations and assessments of this matter. This assessment should bear mind our position statements N6, N7, N9 and N11 in Section N of our document detailing our approach to groundwater protection which will allow us avoid any potential challenges that may arise from interested parties quoting this document.

I hope that this is self-explanatory but should you wish to discuss further please do hesitate to contact me.

Regards

[redacted]
Technical Specialist - Groundwater & Contaminated Land

Lincolnshire and Northamptonshire Area
Environment Agency
✉ Ceres House, Searby Road, Lincoln, LN2 4DW.
☎ [redacted]
☎ [redacted] (internal)
☎ [redacted]
[redacted]
www.gov.uk/environment-agency

From: [redacted]
Sent: 10 August 2020 12:29
To: [redacted]

APPENDIX HRA B

ENVIRONMENT AGENCY HRA TEMPLATE SIGN POSTING DOCUMENT FOR THE WESTERN EXTENSION

APPENDIX HRA B

Sections of Hydrogeological Risk Assessment (HRA) Review report where the items in the Environment Agency (EA) template for HRAs[1] are presented for the Western Extension

EA TEMPLATE TABLE OF CONTENTS	HRA Review report sections where item is presented for the Western Extension
1.0 INTRODUCTION	
1.1 Report Context	The operator of the proposed installation (Augean), the agent who completed this report (MJCA), an outline of the proposed installation and how it relates to historically operated areas of landfill and cross reference to appropriate Conceptual Site Model (i.e. ESID report) are included in Section 1 of the report
1.2 Conceptual Hydrogeological Site Model	**Sources** Summary of wastes including quantities, types, ratios of types and rates of filling are included in the cross referenced ESID report A summary of leachate quality is presented in Section 2 of the report, associated tables and appendix. **Pathways** A summary of all relevant pathways including their nature and characteristics are included in Section 2 of the report, associated tables and appendices. **Receptors** Receptors for hazardous substances and non-hazardous pollutants are included in Section 2 of the report with cross references to the ESID report as appropriate. The specification of appropriate Environmentally Assessment Levels (EALs) are referenced in Section 2 and are presented in the associated tables
2.0 HYDROGEOLOGICAL RISK ASSESSMENT	
2.1 The Nature of the Hydrogeological Risk Assessment	Consistent with those at the currently permitted site as presented in the 2014 HRA. The site setting is summarised in Section 2 in respect of geology and aquifer designations. A detailed quantitative HRA has been undertaken for the western extension.
2.2 The Proposed Assessment Scenarios	
2.2.1 Lifecycle Phases	The lifecycle phases are confirmed in Section 2 of the report
2.3 The Priority Contaminants to be Modelled	The hazardous substances and non-hazardous pollutants included in the HRA are consistent with the 2014 HRA for the site comprising a range of substances which are

EA TEMPLATE TABLE OF CONTENTS	HRA Review report sections where item is presented for the Western Extension
	present in the leachate as set out in Section 2 of the report. The source term used in the 2021 HRA is presented in Table HRA 4.
2.4 Review of Technical Precautions	The technical precautions at the current site are considered in Section 3 of the report together with reference for these in the western extension consistent with the currently permitted site. Management of the site is included in the cross-referenced ESID report. Consistent with the 2014 HRA the technical precautions include the placement of the basal and perimeter liner, leachate management and capping of the landfill.
2.5 Numerical Modelling	
2.5.1 Justification for Modelling Approach and Software	The model approach is presented in Sections 4 and 5 of the report and is consistent with the 2014 HRA for the current permitted site.
2.5.2 Model Parameterisation	The model parameterisation is referenced in Sections 2 and 3 of the report and is presented in the associated tables and appendices including those parameters taken from the 2014 HRA for the current permitted site.
2.5.3 Sensitivity Analysis	Sensitivity analyses are presented in Section 5 of the report.
2.5.4 Model Validation	A review of monitoring data compared with model input parameters is presented in Sections 2 and 3 of the report together with water quality monitoring data in Section 6 of the report.
2.5.5 Accidents and their consequences	Accidents and their consequences are consistent with those at the currently permitted site as presented in the 2014 HRA. Section 2.5.5 Accidents and their consequences from the 2014 HRA is reproduced at this appendix for ease of reference.
2.6 Emissions to Groundwater	
2.6.1 Hazardous Substances	The results of the modelling including potential emissions to groundwater are presented in Section 5 of the report.
2.6.2 Non-hazardous pollutants	The results of the modelling including potential emissions to groundwater are presented in Section 5 of the report.
2.6.2 Surface Water Management	Management of the site is included in the cross-referenced ESID report (reference 8).
2.7 Hydrogeological Completion Criteria	The completion criteria for the site is consistent with those from the 2014 HRA for the current permitted site. Section 2.7 Hydrogeological completion criteria from the 2014 HRA is reproduced at this appendix for ease of reference.

EA TEMPLATE TABLE OF CONTENTS	HRA Review report sections where item is presented for the Western Extension
3.0 REQUISITE SURVEILLANCE	
3.1 The Risk Based Monitoring Scheme	Leachate, groundwater and surface water monitoring are specified in Table HRA 8 to Table HRA 12.
3.1.1 Leachate Monitoring	Leachate monitoring for the currently permitted site is reviewed in sections 2 and 3 of the report. Leachate monitoring and compliance limits are presented in Table HRA 8 to Table HRA 10.
3.1.2 Groundwater Monitoring	Groundwater monitoring is reviewed in sections 2 and 6 of the report. Groundwater monitoring and compliance limits are presented in Table HRA 8 and Table HRA 11.
3.1.3 Surface Water Monitoring	Surface water monitoring is reviewed in section 6 of the report. Surface water monitoring and compliance limits are presented in Table HRA 8 and Table HRA 12.
4.0 CONCLUSIONS	
4.1 Compliance with the Landfill Directive	The compliance of the site with the Landfill Directive is consistent with that presented in the 2014HRA. Section 4.1 Compliance with the Landfill Directive from the 2014 HRA is reproduced at this appendix for ease of reference.
4.2 Compliance with the Groundwater Regulations, 2009	Schedule 22 of the Environmental Permitting (England and Wales) Regulations 2016 have replaced the 2009 regulations referenced in the EA template and the 2010 regulations referred to in the 2014 HRA. Compliance with Schedule 22 of the Environmental Permitting (England and Wales) Regulations 2016 is presented in Sections 5 and 7 of the report.

Notes:

[1] Environmental Permitting (England and Wales) Regulations - Information in support of an application for a landfill permit. Hydrogeological Risk Assessment Report. Version 1, March 2010

ii. As the site is operational, leachate levels, leachate quality, groundwater level, groundwater quality and surface water quality currently are monitored at the site to assess compliance with the EP and the EPR and to provide validation for the existing HRAs. Monitoring will continue throughout the life of the current landfill and the western landfill area and the HRA will be reviewed on a regular basis.

2.5.5 Accidents and their consequences

i. Technical precautions are included in the landfill design to minimise the impact of accidents on the aqueous environment. The construction of the low hydraulic conductivity basal and perimeter liners together with leachate drainage is certified by the Environment Agency through the CQA validation process prior to the placement of wastes to confirm that the lining and drainage systems are installed in accordance with the specifications. The placement of the low hydraulic conductivity cap over the filled phases is the subject also of a CQA validation process.

ii. Drilling through the liner following construction of the liner, for example where leachate monitoring wells are installed, may result in the unrestricted flow of leachate into the surrounding natural strata. As leachate monitoring wells are and will be constructed progressively during filling of the landfill there is no risk of drilling through the liner during formation of the wells. Concrete pads extending to a radius of 2m from the original well position are constructed to provide a marker of the location of the base of the site in the event that it is necessary to install leachate wells retrospectively. Boreholes would be positioned to intercept the concrete pad which would form the base of the borehole and will prevent breach of the liner should replacement leachate wells be necessary. It is unlikely that replacement wells will penetrate the liner.

iii. During the operational phase and post closure managed phase leachate levels are managed at or below the leachate level compliance limit through the use of the leachate drainage and abstraction system. Failure of a leachate pump may result in an increased head of leachate in the area of the site served by that pump. Pumps generally can be replaced within one or two weeks during which time the rise in leachate level will be small. It is considered that there is no need for additional quantitative analysis in respect of the impact of temporarily elevated leachate levels following pump failure.

iv. Spills may occur during the removal of leachate from the leachate sump which could result in the discharge of leachate to groundwater or surface water. The leachate management procedures for the site include procedures for the avoidance and remediation of leachate spills and the above ground leachate management system is through enclosed pipes. It is considered that the risk of a spill occurring and the risk from any spills of leachate to groundwater or surface water is low. Additional quantitative analysis in respect of spills is not necessary.

2.7 Hydrogeological completion criteria

i. The concentrations of determinands in the leachate will reduce over time. Long term monitoring of leachate quality will be carried out to determine the time at which the site no longer presents a potential risk to groundwater. The hydrogeological completion criteria will be approaching the EALs as a worst case situation. The completion of the landfill will be determined from the results of the monitoring of leachate quality and in agreement with the Environment Agency.

4. Conclusions

4.1 Compliance with the Landfill Directive

i. It is likely that the leachate generated in the western landfill area of the site will contain hazardous substances and non-hazardous pollutants hence the leachate will be controlled. Details of the leachate management and collection system are given in the ESID report.

ii. The site is designed and will be operated based on the principle of containment. The construction of the basal and perimeter liner and the capping system for current and future phases at the site is subject to an engineering specification and CQA validation procedures. The landfill design for all phases at the site will comply with Annex I of the Landfill Directive (reference 12). Where the design deviates from the default design set out in Annex I of the Landfill Directive the HRA demonstrates that the design complies with the regulations regarding the protection of groundwater in Schedule 22 of the EPR and the Groundwater Directive hence complies with paragraph 3.4 in Annex 1 to the Landfill Directive.

iii. It is concluded that the site presents no significant risk to groundwater hence will be compliant with the Landfill Directive.

APPENDIX HRA C

ELECTRONIC COPY OF THE LEACHATE QUALITY AND GROUNDWATER QUALITY MONITORING DATA, ELECTRONIC COPY OF THE CAP DESIGN INFILTRATION CALCULATIONS, ELECTRONIC COPY OF THE HRA REVIEW RE-RUN OF THE LANDSIM MODEL AND ELECTRONIC COPY OF THE 2021 HRA LANDSIM MODEL TO INCLUDE THE WESTERN EXTENSION

APPENDIX HRA D

THE RESULTS OF HYDRAULIC CONDUCTIVITY TESTING OF 270 SAMPLES OF CLAY LINER MATERIAL FROM THE CONSTRUCTION OF PHASES 6 AND 10 AT ENRMF AND PHASES 3 TO 7A AT THE NEARBY AUGEAN THORNHAUGH LANDFILL FOR THE PURPOSE OF CQA VERIFICATION WITH A CQA CRITERION OF 1 X 10^{-9}M/S

Site	Phase	Date	Samples	Location	Hydraulic Conductivity (m/s)	LOG data
ENRMF	10		PERM 1		9E-11	10.04575749
ENRMF	10		PERM 2		9.68E-11	10.01412464
ENRMF	10		PERM 3		9.82E-11	10.00788851
ENRMF	10		PERM 4		9.54E-11	10.02045163
ENRMF	10		PERM 5		1.17E-10	9.931814138
ENRMF	10		PERM 6		9.33E-11	10.03011836
ENRMF	10		PERM 7		9.56E-11	10.01954211
ENRMF	10		PERM 8		9.15E-11	10.03857891
ENRMF	10		PERM 9		8.88E-11	10.05158703
ENRMF	10		PERM 10		8.00E-11	10.09691001
ENRMF	10		PERM 11		8.45E-11	10.07314329
ENRMF	10		PERM 12		8.98E-11	10.04672366
ENRMF	10		PERM 13		1.27E-10	9.896196279
ENRMF	10		PERM 14		9.46E-11	10.02410886
ENRMF	10		PERM 15		1.33E-10	9.876148359
ENRMF	6A		P1/L1/08P		7.0E-11	10.15490196
ENRMF	6A		P1/L4/17P		4.3E-11	10.36653154
ENRMF	6A		P2/L1/22P		8.3E-11	10.08092191
ENRMF	6A		P2/L2/25P		5.6E-11	10.25181197
ENRMF	6A		P2/L3/28P		4.2E-11	10.37675071
ENRMF	6A		P2/L4/31P		7.1E-11	10.14874165
ENRMF	6A		SWP2/L2/37P		7.1E-11	10.14874165
ENRMF	6A		SWP2/L4/44P		5.8E-11	10.23657201
ENRMF	6A		P3/L1/45P		5.6E-11	10.25181197
ENRMF	6A		P3/L1/47P		8.3E-11	10.08092191
ENRMF	6A		P3/L1/49P		7.4E-11	10.13076828
ENRMF	6A		P3/L1/51P		5.5E-11	10.25963731
ENRMF	6A		P4/L1/53P		9.8E-11	10.00877392
ENRMF	6A		P4/L1/55P		9.8E-11	10.00877392
ENRMF	6A		P4/L1/57P		7.1E-11	10.14874165
ENRMF	6A		P4/L1/59P		5.6E-11	10.25181197
ENRMF	6A		P5/L1/61P		9.8E-11	10.00877392
ENRMF	6A		P5/L2/63P		7.1E-11	10.14874165
ENRMF	6A		P5/L3/65P		8.4E-11	10.07572071
ENRMF	6A		P5/L4/68P		9.7E-11	10.01322827
ENRMF	6A		P5/L5/70P		5.5E-11	10.25963731
ENRMF	6A		P5/L6/72P		9.8E-11	10.00877392
ENRMF	6B		P1/L1/18P		1.2E-10	9.920818754
ENRMF	6B		P1/L2/21P		2.3E-10	9.638272164
ENRMF	6B		P2/L1/22P		5.5E-11	10.25963731
ENRMF	6B		P1/L3/25P		1.7E-10	9.769551079
ENRMF	6B		P1/L1/32P		6.2E-11	10.20760831
ENRMF	6B		P2/L3/38P		7.5E-10	9.124938737
ENRMF	6B		P1/L4/40P		9.4E-10	9.026872146
ENRMF	6B		P2/L1/44P		3.8E-11	10.4202164
ENRMF	6B		P2/L2/54P		1.4E-10	9.853871964
ENRMF	6B		P2/L3/58P		5.1E-10	9.292429824
ENRMF	6B		P2/L4/61P		8.4E-10	9.075720714
ENRMF	6B		P3/L2/67P		5.5E-10	9.259637311
ENRMF	6B		P2/L4/71P		9.8E-10	9.008773924
ENRMF	6B		P2/L2/73P		1.3E-10	9.886056648
ENRMF	6B		P2/L3/77P		7.6E-11	10.11918641
ENRMF	6C		BTL/L2/01P		2.5E-11	10.60205999
ENRMF	6C		BTL/L2/04P		2.3E-11	10.63827216
ENRMF	6C		BTL/L3/06P		1.9E-11	10.7212464
ENRMF	6C		BTL/L3/07P		3.8E-11	10.4202164
ENRMF	6C		SWTL-L2-09P		2.8E-11	10.55284197
ENRMF	6C		SWTL-L3-15P		6.0E-11	10.22184875
ENRMF	6C		P1-L1-21P		9.2E-11	10.03621217
ENRMF	6C		P1-L1-26P		1.5E-10	9.823908741
ENRMF	6C		P1-L2-31P		1.8E-10	9.744727495
ENRMF	6C		P1-L2-37P		9.3E-10	9.031517051
ENRMF	6C		P1-L3-42P		1.8E-10	9.744727495
ENRMF	6C		P1-L3-47P		5.4E-11	10.26760624
ENRMF	6C		P1-L4-57P		1.3E-10	9.886056648
ENRMF	6C		P1-L4-63P		1.1E-10	9.958607315
ENRMF	6C		P2/L1/68P		5.4E-11	10.26760624
ENRMF	6C		P2/L1/73P		8.6E-11	10.06550155
ENRMF	6C		P2/L2/78P		4.6E-11	10.33724217
ENRMF	6C		P2/L2/81P		1.3E-10	9.886056648
ENRMF	6C		P2/L2/86P		4.1E-11	10.38721614

Site	Phase	Date	Samples	Location	Hydraulic Conductivity (m/s)	LOG data
ENRMF	6C		P2/L2/91P		1.5E-10	9.823908741
ENRMF	6C		P2/L3/103P		3.0E-10	9.522878745
ENRMF	6C		P2/L4/118P		7.5E-11	10.12493874
ENRMF	6C		P1/L4/119P		1.3E-11	10.88605665
ENRMF	6C		P1/L4/120P		1.3E-11	10.88605665
TH	3				1.50E-11	10.82390874
TH	3				4.00E-11	10.39794001
TH	5	09/06/2005			1.40E-11	10.85387196
TH	5	11/07/2005			6.90E-11	10.16115091
TH	5	10/06/2005			7.50E-11	10.12493874
TH	5	10/06/2005			8.10E-11	10.09151498
TH	5	12/07/2005			8.20E-11	10.08618615
TH	5	11/07/2005			8.30E-11	10.08092191
TH	5	09/06/2005			8.50E-11	10.07058107
TH	5	20/07/2005			9.00E-11	10.04575749
TH	5	12/07/2005			9.80E-11	10.00877392
TH	5	07/07/2005			1.10E-10	9.958607315
TH	5	14/07/2005			1.10E-10	9.958607315
TH	5	27/07/2005			1.30E-10	9.886056648
TH	5	19/07/2005			1.40E-10	9.853871964
TH	5	23/07/2005			1.50E-10	9.823908741
TH	5	13/07/2005			1.60E-10	9.795880017
TH	5	19/07/2005			1.70E-10	9.769551079
TH	5	22/07/2005			2.40E-10	9.619788758
TH	5	28/07/2005			2.60E-10	9.585026652
TH	5	20/07/2005			9.40E-10	9.026872146
TH	4B N	23/07/2019	PERM 1	Compaction trial layer 1 (C1/L1)	1.00E-10	10
TH	4B N	23/07/2019	PERM 2	Compaction trial layer 1 (C2/L1)	9.46E-10	9.024108864
TH	4B N	23/07/2019	PERM 3	Compaction trial layer 1 (D1/L1)	8.27E-11	10.08249449
TH	4B N	23/07/2019	PERM 4	C2/L2	9.01E-11	10.04527521
TH	4B N	23/07/2019	PERM 5	D1/L2	9.03E-11	10.04431225
TH	4B N	23/07/2019	PERM 6	D2/L2	8.90E-11	10.05060999
TH	4B N	01/08/2019	PERM 7	E1/L2	9.10E-11	10.04095861
TH	4B N	06/08/2019	PERM 8	A1/L3	2.63E-10	9.580044252
TH	4B N	07/08/2019	PERM 9	D1/L4	1.70E-10	9.769551079
TH	4B N	07/08/2019	PERM 10	A1/L4	1.07E-10	9.970616222
TH	4B N	20/08/2019	PERM 11	E3/L1	9.55E-11	10.01999663
TH	4B N	21/08/2019	PERM 12	C3/L3	9.12E-11	10.04000516
TH	4B N	30/08/2019	PERM 13	D4/L3	9.23E-11	10.0347983
TH	4B N	03/09/2019	PERM 14	D3/L4	8.73E-11	10.05898576
TH	4B N	05/09/2019	PERM 15	B4/L5	8.44E-11	10.07365755
TH	4B N	05/09/2019	PERM 16	C5/L5	8.06E-11	10.09366496
TH	4B N	07/09/2019	PERM 17	GE/L5 (BUND)	8.10E-11	10.09151498
TH	4B N	11/09/2019	PERM 18	F2/L3	8.53E-11	10.06905097
TH	4B N	03/09/2019	PERM 19	E4/L7 (BUND)	8.85E-11	10.05305673
TH	4B N	05/09/2019	PERM 20	E3/L4	8.08E-11	10.09258864
TH	4B S		P1-L1-17P		1.8E-10	9.744727495
TH	4B S		P1-L1-22P		1.1E-10	9.958607315
TH	4B S		P1-L1-27P		2.2E-10	9.657577319
TH	4B S		P2-L1-33P		1.3E-10	9.886056648
TH	4B S		P2-L1-38P		6.7E-10	9.173925197
TH	4B S		P2-L1-42P		2.0E-10	9.698970004
TH	4B S		P4-L1-46P		1.8E-10	9.744727495
TH	4B S		P4-L1-50P		2.0E-10	9.698970004
TH	4B S		P4-L1-57P		1.7E-10	9.769551079
TH	4B S		P1-L2-58P		1.8E-10	9.744727495
TH	4B S		P1-L2-63P		4.2E-11	10.37675071
TH	4B S		P1-L2-68P		7.6E-11	10.11918641
TH	4B S		P3-L1-72P		5.8E-11	10.23657201
TH	4B S		P3-L1-77P		8.6E-11	10.06550155
TH	4B S		P3-L1-83P		7.4E-11	10.13076828
TH	4B S		P2-L2-87P		5.0E-11	10.30103
TH	4B S		P2-L2-92P		4.0E-11	10.39794001
TH	4B S		P2-L2-97P		9.8E-11	10.00877392
TH	4B S		P4-L2-108P		7.1E-11	10.14874165
TH	4B S		P4-L2-113P		1.0E-10	10
TH	4B S		P4-L2-119P		1.3E-10	9.886056648
TH	4B S		P3-L2-125P		5.1E-11	10.29242982

Site	Phase	Date	Samples	Location	Hydraulic Conductivity (m/s)	LOG data
TH	4B S		P3-L2-131P		8.7E-11	10.06048075
TH	4B S		P3-L2-136P		8.7E-11	10.06048075
TH	4B S		P5-L1-141P		4.00E-11	10.39794001
TH	5 ext		7		6.58E-11	10.18177411
TH	5 ext		1		1.00E-10	10
TH	5 ext		3		1.45E-10	9.838631998
TH	5 ext		6		2.77E-10	9.557520231
TH	5 ext		5		3.24E-10	9.48945499
TH	5 ext		9		3.30E-10	9.48148606
TH	5 ext		4		5.39E-10	9.268411235
TH	5 ext		8		6.08E-10	9.216096421
TH	5 ext		2		8.73E-10	9.058985756
TH	5A	14/06/2005			8.40E-11	10.07572071
TH	5A	06/06/2005			8.60E-11	10.06550155
TH	5A	06/06/2005			9.00E-11	10.04575749
TH	5A	08/06/2005			9.00E-11	10.04575749
TH	5A	08/06/2005			9.10E-11	10.04095861
TH	5A	06/06/2005			9.50E-11	10.02227639
TH	5A	14/06/2005			1.10E-10	9.958607315
TH	5B	04/07/2005			6.90E-11	10.16115091
TH	5B	17/06/2005			7.00E-11	10.15490196
TH	5B	21/06/2005			7.40E-11	10.13076828
TH	5B	17/06/2005			7.50E-11	10.12493874
TH	5B	13/06/2005			7.60E-11	10.11918641
TH	5B	05/07/2005			8.10E-11	10.09151498
TH	5B	10/06/2005			8.40E-11	10.07572071
TH	5B	05/07/2005			8.80E-11	10.05551733
TH	5B	13/06/2005			9.30E-11	10.03151705
TH	5B	21/06/2005			9.70E-11	10.01322827
TH	5B	10/06/2005			1.10E-10	9.958607315
TH	5B	04/07/2005			2.30E-10	9.638272164
TH	5B/C	20/07/2005			7.30E-11	10.13667714
TH	5B/C	20/07/2005			7.90E-11	10.10237291
TH	5C	05/07/2005			6.90E-11	10.16115091
TH	5C	11/07/2005			7.90E-11	10.10237291
TH	5C	03/08/2005			5.10E-10	9.292429824
TH	5C/D	08/07/2005			8.90E-11	10.05060999
TH	5C/D	08/07/2005			9.70E-11	10.01322827
TH	5D	11/07/2005			7.30E-11	10.13667714
TH	5D	05/07/2005			7.40E-11	10.13076828
TH	5D	11/07/2005			7.90E-11	10.10237291
TH	5D	11/07/2005			8.00E-11	10.09691001
TH	5D	11/07/2005			9.30E-11	10.03151705
TH	5D	03/08/2005			9.40E-11	10.02687215
TH	5D	06/07/2005			9.80E-11	10.00877392
TH	5D	03/08/2005			1.20E-10	9.920818754
TH	5D	05/07/2005			1.90E-10	9.721246399
TH	6A	30/06/2004			3.50E-11	10.45593196
TH	6A	25/05/2004			4.90E-11	10.30980392
TH	6A	27/06/2004			5.00E-11	10.30103
TH	6A	03/07/2004			5.10E-11	10.29242982
TH	6A	25/05/2004			5.30E-11	10.27572413
TH	6A	26/06/2004			5.50E-11	10.25963731
TH	6A	29/06/2004			5.60E-11	10.25181197
TH	6A	01/07/2004			5.60E-11	10.25181197
TH	6A	26/06/2004			5.80E-11	10.23657201
TH	6A	02/07/2004			5.80E-11	10.23657201
TH	6A	28/06/2004			5.90E-11	10.22914799
TH	6A	05/07/2004			5.90E-11	10.22914799
TH	6A	29/06/2004			6.00E-11	10.22184875
TH	6A	30/06/2004			6.10E-11	10.21467016
TH	6A	27/06/2004			6.20E-11	10.20760831
TH	6A	05/07/2004			6.20E-11	10.20760831
TH	6A	29/06/2004			6.30E-11	10.20065945
TH	6A	30/06/2004			6.30E-11	10.20065945
TH	6A	26/06/2004			6.40E-11	10.19382003
TH	6A	26/06/2004			6.40E-11	10.19382003
TH	6A	26/06/2004			6.40E-11	10.19382003
TH	6A	30/06/2004			6.40E-11	10.19382003
TH	6A	03/07/2004			6.40E-11	10.19382003
TH	6A	26/06/2004			6.50E-11	10.18708664

Site	Phase	Date	Samples	Location	Hydraulic Conductivity (m/s)	LOG data
TH	6A	29/06/2004			6.60E-11	10.18045606
TH	6A	02/07/2004			6.60E-11	10.18045606
TH	6A	24/06/2004			6.70E-11	10.1739252
TH	6A	03/07/2004			6.70E-11	10.1739252
TH	6A	24/06/2004			6.80E-11	10.16749109
TH	6A	01/07/2004			6.90E-11	10.16115091
TH	6A	28/06/2004			7.00E-11	10.15490196
TH	6A	30/06/2004			7.20E-11	10.1426675
TH	6A	23/06/2004			7.50E-11	10.12493874
TH	6A	29/06/2004			7.50E-11	10.12493874
TH	6A	26/06/2004			7.90E-11	10.10237291
TH	6B	16/11/2004			2.60E-11	10.58502665
TH	6B	01/11/2004			3.30E-11	10.48148606
TH	6B	12/11/2004			5.00E-11	10.30103
TH	6B	14/09/2004			6.40E-11	10.19382003
TH	6B	02/11/2004			6.50E-11	10.18708664
TH	6B	24/11/2004			6.50E-11	10.18708664
TH	6B	10/11/2004			6.60E-11	10.18045606
TH	6B	04/11/2004			6.70E-11	10.1739252
TH	6B	26/11/2004			6.80E-11	10.16749109
TH	6B	07/09/2004			6.90E-11	10.16115091
TH	6B	03/12/2004			7.10E-11	10.14874165
TH	6B	16/11/2004			7.30E-11	10.13667714
TH	6B	08/09/2004			7.50E-11	10.12493874
TH	6B	09/11/2004			7.70E-11	10.11350927
TH	6B	06/09/2004			7.90E-11	10.10237291
TH	6B	03/11/2004			8.00E-11	10.09691001
TH	6B	03/12/2004			8.00E-11	10.09691001
TH	6B	09/09/2004			8.30E-11	10.08092191
TH	6B	07/12/2004			8.30E-11	10.08092191
TH	6B	05/11/2004			8.50E-11	10.07058107
TH	6B	02/11/2004			8.60E-11	10.06550155
TH	6B	11/11/2004			8.60E-11	10.06550155
TH	6B	23/11/2004			8.80E-11	10.05551733
TH	6B	17/11/2004			9.20E-11	10.03621217
TH	6B	03/11/2004			9.30E-11	10.03151705
TH	6B	30/11/2004			9.30E-11	10.03151705
TH	6B	13/09/2004			9.60E-11	10.01772877
TH	6B	06/12/2004			9.70E-11	10.01322827
TH	6B	04/11/2004			9.90E-11	10.00436481
TH	6B	07/09/2004			1.00E-10	10
TH	6B	06/12/2004			1.10E-10	9.958607315
TH	6B	01/11/2004			1.30E-10	9.886056648
TH	6B	13/09/2004			2.40E-10	9.619788758
TH	6B	15/09/2004			4.00E-10	9.397940009
TH	7A	04/06/2015	Perm 1	TP4/L2 - Brown	1.69E-10	9.772113295
TH	7A	04/06/2015	Perm 2	TP1/L2 - Brown	2.94E-10	9.53165267
TH	7A	10/06/2015	Perm 3	IB2/L3 - Brown	4.78E-10	9.320572103
TH	7A	11/06/2015	Perm 4	IB1/L4 - Brown	2.53E-10	9.596879479
TH	7A	17/06/2015	Perm 5	TP1/L2 - Grey	1.15E-10	9.93930216
TH	7A	17/06/2015	Perm 6	TP3/L2 - Grey	2.94E-10	9.53165267
TH	7A	18/06/2015	Perm 7	IB1/L7 - Brown	1.55E-10	9.809668302
TH	7A	25/06/2015	Perm 8	IB2/L8 - Brown	8.82E-11	10.05453141
TH	7A	01/07/2015	Perm 9	A2/L2 - Brown	5.81E-10	9.235823868
TH	7A	02/07/2015	Perm 10	B2/L2 - Grey	3.62E-10	9.441291429
TH	7A	02/07/2015	Perm 11	D1/L1 - Grey	1.15E-10	9.93930216
TH	7A	02/07/2015	Perm 12	C2/L2 - Grey	7.15E-11	10.14569396
TH	7A	06/07/2015	Perm 13	D2/Ls - Grey	6.46E-11	10.18976748
TH	7A	13/07/2015	Perm 14	B4/L2 - Grey	3.95E-10	9.403402904
TH	7A	20/07/2015	Perm 15	A4/L2 - Brown	1.20E-10	9.920818754

Hydraulic Conductivity (m/s)	
Mean	1.36E-10
Standard Error	1.02E-11
Median	8.6E-11
Mode	9.8E-11
Standard Deviation	1.67E-10
Sample Variance	2.78E-20
Kurtosis	12.42
Skewness	3.46
Range	9.67E-10
Minimum	1.3E-11
Maximum	9.8E-10
Sum	3.67946E-08
Count	270
Largest(1)	9.8E-10
Smallest(1)	1.3E-11
Confidence Level(95.0%)	1.99921E-11

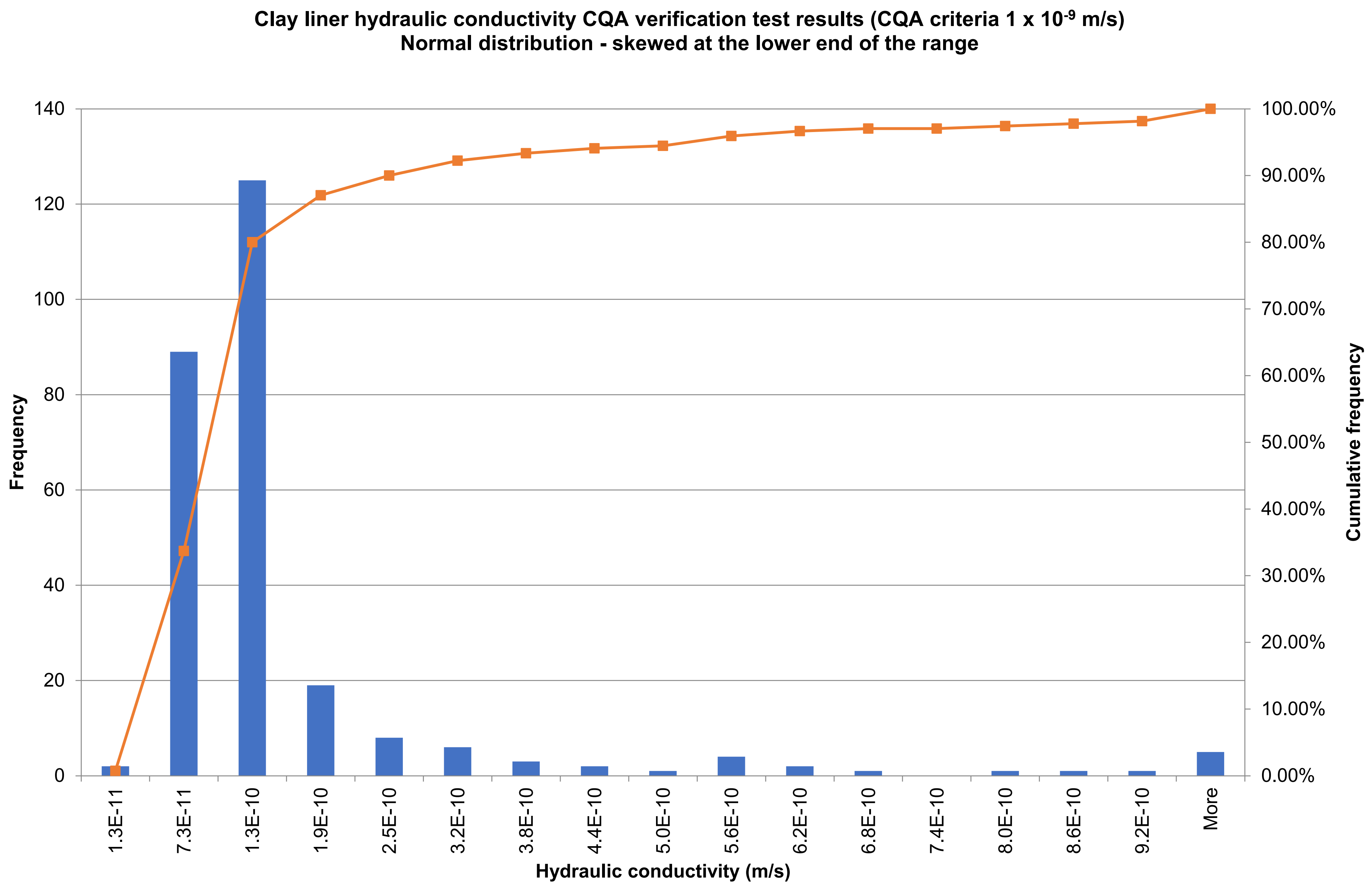
Normal distribution graph data

Bin	Frequency	Cumulative %
1.3E-11	2	0.74%
7.3E-11	89	33.70%
1.3E-10	125	80.00%
1.9E-10	19	87.04%
2.5E-10	8	90.00%
3.2E-10	6	92.22%
3.8E-10	3	93.33%
4.4E-10	2	94.07%
5.0E-10	1	94.44%
5.6E-10	4	95.93%
6.2E-10	2	96.67%
6.8E-10	1	97.04%
7.4E-10	0	97.04%
8.0E-10	1	97.41%
8.6E-10	1	97.78%
9.2E-10	1	98.15%
More	5	100.00%

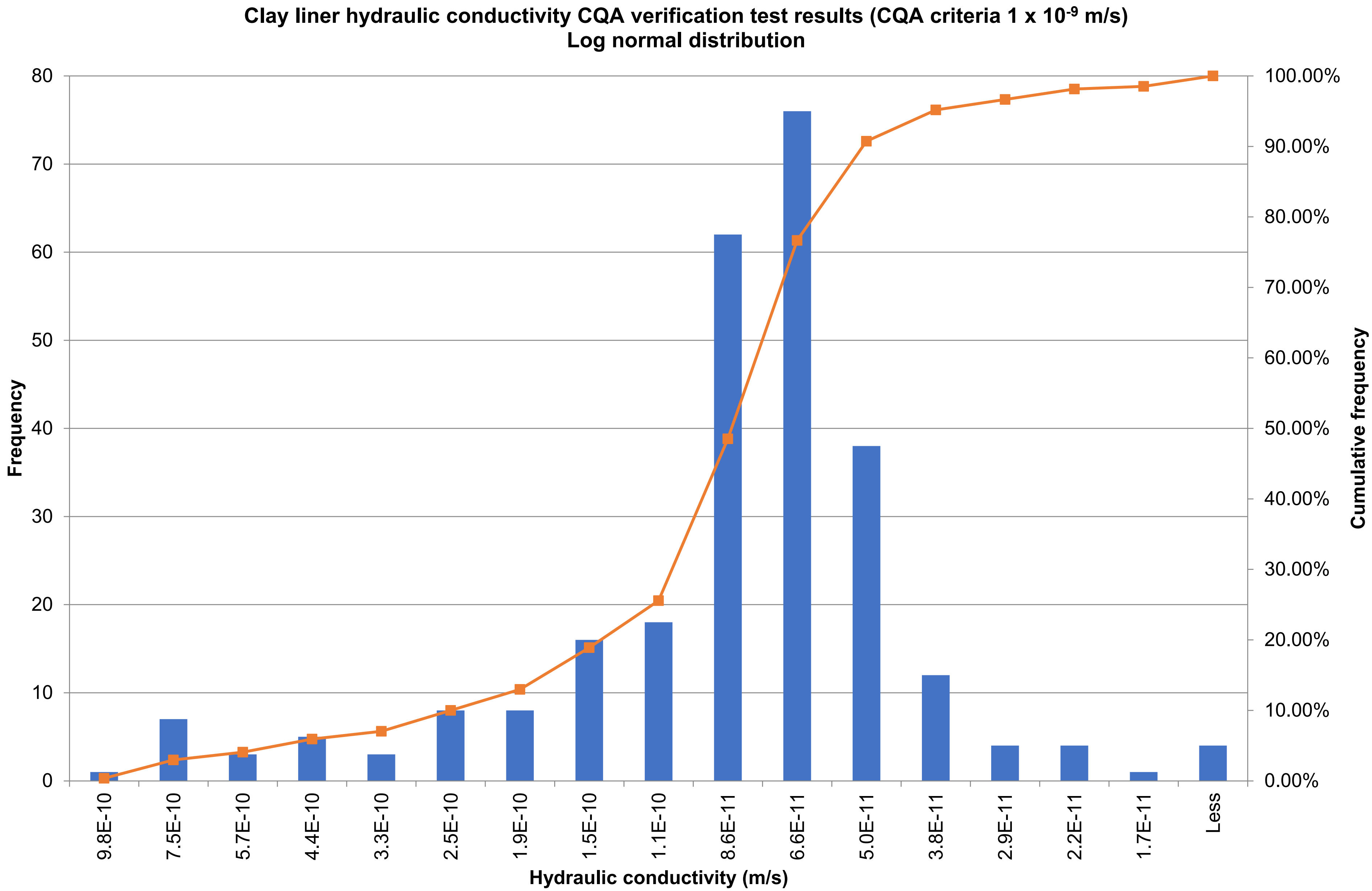
Inverse log values	LOG data	
9.7E-11	Mean	10.015
	Standard Error	0.019
8.6E-11	Median	10.066
9.8E-11	Mode	10.009
	Standard Deviation	0.317
	Sample Variance	0.100
	Kurtosis	2.267
	Skewness	-0.963
	Range	1.877
9.8E-10	Minimum	9.009
1.3E-11	Maximum	10.886
	Sum	2704.165
	Count	270
1.3E-11	Largest(1)	10.886
9.8E-10	Smallest(1)	9.009
	Confidence Level(95.0%)	0.038

Log normal distribution graph data

Inverse log values	Bin	Frequency	Cumulative %
9.8E-10	9.009	1	0.37%
7.5E-10	9.126	7	2.96%
5.7E-10	9.243	3	4.07%
4.4E-10	9.361	5	5.93%
3.3E-10	9.478	3	7.04%
2.5E-10	9.595	8	10.00%
1.9E-10	9.713	8	12.96%
1.5E-10	9.830	16	18.89%
1.1E-10	9.947	18	25.56%
8.6E-11	10.065	62	48.52%
6.6E-11	10.182	76	76.67%
5.0E-11	10.299	38	90.74%
3.8E-11	10.417	12	95.19%
2.9E-11	10.534	4	96.67%
2.2E-11	10.651	4	98.15%
1.7E-11	10.769	1	98.52%
Less	More	4	100.00%



Appendix HRA D 1E-9m_s CQA data



Appendix HRA D 1E-9m_s CQA data

APPENDIX HRA E

CAP DESIGN INFILTRATION CALCULATIONS

Appendix HRA E

Cap design infiltration calculations

Cap design

E.1 At the time of the 2014 HRA Phases 3A and 3B and parts of Phases 1A, 1B, 2A and 2B had been capped with a 0.3m thick regulating layer and a non-woven Geosynthetic Clay Liner (GCL) overlain by a 1mm thick Low Density Polyethylene (LDPE) geomembrane and a drainage geocomposite. During the review period further capping works have been completed on parts of Phases 1A, 1B, 2A, 3B and 4A, Phase 5A and 5B and part of Phase 6. The capping system of the phases constructed during the review period consists of a regulating layer, a low permeability clay cap with a minimum thickness of 1m and a drainage geocomposite layer overlain by restoration soils.

E.2 The hydraulic conductivity testing results of clay samples taken during the capping works carried out over the review period in Phases 1 to 6 are presented have been reviewed. The test results ranged from 6.27×10^{-11}m/s to 8.85×10^{-10}m/s with an average of 1.38×10^{-10}m/s and a geometric mean of $1.17 \text{ X } 10^{-10}$. The hydraulic conductivity testing results are provided with this appendix.

Model methodology – Recharge to a capped landfill

E.3 Recharge to the cap through the restoration soils is calculated using the method presented in Ruston and Redshaw (1979)[1]. The method is a soil moisture deficit model which takes into account the fraction of precipitation which may by-pass the soil moisture store. The model takes into account the root constant and wilting point in calculating the soil moisture deficit. The soil moisture deficit method is in common use in the UK and worldwide for calculating recharge. Other than the fraction of precipitation which may by-pass the soil moisture store water will be present at the surface of the cap only when the soil moisture deficit is zero. The precipitation values used in the model are average monthly rainfall data for the Wittering Airfield rainfall monitoring station for the period 1981 to 2010 presented in the ESID (reference 8). The potential evapotranspiration values used in the model are the average monthly potential evapotranspiration data presented in the 2004 HRA (reference 6) and at

[1] Rushton, K.R. and Redshaw, S.C., 1979. Seepage and Groundwater Flow. Wiley. Pages 134 and 135.

Appendix HRA 1C of the 2014 HRA (reference 1). The average monthly potential evapotranspiration comprises MORECS potential evapotranspiration data for RAF Wittering for the period 1961 to 1990 provided by the Met Office.

E.4 The results of the recharge calculations are entered into the hydraulics section of the model which comprises a series of calculations for a given time step which is in this instance 1 month. The recharge is converted into a head of water on the cap. The low permeability clay cap will be overlain by a suitable protection and drainage geocomposite layer. The minimum capacity of the drainage geocomposite layer per metre width of drainage layer is $0.0002m^3/s/m$ (0.2l/s/m) as agreed with the Environment Agency with confirmatory testing carried out as part of the CQA verification of the cap installation works. The minimum capacity of the drainage geocomposite layer per metre width of drainage layer of $0.0002m^3/s/m$ has been reduced by a number of reduction factors. These reduction factors for surface water drains for landfill caps based on Table 8.5 of Designing with Geosynthetics[2] are:

RF_{IN} reduction factor for elastic deformation of the adjacent geotextile intruding into the drainage core = 1.3 to 1.5.

RF_{CR} reduction factor for creep deformation of the drainage core itself and/or creep intrusion of the adjacent geotextile intruding into the drainage core space = 1.2 to 1.4.

RF_{CC} reduction factor for chemical clogging and/or precipitation of chemicals onto the geotextile or within the drainage core space = 1.0 to 1.2.

RF_{BC} reduction factor for biological clogging of the geotextile or within the drainage core space = 1.2 to 1.5.

E.5 The maximum reduction factors have been assumed in the calculations as a conservative assumption. The reduced capacity of the drainage geocomposite layer per metre width has then been divided by the longest drainage run from the top to the edge of the cap of approximately 200m to give a capacity per square metre. Conservatively it is assumed in the model that the head build up on the cap is equal to the volume per unit area of recharge from the soil divided by the ratio of the capacity of the drainage geocomposite to the volume per unit area of recharge from the soil. Consequently it is assumed that the head of water on the cap reflects the

2. Koerner, R. M., 2012. Designing with Geosynthetics 6th Edition.

average head of water which would be generated if all of the recharge during each time step were to accumulate instantaneously on top of the cap prior to being dissipated by the drainage geocomposite. In reality due to the domed profile of the cap, the head build up on the cap will be dissipated continuously by the drainage geocomposite and it is unlikely that the average head on the cap will be as high as the heads modelled in this assessment. On this basis it is considered that this assumption will result in a significant overestimate of the head build up on the cap hence the rate of infiltration through the cap compared with those which are likely to occur.

E.6 It is assumed that the cap is saturated. The equation used to calculate the rate of flow per metre squared through the clay cap is:

$$Q_{CC} = k_{CC} \times i_{CC}$$

Where:

Q_{CC} is the flow per metre squared through the clay cap ($m^3/s/m^2$)

k_{CC} is the hydraulic conductivity of the clay cap (m/s)

i_{CC} is the hydraulic gradient across the clay cap (m/m).

The equation used to calculate i_{CC} is:

$$i_{CC} = (h_{CC} + b_{CC}) / b_{CC}$$

Where:

h_{CC} is the head of water on the clay cap calculated for each time step (m)

b_{CC} is the thickness of the clay cap (m)

E.7 The model is provided with this appendix (an electronic copy of the model is provided at Appendix HRA C). The results of the calculations for 720 time steps which is 60 years are calculated. The modelled annual average infiltration rate over the 60 year period is approximately 1.6mm per year. The model stabilises over the first few years hence it is not deemed necessary to calculate further time steps. Due to the conservative assumptions made as part of the model it is considered unlikely that the rate of infiltration through the cap will exceed the value calculated.

RECHARGE TO A CAPPED LANDFILL AND FLOW THROUGH THE CAP

Notation	Parameter	Value	Units	Comment
Ro	% of precipitation that runs off	15	%	for a light soil with a 1 in 25 to 1 in 10 slope from Naylor, J.A., et al., 1978. The investigation of landfill sites. Water Research Centre Technical Report TR91
BPF	% of effective precipitation which forms by-pass flow	15	%	from Rushton, K.R. and Redshaw, S.C., 1979. Seepage and Groundwater Flow. Wiley.
C	Root Constant	75	mm	for permanent grass from Shaw, E.M., 1994, Hydrology in Practice. Third Edition. Chapman &Hall
D	Wilting Point	125	mm	for permanent grass from Shaw, E.M., 1994, Hydrology in Practice. Third Edition. Chapman &Hall

Recharge calculation method is taken from: Rushton, K.R. and Redshaw, S.C., 1979. Seepage and Groundwater Flow. Wiley. (pages 134 and 135).

Month	Precipitation	Runoff	P-R	Potential Evapotranspiration		Bypass Recharge	P-R-BPR	PE-P-R-BPR		Potential SMD					Soil Moisture Deficit	Recharge	Cumulative recharge
	P	R	P-R	PE		BPR		Def	10%Def						MC	Rc	Rcc
	mm	mm	mm	mm		mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm
January	48.0	7	40.8	14.4	5.04	5.04	35.76	-21.36		0.00	0.00	0.00	0.00	0.00	0.00	26.40	26.40
February	36.8	6	31.3	17.1	2.96	2.96	28.33	-11.23		0.00	0.00	0.00	0.00	0.00	0.00	14.18	40.58
March	42.0	6	35.7	36.8	0.78	0.78	34.92	1.88		1.88	1.88	1.88	1.88	1.88	1.88	0.78	41.36
April	49.6	7	42.2	53.9	-0.65	0.00	42.16	11.74		13.62	13.62	13.62	13.62	13.62	13.62	0.00	41.36
May	54.9	8	46.7	84.6	-4.46	0.00	46.67	37.94		51.56	51.56	51.56	51.56	51.56	51.56	0.00	41.36
June	52.0	8	44.2	89.0	-5.55	0.00	44.20	44.80	4.48	96.36	56.04	56.04	56.04	56.04	56.04	0.00	41.36
July	52.4	8	44.5	94.9	-6.38	0.00	44.54	50.36	5.04	146.72	61.07	61.07	61.07	61.07	61.07	0.00	41.36
August	55.8	8	47.4	81.8	-3.90	0.00	47.43	34.37	3.44	181.09	64.51	64.51	64.51	64.51	64.51	0.00	41.36
September	55.2	8	46.9	58.2	-0.45	0.00	46.92	11.28	1.13	192.37	65.64	65.64	65.64	65.64	65.64	0.00	41.36
October	59.3	9	50.4	34.6	3.71	3.71	46.70	-12.10		180.27	53.54	53.54	53.54	53.54	53.54	3.71	45.07
November	55.8	8	47.4	20.1	5.36	5.36	42.08	-21.98		158.29	31.56	31.56	31.56	31.56	31.56	5.36	50.42
December	47.2	7	40.1	13.4	5.07	5.07	35.05	-21.65		136.64	9.91	9.91	9.91	9.91	9.91	5.07	55.49
Total annual precipitation:	609.00														**Total annual recharge:**	55.49	
															Total annual recharge as a percentage of total annual precipitation:	9	

			Comments
K cap	1.00E-10	m/s	
Soil and drainage layer porosity	0.3	m3/m3	
Cap thickness	1	m	
Drainage geocomposite minimum flow	0.0002	m3/s per m width	CQA specification and confirmatory testing
RF_{IN} (elastic deformation)	1.5	unitless	Reduction factors for surface water drains for landfill caps based on Table 8.5 of Koerner, R.M., 2012, Designing with Geosynthetics 6th Edition. Maximum from range given applied to calculation
RF_{CR} (creep deformation)	1.4	unitless	
RF_{CC} (chemical clogging)	1.2	unitless	
RF_{BC} (biological clogging)	1.5	unitless	
Reduced drainage geocomposite minimum flow	5.29E-05	m3/s per m width	
Drainage layer capacity per square metre	2.65E-07	m3/s/m2	Flow per metre width divided by longest drainage run (200m)

Calculated infiltration through the cap	1.58	mm/yr

	Timestep number	Month	Number of days in month	Monthly recharge	Recharge available from soil	recharge flux per unit area	Potential head build up on cap	head buildup on cap liner	Head gradient across the cap	CAP leakage per square metre	Flow through cap per unit area
Unit				mm	m/s	m3/s/m2	m/s	m	m/m	m3/month/m2	m3/s/m2
Annual average			3.65E+02	5.55E+01						1.58E-03	
Year											
1	1	January	31	26.4	9.86E-09	9.86E-09	3.29E-08	3.28E-03	1.00E+00	2.69E-04	1.00E-10
	2	February	29	14.18	5.66E-09	5.66E-09	1.89E-08	1.01E-03	1.001011	2.51E-04	1.00E-10
	3	March	31	0.78	2.91E-10	2.91E-10	9.71E-10	2.86E-06	1.000003	2.68E-04	1.00E-10
	4	April	30	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1	0.00E+00	0.00E+00
	5	May	31	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1	0.00E+00	0.00E+00
	6	June	30	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1	0.00E+00	0.00E+00
	7	July	31	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1	0.00E+00	0.00E+00
	8	August	31	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1	0.00E+00	0.00E+00
	9	September	30	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1	0.00E+00	0.00E+00
	10	October	31	3.705	1.38E-09	1.38E-09	4.61E-09	6.46E-05	1.000065	2.68E-04	1.00E-10
	11	November	30	5.355	2.07E-09	2.07E-09	6.89E-09	1.39E-04	1.000139	2.59E-04	1.00E-10
	12	December	31	5.07	1.89E-09	1.89E-09	6.31E-09	1.21E-04	1.000121	2.68E-04	1.00E-10
	13	January	31	26.4	9.86E-09	9.86E-09	3.29E-08	3.28E-03	1.003279	2.69E-04	1.00E-10
	14	February	28	14.18	5.86E-09	5.86E-09	1.95E-08	1.05E-03	1.001047	2.42E-04	1.00E-10
	15	March	31	0.78	2.91E-10	2.91E-10	9.71E-10	2.86E-06	1.000003	2.68E-04	1.00E-10
	16	April	30	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1	0.00E+00	0.00E+00
	17	May	31	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1	0.00E+00	0.00E+00
	18	June	30	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1	0.00E+00	0.00E+00
	19	July	31	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1	0.00E+00	0.00E+00
	20	August	31	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1	0.00E+00	0.00E+00
	21	September	30	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1	0.00E+00	0.00E+00
	22	October	31	3.705	1.38E-09	1.38E-09	4.61E-09	6.46E-05	1.000065	2.68E-04	1.00E-10
	23	November	30	5.355	2.07E-09	2.07E-09	6.89E-09	1.39E-04	1.000139	2.59E-04	1.00E-10
	24	December	31	5.07	1.89E-09	1.89E-09	6.31E-09	1.21E-04	1.000121	2.68E-04	1.00E-10
	25	January	31	26.4	9.86E-09	9.86E-09	3.29E-08	3.28E-03	1.003279	2.69E-04	1.00E-10
	26	February	28	14.18	5.86E-09	5.86E-09	1.95E-08	1.05E-03	1.001047	2.42E-04	1.00E-10
	27	March	31	0.78	2.91E-10	2.91E-10	9.71E-10	2.86E-06	1.000003	2.68E-04	1.00E-10
	28	April	30	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1	0.00E+00	0.00E+00
	29	May	31	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1	0.00E+00	0.00E+00
	30	June	30	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1	0.00E+00	0.00E+00
	31	July	31	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1	0.00E+00	0.00E+00
	32	August	31	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1	0.00E+00	0.00E+00
	33	September	30	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1	0.00E+00	0.00E+00
	34	October	31	3.705	1.38E-09	1.38E-09	4.61E-09	6.46E-05	1.000065	2.68E-04	1.00E-10
	35	November	30	5.355	2.07E-09	2.07E-09	6.89E-09	1.39E-04	1.000139	2.59E-04	1.00E-10
	36	December	31	5.07	1.89E-09	1.89E-09	6.31E-09	1.21E-04	1.000121	2.68E-04	1.00E-10
	37	January	31	26.4	9.86E-09	9.86E-09	3.29E-08	3.28E-03	1.003279	2.69E-04	1.00E-10
	38	February	28	14.18	5.86E-09	5.86E-09	1.95E-08	1.05E-03	1.001047	2.42E-04	1.00E-10
	39	March	31	0.78	2.91E-10	2.91E-10	9.71E-10	2.86E-06	1.000003	2.68E-04	1.00E-10
	40	April	30	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1	0.00E+00	0.00E+00
	41	May	31	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1	0.00E+00	0.00E+00
	42	June	30	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1	0.00E+00	0.00E+00
	43	July	31	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1	0.00E+00	0.00E+00
	44	August	31	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1	0.00E+00	0.00E+00
	45	September	30	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1	0.00E+00	0.00E+00
	46	October	31	3.705	1.38E-09	1.38E-09	4.61E-09	6.46E-05	1.000065	2.68E-04	1.00E-10
	47	November	30	5.355	2.07E-09	2.07E-09	6.89E-09	1.39E-04	1.000139	2.59E-04	1.00E-10
	48	December	31	5.07	1.89E-09	1.89E-09	6.31E-09	1.21E-04	1.000121	2.68E-04	1.00E-10
	49	January	31	26.4	9.86E-09	9.86E-09	3.29E-08	3.28E-03	1.003279	2.69E-04	1.00E-10
	50	February	29	14.18	5.66E-09	5.66E-09	1.89E-08	1.01E-03	1.001011	2.51E-04	1.00E-10
	51	March	31	0.78	2.91E-10	2.91E-10	9.71E-10	2.86E-06	1.000003	2.68E-04	1.00E-10
	52	April	30	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1	0.00E+00	0.00E+00
	53	May	31	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1	0.00E+00	0.00E+00
	54	June	30	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1	0.00E+00	0.00E+00
	55	July	31	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1	0.00E+00	0.00E+00
	56	August	31	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1	0.00E+00	0.00E+00
	57	September	30	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1	0.00E+00	0.00E+00
	58	October	31	3.705	1.38E-09	1.38E-09	4.61E-09	6.46E-05	1.000065	2.68E-04	1.00E-10
	59	November	30	5.355	2.07E-09	2.07E-09	6.89E-09	1.39E-04	1.000139	2.59E-04	1.00E-10
	60	December	31	5.07	1.89E-09	1.89E-09	6.31E-09	1.21E-04	1.000121	2.68E-04	1.00E-10
	61	January	31	26.4	9.86E-09	9.86E-09	3.29E-08	3.28E-03	1.003279	2.69E-04	1.00E-10
	62	February	28	14.18	5.86E-09	5.86E-09	1.95E-08	1.05E-03	1.001047	2.42E-04	1.00E-10
	63	March	31	0.78	2.91E-10	2.91E-10	9.71E-10	2.86E-06	1.000003	2.68E-04	1.00E-10
	64	April	30	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1	0.00E+00	0.00E+00
	65	May	31	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1	0.00E+00	0.00E+00
	66	June	30	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1	0.00E+00	0.00E+00
	67	July	31	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1	0.00E+00	0.00E+00
	68	August	31	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1	0.00E+00	0.00E+00
	69	September	30	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1	0.00E+00	0.00E+00
	70	October	31	3.705	1.38E-09	1.38E-09	4.61E-09	6.46E-05	1.000065	2.68E-04	1.00E-10
	71	November	30	5.355	2.07E-09	2.07E-09	6.89E-09	1.39E-04	1.000139	2.59E-04	1.00E-10
	72	December	31	5.07	1.89E-09	1.89E-09	6.31E-09	1.21E-04	1.000121	2.68E-04	1.00E-10
	73	January	31	26.4	9.86E-09	9.86E-09	3.29E-08	3.28E-03	1.003279	2.69E-04	1.00E-10
	74	February	28	14.18	5.86E-09	5.86E-09	1.95E-08	1.05E-03	1.001047	2.42E-04	1.00E-10
	75	March	31	0.78	2.91E-10	2.91E-10	9.71E-10	2.86E-06	1.000003	2.68E-04	1.00E-10
	76	April	30	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1	0.00E+00	0.00E+00
	77	May	31	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1	0.00E+00	0.00E+00
	78	June	30	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1	0.00E+00	0.00E+00
	79	July	31	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1	0.00E+00	0.00E+00
	80	August	31	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1	0.00E+00	0.00E+00
	81	September	30	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1	0.00E+00	0.00E+00
	82	October	31	3.705	1.38E-09	1.38E-09	4.61E-09	6.46E-05	1.000065	2.68E-04	1.00E-10
	83	November	30	5.355	2.07E-09	2.07E-09	6.89E-09	1.39E-04	1.000139	2.59E-04	1.00E-10
	84	December	31	5.07	1.89E-09	1.89E-09	6.31E-09	1.21E-04	1.000121	2.68E-04	1.00E-10
	85	January	31	26.4	9.86E-09	9.86E-09	3.29E-08	3.28E-03	1.003279	2.69E-04	1.00E-10
	86	February	28	14.18	5.86E-09	5.86E-09	1.95E-08	1.05E-03	1.001047	2.42E-04	1.00E-10
	87	March	31	0.78	2.91E-10	2.91E-10	9.71E-10	2.86E-06	1.000003	2.68E-04	1.00E-10
	88	April	30	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1	0.00E+00	0.00E+00
	89	May	31	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1	0.00E+00	0.00E+00
	90	June	30	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1	0.00E+00	0.00E+00
	91	July	31	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1	0.00E+00	0.00E+00
	92	August	31	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1	0.00E+00	0.00E+00
	93	September	30	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1	0.00E+00	0.00E+00
	94	October	31	3.705	1.38E-09	1.38E-09	4.61E-09	6.46E-05	1.000065	2.68E-04	1.00E-10
	95	November	30	5.355	2.07E-09	2.07E-09	6.89E-09	1.39E-04	1.000139	2.59E-04	1.00E-10
	96	December	31	5.07	1.89E-09	1.89E-09	6.31E-09	1.21E-04	1.000121	2.68E-04	1.00E-10
	97	January	31	26.4	9.86E-09	9.86E-09	3.29E-08	3.28E-03	1.003279	2.69E-04	1.00E-10
	98	February	29	14.18	5.66E-09	5.66E-09	1.89E-08	1.01E-03	1.001011	2.51E-04	1.00E-10
	99	March	31	0.78	2.91E-10	2.91E-10	9.71E-10	2.86E-06	1.000003	2.68E-04	1.00E-10
	100	April	30	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1	0.00E+00	0.00E+00
	101	May	31	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1	0.00E+00	0.00E+00
	102	June	30	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1	0.00E+00	0.00E+00
	103	July	31	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1	0.00E+00	0.00E+00
	104	August	31	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1	0.00E+00	0.00E+00
	105	September	30	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1	0.00E+00	0.00E+00
	106	October	31	3.705	1.38E-09	1.38E-09	4.61E-09	6.46E-05	1.000065	2.68E-04	1.00E-10
	107	November	30	5.355	2.07E-09	2.07E-09	6.89E-09	1.39E-04	1.000139	2.59E-04	1.00E-10
	108	December	31	5.07	1.89E-09	1.89E-09	6.31E-09	1.21E-04	1.000121	2.68E-04	1.00E-10
	109	January	31	26.4	9.86E-09	9.86E-09	3.29E-08	3.28E-03	1.003279	2.69E-04	1.00E-10
	110	February	28	14.18	5.86E-09	5.86E-09	1.95E-08	1.05E-03	1.001047	2.42E-04	1.00E-10
	111	March	31	0.78	2.91E-10	2.91E-10	9.71E-10	2.86E-06	1.000003	2.68E-04	1.00E-10
	112	April	30	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1	0.00E+00	0.00E+00
	113	May	31	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1	0.00E+00	0.00E+00
	114	June	30	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1	0.00E+00	0.00E+00
	115	July	31	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1	0.00E+00	0.00E+00
	116	August	31	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1	0.00E+00	0.00E+00
	117	September	30	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1	0.00E+00	0.00E+00
	118	October	31	3.705	1.38E-09	1.38E-09	4.61E-09	6.46E-05	1.000065	2.68E-04	1.00E-10
	119	November	30	5.355	2.07E-09	2.07E-09	6.89E-09	1.39E-04	1.000139	2.59E-04	1.00E-10
	120	December	31	5.07	1.89E-09	1.89E-09	6.31E-09	1.21E-04	1.000121	2.68E-04	1.00E-10
	121	January	31	26.4	9.86E-09	9.86E-09	3.29E-08	3.28E-03	1.003279	2.69E-04	1.00E-10
	122	February	28	14.18	5.86E-09	5.86E-09	1.95E-08	1.05E-03	1.001047	2.42E-04	1.00E-10
	123	March	31	0.78	2.91E-10	2.91E-10	9.71E-10	2.86E-06	1.000003	2.68E-04	1.00E-10
	124	April	30	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1	0.00E+00	0.00E+00
	125	May	31	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1	0.00E+00	0.00E+00
	126	June	30	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1	0.00E+00	0.00E+00
	127	July	31	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1	0.00E+00	0.00E+00
	128	August	31	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1	0.00E+00	0.00E+00
	129	September	30	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1	0.00E+00	0.00E+00
	130	October	31	3.705	1.38E-09	1.38E-09	4.61E-09	6.46E-05	1.000065	2.68E-04	1.00E-10

Date	Phase	Sample reference	Location/ Layer	Hydraulic conductivity (m/s)
04/12/2018	6	PERM 1	TP/L1	9.80E-11
04/12/2018	6	PERM 2	TP/L1	1.63E-10
06/12/2018	6	PERM 3	TP/L2	1.78E-10
06/12/2018	6	PERM 4	TP/L2	1.63E-10
06/12/2018	6	PERM 5	TP/L3	1.72E-10
06/12/2018	6	PERM 6	TP/L3	1.21E-10
12/12/2018	6	PERM 7	B2/L1	1.58E-10
14/12/2018	6	PERM 8	A2/L2	2.11E-10
18/01/2019	6	PERM 9	C1/L2	1.43E-10
21/01/2019	6	PERM 10	B3/L1	8.85E-10
23/01/2019	6	PERM 11	C1/L4	1.36E-10
05/02/2019	6	PERM 12	A3/L3	8.65E-11
09/12/2019	5	PERM 1	F2/L2	9.78E-11
09/12/2019	5	PERM 2	E4/L2	9.02E-11
11/12/2019	5	PERM 3	E5/L1	8.90E-11
07/01/2020	5	PERM 4	F3/L3	9.00E-11
07/01/2020	5	PERM 5	F1/L3	8.55E-11
08/01/2020	5	PERM 6	E5/L3	9.63E-11
09/01/2020	5	PERM 7	D1/L2	8.37E-11
09/01/2020	5	PERM 8	E3/L4	9.09E-11
09/01/2020	5	PERM 9	D2/L4	1.19E-10
21/01/2020	5	PERM 10	E6/L4	8.58E-11
28/01/2020	5	PERM 11	C2/L1	8.58E-11
29/01/2020	5	PERM 12	C1/L2	8.68E-11
29/01/2020	5	PERM 13	C4/L3	8.71E-11
29/01/2020	5	PERM 14	C2/L3	8.19E-11
04/02/2020	5	PERM 15	B2/L1	9.61E-11
05/02/2020	5	PERM 16	B3/L4	9.34E-11
05/02/2020	5	PERM 17	B2/L4	9.02E-11
19/02/2020	5	PERM 18	A4/L3	9.51E-11
19/02/2020	5	PERM 19	A3/L3	9.64E-11
27/05/2020	1-4	PERM 1	CTP/1	9.89E-11
27/05/2020	1-4	PERM 2	CTP/2	8.20E-11
05/06/2020	1-4	PERM 3	L3/1	1.10E-10
05/06/2020	1-4	PERM 4	J4/1	1.87E-10
05/06/2020	1-4	PERM 5	K2/1	2.18E-10
05/06/2020	1-4	PERM 6	H2/1	1.92E-10
08/06/2020	1-4	PERM 7	K4/2	1.75E-10
08/06/2020	1-4	PERM 8	I3/2	1.16E-10
08/06/2020	1-4	PERM 9	I1/1	2.35E-10
09/06/2020	1-4	PERM 10	J4/3	3.34E-10
09/06/2020	1-4	PERM 11	K4/3	1.83E-10
09/06/2020	1-4	PERM 12	J2/3	6.45E-11
09/06/2020	1-4	PERM 13	J1/2	9.72E-11
10/06/2020	1-4	PERM 14	J1/2	7.73E-11
10/06/2020	1-4	PERM 15	I2/3	6.63E-11
11/06/2020	1-4	PERM 16	K4/4	8.14E-11

Appendix HRA E clay cap permeability results

12/06/2020	1-4	PERM 17	J4/4	8.19E-11
15/06/2020	1-4	PERM 18	I3/4	4.02E-10
15/06/2020	1-4	PERM 19	G4/3	3.51E-10
15/06/2020	1-4	PERM 20	H2/3	3.00E-10
15/06/2020	1-4	PERM 21	F1/2	4.42E-10
16/06/2020	1-4	PERM 22	E1/2	1.81E-10
16/06/2020	1-4	PERM 23	H1/4	7.49E-11
16/06/2020	1-4	PERM 24	G3/3	1.72E-10
16/06/2020	1-4	PERM 25	F4/3	4.47E-10
17/06/2020	1-4	PERM 26	E3/3	9.72E-11
13/07/2020	1-4	PERM 29	B3/4	1.14E-10
13/07/2020	1-4	PERM30	B2/4	1.47E-10
28/07/2020	1-4	PERM 31	L5/2	9.89E-11
28/07/2020	1-4	PERM 32	K6/2	1.68E-10
28/07/2020	1-4	PERM 33	L7/2	7.41E-11
29/07/2020	1-4	PERM 34	K8/2	1.15E-10
29/07/2020	1-4	PERM 35	J5/1	1.22E-10
29/07/2020	1-4	PERM 36	J7/1	7.64E-11
29/07/2020	1-4	PERM 37	L8/4	9.75E-11
29/07/2020	1-4	PERM 38	L5/4	7.95E-11
30/07/2020	1-4	PERM 39	K7/4	9.44E-11
30/07/2020	1-4	PERM 40	I6/3	1.80E-10
31/07/2020	1-4	PERM 41	I5/4	8.36E-11
31/07/2020	1-4	PERM 42	J8/4	9.54E-11
31/07/2020	1-4	PERM 43	H8/4	9.55E-11
06/08/2020	1-4	PERM 44	H6/1	8.85E-11
06/08/2020	1-4	PERM 45	F6/1	1.15E-10
06/08/2020	1-4	PERM 46	E6/1	6.27E-11
07/08/2020	1-4	PERM 47	G6/2	9.75E-11
07/08/2020	1-4	PERM 48	H7/1	6.79E-11
07/08/2020	1-4	PERM 49	F5/2	9.34E-11
07/08/2020	1-4	PERM 50	F8/2	8.74E-11
10/08/2020	1-4	PERM 51	G5/3	9.01E-11
10/08/2020	1-4	PERM 52	F7/3	7.77E-11
10/08/2020	1-4	PERM 53	H8/3	8.91E-11
11/08/2020	1-4	PERM 54	H5/4	8.91E-11
11/08/2020	1-4	PERM 55	G8/4	7.33E-11
09/09/2020	1-4	PERM 56	D7/2	8.24E-11
09/09/2020	1-4	PERM 57	D8/2	9.18E-11
09/09/2020	1-4	PERM 58	D7/4	8.24E-11
09/09/2020	1-4	PERM 59	D8/4	9.15E-11
			MIN	6.27E-11
			MEAN	1.38E-10
			GEOMEAN	1.17E-10
			MAX	8.85E-10

APPENDIX HRA F

HARD COPY OF THE HRA REVIEW RE-RUN OF THE LANDSIM MODEL

Calculation Settings

Number of iterations: 1001

Results calculated using sampled PDFs

Full Calculation

Clay Liner:

Retarded values used for simulation

Biodegradation

Unsaturated Pathway:

Retarded values used for simulation

Biodegradation

Saturated Vertical Pathway:

No Vertical Pathway

Aquifer Pathway:

Unretarded values used for simulation

Biodegradation

Timeslices at: 100, 1000, 10000, 19999

Decline in Contaminant Concentration in Leachate

Toluene	Non-Volatile
c (kg/l): 0.2919	m (kg/l): 0.0298
Zinc	Non-Volatile
c (kg/l): 0.0561	m (kg/l): 0.0403

Contaminant Half-lives (years)

Clay Liner:

Ammoniacal_N	SINGLE(1e+009)
Arsenic	SINGLE(1e+009)
Cadmium	SINGLE(1e+009)
Chloride	SINGLE(1e+009)
Dichlorprop	SINGLE(1e+009)
Manganese	SINGLE(1e+009)
Naphthalene	UNIFORM(0.137,8.2)
TCE (Trichloroethene)	LOGUNIFORM(0.18,2.16)
Toluene	UNIFORM(0.14,1.5)
Zinc	SINGLE(1e+009)

Unsaturated Pathway:

Ammoniacal_N	UNIFORM(5,10)
Arsenic	SINGLE(1e+009)
Cadmium	SINGLE(1e+009)
Chloride	SINGLE(1e+009)
Dichlorprop	UNIFORM(0.33,0.59)
Manganese	SINGLE(1e+009)
Naphthalene	UNIFORM(0.137,8.2)
TCE (Trichloroethene)	UNIFORM(0.5,1)
Toluene	UNIFORM(0.14,1.5)
Zinc	SINGLE(1e+009)

Aquifer Pathway:

Ammoniacal_N	UNIFORM(5,10)
Arsenic	SINGLE(1e+009)
Cadmium	SINGLE(1e+009)
Chloride	SINGLE(1e+009)
Dichlorprop	SINGLE(1e+009)
Manganese	SINGLE(1e+009)
Naphthalene	SINGLE(1e+009)
TCE (Trichloroethene)	SINGLE(1e+009)
Toluene	SINGLE(1e+009)
Zinc	SINGLE(1e+009)

Background Concentrations of Contaminants

Justification for Contaminant Properties

Table HRA 2

All units in milligrams per litre

Phase: Permitted eastern area

Infiltration Information

Cap design infiltration (mm/year):	SINGLE(1.6)
Infiltration to waste (mm/year):	NORMAL(609,60.9)
End of filling (years from start of waste deposit):	14

Justification for Specified Infiltration
Table HRA 3

Duration of management control (years from the start of waste disposal): 20000

Cell dimensions

Cell width (m):	416
Cell length (m):	255.37
Cell top area (ha):	12.7547
Cell base area (ha):	10.6234
Number of cells:	1
Total base area (ha):	10.6234
Total top area (ha):	12.7547
Head of Leachate when surface water breakout occurs (m)	SINGLE(6.5)
Waste porosity (fraction)	UNIFORM(0.37,0.56)
Final waste thickness (m):	SINGLE(15.5)
Field capacity (fraction):	SINGLE(0.36)
Waste dry density (kg/l)	SINGLE(1.53)

Justification for Landfill Geometry
Table HRA 3 (2020 HRA review waste porposity Table HRA 2)

Source concentrations of contaminants

All units in milligrams per litre

Declining source term

Ammoniacal_N	TRIANGULAR(112,325,2460)
	Data are spot measurements of Leachate Quality
Arsenic	LOGTRIANGULAR(0.02,0.87,17.3)
	Substance to be treated as List 1
Cadmium	LOGTRIANGULAR(0.00021,0.0776,1.7)
	Data are spot measurements of Leachate Quality
Chloride	LOGTRIANGULAR(5330,25358,89000)
	Data are spot measurements of Leachate Quality
Dichlorprop	LOGTRIANGULAR(0.009,1.3,16)
Manganese	LOGTRIANGULAR(0.4,5.51,310)
	Data are spot measurements of Leachate Quality
Naphthalene	LOGTRIANGULAR(0.0042,0.67,19)
	Substance to be treated as List 1
TCE (Trichloroethene)	LOGTRIANGULAR(0.12,0.79,18)
	Substance to be treated as List 1
Toluene	LOGTRIANGULAR(0.03,4.2,180)
	Substance to be treated as List 1
Zinc	LOGTRIANGULAR(0.023,1,76)
	Data are spot measurements of Leachate Quality

Justification for Species Concentration in Leachate

2014 HRA Table HRA 1 & 2 - Updates in 2020 HRA Review Table HRA 1

Drainage Information

Fixed Head.

Head on EBS is given as (m): SINGLE(1)

Justification for Specified Head

Table HRA 3 - Amended 2020 HRA review to long term leachate level compliance limit

Barrier Information

There is a composite barrier

Justification for Engineered Barrier Type
Table HRA 3

Liner installed under CQA	
Design thickness of clay (m):	TRIANGULAR(1,1.5,2.5)
Density of clay (kg/l):	TRIANGULAR(1.49,1.64,1.78)
Pathway moisture content (fraction):	UNIFORM(0.14,0.25)
Onset of FML degradation (years since filling commenced)	150
Pathway longitudinal dispersivity (m):	TRIANGULAR(0.1,0.15,0.25)
Time for area of defects to double (years)	100

Membrane defects (number per hectare):

Pin holes:	Minimum 0, Maximum 25
Holes:	Minimum 0, Maximum 5
Tears:	Minimum 0, Most Likely 0.1, Maximum 2

The most likely value for the PDFs representing the density of pinholes and holes will move from the minimum value selected above to the maximum value selected above over the time period before FML degradation commences

Justification for Composite: Flexible Membrane Liner
Table HRA 3

Hydraulic conductivity of mineral lower liner (m/s): LOGTRIANGULAR(4.1e-011,6e-011,1.5e-010)

Justification for Composite: Clay or BES Substrate Properties
Table HRA 3

Retardation parameters for clay liner

Uncertainty in Kd (l/kg):	
Ammoniacal_N	TRIANGULAR(0,0.97,2.4)
Arsenic	UNIFORM(25,250)
Cadmium	LOGTRIANGULAR(14,663,2079)
Chloride	SINGLE(0)
Dichlorprop: Calculated kd	
Partition to Organic Carbon ml/g	UNIFORM(46.06,80)
Manganese	LOGTRIANGULAR(3,49,810)
Naphthalene: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(1190)
TCE (Trichloroethene): Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(94)
Toluene: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(140)
Zinc	LOGTRIANGULAR(1.1,200,36000)
Fraction of Organic Carbon (fraction)	TRIANGULAR(0.002,0.004,0.01)

Justification for Liner Kd Values by Species
Table HRA 4

Lincolnshire Limestone pathway parameters

Modelled as unsaturated pathway

Pathway length (m):	NORMAL(8.68,1.26)
Flow Model:	porous medium
Pathway moisture content (fraction):	UNIFORM(0.004,0.01)
Pathway Density (kg/l):	SINGLE(2)

Justification for Unsat Zone Geometry
Table HRA 3

Pathway hydraulic conductivity values (m/s):	LOGTRIANGULAR(1.16e-005,5e-005,0.000116)

Justification for Unsat Zone Hydraulics Properties
Table HRA 3

Pathway longitudinal dispersivity (m):	NORMAL(0.868,0.126)

Justification for Unsat Zone Dispersion Properties
Table HRA 3

Retardation parameters for Lincolnshire Limestone pathway

Modelled as unsaturated pathway

Uncertainty in Kd (l/kg):	
Ammoniacal_N	LOGUNIFORM(0.065,0.65)
Arsenic	UNIFORM(25,31)
Cadmium	LOGUNIFORM(127,1348)
Chloride	SINGLE(0)
Dichlorprop: Calculated kd	
Partition to Organic Carbon ml/g	UNIFORM(46.06,80)
Manganese	LOGTRIANGULAR(3,49,810)
Naphthalene: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(1190)
TCE (Trichloroethene): Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(94)
Toluene: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(140)
Zinc	LOGTRIANGULAR(1.1,200,36000)
Fraction of Organic Carbon (fraction)	UNIFORM(0.0007,0.0009)

Justification for Kd Values by Species

Table HRA 4

Aquifer Pathway Dimensions for Phase

Pathway length (m):	UNIFORM(40,340)
Pathway width (m):	SINGLE(425)

Phase: P7-9&11 Permitted western area

Infiltration Information

Cap design infiltration (mm/year):	SINGLE(1.6)
Infiltration to waste (mm/year):	NORMAL(609,60.9)
End of filling (years from start of waste deposit):	10

Justification for Specified Infiltration
Table HRA 3

Duration of management control (years from the start of waste disposal): 20000

Cell dimensions

Cell width (m):	180
Cell length (m):	335
Cell top area (ha):	6.9
Cell base area (ha):	6.03
Number of cells:	1
Total base area (ha):	6.03
Total top area (ha):	6.9
Head of Leachate when surface water breakout occurs (m)	SINGLE(3.7)
Waste porosity (fraction)	UNIFORM(0.37,0.56)
Final waste thickness (m):	SINGLE(11)
Field capacity (fraction):	SINGLE(0.36)
Waste dry density (kg/l)	SINGLE(1.53)

Justification for Landfill Geometry
Table HRA 3 (2020 HRA review waste porosity Table HRA 2)

Source concentrations of contaminants

All units in milligrams per litre

Declining source term

Ammoniacal_N	TRIANGULAR(92,193,2460)
	Data are spot measurements of Leachate Quality
Arsenic	LOGTRIANGULAR(0.02,0.87,17.3)
	Substance to be treated as List 1
Cadmium	LOGTRIANGULAR(0.00021,0.0776,1.7)
	Data are spot measurements of Leachate Quality
Chloride	TRIANGULAR(5330,30693,120000)
	Data are spot measurements of Leachate Quality
Dichlorprop	LOGTRIANGULAR(0.009,1.3,16)
Manganese	LOGTRIANGULAR(0.4,5.51,310)
	Data are spot measurements of Leachate Quality
Naphthalene	LOGTRIANGULAR(0.0042,0.67,19)
	Substance to be treated as List 1
TCE (Trichloroethene)	LOGTRIANGULAR(0.12,0.79,18)
	Substance to be treated as List 1
Toluene	LOGTRIANGULAR(0.03,4.2,180)
	Substance to be treated as List 1
Zinc	LOGTRIANGULAR(0.023,1,76)
	Data are spot measurements of Leachate Quality

Justification for Species Concentration in Leachate
2014 HRA Table HRA 1 & 2 - Updates in 2020 HRA Review Table HRA 1

Drainage Information

Fixed Head.
Head on EBS is given as (m): SINGLE(1)

Justification for Specified Head
Table HRA 3

Barrier Information

There is a composite barrier

Justification for Engineered Barrier Type
Table HRA 3

Liner installed under CQA	
Design thickness of clay (m):	SINGLE(1)
Density of clay (kg/l):	TRIANGULAR(1.49,1.64,1.78)
Pathway moisture content (fraction):	UNIFORM(0.14,0.25)
Onset of FML degradation (years since filling commenced)	150
Pathway longitudinal dispersivity (m):	SINGLE(0.1)
Time for area of defects to double (years)	100

Membrane defects (number per hectare):	
Pin holes:	Minimum 0, Maximum 25
Holes:	Minimum 0, Maximum 5
Tears:	Minimum 0, Most Likely 0.1, Maximum 2

The most likely value for the PDFs representing the density of pinholes and holes will move from the minimum value selected above to the maximum value selected above over the time period before FML degradation commences

Justification for Composite: Flexible Membrane Liner
Table HRA 3

Hydraulic conductivity of mineral lower liner (m/s):	LOGNORMAL(1.4e-010,1.7e-010)

Justification for Composite: Clay or BES Substrate Properties
Table HRA 3. Updated hydraulic conductivity 2020 HRA review

Retardation parameters for clay liner

Uncertainty in Kd (l/kg):	
Ammoniacal_N	TRIANGULAR(0,0.97,2.4)
Arsenic	UNIFORM(25,250)
Cadmium	LOGTRIANGULAR(14,663,2079)
Chloride	SINGLE(0)
Dichlorprop: Calculated kd	
Partition to Organic Carbon ml/g	UNIFORM(46.06,80)
Manganese	LOGTRIANGULAR(3,49,810)
Naphthalene: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(1190)
TCE (Trichloroethene): Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(94)
Toluene: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(140)
Zinc	LOGTRIANGULAR(1.1,200,36000)
Fraction of Organic Carbon (fraction)	TRIANGULAR(0.002,0.004,0.01)

Justification for Liner Kd Values by Species
Table HRA 4

Lincolnshire Limestone pathway parameters

Modelled as unsaturated pathway

Pathway length (m):	NORMAL(9.49,1.66)
Flow Model:	porous medium
Pathway moisture content (fraction):	UNIFORM(0.004,0.01)
Pathway Density (kg/l):	SINGLE(2)

Justification for Unsat Zone Geometry
Table HRA 3

Pathway hydraulic conductivity values (m/s):	LOGTRIANGULAR(1.16e-005,5e-005,0.000116)

Justification for Unsat Zone Hydraulics Properties
Table HRA 3

Pathway longitudinal dispersivity (m):	NORMAL(0.949,0.166)

Justification for Unsat Zone Dispersion Properties
Table HRA 3

Retardation parameters for Lincolnshire Limestone pathway

Modelled as unsaturated pathway

Uncertainty in Kd (l/kg):

Ammoniacal_N	LOGUNIFORM(0.065,0.65)
Arsenic	UNIFORM(25,31)
Cadmium	LOGUNIFORM(127,1348)
Chloride	SINGLE(0)
Dichlorprop: Calculated kd	
Partition to Organic Carbon ml/g	UNIFORM(46.06,80)
Manganese	LOGTRIANGULAR(3,49,810)
Naphthalene: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(1190)
TCE (Trichloroethene): Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(94)
Toluene: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(140)
Zinc	LOGTRIANGULAR(1.1,200,36000)

Fraction of Organic Carbon (fraction) UNIFORM(0.0007,0.0009)

Justification for Kd Values by Species

Table HRA 4

Aquifer Pathway Dimensions for Phase

Pathway length (m):	UNIFORM(40,380)
Pathway width (m):	SINGLE(202)

Phase: P6 & 10 Permitted western area

Infiltration Information

Cap design infiltration (mm/year):	SINGLE(1.6)
Infiltration to waste (mm/year):	NORMAL(609,60.9)
End of filling (years from start of waste deposit):	6

Justification for Specified Infiltration
As WLA

Duration of management control (years from the start of waste disposal): 20000

Cell dimensions

Cell width (m):	90
Cell length (m):	255
Cell top area (ha):	4.3
Cell base area (ha):	2.295
Number of cells:	1
Total base area (ha):	2.295
Total top area (ha):	4.3
Head of Leachate when surface water breakout occurs (m)	SINGLE(3.7)
Waste porosity (fraction)	UNIFORM(0.37,0.56)
Final waste thickness (m):	SINGLE(11)
Field capacity (fraction):	SINGLE(0.36)
Waste dry density (kg/l)	SINGLE(1.53)

Justification for Landfill Geometry
As WLA

Source concentrations of contaminants

All units in milligrams per litre

Declining source term

Ammoniacal_N	TRIANGULAR(92,193,2460)
	Data are spot measurements of Leachate Quality
Arsenic	LOGTRIANGULAR(0.02,0.87,17.3)
	Substance to be treated as List 1
Cadmium	LOGTRIANGULAR(0.00021,0.0776,1.7)
	Data are spot measurements of Leachate Quality
Chloride	LOGTRIANGULAR(5330,30693,120000)
	Data are spot measurements of Leachate Quality
Dichlorprop	LOGTRIANGULAR(0.009,1.3,16)
Manganese	LOGTRIANGULAR(0.4,5.51,310)
	Data are spot measurements of Leachate Quality
Naphthalene	LOGTRIANGULAR(0.0042,0.67,19)
	Substance to be treated as List 1
TCE (Trichloroethene)	LOGTRIANGULAR(0.12,0.79,18)
	Substance to be treated as List 1
Toluene	LOGTRIANGULAR(0.03,4.2,180)
	Substance to be treated as List 1
Zinc	LOGTRIANGULAR(0.023,1,76)
	Data are spot measurements of Leachate Quality

Justification for Species Concentration in Leachate
As WLA

Drainage Information

Fixed Head.
Head on EBS is given as (m): SINGLE(1)

Justification for Specified Head
As WLA

Barrier Information

There is a composite barrier

Justification for Engineered Barrier Type
As WLA

Liner installed under CQA	
Design thickness of clay (m):	SINGLE(1)
Density of clay (kg/l):	TRIANGULAR(1.49,1.64,1.78)
Pathway moisture content (fraction):	LOGUNIFORM(0.14,0.25)
Onset of FML degradation (years since filling commenced)	150
Pathway longitudinal dispersivity (m):	SINGLE(0.1)
Time for area of defects to double (years)	100

Membrane defects (number per hectare):	
Pin holes:	Minimum 0, Maximum 25
Holes:	Minimum 0, Maximum 5
Tears:	Minimum 0, Most Likely 0.1, Maximum 2

The most likely value for the PDFs representing the density of pinholes and holes will move from the minimum value selected above to the maximum value selected above over the time period before FML degradation commences

Justification for Composite: Flexible Membrane Liner
Unjustified value

Hydraulic conductivity of mineral lower liner (m/s): LOGTRIANGULAR(5.6e-011,9.3e-011,2.7e-010)

Justification for Composite: Clay or BES Substrate Properties
As WLA - updated hydraulic conductivity (See 2020 HRA Review)

Retardation parameters for clay liner

Uncertainty in Kd (l/kg):	
Ammoniacal_N	TRIANGULAR(0,0.97,2.4)
Arsenic	UNIFORM(25,250)
Cadmium	TRIANGULAR(14,663,2079)
Chloride	SINGLE(0)
Dichlorprop: Calculated kd	
Partition to Organic Carbon ml/g	UNIFORM(46.06,80)
Manganese	TRIANGULAR(3,49,810)
Naphthalene: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(1190)
TCE (Trichloroethene): Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(94)
Toluene: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(140)
Zinc	TRIANGULAR(1.1,200,36000)
Fraction of Organic Carbon (fraction)	TRIANGULAR(0.2,0.4,1)

Justification for Liner Kd Values by Species
As WLA

Lincolnsire Limestone pathway parameters

Modelled as unsaturated pathway

Pathway length (m):	NORMAL(9.49,1.66)
Flow Model:	porous medium
Pathway moisture content (fraction):	UNIFORM(0.004,0.01)
Pathway Density (kg/l):	SINGLE(2)

Justification for Unsat Zone Geometry
As WLA

Pathway hydraulic conductivity values (m/s): LOGTRIANGULAR(1.16e-005,5e-005,0.000116)

Justification for Unsat Zone Hydraulics Properties
As WLA

Pathway longitudinal dispersivity (m): NORMAL(0.949,0.166)

Justification for Unsat Zone Dispersion Properties
As WLA

Retardation parameters for Lincolnsire Limestone pathway

Modelled as unsaturated pathway

Uncertainty in Kd (l/kg):	
Ammoniacal_N	LOGUNIFORM(0.065,0.65)
Arsenic	UNIFORM(25,31)
Cadmium	LOGUNIFORM(127,1348)
Chloride	SINGLE(0)
Dichlorprop: Calculated kd	
Partition to Organic Carbon ml/g	UNIFORM(46.06,80)
Manganese	LOGTRIANGULAR(3,49,810)
Naphthalene: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(1190)
TCE (Trichloroethene): Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(94)
Toluene: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(140)
Zinc	LOGTRIANGULAR(1.1,200,36000)
Fraction of Organic Carbon (fraction)	UNIFORM(0.0007,0.0009)

Justification for Kd Values by Species

As WLA

Aquifer Pathway Dimensions for Phase

Pathway length (m):	UNIFORM(40,370)
Pathway width (m):	SINGLE(130)

pathway parameters

No Vertical Pathway

Lincolnshire Limestone pathway parameters

Modelled as aquifer pathway.

Mixing zone (m):	NORMAL(7.42,1.44)

Justification for Aquifer Geometry
Table HRA 3 - Updated 2020 HRA review

Pathway regional gradient (-):	TRIANGULAR(0.0081,0.0107,0.0123)
Pathway hydraulic conductivity values (m/s):	LOGTRIANGULAR(1.16e-005,5e-005,0.000116)
Pathway porosity (fraction):	UNIFORM(0.004,0.01)

Justification for Aquifer Hydraulics Properties
Table HRA 3

Pathway longitudinal dispersivity (m):	UNIFORM(4,38)
Pathway transverse dispersivity (m):	UNIFORM(0.4,3.8)

Justification for Aquifer Dispersion Details
Table HRA 3 - Updated 2020 HRA review

Retardation parameters for Lincolnshire Limestone pathway

Modelled as aquifer pathway.
No retardation values used in this simulation.
Check 'Unretarded Contaminant Transport' setting under simulation preferences.

APPENDIX HRA G

A COPY OF TABLE HRA 3 WITH THE INPUT PARAMETERS FOR THE CHEMICAL AND ATTENUATION PROPERTIES FROM THE 2014 HRA

Table HRA 3

Input parameters for the LandSim hydrogeological risk assessment model – chemical and attenuation properties

Parameter	Pathway (CL = clay liner, LL=Lincolnshire Limestone)	K_{oc} (l/kg)			K_d (l/kg)			Half life (years)	
		Minimum	Most likely	Maximum	Minimum	Most likely	Maximum	Minimum	Maximum
Hazardous substances									
Cadmium	CL[1]				*14*	*663*	*2079*	-	-
	LL				*127*		*1348*	-	-
Dichlorprop	CL[1]	46.06		80				-	-
	LL							0.33	0.59
Naphthalene	CL[1] & LL		1190					*0.137*	*8.2*
Toluene	CL[1] & LL		140					0.14	1.5
Trichloroethene	CL[1]		94					*0.18*	*2.16*
	LL							0.5	1-
Non hazardous pollutant									
Chloride	CL[1] & LL					0		-	-
Ammoniacal nitrogen	CL[1]				0	0.97	2.4	-	-
	LL				*0.065*		*0.65*	5	10
Manganese	CL[1] & LL				*3*	*49*	*810*	-	-
Zinc	CL[1] & LL				*1.1*	*200*	*36000*	-	-

Notes:

Probability density functions key:

- Unshaded: single value
- Horizontal shading: uniform distribution
- Solid shading: triangular distribution
- Numbers in italics: log distributions (triangular or uniform).

Derivation of parameter values:

With the exception of the values for dichorprop, manganese and zinc the parameter values above have been derived from the 2004 HRA (Appendix HRA 1D). It is assumed conservatively that dichlorprop does not degrade in an anaerobic environment. The half live for dichloprop in the Lincolnshire Limestone is conservatively based on times for full degradation of dichlorprop in groundwater (reference 19 & 20) and the half life for trichloroethene is based on aqueous aerobic biodegradation rates presented in reference 21 The K_d values for manganese and zinc are from reference 22. The K_{oc} values for dichlorprop are from references 23 and 24.

1 For the purpose of this assessment it is assumed conservatively that the clay liner is anaerobic.

APPENDIX HRA H

HARD COPY OF THE 2021 HRA LANDSIM MODEL TO INCLUDE THE WESTERN EXTENSION

Calculation Settings

Number of iterations: 1001

Results calculated using sampled PDFs

Full Calculation

Clay Liner:

Retarded values used for simulation

Biodegradation

Unsaturated Pathway:

Retarded values used for simulation

Biodegradation

Saturated Vertical Pathway:

No Vertical Pathway

Aquifer Pathway:

Unretarded values used for simulation

No Biodegradation

Timeslices at: 100, 1000, 10000, 19999

Decline in Contaminant Concentration in Leachate

Toluene	Non-Volatile
c (kg/l): 0.2919	m (kg/l): 0.0298
Zinc	Non-Volatile
c (kg/l): 0.0561	m (kg/l): 0.0403

Contaminant Half-lives (years)

Clay Liner:

Ammoniacal_N	SINGLE(1e+009)
Arsenic	SINGLE(1e+009)
Cadmium	SINGLE(1e+009)
Chloride	SINGLE(1e+009)
Dichlorprop	SINGLE(1e+009)
Manganese	SINGLE(1e+009)
Naphthalene	UNIFORM(0.137,8.2)
TCE (Trichloroethene)	LOGUNIFORM(0.18,2.16)
Toluene	UNIFORM(0.14,1.5)
Zinc	SINGLE(1e+009)

Unsaturated Pathway:

Ammoniacal_N	UNIFORM(5,10)
Arsenic	SINGLE(1e+009)
Cadmium	SINGLE(1e+009)
Chloride	SINGLE(1e+009)
Dichlorprop	UNIFORM(0.33,0.59)
Manganese	SINGLE(1e+009)
Naphthalene	UNIFORM(0.137,8.2)
TCE (Trichloroethene)	UNIFORM(0.5,1)
Toluene	UNIFORM(0.14,1.5)
Zinc	SINGLE(1e+009)

Background Concentrations of Contaminants

Justification for Contaminant Properties

Table HRA 5

All units in milligrams per litre

Phase: Permitted eastern area

Infiltration Information

Cap design infiltration (mm/year):	SINGLE(1.6)
Infiltration to waste (mm/year):	NORMAL(609,60.9)
End of filling (years from start of waste deposit):	14

Justification for Specified Infiltration
Table HRA 5

Duration of management control (years from the start of waste disposal): 20000

Cell dimensions

Cell width (m):	416
Cell length (m):	255.37
Cell top area (ha):	12.7547
Cell base area (ha):	10.6234
Number of cells:	1
Total base area (ha):	10.6234
Total top area (ha):	12.7547
Head of Leachate when surface water breakout occurs (m)	SINGLE(6.5)
Waste porosity (fraction)	UNIFORM(0.37,0.56)
Final waste thickness (m):	SINGLE(19)
Field capacity (fraction):	SINGLE(0.36)
Waste dry density (kg/l)	SINGLE(1.53)

Justification for Landfill Geometry
Table HRA 5

Source concentrations of contaminants

All units in milligrams per litre

Declining source term

Ammoniacal_N	TRIANGULAR(112,325,2952)
	Data are spot measurements of Leachate Quality
Arsenic	LOGTRIANGULAR(0.02,0.87,17.3)
	Substance to be treated as List 1
Cadmium	LOGTRIANGULAR(0.00021,0.0776,1.7)
	Data are spot measurements of Leachate Quality
Chloride	LOGTRIANGULAR(9150,23600,106800)
	Data are spot measurements of Leachate Quality
Dichlorprop	LOGTRIANGULAR(0.009,1.3,16)
	Substance to be treated as List 1
Manganese	LOGTRIANGULAR(0.4,5.51,372)
	Data are spot measurements of Leachate Quality
Naphthalene	LOGTRIANGULAR(0.0042,0.67,19)
	Data are spot measurements of Leachate Quality
TCE (Trichloroethene)	LOGTRIANGULAR(0.12,0.79,18)
	Substance to be treated as List 1
Toluene	LOGTRIANGULAR(0.03,4.2,180)
	Substance to be treated as List 1
Zinc	LOGTRIANGULAR(0.023,1,91.2)
	Data are spot measurements of Leachate Quality

Justification for Species Concentration in Leachate
Table HRA 4

Drainage Information

Fixed Head.
Head on EBS is given as (m): SINGLE(1)

Justification for Specified Head
Table HRA 5

Barrier Information

There is a composite barrier

Justification for Engineered Barrier Type
Table HRA 5

Liner installed under CQA	
Design thickness of clay (m):	TRIANGULAR(1,1.5,2.5)
Density of clay (kg/l):	TRIANGULAR(1.49,1.64,1.78)
Pathway moisture content (fraction):	UNIFORM(0.14,0.25)
Onset of FML degradation (years since filling commenced)	150
Pathway longitudinal dispersivity (m):	TRIANGULAR(0.1,0.15,0.25)
Time for area of defects to double (years)	100

Membrane defects (number per hectare):

Pin holes:	Minimum 0, Maximum 25
Holes:	Minimum 0, Maximum 5
Tears:	Minimum 0, Most Likely 0.1, Maximum 2

The most likely value for the PDFs representing the density of pinholes and holes will move from the minimum value selected above to the maximum value selected above over the time period before FML degradation commences

Justification for Composite: Flexible Membrane Liner
Table HRA 5

Hydraulic conductivity of mineral lower liner (m/s): LOGTRIANGULAR(4.1e-011,6e-011,1.5e-010)

Justification for Composite: Clay or BES Substrate Properties
Table HRA 5

Retardation parameters for clay liner

Uncertainty in Kd (l/kg):	
Ammoniacal_N	TRIANGULAR(0,0.97,2.4)
Arsenic	LOGUNIFORM(25,250)
Cadmium	LOGTRIANGULAR(14,663,2079)
Chloride	SINGLE(0)
Dichlorprop: Calculated kd	
Partition to Organic Carbon ml/g	UNIFORM(46.06,80)
Manganese	LOGTRIANGULAR(3,49,810)
Naphthalene: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(1190)
TCE (Trichloroethene): Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(94)
Toluene: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(140)
Zinc	LOGTRIANGULAR(1.1,200,36000)
Fraction of Organic Carbon (fraction)	TRIANGULAR(0.002,0.004,0.01)

Justification for Liner Kd Values by Species
Table HRA 3, Table HRA 5 and 2014 HRA

Lincolnshire Limestone pathway parameters

Modelled as unsaturated pathway

Pathway length (m):	NORMAL(7.97,1.24)
Flow Model:	porous medium
Pathway moisture content (fraction):	UNIFORM(0.004,0.01)
Pathway Density (kg/l):	SINGLE(2)

Justification for Unsat Zone Geometry
Table HRA 5

Pathway hydraulic conductivity values (m/s): LOGTRIANGULAR(1.16e-005,5e-005,0.000116)

Justification for Unsat Zone Hydraulics Properties
Table HRA 5

Pathway longitudinal dispersivity (m): NORMAL(0.797,0.124)

Justification for Unsat Zone Dispersion Properties
Table HRA 5

Retardation parameters for Lincolnshire Limestone pathway

Modelled as unsaturated pathway

Uncertainty in Kd (l/kg):

Ammoniacal_N	LOGUNIFORM(0.065,0.65)
Arsenic	UNIFORM(25,31)
Cadmium	LOGUNIFORM(127,1348)
Chloride	SINGLE(0)
Dichlorprop: Calculated kd	
Partition to Organic Carbon ml/g	UNIFORM(46.06,80)
Manganese	LOGTRIANGULAR(3,49,810)
Naphthalene: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(1190)
TCE (Trichloroethene): Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(94)
Toluene: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(140)
Zinc	LOGTRIANGULAR(1.1,200,36000)
Fraction of Organic Carbon (fraction)	UNIFORM(0.0007,0.0009)

Justification for Kd Values by Species

Table HRA 3, Table HRA 5 and 2014 HRA

Aquifer Pathway Dimensions for Phase

Pathway length (m):	UNIFORM(355,655)
Pathway width (m):	SINGLE(425)

Phase: P7-9&11 Permitted western area

Infiltration Information

Cap design infiltration (mm/year):	SINGLE(1.6)
Infiltration to waste (mm/year):	NORMAL(609,60.9)
End of filling (years from start of waste deposit):	5

Justification for Specified Infiltration
Table HRA 5

Duration of management control (years from the start of waste disposal): 20000

Cell dimensions

Cell width (m):	180
Cell length (m):	335
Cell top area (ha):	6.9
Cell base area (ha):	6.03
Number of cells:	1
Total base area (ha):	6.03
Total top area (ha):	6.9
Head of Leachate when surface water breakout occurs (m)	SINGLE(3.7)
Waste porosity (fraction)	UNIFORM(0.37,0.56)
Final waste thickness (m):	SINGLE(14.1)
Field capacity (fraction):	SINGLE(0.36)
Waste dry density (kg/l)	SINGLE(1.53)

Justification for Landfill Geometry
Table HRA 5

Source concentrations of contaminants

All units in milligrams per litre

Declining source term

Ammoniacal_N	LOGTRIANGULAR(92,193,2952) *Data are spot measurements of Leachate Quality*
Arsenic	LOGTRIANGULAR(0.02,0.87,17.3) *Substance to be treated as List 1*
Cadmium	LOGTRIANGULAR(0.00021,0.0776,1.7) *Data are spot measurements of Leachate Quality*
Chloride	LOGTRIANGULAR(10000,28500,144000) *Data are spot measurements of Leachate Quality*
Dichlorprop	LOGTRIANGULAR(0.009,1.3,16) *Substance to be treated as List 1*
Manganese	LOGTRIANGULAR(0.4,5.51,372) *Data are spot measurements of Leachate Quality*
Naphthalene	LOGTRIANGULAR(0.0042,0.67,19) *Data are spot measurements of Leachate Quality*
TCE (Trichloroethene)	LOGTRIANGULAR(0.12,0.79,18) *Substance to be treated as List 1*
Toluene	LOGTRIANGULAR(0.03,4.2,180) *Substance to be treated as List 1*
Zinc	LOGTRIANGULAR(0.023,1,91.2) *Data are spot measurements of Leachate Quality*

Justification for Species Concentration in Leachate
Table HRA 4

Drainage Information

Fixed Head.
Head on EBS is given as (m): SINGLE(1)

Justification for Specified Head
Table HRA 5

Barrier Information

There is a composite barrier

Justification for Engineered Barrier Type
Table HRA 5

Liner installed under CQA	
Design thickness of clay (m):	SINGLE(1)
Density of clay (kg/l):	TRIANGULAR(1.49,1.64,1.78)
Pathway moisture content (fraction):	UNIFORM(0.14,0.25)
Onset of FML degradation (years since filling commenced)	150
Pathway longitudinal dispersivity (m):	SINGLE(0.1)
Time for area of defects to double (years)	100

Membrane defects (number per hectare):

Pin holes:	Minimum 0, Maximum 25
Holes:	Minimum 0, Maximum 5
Tears:	Minimum 0, Most Likely 0.1, Maximum 2

The most likely value for the PDFs representing the density of pinholes and holes will move from the minimum value selected above to the maximum value selected above over the time period before FML degradation commences

Justification for Composite: Flexible Membrane Liner
Table HRA 5

Hydraulic conductivity of mineral lower liner (m/s): LOGNORMAL(1.4e-010,1.7e-010)

Justification for Composite: Clay or BES Substrate Properties
Table HRA 5

Retardation parameters for clay liner

Uncertainty in Kd (l/kg):	
Ammoniacal_N	TRIANGULAR(0,0.97,2.4)
Arsenic	LOGUNIFORM(25,250)
Cadmium	LOGTRIANGULAR(14,663,2079)
Chloride	SINGLE(0)
Dichlorprop: Calculated kd	
Partition to Organic Carbon ml/g	UNIFORM(46.06,80)
Manganese	LOGTRIANGULAR(3,49,810)
Naphthalene: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(1190)
TCE (Trichloroethene): Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(94)
Toluene: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(140)
Zinc	LOGTRIANGULAR(1.1,200,36000)
Fraction of Organic Carbon (fraction)	TRIANGULAR(0.002,0.004,0.01)

Justification for Liner Kd Values by Species
Table HRA 3, Table HRA 5 and 2014 HRA

Lincolnshire Limestone pathway parameters

Modelled as unsaturated pathway

Pathway length (m):	NORMAL(9.29,1.7)
Flow Model:	porous medium
Pathway moisture content (fraction):	UNIFORM(0.004,0.01)
Pathway Density (kg/l):	SINGLE(2)

Justification for Unsat Zone Geometry
Table HRA 5

Pathway hydraulic conductivity values (m/s): LOGTRIANGULAR(1.16e-005,5e-005,0.000116)

Justification for Unsat Zone Hydraulics Properties
Table HRA 5

Pathway longitudinal dispersivity (m): NORMAL(0.929,0.17)

Justification for Unsat Zone Dispersion Properties
Table HRA 5

Retardation parameters for Lincolnshire Limestone pathway

Modelled as unsaturated pathway

Uncertainty in Kd (l/kg):

Ammoniacal_N	LOGUNIFORM(0.065,0.65)
Arsenic	UNIFORM(25,31)
Cadmium	LOGUNIFORM(127,1348)
Chloride	SINGLE(0)
Dichlorprop: Calculated kd	
Partition to Organic Carbon ml/g	UNIFORM(46.06,80)
Manganese	LOGTRIANGULAR(3,49,810)
Naphthalene: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(1190)
TCE (Trichloroethene): Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(94)
Toluene: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(140)
Zinc	LOGTRIANGULAR(1.1,200,36000)

Fraction of Organic Carbon (fraction) UNIFORM(0.0007,0.0009)

Justification for Kd Values by Species

Table HRA 3, Table HRA 5 and 2014 HRA

Aquifer Pathway Dimensions for Phase

Pathway length (m):	UNIFORM(355,695)
Pathway width (m):	SINGLE(202)

Phase: P6&10 Permitted western area

Infiltration Information

Cap design infiltration (mm/year):	SINGLE(1.6)
Infiltration to waste (mm/year):	NORMAL(609,60.9)
End of filling (years from start of waste deposit):	5

Justification for Specified Infiltration
Table HRA 5

Duration of management control (years from the start of waste disposal): 20000

Cell dimensions

Cell width (m):	90
Cell length (m):	255
Cell top area (ha):	4.3
Cell base area (ha):	2.295
Number of cells:	1
Total base area (ha):	2.295
Total top area (ha):	4.3
Head of Leachate when surface water breakout occurs (m)	SINGLE(3.7)
Waste porosity (fraction)	UNIFORM(0.37,0.56)
Final waste thickness (m):	SINGLE(15.2)
Field capacity (fraction):	SINGLE(0.36)
Waste dry density (kg/l)	SINGLE(1.53)

Justification for Landfill Geometry
Table HRA 5

Source concentrations of contaminants

All units in milligrams per litre

Declining source term

Ammoniacal_N	LOGTRIANGULAR(92,193,2952) *Data are spot measurements of Leachate Quality*
Arsenic	LOGTRIANGULAR(0.02,0.87,17.3) *Substance to be treated as List 1*
Cadmium	LOGTRIANGULAR(0.00021,0.0776,1.7) *Data are spot measurements of Leachate Quality*
Chloride	LOGTRIANGULAR(10000,28500,144000) *Data are spot measurements of Leachate Quality*
Dichlorprop	LOGTRIANGULAR(0.009,1.3,16) *Substance to be treated as List 1*
Manganese	LOGTRIANGULAR(0.4,5.51,372) *Data are spot measurements of Leachate Quality*
Naphthalene	LOGTRIANGULAR(0.0042,0.67,19) *Data are spot measurements of Leachate Quality*
TCE (Trichloroethene)	LOGTRIANGULAR(0.12,0.79,18) *Substance to be treated as List 1*
Toluene	LOGTRIANGULAR(0.03,4.2,180) *Substance to be treated as List 1*
Zinc	LOGTRIANGULAR(0.023,1,91.2) *Data are spot measurements of Leachate Quality*

Justification for Species Concentration in Leachate
Table HRA 4

Drainage Information

Fixed Head.
Head on EBS is given as (m): SINGLE(1)

Justification for Specified Head
Table HRA 5

Barrier Information

There is a composite barrier

Justification for Engineered Barrier Type
Table HRA 5

Liner installed under CQA	
Design thickness of clay (m):	SINGLE(1)
Density of clay (kg/l):	TRIANGULAR(1.49,1.64,1.78)
Pathway moisture content (fraction):	LOGUNIFORM(0.14,0.25)
Onset of FML degradation (years since filling commenced)	150
Pathway longitudinal dispersivity (m):	SINGLE(0.1)
Time for area of defects to double (years)	100

Membrane defects (number per hectare):	
Pin holes:	Minimum 0, Maximum 25
Holes:	Minimum 0, Maximum 5
Tears:	Minimum 0, Most Likely 0.1, Maximum 2

The most likely value for the PDFs representing the density of pinholes and holes will move from the minimum value selected above to the maximum value selected above over the time period before FML degradation commences

Justification for Composite: Flexible Membrane Liner
Table HRA 5

Hydraulic conductivity of mineral lower liner (m/s): LOGTRIANGULAR(5.6e-011,9.3e-011,2.7e-010)

Justification for Composite: Clay or BES Substrate Properties
Table HRA 5

Retardation parameters for clay liner

Uncertainty in Kd (l/kg):	
Ammoniacal_N	TRIANGULAR(0,0.97,2.4)
Arsenic	LOGUNIFORM(25,250)
Cadmium	LOGTRIANGULAR(14,663,2079)
Chloride	SINGLE(0)
Dichlorprop: Calculated kd	
Partition to Organic Carbon ml/g	UNIFORM(46.06,80)
Manganese	LOGTRIANGULAR(3,49,810)
Naphthalene: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(1190)
TCE (Trichloroethene): Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(94)
Toluene: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(140)
Zinc	LOGTRIANGULAR(1.1,200,36000)
Fraction of Organic Carbon (fraction)	TRIANGULAR(0.002,0.004,0.01)

Justification for Liner Kd Values by Species
Table HRA 3, Table HRA 5 and 2014 HRA

Lincolnsire Limestone pathway parameters

Modelled as unsaturated pathway

Pathway length (m):	NORMAL(9.29,1.7)
Flow Model:	porous medium
Pathway moisture content (fraction):	UNIFORM(0.004,0.01)
Pathway Density (kg/l):	SINGLE(2)

Justification for Unsat Zone Geometry
Table HRA 5

Pathway hydraulic conductivity values (m/s):	LOGTRIANGULAR(1.16e-005,5e-005,0.000116)

Justification for Unsat Zone Hydraulics Properties
Table HRA 5

Pathway longitudinal dispersivity (m):	NORMAL(0.929,0.17)

Justification for Unsat Zone Dispersion Properties
Table HRA 5

Retardation parameters for Lincolnsire Limestone pathway

Modelled as unsaturated pathway

Uncertainty in Kd (l/kg):	
Ammoniacal_N	LOGUNIFORM(0.065,0.65)
Arsenic	UNIFORM(25,31)
Cadmium	LOGUNIFORM(127,1348)
Chloride	SINGLE(0)
Dichlorprop: Calculated kd	
Partition to Organic Carbon ml/g	UNIFORM(46.06,80)
Manganese	LOGTRIANGULAR(3,49,810)
Naphthalene: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(1190)
TCE (Trichloroethene): Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(94)
Toluene: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(140)
Zinc	LOGTRIANGULAR(1.1,200,36000)
Fraction of Organic Carbon (fraction)	UNIFORM(0.0007,0.0009)

Justification for Kd Values by Species

Table HRA 3, Table HRA 5 and 2014 HRA

Aquifer Pathway Dimensions for Phase

Pathway length (m):	UNIFORM(355,685)
Pathway width (m):	SINGLE(130)

Phase: N Western extension

Infiltration Information

Cap design infiltration (mm/year):	SINGLE(1.6)
Infiltration to waste (mm/year):	NORMAL(609,60.9)
End of filling (years from start of waste deposit):	10

Justification for Specified Infiltration
Table HRA 5

Duration of management control (years from the start of waste disposal): 20000

Cell dimensions

Cell width (m):	120
Cell length (m):	391.667
Cell top area (ha):	6.51
Cell base area (ha):	4.7
Number of cells:	1
Total base area (ha):	4.7
Total top area (ha):	6.51
Head of Leachate when surface water breakout occurs (m)	SINGLE(4)
Waste porosity (fraction)	UNIFORM(0.37,0.56)
Final waste thickness (m):	SINGLE(13.8)
Field capacity (fraction):	SINGLE(0.36)
Waste dry density (kg/l)	SINGLE(1.53)

Justification for Landfill Geometry
Table HRA 5

Source concentrations of contaminants

All units in milligrams per litre

Declining source term

Ammoniacal_N	LOGTRIANGULAR(92,193,2952) *Data are spot measurements of Leachate Quality*
Arsenic	LOGTRIANGULAR(0.02,0.87,17.3) *Substance to be treated as List 1*
Cadmium	LOGTRIANGULAR(0.00021,0.0776,1.7) *Data are spot measurements of Leachate Quality*
Chloride	LOGTRIANGULAR(10000,28500,144000) *Data are spot measurements of Leachate Quality*
Dichlorprop	LOGTRIANGULAR(0.009,1.3,16) *Substance to be treated as List 1*
Manganese	LOGTRIANGULAR(0.4,5.51,372) *Data are spot measurements of Leachate Quality*
Naphthalene	LOGTRIANGULAR(0.0042,0.67,19) *Data are spot measurements of Leachate Quality*
TCE (Trichloroethene)	LOGTRIANGULAR(0.12,0.79,18) *Substance to be treated as List 1*
Toluene	LOGTRIANGULAR(0.03,4.2,180) *Substance to be treated as List 1*
Zinc	LOGTRIANGULAR(0.023,1,91.2) *Data are spot measurements of Leachate Quality*

Justification for Species Concentration in Leachate
Table HRA 4

Drainage Information

Fixed Head.
Head on EBS is given as (m): SINGLE(1)

Justification for Specified Head
Table HRA 5

Barrier Information

There is a composite barrier

Justification for Engineered Barrier Type
Table HRA 5

Liner installed under CQA	
Design thickness of clay (m):	SINGLE(1)
Density of clay (kg/l):	TRIANGULAR(1.49,1.64,1.78)
Pathway moisture content (fraction):	UNIFORM(0.14,0.25)
Onset of FML degradation (years since filling commenced)	150
Pathway longitudinal dispersivity (m):	SINGLE(0.1)
Time for area of defects to double (years)	100

Membrane defects (number per hectare):	
Pin holes:	Minimum 0, Maximum 25
Holes:	Minimum 0, Maximum 5
Tears:	Minimum 0, Most Likely 0.1, Maximum 2

The most likely value for the PDFs representing the density of pinholes and holes will move from the minimum value selected above to the maximum value selected above over the time period before FML degradation commences

Justification for Composite: Flexible Membrane Liner
Table HRA 5

Hydraulic conductivity of mineral lower liner (m/s):	LOGNORMAL(1.4e-010,1.7e-010)

Justification for Composite: Clay or BES Substrate Properties
Table HRA 5

Retardation parameters for clay liner

Uncertainty in Kd (l/kg):	
Ammoniacal_N	TRIANGULAR(0,0.97,2.4)
Arsenic	LOGUNIFORM(25,250)
Cadmium	LOGTRIANGULAR(14,663,2079)
Chloride	SINGLE(0)
Dichlorprop: Calculated kd	
Partition to Organic Carbon ml/g	UNIFORM(46.06,80)
Manganese	LOGTRIANGULAR(3,49,810)
Naphthalene: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(1190)
TCE (Trichloroethene): Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(94)
Toluene	SINGLE(140)
Zinc	LOGTRIANGULAR(1.1,200,36000)
Fraction of Organic Carbon (fraction)	TRIANGULAR(0.002,0.004,0.01)

Justification for Liner Kd Values by Species
Table HRA 3, Table HRA 5 and 2014 HRA

Lincolnshire Limestone pathway parameters

Modelled as unsaturated pathway

Pathway length (m):	NORMAL(6.47,1.48)
Flow Model:	porous medium
Pathway moisture content (fraction):	UNIFORM(0.004,0.01)
Pathway Density (kg/l):	SINGLE(2)

Justification for Unsat Zone Geometry
Table HRA 5

Pathway hydraulic conductivity values (m/s):	LOGTRIANGULAR(1.16e-005,5e-005,0.000116)

Justification for Unsat Zone Hydraulics Properties
Table HRA 5

Pathway longitudinal dispersivity (m):	NORMAL(0.647,0.148)

Justification for Unsat Zone Dispersion Properties
Table HRA 5

Retardation parameters for Lincolnshire Limestone pathway

Modelled as unsaturated pathway

Uncertainty in Kd (l/kg):

Ammoniacal_N	LOGUNIFORM(0.065,0.65)
Arsenic	UNIFORM(25,31)
Cadmium	LOGUNIFORM(127,1348)
Chloride	SINGLE(0)
Dichlorprop: Calculated kd	
Partition to Organic Carbon ml/g	UNIFORM(46.06,80)
Manganese	LOGTRIANGULAR(3,49,810)
Naphthalene: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(1190)
TCE (Trichloroethene): Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(94)
Toluene: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(140)
Zinc	LOGTRIANGULAR(1.1,200,36000)

Fraction of Organic Carbon (fraction) UNIFORM(0.0007,0.0009)

Justification for Kd Values by Species

Table HRA 3, Table HRA 5 and 2014 HRA

Aquifer Pathway Dimensions for Phase

Pathway length (m):	UNIFORM(695,1135)
Pathway width (m):	SINGLE(148)

Phase: S Western extension

Infiltration Information

Cap design infiltration (mm/year):	SINGLE(1.6)
Infiltration to waste (mm/year):	NORMAL(609,60.9)
End of filling (years from start of waste deposit):	10

Justification for Specified Infiltration
Table HRA 5

Duration of management control (years from the start of waste disposal): 20000

Cell dimensions

Cell width (m):	160
Cell length (m):	593.125
Cell top area (ha):	14.45
Cell base area (ha):	9.49
Number of cells:	1
Total base area (ha):	9.49
Total top area (ha):	14.45
Head of Leachate when surface water breakout occurs (m)	SINGLE(4)
Waste porosity (fraction)	UNIFORM(0.37,0.56)
Final waste thickness (m):	SINGLE(14.7)
Field capacity (fraction):	SINGLE(0.36)
Waste dry density (kg/l)	SINGLE(1.53)

Justification for Landfill Geometry
Table HRA 5

Source concentrations of contaminants

All units in milligrams per litre

Declining source term

Ammoniacal_N	LOGTRIANGULAR(92,193,2952)
	Data are spot measurements of Leachate Quality
Arsenic	LOGTRIANGULAR(0.02,0.87,17.3)
	Substance to be treated as List 1
Cadmium	LOGTRIANGULAR(0.00021,0.0776,1.7)
	Data are spot measurements of Leachate Quality
Chloride	LOGTRIANGULAR(10000,28500,144000)
	Data are spot measurements of Leachate Quality
Dichlorprop	LOGTRIANGULAR(0.009,1.3,16)
	Substance to be treated as List 1
Manganese	LOGTRIANGULAR(0.4,5.51,372)
	Data are spot measurements of Leachate Quality
Naphthalene	LOGTRIANGULAR(0.0042,0.67,19)
	Data are spot measurements of Leachate Quality
TCE (Trichloroethene)	LOGTRIANGULAR(0.12,0.79,18)
	Substance to be treated as List 1
Toluene	LOGTRIANGULAR(0.03,4.2,180)
	Substance to be treated as List 1
Zinc	LOGTRIANGULAR(0.023,1,91.2)
	Data are spot measurements of Leachate Quality

Justification for Species Concentration in Leachate
Table HRA 4

Drainage Information

Fixed Head.
Head on EBS is given as (m): SINGLE(1)

Justification for Specified Head
Table HRA 5

Barrier Information

There is a composite barrier

Justification for Engineered Barrier Type
Table HRA 5

Liner installed under CQA	
Design thickness of clay (m):	SINGLE(1)
Density of clay (kg/l):	TRIANGULAR(1.49,1.64,1.78)
Pathway moisture content (fraction):	UNIFORM(0.14,0.25)
Onset of FML degradation (years since filling commenced)	150
Pathway longitudinal dispersivity (m):	SINGLE(0.1)
Time for area of defects to double (years)	100

Membrane defects (number per hectare):

Pin holes:	Minimum 0, Maximum 25
Holes:	Minimum 0, Maximum 5
Tears:	Minimum 0, Most Likely 0.1, Maximum 2

The most likely value for the PDFs representing the density of pinholes and holes will move from the minimum value selected above to the maximum value selected above over the time period before FML degradation commences

Justification for Composite: Flexible Membrane Liner
Table HRA 5

Hydraulic conductivity of mineral lower liner (m/s): LOGNORMAL(1.4e-010,1.7e-010)

Justification for Composite: Clay or BES Substrate Properties
Table HRA 5

Retardation parameters for clay liner

Uncertainty in Kd (l/kg):	
Ammoniacal_N	TRIANGULAR(0,0.97,2.4)
Arsenic	LOGUNIFORM(25,250)
Cadmium	LOGTRIANGULAR(14,663,2079)
Chloride	SINGLE(0)
Dichlorprop: Calculated kd	
Partition to Organic Carbon ml/g	UNIFORM(46.06,80)
Manganese	LOGTRIANGULAR(3,49,810)
Naphthalene: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(1190)
TCE (Trichloroethene): Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(94)
Toluene: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(140)
Zinc	LOGTRIANGULAR(1.1,200,36000)
Fraction of Organic Carbon (fraction)	TRIANGULAR(0.002,0.004,0.01)

Justification for Liner Kd Values by Species
Table HRA 3, Table HRA 5 and 2014 HRA

Lincolnshire Limestone pathway parameters

Modelled as unsaturated pathway

Pathway length (m):	NORMAL(10.66,0.76)
Flow Model:	porous medium
Pathway moisture content (fraction):	UNIFORM(0.004,0.01)
Pathway Density (kg/l):	SINGLE(2)

Justification for Unsat Zone Geometry
Table HRA 5

Pathway hydraulic conductivity values (m/s): LOGTRIANGULAR(1.16e-005,5e-005,0.000116)

Justification for Unsat Zone Hydraulics Properties
Table HRA 5

Pathway longitudinal dispersivity (m): NORMAL(1.066,0.076)

Justification for Unsat Zone Dispersion Properties
Table HRA 5

Retardation parameters for Lincolnshire Limestone pathway

Modelled as unsaturated pathway

Uncertainty in Kd (l/kg):

Ammoniacal_N	LOGUNIFORM(0.065,0.65)
Arsenic	UNIFORM(25,31)
Cadmium	LOGUNIFORM(127,1348)
Chloride	SINGLE(0)
Dichlorprop: Calculated kd	
Partition to Organic Carbon ml/g	UNIFORM(46.06,80)
Manganese	LOGTRIANGULAR(3,49,810)
Naphthalene: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(1190)
TCE (Trichloroethene): Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(94)
Toluene: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(140)
Zinc	LOGTRIANGULAR(1.1,200,36000)

Fraction of Organic Carbon (fraction) UNIFORM(0.0007,0.0009)

Justification for Kd Values by Species

Table HRA 3, Table HRA 5 and 2014 HRA

Aquifer Pathway Dimensions for Phase

Pathway length (m):	UNIFORM(40,695)
Pathway width (m):	SINGLE(221)

pathway parameters

No Vertical Pathway

Lincolnshire Limestone pathway parameters
Modelled as aquifer pathway.

Mixing zone (m):	NORMAL(8.16,1.25)

Justification for Aquifer Geometry
Table HRA 5

Pathway regional gradient (-):	TRIANGULAR(0.0083,0.012,0.0136)
Pathway hydraulic conductivity values (m/s):	LOGTRIANGULAR(1.16e-005,5e-005,0.000116)
Pathway porosity (fraction):	UNIFORM(0.004,0.01)

Justification for Aquifer Hydraulics Properties
Table HRA 5

Pathway longitudinal dispersivity (m):	UNIFORM(4,113.5)
Pathway transverse dispersivity (m):	UNIFORM(0.4,11.35)

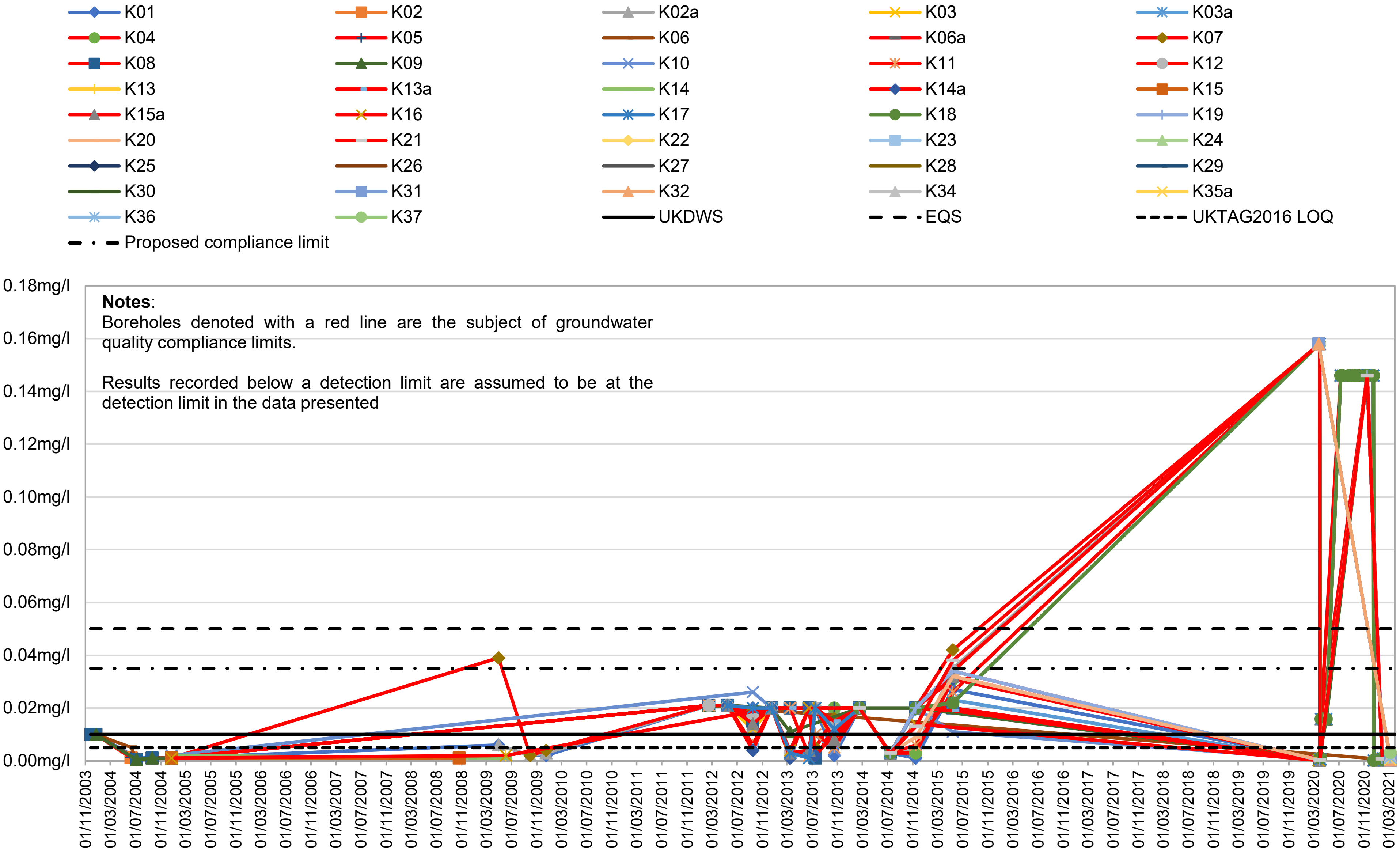
Justification for Aquifer Dispersion Details
Table HRA 5

Retardation parameters for Lincolnshire Limestone pathway
Modelled as aquifer pathway.
No retardation values used in this simulation.
Check 'Unretarded Contaminant Transport' setting under simulation preferences.

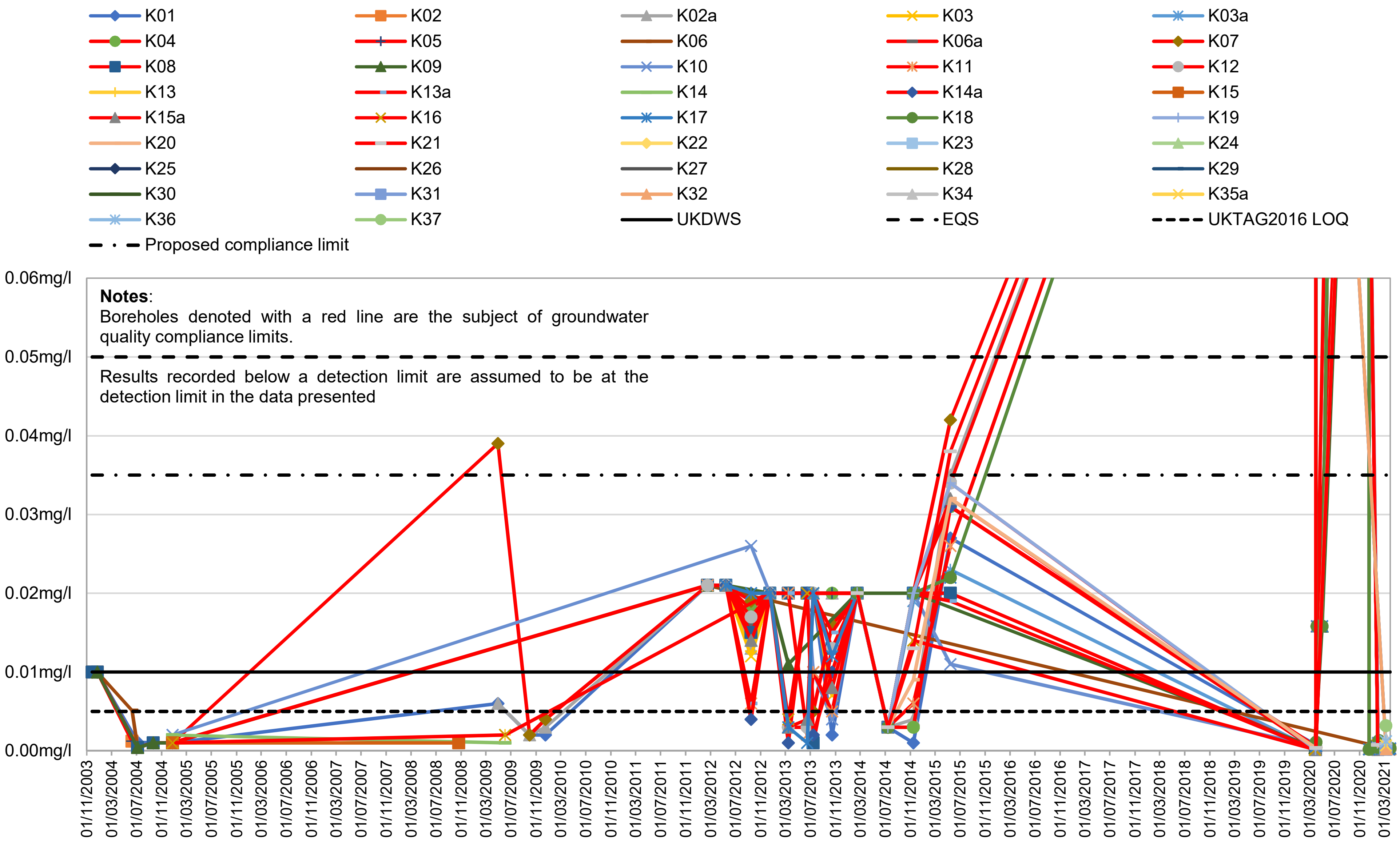
APPENDIX HRA I

GROUNDWATER QUALITY CHEMOGRAPHS FOR DETERMINANDS THE SUBJECT OF COMPLIANCE LIMITS

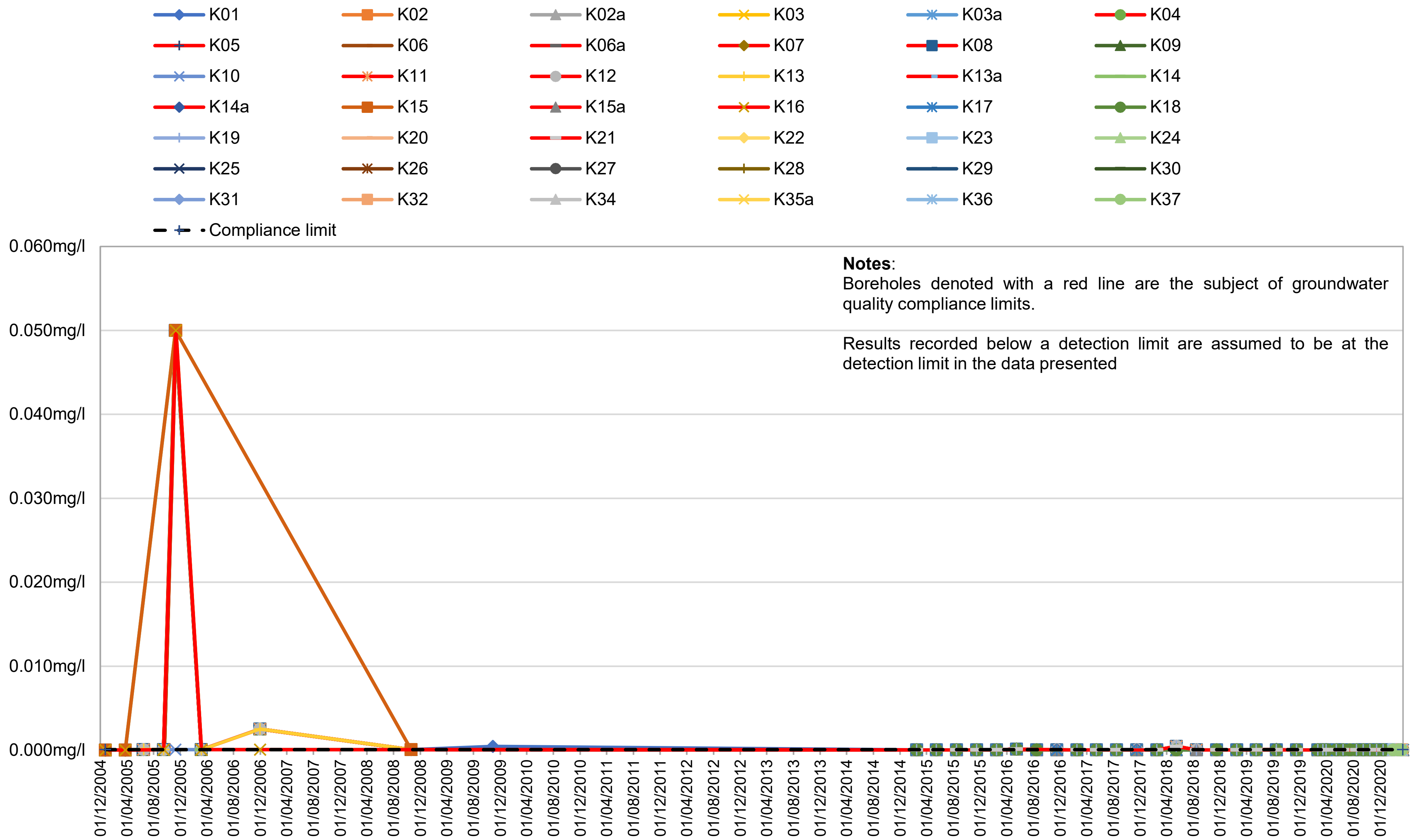
Chemograph of the concentration of arsenic recorded in the groundwater up and down hydraulic gradient of the current ENRMF landfill between November 2003 and March 2021



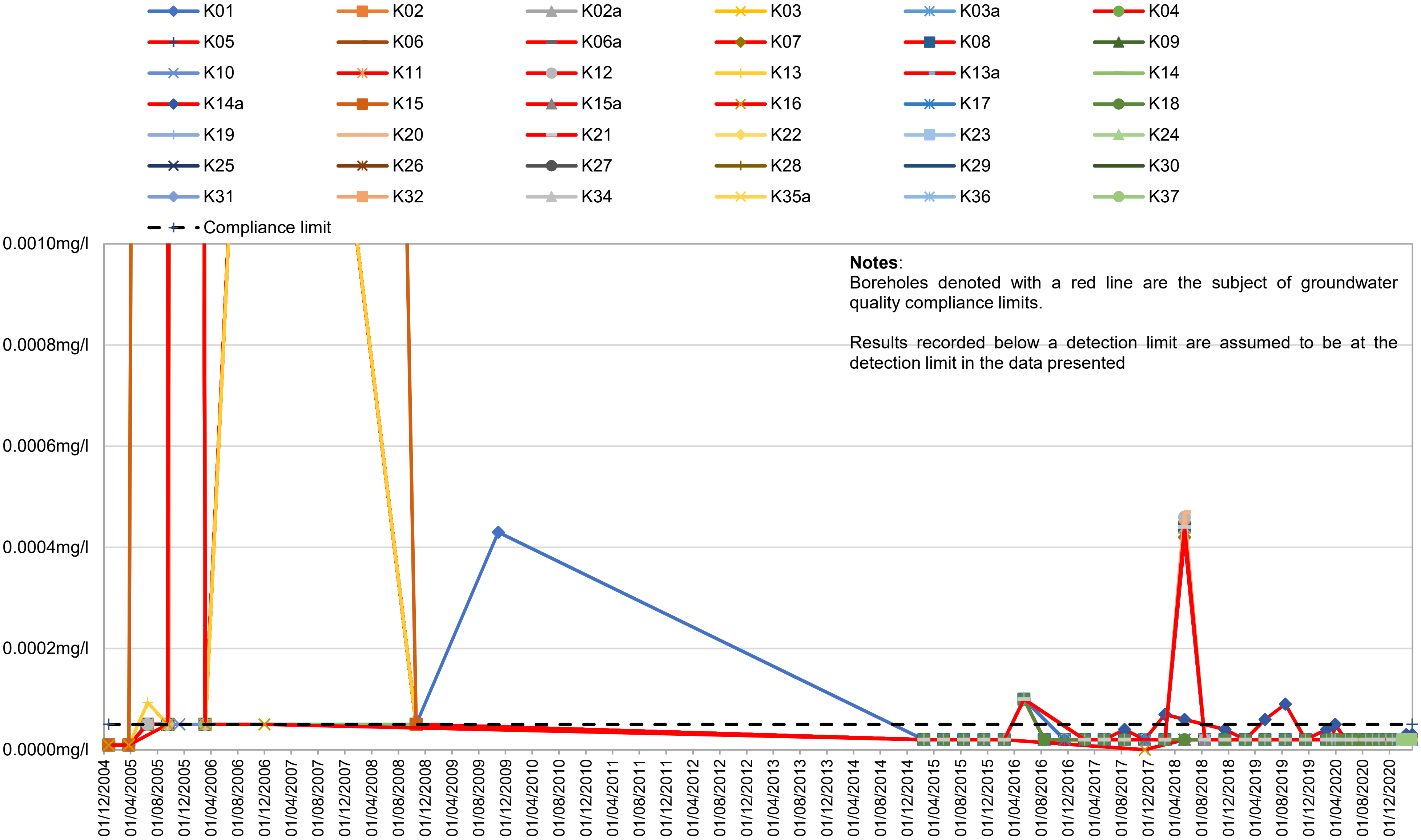
Chemograph of the concentration of arsenic recorded in the groundwater up and down hydraulic gradient of the current ENRMF landfill between November 2003 and March 2021

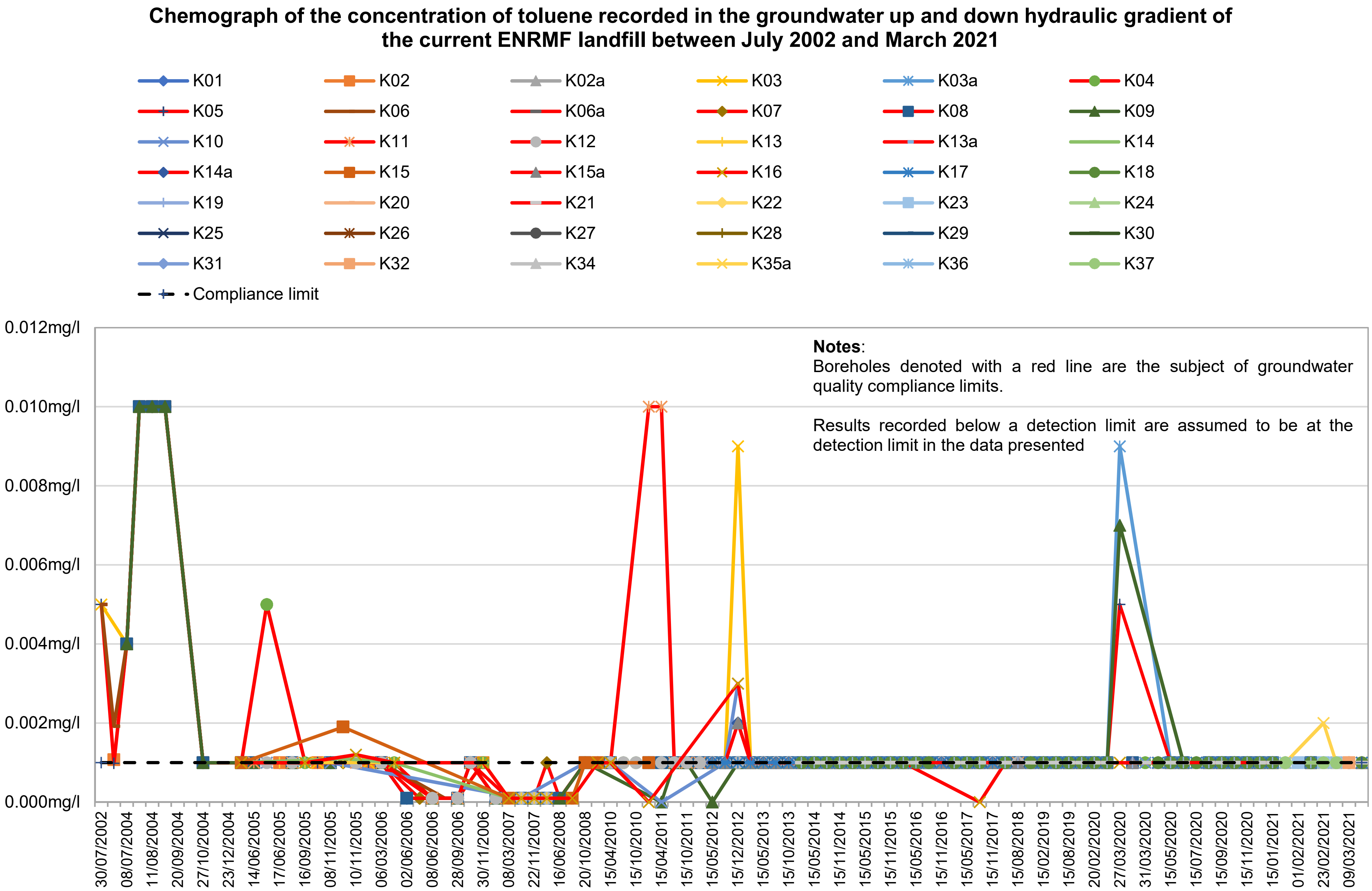


Chemograph of the concentration of dichlorprop recorded in the groundwater up and down hydraulic gradient of the current ENRMF landfill between December 2004 and March 2021

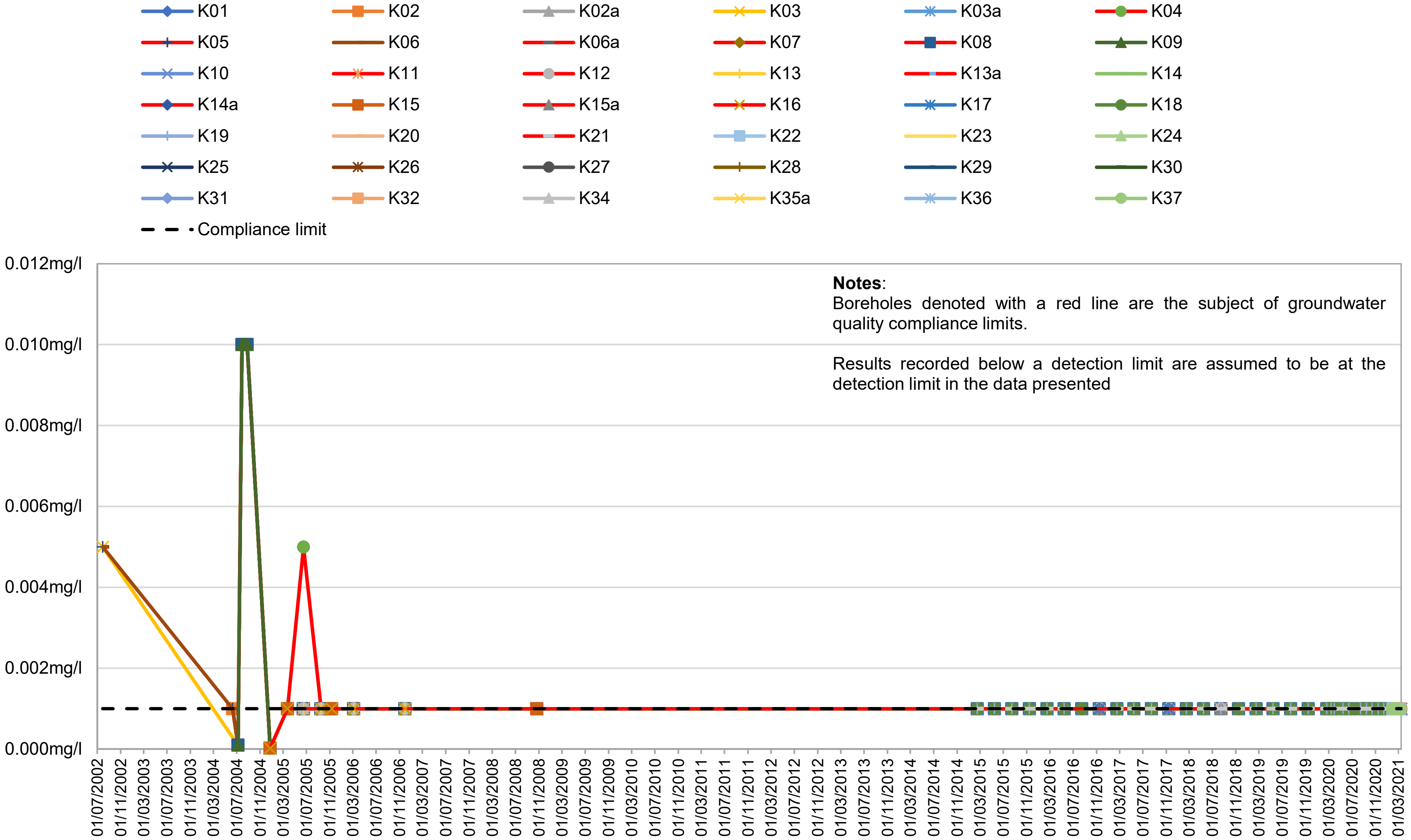


Chemograph of the concentration of dichlorprop recorded in the groundwater up and down hydraulic gradient of the current ENRMF landfill between May 2014 and March 2021

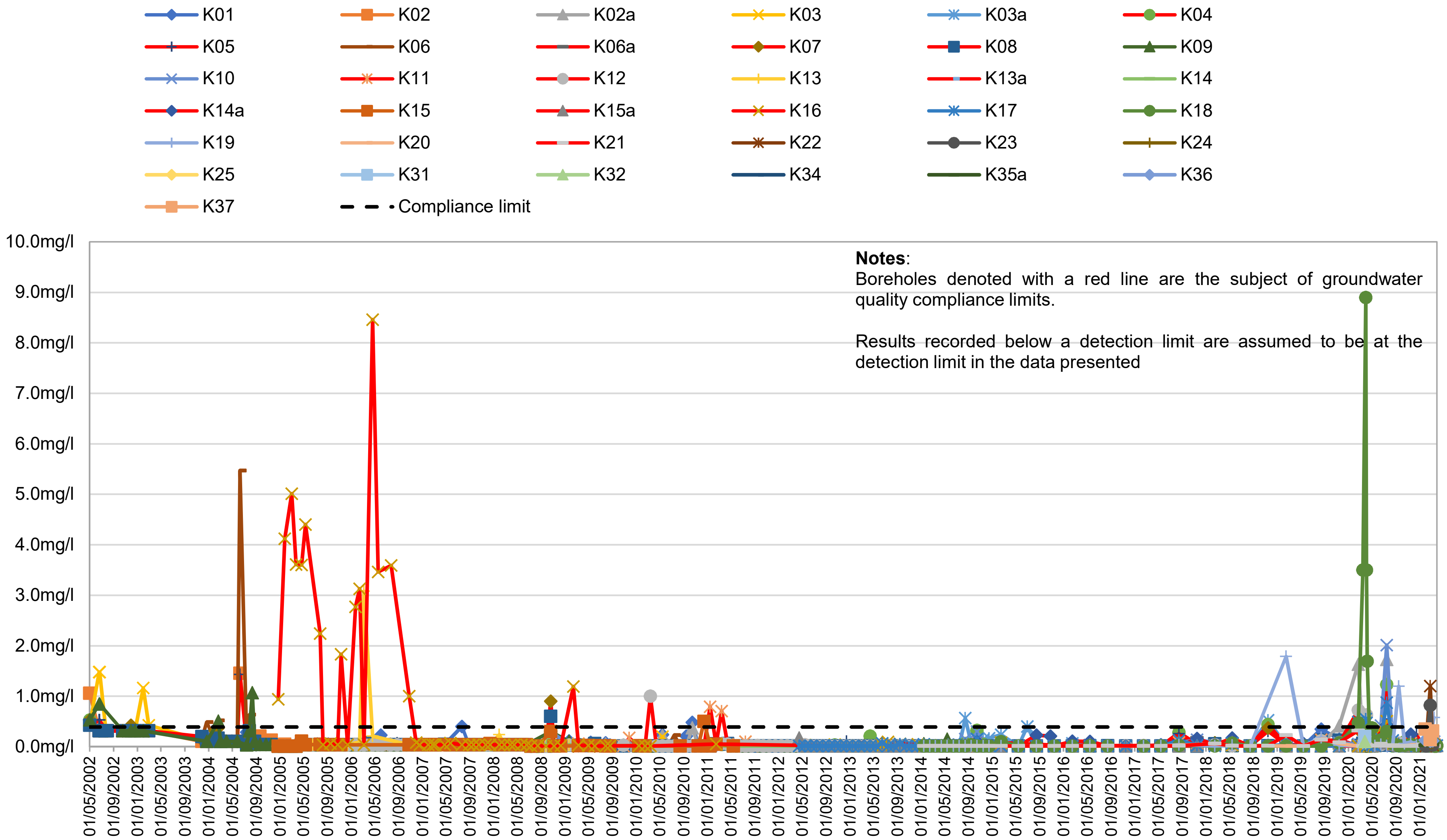


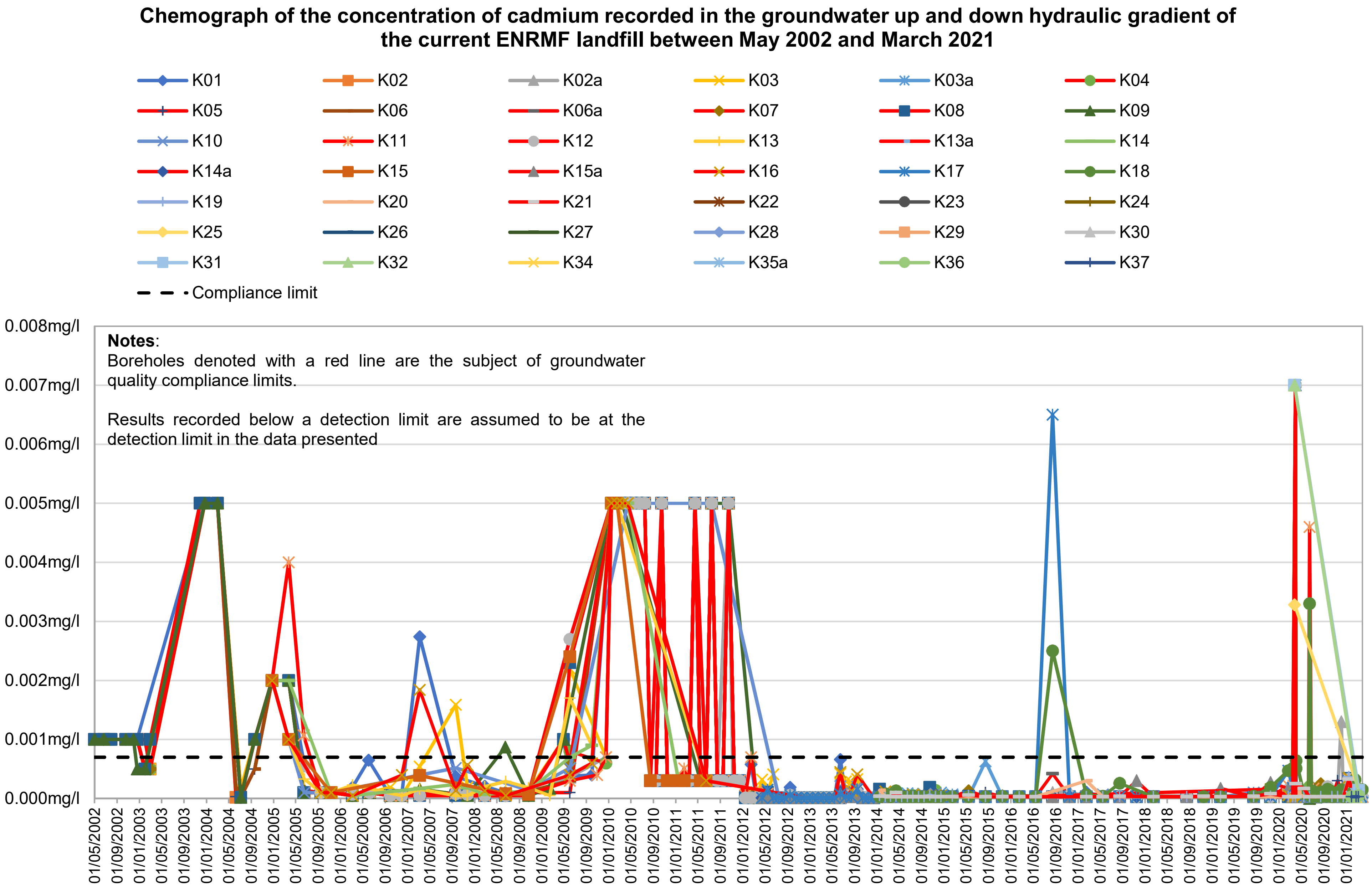

Chemograph of the concentration of toluene recorded in the groundwater up and down hydraulic gradient of the current ENRMF landfill between July 2002 and March 2021
K01
K02
K02a
K03
K03a
K04
K05
K06
K06a
K07
K08
K09
K10
K11
K12
K13
K13a
K14
K14a
K15
K15a
K16
K17
K18
K19
K20
K21
K22
K23
K24
K25
K26
K27
K28
K29
K30
K31
K32
K34
K35a
K36
K37
Compliance limit
0.012mg/l
0.010mg/l
0.008mg/l
0.006mg/l
0.004mg/l
0.002mg/l
0.000mg/l
Notes:
Boreholes denoted with a red line are the subject of groundwater quality compliance limits.
Results recorded below a detection limit are assumed to be at the detection limit in the data presented
30/07/2002
08/07/2004
11/08/2004
20/09/2004
27/10/2004
23/12/2004
14/06/2005
17/06/2005
16/09/2005
08/11/2005
10/11/2005
06/03/2006
02/06/2006
08/06/2006
28/09/2006
30/11/2006
08/03/2007
22/11/2007
16/06/2008
20/10/2008
15/04/2010
15/10/2010
15/04/2011
15/10/2011
15/05/2012
15/12/2012
15/05/2013
15/10/2013
15/05/2014
15/11/2014
15/05/2015
15/11/2015
15/05/2016
15/11/2016
15/05/2017
15/11/2017
15/08/2018
15/02/2019
15/08/2019
20/02/2020
27/03/2020
31/03/2020
15/05/2020
15/07/2020
15/09/2020
15/11/2020
15/01/2021
01/02/2021
23/02/2021
09/03/2021

Chemograph of the concentration of trichlororethene recorded in the groundwater up and down hydraulic gradient of the current ENRMF landfill between July 2002 and March 2021



Chemograph of the concentration of ammoniacal nitrogen recorded in the groundwater up and down hydraulic gradient of the current ENRMF landfill between May 2002 and March 2021




Chemograph of the concentration of cadmium recorded in the groundwater up and down hydraulic gradient of the current ENRMF landfill between May 2002 and March 2021
K01
K02
K02a
K03
K03a
K04
K05
K06
K06a
K07
K08
K09
K10
K11
K12
K13
K13a
K14
K14a
K15
K15a
K16
K17
K18
K19
K20
K21
K22
K23
K24
K25
K26
K27
K28
K29
K30
K31
K32
K34
K35a
K36
K37
Compliance limit
Notes:
Boreholes denoted with a red line are the subject of groundwater quality compliance limits.
Results recorded below a detection limit are assumed to be at the detection limit in the data presented
0.008mg/l
0.007mg/l
0.006mg/l
0.005mg/l
0.004mg/l
0.003mg/l
0.002mg/l
0.001mg/l
0.000mg/l
01/05/2002
01/09/2002
01/01/2003
01/05/2003
01/09/2003
01/01/2004
01/05/2004
01/09/2004
01/01/2005
01/05/2005
01/09/2005
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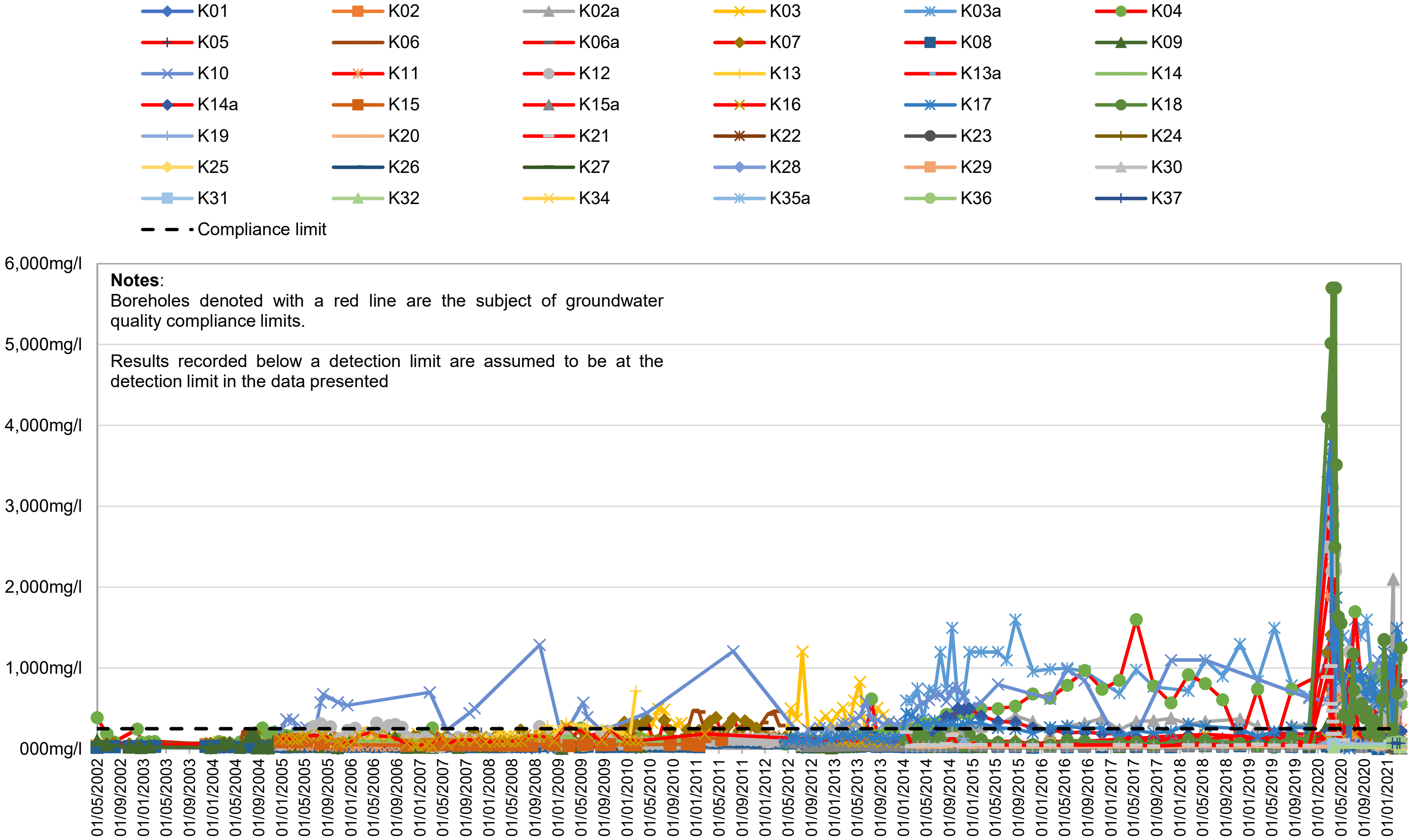
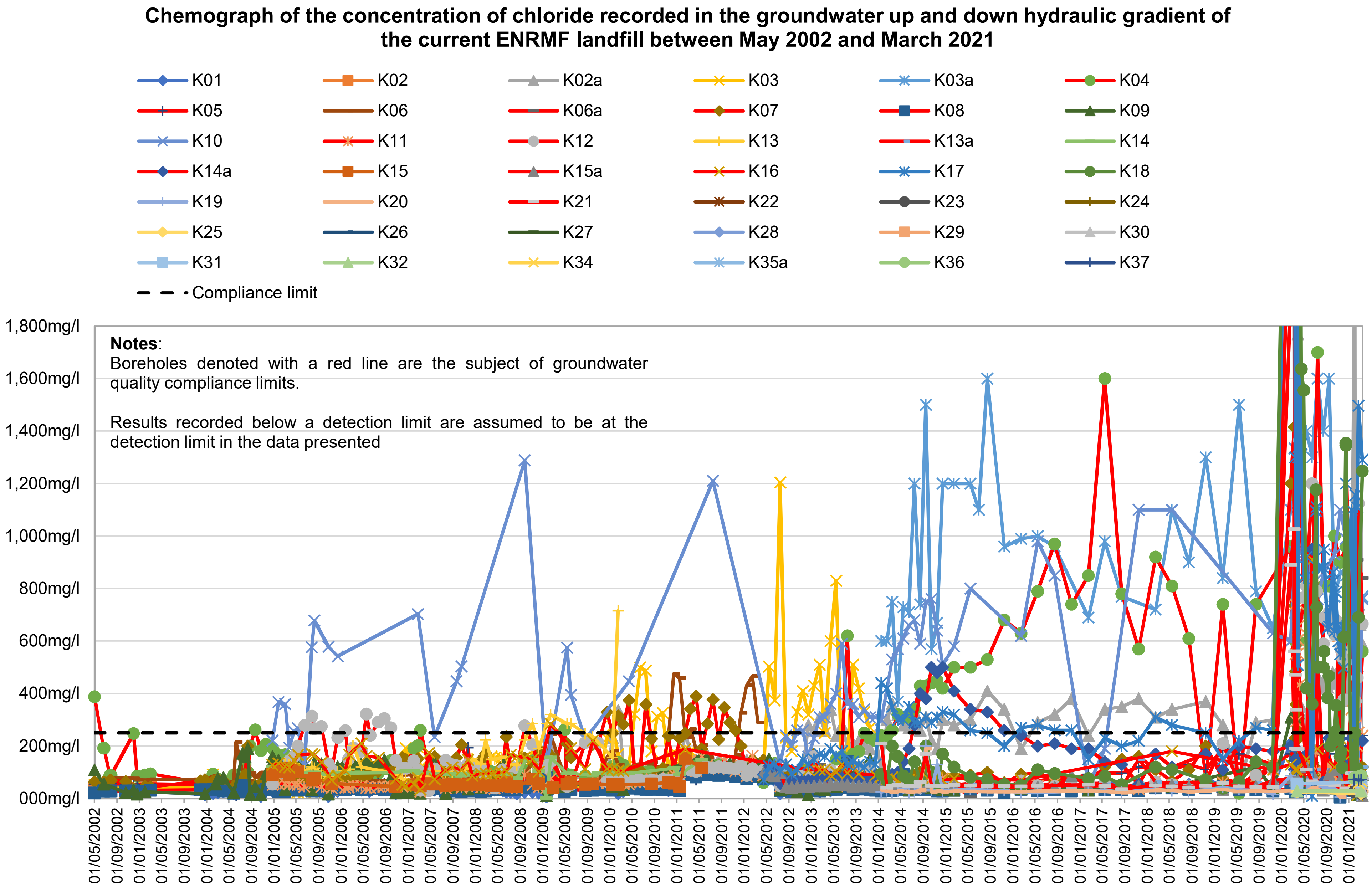
01/09/2016
01/01/2017
01/05/2017
01/09/2017
01/01/2018
01/05/2018
01/09/2018
01/01/2019
01/05/2019
01/09/2019
01/01/2020
01/05/2020
01/09/2020
01/01/2021

Chemograph of the concentration of chloride recorded in the groundwater up and down hydraulic gradient of the current ENRMF landfill between May 2002 and March 2021





Chemograph of the concentration of chloride recorded in the groundwater up and down hydraulic gradient of the current ENRMF landfill between May 2002 and March 2021
K01
K02
K02a
K03
K03a
K04
K05
K06
K06a
K07
K08
K09
K10
K11
K12
K13
K13a
K14
K14a
K15
K15a
K16
K17
K18
K19
K20
K21
K22
K23
K24
K25
K26
K27
K28
K29
K30
K31
K32
K34
K35a
K36
K37
Compliance limit
Notes:
Boreholes denoted with a red line are the subject of groundwater quality compliance limits.
Results recorded below a detection limit are assumed to be at the detection limit in the data presented
1,800mg/l
1,600mg/l
1,400mg/l
1,200mg/l
1,000mg/l
800mg/l
600mg/l
400mg/l
200mg/l
000mg/l
01/05/2002
01/09/2002
01/01/2003
01/05/2003
01/09/2003
01/01/2004
01/05/2004
01/09/2004
01/01/2005
01/05/2005
01/09/2005
01/01/2006
01/05/2006
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01/01/2007
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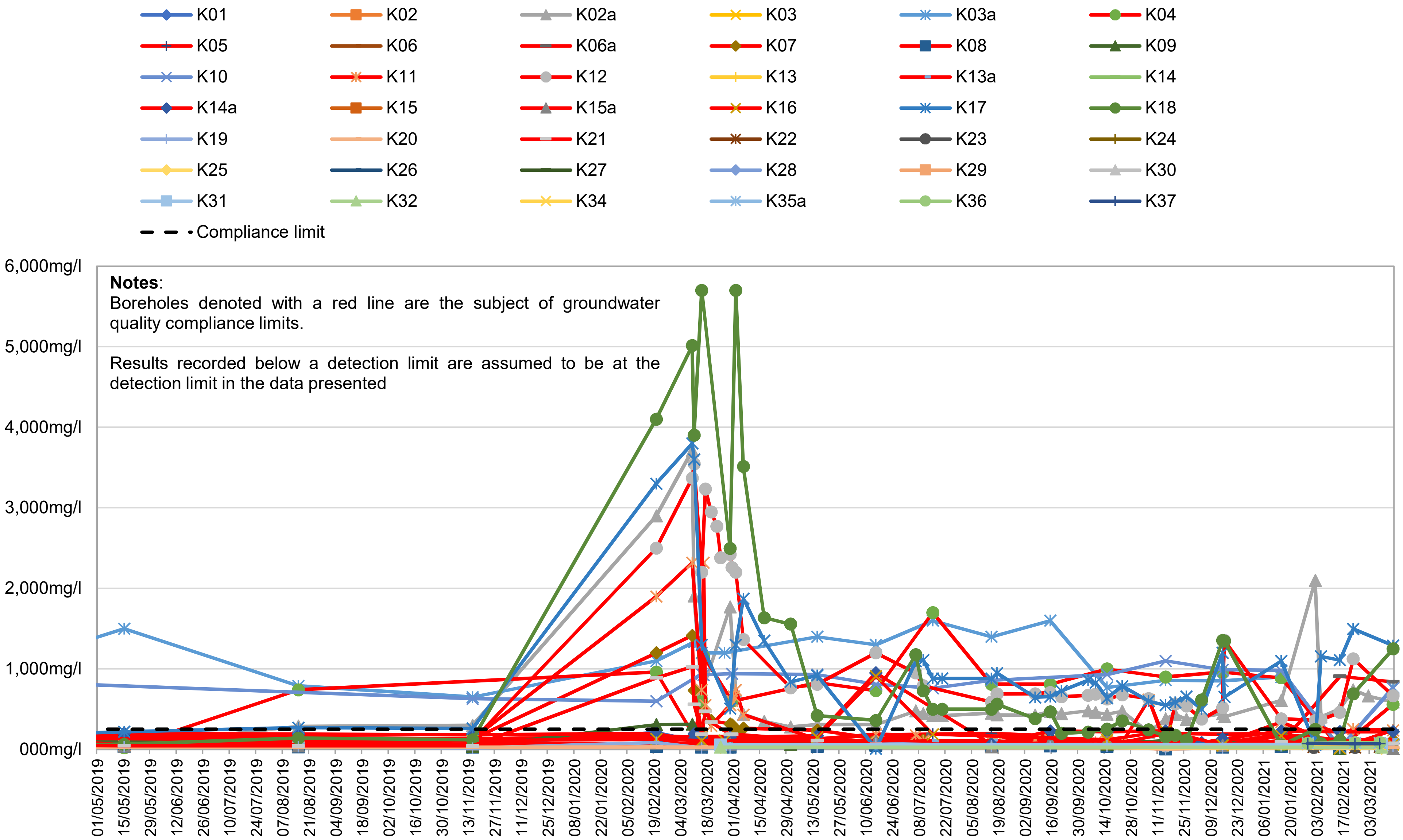
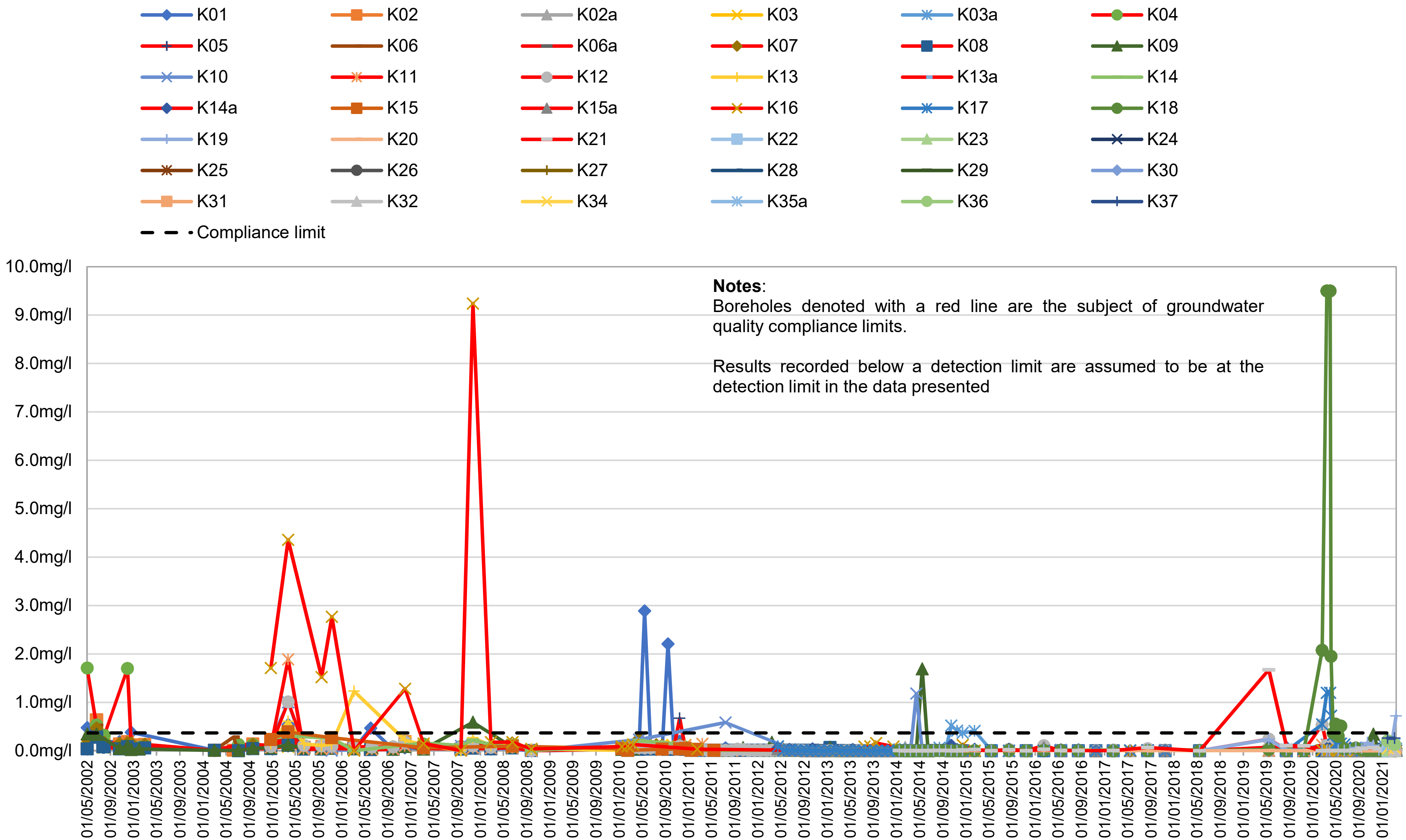
01/01/2016
01/05/2016
01/09/2016
01/01/2017
01/05/2017
01/09/2017
01/01/2018
01/05/2018
01/09/2018
01/01/2019
01/05/2019
01/09/2019
01/01/2020
01/05/2020
01/09/2020
01/01/2021

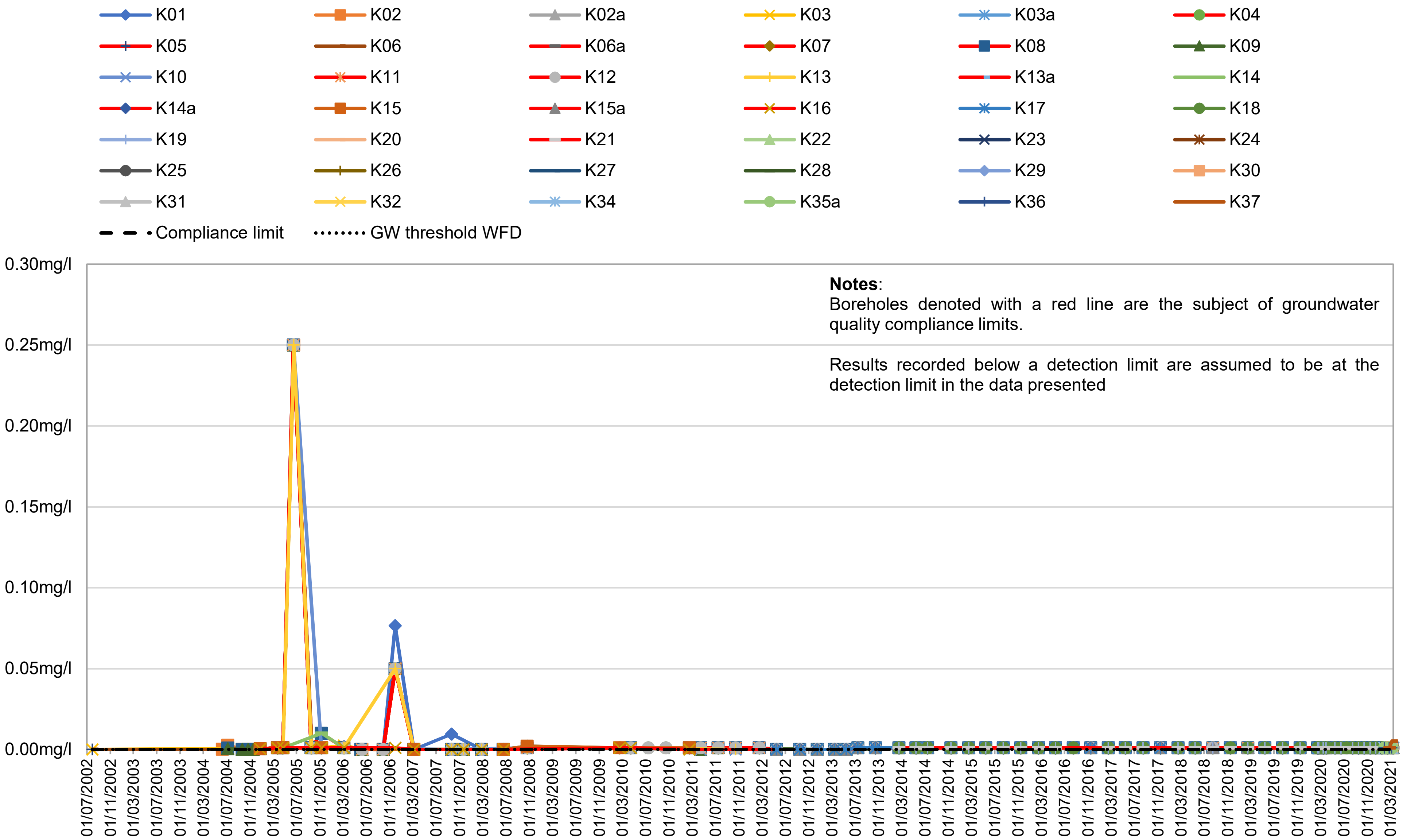
Chemograph of the concentration of chloride recorded in the groundwater up and down hydraulic gradient of the current ENRMF landfill between May 2019 and March 2021

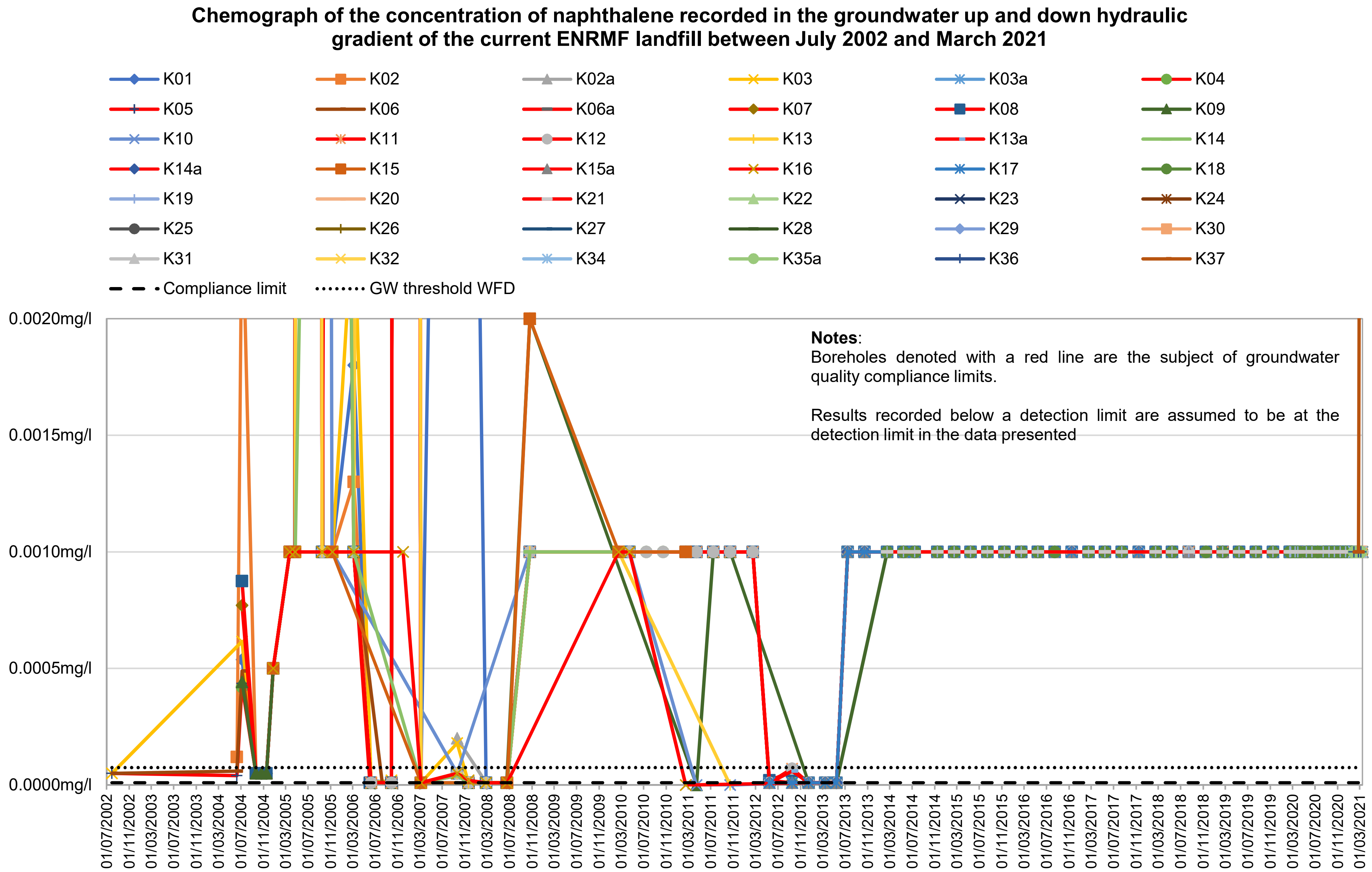


Chemograph of the concentration of manganese recorded in the groundwater up and down hydraulic gradient of the current ENRMF landfill between May 2002 and March 2021



Chemograph of the concentration of naphthalene recorded in the groundwater up and down hydraulic gradient of the current ENRMF landfill between July 2002 and March 2021




Chemograph of the concentration of naphthalene recorded in the groundwater up and down hydraulic gradient of the current ENRMF landfill between July 2002 and March 2021
K01
K02
K02a
K03
K03a
K04
K05
K06
K06a
K07
K08
K09
K10
K11
K12
K13
K13a
K14
K14a
K15
K15a
K16
K17
K18
K19
K20
K21
K22
K23
K24
K25
K26
K27
K28
K29
K30
K31
K32
K34
K35a
K36
K37
Compliance limit
GW threshold WFD
Notes:
Boreholes denoted with a red line are the subject of groundwater quality compliance limits.
Results recorded below a detection limit are assumed to be at the detection limit in the data presented
0.0020mg/l
0.0015mg/l
0.0010mg/l
0.0005mg/l
0.0000mg/l
01/07/2002
01/11/2002
01/03/2003
01/07/2003
01/11/2003
01/03/2004
01/07/2004
01/11/2004
01/03/2005
01/07/2005
01/11/2005
01/03/2006
01/07/2006
01/11/2006
01/03/2007
01/07/2007
01/11/2007
01/03/2008
01/07/2008
01/11/2008
01/03/2009
01/07/2009
01/11/2009
01/03/2010
01/07/2010
01/11/2010
01/03/2011
01/07/2011
01/11/2011
01/03/2012
01/07/2012
01/11/2012
01/03/2013
01/07/2013
01/11/2013
01/03/2014
01/07/2014
01/11/2014
01/03/2015
01/07/2015
01/11/2015
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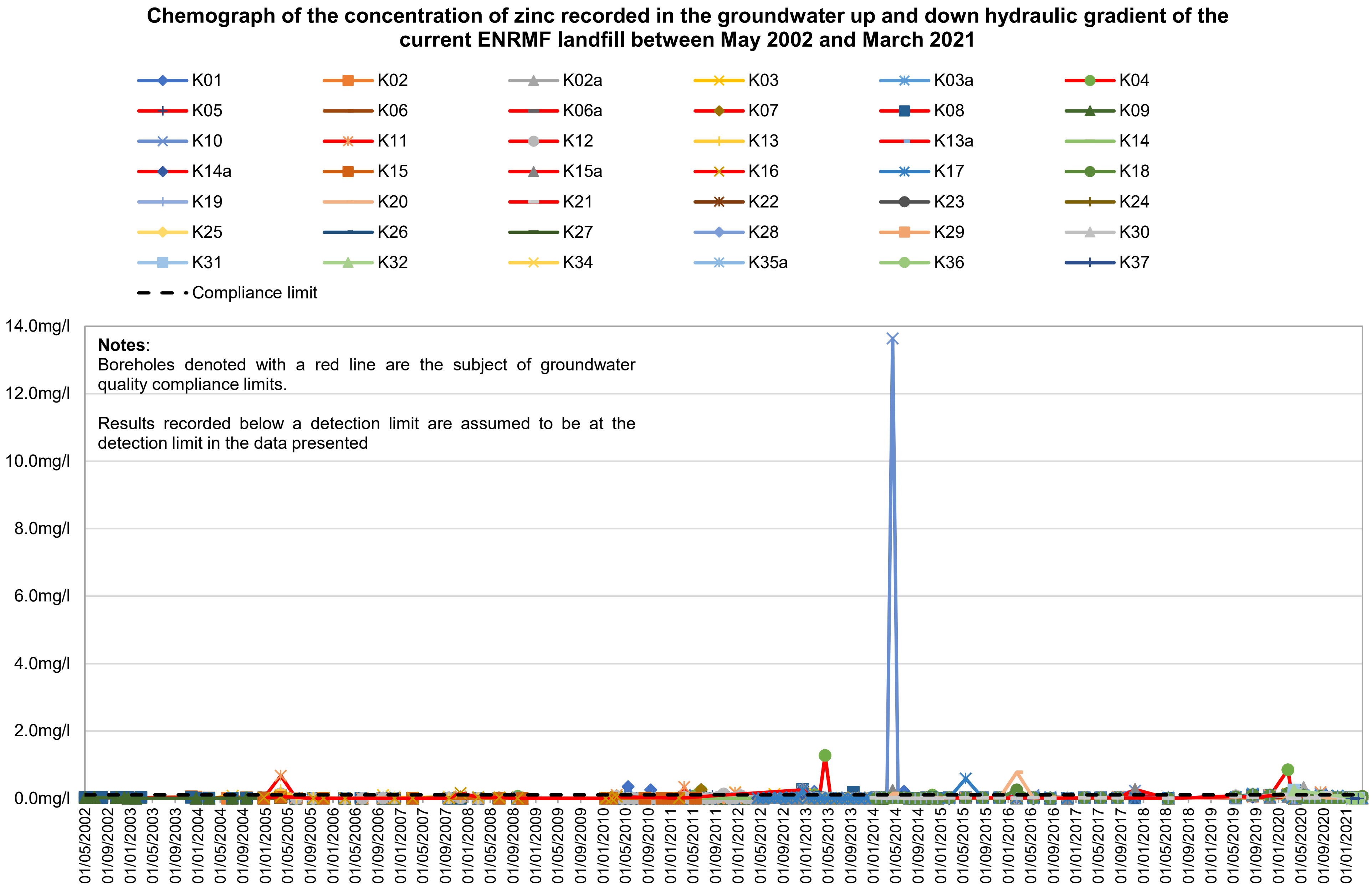
01/03/2018
01/07/2018
01/11/2018
01/03/2019
01/07/2019
01/11/2019
01/03/2020
01/07/2020
01/11/2020
01/03/2021



Chemograph of the concentration of zinc recorded in the groundwater up and down hydraulic gradient of the current ENRMF landfill between May 2002 and March 2021
K01
K02
K02a
K03
K03a
K04
K05
K06
K06a
K07
K08
K09
K10
K11
K12
K13
K13a
K14
K14a
K15
K15a
K16
K17
K18
K19
K20
K21
K22
K23
K24
K25
K26
K27
K28
K29
K30
K31
K32
K34
K35a
K36
K37
Compliance limit
Notes:
Boreholes denoted with a red line are the subject of groundwater quality compliance limits.
Results recorded below a detection limit are assumed to be at the detection limit in the data presented
14.0mg/l
12.0mg/l
10.0mg/l
8.0mg/l
6.0mg/l
4.0mg/l
2.0mg/l
0.0mg/l
01/05/2002
01/09/2002
01/01/2003
01/05/2003
01/09/2003
01/01/2004
01/05/2004
01/09/2004
01/01/2005
01/05/2005
01/09/2005
01/01/2006
01/05/2006
01/09/2006
01/01/2007
01/05/2007
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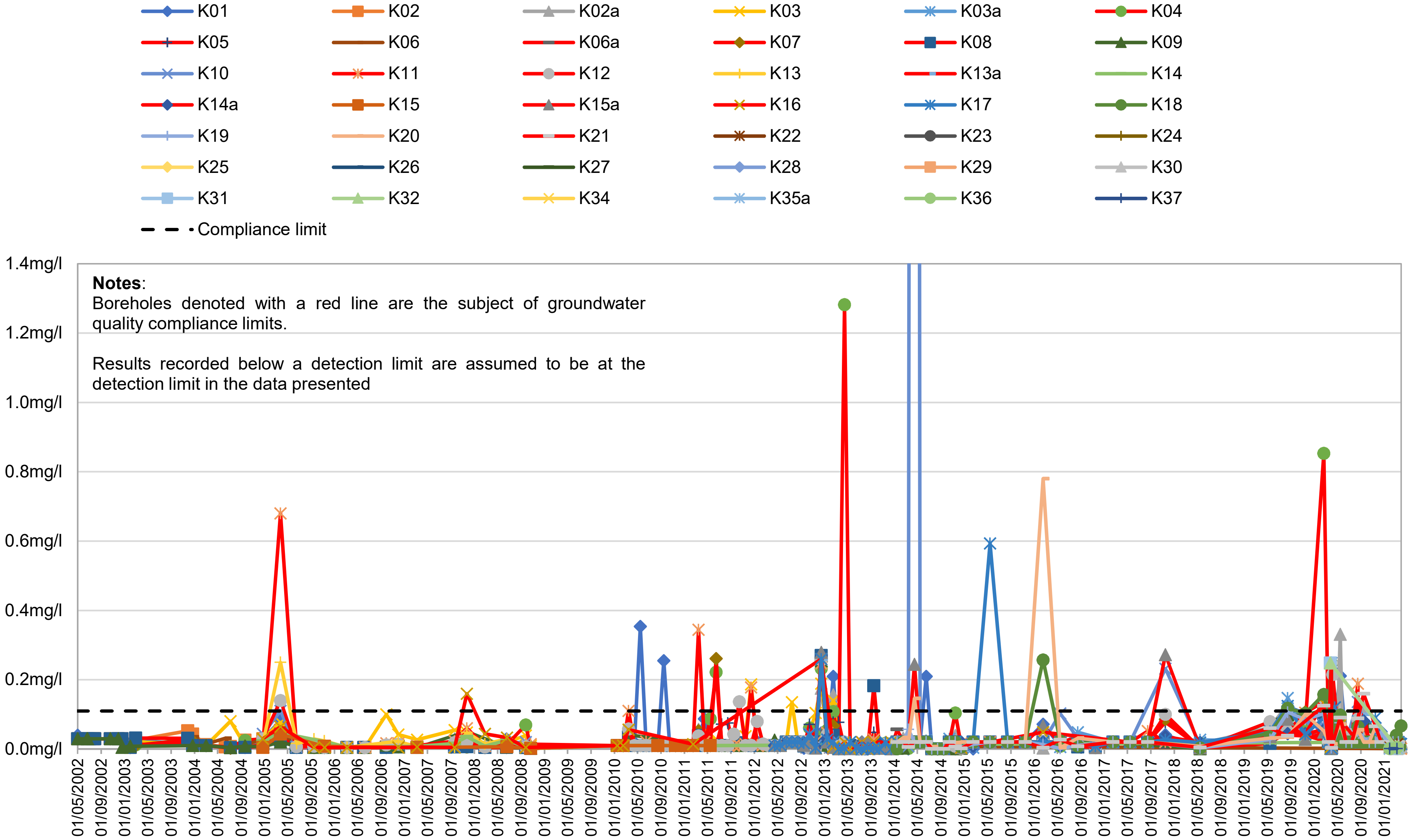
01/01/2017
01/05/2017
01/09/2017
01/01/2018
01/05/2018
01/09/2018
01/01/2019
01/05/2019
01/09/2019
01/01/2020
01/05/2020
01/09/2020
01/01/2021

Chemograph of the concentration of zinc recorded in the groundwater up and down hydraulic gradient of the current ENRMF landfill between May 2002 and March 2021



APPENDIX HRA J

SURFACE WATER QUALITY MONITORING RESULTS FOR SWSEOFALL IN JANUARY 2021

Certificate of Analysis

Certificate Number	21-00618-2	*Issued:*	02-Feb-21

Client Augean PLC
Land Resources (East Northlands)
East Northants Resource Ma Fa
Stamford Road
Kingscliffe
PE8 6XX

Our Reference 21-00618-2

Client Reference AUGKCGWQ

Order No 210376

Contract Title AUGEAN LAB SUITES APRIL 2019

Description 1(9) Water samples.

Date Received 14-Jan-21

Date Started 14-Jan-21

Date Completed 02-Feb-21

Test Procedures Identified by prefix DETSn (details on request).

Notes This test supersedes 21-00618-1, additional testing added,
Opinions and interpretations are outside the laboratory's scope of ISO 17025 accreditation. This certificate is issued in accordance with the accreditation requirements of the United Kingdom Accreditation Service. The results reported herein relate only to the material supplied to the laboratory. This certificate shall not be reproduced except in full, without the prior written approval of the laboratory.

Approved By [redacted]

[redacted]
Contracts Manager

UKAS TESTING
2139

Derwentside Environmental Testing Services Limited
Unit 2, Park Road Industrial Estate South, Consett, Co Durham, DH8 5PY
Tel: [redacted] • email: [redacted]

Summary of Chemical Analysis
Water Samples

Our Ref 21-00618-2
Client Ref AUGKCGWQ
Contract Title AUGEAN LAB SUITES APRIL 2019

			Lab No	1786383
			.Sample ID	SWSE O-FALL
			Depth	
			Other ID	
			Sample Type	WATER
			Sampling Date	11/01/2021
			Sampling Time	n/s
Test	**Method**	**LOD**	**Units**	
Metals				
Antimony, Dissolved ug/l	DETSC 2306	0.17	ug/l	4.2
Arsenic, Dissolved ug/l	DETSC 2306	0.16	ug/l	0.76
Cadmium, Dissolved ug/l	DETSC 2306	0.03	ug/l	0.24
Calcium, Dissolved mg/l	DETSC 2306	0.09	mg/l	130
Copper, Dissolved ug/l	DETSC 2306	0.4	ug/l	1.8
Iron, Dissolved ug/l	DETSC 2306	5.5	ug/l	57
Lead, Dissolved ug/l	DETSC 2306	0.09	ug/l	0.56
Magnesium, Dissolved mg/l	DETSC 2306	0.02	mg/l	4.5
Manganese, Dissolved ug/l	DETSC 2306	0.22	ug/l	24
Potassium Soluble [K_Sol]	DETSC 2306	0.08	mg/l	41
Selenium, Dissolved ug/l	DETSC 2306	0.25	ug/l	0.71
Sodium, Dissolved mg/l	DETSC 2306	0.07	mg/l	47
Tin, Dissolved ug/l	DETSC 2306*	0.4	ug/l	< 0.4
Zinc Soluble [Zn_Sol]	DETSC 2306	1.3	ug/l	6.5
Inorganics				
Conductivity uS/cm	DETSC 2009	1	uS/cm	976
pH pH	DETSC 2008		pH	7.2
Suspended Solids mg/l	DETSC 2034	5	mg/l	30
Ammoniacal Nitrogen as N [Amm_N]	DETSC 2207	0.015	mg/l	0.088
Chloride [CL]	DETSC 2055	0.1	mg/l	170
Petroleum Hydrocarbons				
Oil and Grease, Visual	DETSC 2140*			N
Acid Herbicides				
Dichlorprop [Dichlorprop]	DETSC 3448	0.02	ug/l	< 0.02
VOCs				
Trichloroethene [Trichloroethene]	DETSC 3432*	1	ug/l	< 1
Toluene [Toluene]	DETSC 3432	1	ug/l	< 1
Naphthalene [NAPHTHALENE]	DETSC 3432	1	ug/l	< 1

Key: * -not accredited. n/s -not supplied.

Information in Support of the Analytical Results

Our Ref 21-00618-2
Client Ref AUGKCGWQ
Contract AUGEAN LAB SUITES APRIL 2019

Containers Received & Deviating Samples

Lab No	Sample ID	Date Sampled	Containers Received	Holding time exceeded for tests	Inappropriate container for tests
1786376	KCGW02a WATER	12/01/21	PB to 250ml		Acid Herbicides, VOC
1786377	KCGW11 WATER	12/01/21	PB to 250ml		Acid Herbicides, VOC
1786378	KCGW12 WATER	12/01/21	PB to 250ml		Acid Herbicides, VOC
1786379	KCGW17 WATER	12/01/21	PB to 250ml		Acid Herbicides, VOC
1786380	KCGW18 WATER	12/01/21	PB to 250ml		Acid Herbicides, VOC
1786381	SWSE O-FALL WATER	11/01/21	PB to 250ml	pH/Cond/TDS (1 days), Suspended s (2 days)	Acid Herbicides, VOC
1786382	SWSE O-FALL WATER	11/01/21	PB to 250ml	pH/Cond/TDS (1 days), Suspended s (2 days)	Acid Herbicides, VOC
1786383	SWSE O-FALL WATER	11/01/21	PB to 250ml	pH/Cond/TDS (1 days), Suspended s (2 days)	Acid Herbicides, VOC
1786384	SWSE O-FALL WATER	12/01/21	PB to 250ml	pH/Cond/TDS (1 days)	Acid Herbicides, VOC

Key: P-Plastic B-Bottle

DETS cannot be held responsible for the integrity of samples received whereby the laboratory did not undertake the sampling. In this instance samples received may be deviating. Deviating Sample criteria are based on British and International standards and laboratory trials in conjunction with the UKAS note 'Guidance on Deviating Samples'. All samples received are listed above. However, those samples that have additional comments in relation to hold time, inappropriate containers etc are deviating due to the reasons stated. This means that the analysis is accredited where applicable, but results may be compromised due to sample deviations. If no sampled date (soils) or date+time (waters) has been supplied then samples are deviating. However, if you are able to supply a sampled date (and time for waters) this will prevent samples being reported as deviating where specific hold times are not exceeded and where the container supplied is suitable.

Disposal

From the issue date of this test certificate, samples will be held for the following times prior to disposal :-
Soils - 1 month, Liquids - 2 weeks, Asbestos (test portion) - 6 months

End of Report