Risk Assessment for Treated Soils

MG – RA V2

3C Waste Ltd

# Risk Assessment for Treated Soils

# Maw Green

12 March 2021

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# Project Quality Assurance Information Sheet

| | | |
|---|---|---|
| Report Type | : | Risk Assessment for Treated Soils |
| Site Location | : | Maw Green |
| Report Number | : | MG – RA V2 |
| Report Status | : | Issue 3 |
| Report Date | : | 12 March 2021 |
| Prepared for | : | 3C Waste Ltd |
| Prepared by | : | Provectus Soils Management Limited<br>Wyvols Court<br>Swallowfield<br>Reading<br>Berkshire<br>RG7 1WY |
| Compiled by | : | Projects Director |
| Reviewed by | : | Regional Manager |
| Authorised by | : | Managing Director |

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## APPENDICES

# 1 INTRODUCTION

## 1.1 Background

3C Waste have opened a soil treatment facility on a landfill on Maw Green Road, Crewe. The treatment facility is operated by Provectus Soils Management under permit number BS7722ID. The site has approximately 125,000m$^2$ of final restoration to undertake to enable the landfill to meet their obligations prior to the site closure. The soil treatment facility was established to provide a source of suitable soils for use in the restoration areas at the site. These restoration areas are highlighted on a drawing in Appendix A.

The Environment Agency has a historical permit request relating to undertaking a risk assessment to generate site specific targets for the restoration area and to meet their new restoration guidance document 'restore your landfill' Jan 2020.

This document provides a site specific risk assessment for the restoration soils above the upper landfill liner. This risk assessment provides soil treatment targets for the treatment facility to ensure the long term protection of receptors at the site.

Section 2 provides a human health risk assessment for the restoration area. Section 3 includes a controlled waters risk assessment. The report is concluded in Section 4 with a summary of the proposed criteria for the restoration area at Maw Green.

## 1.2 Site Specific Risk Assessments

The review of the information provided by FCC Environment/3C Waste established that the following main receptors were present at the site:

- Future site users
- Site workers involved in the restoration of the landfill
- Grazing animals
- Vegetation (grassland, hedgerows, trees)
- Controlled waters receptors with the primary receptor being surface water (Fowle Brook) at the periphery of the landfill

# 2 HUMAN HEALTH RISK ASSESSMENT

## 2.1 Introduction

A human health risk assessment has been produced by Leap Environmental Ltd and is included in its entirety in Appendix B.

## 2.2 Conceptual Site Model

The first step in undertaking a human health risk assessment is to produce a conceptual site model (CSM). The CSM is a series of plausible source-pathway-receptor contaminant linkages determined in line with industry good practice. This CSM is used, in this case, to determine a suitable set of quantitative acceptance criteria for the landfill restoration soils. The focus of the CSM is the predominantly the operational capping area. However, the previous areas of landfilling may also require additional restoration due to settlement of the restoration area being in excess of the expected amount at the pre-settlement filling stage of the landfill.

### 2.2.1 Potential sources of contamination

The assessment is focused on the criteria for treated soils from the soil treatment facility. Therefore, the key potential source of contamination is the treated soils proposed for restoration use.

It is unlikely that treated soils will be used for the upper 300mm of the restoration profile as a growth medium. It is anticipated that the topsoil will be sourced from a third party. The source of this topsoil may contain contaminants that require assessment.

### 2.2.2 Potential Receptors

Based on the proposed final use of the landfill cap, the potential receptors of any contaminants that may be present in the soils are:

- Future site users
- Workers during the placing of the restoration cover and the planting of trees and hedgerows
- Surrounding residents
- Grazing animals
- Trees, hedgerows and grasses planted within the restored cap

Controlled waters receptors (the aquifers and Fowle Brook) are assessed in Section 3.

No buildings are expected to be constructed on the site so below ground structures and utilities are discounted from this assessment.

A detailed list of pollutant linkages including relevant pathways is included in Table 2 in the Leap report in Appendix B.

## 2.3 Generation of Criteria

A number of guidance documents were used by Leap in the generation of criteria for the protection of the identified receptors. These reference documents were as follows:

- Environment Agency Guidance: Sewage sludge in agriculture: code of practice for England, Wales and Northern Ireland. Published 23 May 2018.
- British Standards Institution (BSI) *Specification for topsoil* BS3883:2015.
- Contaminated Land: Applications in Real Environments (CL:AIRE) '*SP1010 - Development of Category 4 Screening Levels for Assessment of Land Affected by Contamination'* Final Project Report (Revision 2), 24 September 2014.
- The LQM/CIEH S4ULs for Human Health Risk Assessment, Nathaniel P et al, 2015. Copyright Land Quality Management Ltd, reproduced with permission: Publication Number S4UL3509
- HPA, Contaminated Land Information Sheet. Risk Assessment Approaches for Polycyclic Aromatic Hydrocarbons (PAHs). Public Health England, 2017.

## 2.4 Topsoil and Subsoil Criteria

### 2.4.1 Topsoil Criteria

The following table provides criteria for the upper 300mm (topsoil) layer on the restoration area to enable the protection of the identified receptors. These criteria do not take into account the permit requirements or controlled waters assessment and are not final criteria for the upper 300mm of restoration area.

**Table 1**. Upper 300mm risk based criteria

| Contaminant | Value | Units | Source |
|---|---|---|---|
| | | **INORGANICS** | |
| Arsenic | 50 | $mgkg^{-1}$ | Sludge on Grassland |
| Cadmium | 3 | $mgkg^{-1}$ | Sludge on Grassland |
| Chromium | 600 | $mgkg^{-1}$ | Sludge on Grassland |
| Hexavalent Chromium | 250 | $mgkg^{-1}$ | POSpark |
| Copper | 225 | $mgkg^{-1}$ | Sludge on Grassland |
| Lead | 300 | $mgkg^{-1}$ | Sludge on Grassland |
| Mercury[1] | 1.5 | $mgkg^{-1}$ | Sludge on Grassland |
| Nickel | 125 | $mgkg^{-1}$ | Sludge on Grassland |
| Selenium | 5 | $mgkg^{-1}$ | Sludge on Grassland |
| Zinc | 200 | $mgkg^{-1}$ | Sludge on Grassland |
| Asbestos | Not present (<0.001%) | % | Reasonably achievable detection limit |
| | | **PETROLEUM HYDROCARBONS** | |
| Aliphatic EC5-6 | 180,000[4] | $mgkg^{-1}$ | POSpark |
| Aliphatic EC6-8 | 320,000[4] | $mgkg^{-1}$ | POSpark |
| Aliphatic EC8-10 | 21,000[4] | $mgkg^{-1}$ | POSpark |
| Aliphatic EC10-12 | 24,000[4] | $mgkg^{-1}$ | POSpark |
| Aliphatic EC12-16 | 26,000[4] | $mgkg^{-1}$ | POSpark |
| Aliphatic EC16-35 | 490,000[4] | $mgkg^{-1}$ | POSpark |
| Aromatic EC5-7 | 92,000[4] | $mgkg^{-1}$ | POSpark |
| Aromatic EC7-8 | 100,000[4] | $mgkg^{-1}$ | POSpark |
| Aromatic EC8-10 | 9,300[4] | $mgkg^{-1}$ | POSpark |
| Aromatic EC10-12 | 10,000[4] | $mgkg^{-1}$ | POSpark |
| Aromatic EC12-16 | 10,000[4] | $mgkg^{-1}$ | POSpark |
| Aromatic EC16-21 | 7,800[4] | $mgkg^{-1}$ | POSpark |
| Aromatic EC21-35 | 7,900[4] | $mgkg^{-1}$ | POSpark |
| | | **OTHER ORGANICS** | |
| Phenol | 1,300[4] | $mgkg^{-1}$ | POSpark |
| Benzo(a)pyrene[2] | 21 | $mgkg^{-1}$ | POSpark |
| Naphthalene[3] | 3,000[4] | $mgkg^{-1}$ | POSpark |

Notes to table

1. As inorganic mercury.
2. Surrogate marker for all genotoxic PAHs.
3. Indicator compound for all non-genotoxic PAHs.
4. Exceeds WM3 thresholds for hazardous waste – final criteria presented later in Table 3

### 2.4.2 Subsoil Criteria

The subsoil will be placed below 300 mm of topsoil and will extend to a minimum of 1m below final ground level.

All the plausible contaminant linkages that have been identified are via direct exposure with contaminants of potential concern and as such, it is considered highly unlikely that future site users or grazing animals will be exposed to contaminants within the restoration subsoil which will placed below 300 mm of topsoil.

The roots of grasses and hedgerows are unlikely to extend below the top 300 mm of topsoil and would therefore, also not be exposed to any contaminants present within the restoration subsoil.

It is possible that the roots of trees could extend into the subsoil and take up contaminants through their root system. There is also potential that, during the excavation of tree pits and the planting of trees, workers could be exposed to contaminants within the subsoil at these locations. As such, the acceptance criteria for tree pits should be the same as the topsoil criteria provided in Table 1.

Notwithstanding the acceptance criteria that have been derived, because the site is a licensed waste facility, as a minimum the topsoil and subsoil restoration cover must not contain substances that would render the material as hazardous waste.

# 3 CONTROLLED WATERS RISK ASSESSMENT

The complete controlled waters risk assessment is included in Appendix C and was completed by Sladen Associates Ltd. A summary of their findings is presented in this section.

## 3.1 Conceptual Model

The restoration area is above the groundwater level at the site and separated from underlying waste deposits by a low permeability membrane. Therefore the primary risk from rainfall onto the restoration area will be surface water receptors.

A proportion of the long term average precipitation falling on the restoration system will result in run-off. The primary flow direction in the restoration/protection soils would be expected to be in a generally sub-horizontal downslope direction. This would be greatest during significant storm events and would typically be expected to represent less than about 5 to 10 % of total precipitation unless the cover system became saturated. The completed restoration will be vegetated and evapotranspiration will represent a significant part of the water balance.

It is expected that both run-off from the restoration system via surface channels and discharge of water from the restoration soils would be directed to a surface drainage system, which would itself discharge to surface water, in the case the Fowle Brook, Figure 3 within the Sladen report in Appendix C shows the proposed arrangement.

A small proportion of infiltration may pass through the geo-membrane or clay sealing layer at the base of the restoration profile and contribute to leachate waters within the underlying wastes. These waters will be controlled by the leachate collection system on site. This pollutant linkage is anticipated to be minimal and is not considered further.

Direct discharge to groundwater from the cap would be expected to be intercepted by a surface drainage system. Given the significant thickness of glacial clay above the underlying sand aquifer, considerable attenuation would be expected to occur prior to discharge to the sand aquifer. Accordingly, it is not considered credible that that pathway would be more critical than direct discharge to surface water. Accordingly, with regard to any potential dissolved contaminants within the water emanating from the restoration soils, it is considered that, for the present site, more detailed assessment is only warranted with respect to the surface water receptor via direct discharge from the drainage system

### 3.2 Compliance Criteria

As the critical receptor is considered to be the surface water system, the relevant compliance criteria will be assumed to be Annual Average Environmental Quality Standards (EQS) levels where these have been published. Where no EQS is available EQS values for similar compounds have been selected.

Where new EQS values have been proposed in the document 'The River Basin Districts Typology, Standards and Groundwater threshold values (Water Framework Directive) (England and Wales) Directions 2015, these have been adopted. Otherwise former EQS values for surface water have been adopted.

For total petroleum hydrocarbons (TPH) the former DWS (0.01 mg/l) was adopted as a relevant compliance criterion for each of the TPHCWG groupings where the expected solubility exceeds that value. Where solubility is less than 0.01 mg/l it is assumed that the fraction can pose no significant risk to controlled waters.

### 3.3 Contaminant Transport Modelling

The patterns of water flow within the restoration system are critical to the assessment of risks to controlled waters. In order further to develop the conceptual model of water flow conditions, a numerical model was developed to simulate flow and contaminant transport in the restoration system. The modelling software chosen simulates 2 dimensional flow and contaminant transport in a vertical section through the restoration area.

Numerical modelling undertaken as part of the present study has made use of the SEEP/W program developed by Geo-Slope International Ltd. Potential patterns of contaminant transport were mapped on the results of the SEEP/W analysis with the use of a companion program CTRAN/W.

### 3.4 Derived Soil Criteria

The criteria for the protection of controlled waters are based upon soil leachate quality rather than dry weight analysis of contaminants. The criteria derived from the modelling are values for an annual average over the restoration area rather than specific criteria for all soils.

The following suite of contaminants are generally present in soils that are treated at the Maw Green site and have had leachate criteria derived for the protection of controlled waters:

- BTEX

- Naphthalene
- Benzo[a]pyrene
- Phenol
- Speciated TPH
- Arsenic
- Cadmium
- Copper
- Chromium
- Lead
- Mercury
- Nickel
- Zinc
- Water Soluble Boron
- Sulphate

In addition, a limited number of soil batches may contain inclusions from materials with the following waste codes:

- 19 02 05* sludges from physico/chemical treatment containing hazardous substances
- 19 02 06 sludges from physico/chemical treatment other than those mentioned in 19 02 05
- 20 03 03 street-cleaning residues

For batches of soil containing the above waste codes then we would include the assessment of leachable ammonium and nitrate. The reason for this is that the above three waste codes contain organic matter that will result in the generation of ammonium and nitrate in soil leachate.

The derived soil leachate criteria are included in Table 2. These criteria are an annual average for soil leachate quality.

**Table 2.** Derived Soil Leachate Criteria

| Substance | Compliance Criterion (mg/l) | Derived Leachate Targets (mg/l) | | |
|---|---|---|---|---|
| | | Zone 2 | Zone 3 | Zone 4 |
| Benzene | 0.01 | 0.015 | 0.032 | 0.15 |
| Toluene | 0.074 | 0.36 | 5 | No Restriction |
| Ethylbenzene | 0.02 | 0.37 | 48 | No Restriction |
| m-Xylene | 0.03 | 0.69 | 130 | No Restriction |
| o-Xylene | 0.03 | 0.5 | 55 | No Restriction |
| p-Xylene | 0.03 | 0.56 | 72 | No Restriction |
| Naphthalene | 0.0024 | 0.04 | 4.4 | No Restriction |
| Benzo[a]pyrene | 0.00000017 | No Restriction | No Restriction | No Restriction |
| Phenol | 0.0077 | 0.016 | 0.052 | 0.61 |
| TPH Aliphatic C5-C6 | 0.01 | 0.19 | 24 | No Restriction |
| TPH Aliphatic C6-C8 | 0.01 | No Restriction | No Restriction | No Restriction |
| TPH Aliphatic C8-C10 | 0.01 | No Restriction | No Restriction | No Restriction |
| TPH Aliphatic C10-C12 | 0.01 | No Restriction | No Restriction | No Restriction |
| TPH Aliphatic C12-C16 | 0.01 | No Restriction | No Restriction | No Restriction |
| TPH Aliphatic C16-C21 | 0.01 | No Restriction | No Restriction | No Restriction |
| TPH Aliphatic C21-C34 | 0.01 | No Restriction | No Restriction | No Restriction |
| TPH Aliphatic C35-C44 | 0.01 | No Restriction | No Restriction | No Restriction |
| TPH Aromatic C8-C10 | 0.01 | 0.18 | 24 | No Restriction |
| TPH Aromatic C10-C12 | 0.01 | 0.072 | 2.1 | No Restriction |
| TPH Aromatic C12-C16 | 0.01 | 0.14 | 2.7 | No Restriction |
| TPH Aromatic C16-C21 | 0.01 | No Restriction | No Restriction | No Restriction |
| TPH Aromatic C21-C35 | 0.01 | No Restriction | No Restriction | No Restriction |
| TPH Aromatic C35-C44 | 0.01 | No Restriction | No Restriction | No Restriction |
| TPH Aromatic C44-C70 | 0.01 | No Restriction | No Restriction | No Restriction |
| Arsenic | 0.05 | 0.063 | 0.074 | 0.11 |
| Cadmium | 0.00025 | 0.00027 | 0.00032 | 0.00046 |
| Copper | 0.028 | 0.035 | 0.042 | 0.059 |
| Chromium | 0.02 | 0.025 | 0.03 | 0.042 |
| Lead | 0.0072 | 0.0091 | 0.011 | 0.015 |
| Mercury | 0.00005 | 0.000055 | 0.000065 | 0.000092 |
| Nickel | 0.02 | 0.025 | 0.03 | 0.042 |
| Zinc | 0.13 | 0.16 | 0.19 | 0.26 |
| Water Soluble Boron | 2 | 2.5 | 3 | 4.2 |
| Sulphate | 400 | 510 | 600 | 840 |
| Nitrate** | 11 | 14 | 17 | 24 |
| Ammonium** | 0.77 | 1.3 | 2.6 | 7.8 |

* Note: Zone 1 Target set at Compliance Criterion (EQS)

** for batches with 19 02 05, 19 02 06 and 20 03 03 waste inclusions

Although there are a number of assumptions inherent in the present analysis, in so far as possible these have been chosen to be consistent with design assumptions for the overall site.

The sensitivity analysis of the parameters used in the modelling has been focused on incorporating a significant number of conservative assumptions into the analysis to provide reassurance to the site owner and local regulators, in particular:

- Apart from for ammonium, the source of potential leachate within the restoration soils has been assumed to be constant with time. This is considered to be particularly conservative for potentially more soluble mobile contaminants.
- Evaporation to the atmosphere has been ignored due to the effect of the soil treatment and residual volatiles being below detect levels, however, this is likely be significant for volatile, relatively mobile, organic compounds.
- The potential leakage to the waste mass has been assumed to be zero.
- Degradation half lives have been assumed to much higher than would likely be observed in aerobic near surface soil conditions.
- The hydraulic conductivity of the restoration soils has been assumed to be significantly higher than would be anticipated.
- The organic matter content of the restoration soils has been assumed to be relatively low.
- A proposed minimum thickness of restoration soils has been adopted as the base case.

Analysis has been undertaken to illustrate the sensitivity of the analysis to seasonal variance in infiltration, variation in cover thickness and variation in restoration soil saturated hydraulic conductivity. In view of the significantly conservative assumptions outlined above, more detailed analysis of sensitivity it is not considered warranted.

### 3.5 Summary

The restoration system will comprise a cap sealing layer which will in turn be overlain by the restoration soils. The restoration soils will have a minimum overall 1.0 m thickness above the barrier layer. However, depending on such factors as the magnitude of post construction settlements, the overall thickness of the restoration soils is likely to be significantly greater in some areas.

Levels of top-up will depend on settlement experienced over the coming years. This will need to be addressed separately as necessary; the intention will be to place the required soil depth initially. In accordance with the specified planning requirements:

- minimum 750mm of subsoil, and

- minimum 250mm of topsoil.
- Woodland planting areas - minimum of 1.5 metres of soil cover over the cap with the upper 0.6m comprising of growth medium with a minimum of 0.9m subsoil below.

The restoration system will be entirely above the site groundwater level and analysis suggests that it will remain unsaturated during average conditions if the saturated conductivity of the restoration soils is relatively high. For lower conductivities saturated conditions may develop, particularly in winter months, which would tend to increase run- off and reduce infiltration and hence reduce potential leaching. Any infiltration into the restoration soils that permeates through the barrier will contribute to leachate within the waste mass and be treated accordingly. It is expected, however, that this will be a small component of the overall water balance and that most of the infiltration will travel laterally within the restoration system and discharge to a surface water drain, which would discharge to the Fowle Brook.

Analysis has been undertaken to derive defensible leachate targets for the treated soils that will be protective to surface water. For some potential contaminants there is the potential for significant attenuation within the restoration system prior to discharge.

Numerical modelling of the flow system in the restoration soils has been undertaken to quantify potential levels of attenuation. Based on the site conceptual model, for the present site, the discharge to groundwater pathway is considered to be less critical than the discharge to perimeter drain and thence to surface water pathway.

For site management, the cover area has been divided into four zones representing different distances from the surface water drainage system.

# 4 PROPOSED SOIL TREATMENT TARGETS

## 4.1 Introduction

The completion of the risk assessment for the restoration area has led to a number of criteria to be proposed. Some of these criteria are contaminant limits based upon dry weight analysis, some are soil leachate targets.

The final criteria will also need to be limited to the landfill requirements and its status as a permitted non-hazardous waste disposal site.

This section provides the following for the restoration area:

- types of waste
- quantity of waste
- waste acceptance criteria and procedures

## 4.2 Types of Waste

The treated materials from the soil treatment facility will be treated to meet the risk based targets for the restoration area. The waste code for the treated materials will be as follows:

- 19 13 02 - Solid wastes from soil remediation other than those mentioned in 19 13 01

Apart from meeting the risk based contaminant targets, the output from the soil treatment facility will be non-hazardous waste, with no odours, nor visual impact from contamination.

## 4.3 Quantity of Waste

The existing restoration area that requires material for filling is approximately 125,000m$^2$. If the entire area was filled with treated soil then this would equate to 125,000m$^3$ or 250,000t assuming a 2t/m$^3$ dry density.

This figure may vary based upon the final post settlement contours of the site or further surveys conducted throughout the lifetime of the soil treatment facility.

## 4.4 Proposed Criteria for Restoration Area

The proposed chemical criteria for the landfill restoration area in Table 3 will ensure the following:

- Prevent harm caused by direct contact or inhalation of contaminants in treated soil
- Prevent detrimental impact to controlled waters receptors
- Ensure all soils are suitable for use on a permitted non-hazardous landfill

In addition to the chemical criteria, the following aesthetic criteria are also proposed:

- No soils with residual odours or visual impact from hydrocarbons to be used in the restoration area
- Soils to be screened to remove oversize inclusions prior to placement

The validation procedures that have been utilised to date, with separate reports for each batch of treated soils sent to the FCC compliance team will continue unchanged. The leachate quality results will be compiled as an average over an annual basis to ensure compliance with the requirements of the controlled waters assessment.

**Table 3.** Restoration Soil Criteria

| Substance | Soil Contaminants (mg/kg) | | Derived Leachate Targets (mg/l) | | | |
|---|---|---|---|---|---|---|
| | Upper 300mm | Below 300mm | Zone 1[2] | Zone 2[2] | Zone 3[2] | Zone 4[2] |
| Benzene | NH | NH | 0.01 | 0.015 | 0.032 | 0.15 |
| Toluene | NH | NH | 0.074 | 0.36 | 5 | - |
| Ethylbenzene | NH | NH | 0.02 | 0.37 | 48 | - |
| m-Xylene | NH | NH | 0.03 | 0.69 | 130 | - |
| o-Xylene | NH | NH | 0.03 | 0.5 | 55 | - |
| p-Xylene | NH | NH | 0.03 | 0.56 | 72 | - |
| Naphthalene | NH | NH | 0.0024 | 0.04 | 4.4 | - |
| Benzo[a]pyrene | 21 | NH | 0.00000017 | - | - | - |
| Phenol | NH | NH | 0.0077 | 0.016 | 0.052 | 0.61 |
| TPH Aliphatic C5-C6 | NH | NH | 0.01 | 0.19 | 24 | - |
| TPH Aliphatic C6-C8 | NH | NH | 0.01 | - | - | - |
| TPH Aliphatic C8-C10 | NH | NH | 0.01 | - | - | - |
| TPH Aliphatic C10-C12 | NH | NH | 0.01 | - | - | - |
| TPH Aliphatic C12-C16 | NH | NH | 0.01 | - | - | - |
| TPH Aliphatic C16-C21 | NH | NH | 0.01 | - | - | - |
| TPH Aliphatic C21-C34 | NH | NH | 0.01 | - | - | - |
| TPH Aliphatic C35-C44 | NH | NH | 0.01 | - | - | - |
| TPH Aromatic C8-C10 | NH | NH | 0.01 | 0.18 | 24 | - |
| TPH Aromatic C10-C12 | NH | NH | 0.01 | 0.072 | 2.1 | - |
| TPH Aromatic C12-C16 | NH | NH | 0.01 | 0.14 | 2.7 | - |
| TPH Aromatic C16-C21 | NH | NH | 0.01 | - | - | - |
| TPH Aromatic C21-C35 | NH | NH | 0.01 | - | - | - |
| TPH Aromatic C35-C44 | NH | NH | 0.01 | - | - | - |
| TPH Aromatic C44-C70 | NH | NH | 0.01 | - | - | - |
| Arsenic | 50 | NH | 0.05 | 0.063 | 0.074 | 0.11 |
| Cadmium | 3 | NH | 0.00025 | 0.00027 | 0.00032 | 0.00046 |
| Copper | 225 | NH | 0.028 | 0.035 | 0.042 | 0.059 |
| Chromium | 600 | NH | 0.02 | 0.025 | 0.03 | 0.042 |
| Hexavalent Chromium | 250 | NH | 0.02 | 0.025 | 0.03 | 0.042 |
| Lead | 300 | NH | 0.0072 | 0.0091 | 0.011 | 0.015 |
| Mercury | 1.5 | NH | 0.00005 | 0.000055 | 0.000065 | 0.000092 |
| Nickel | 125 | NH | 0.02 | 0.025 | 0.03 | 0.042 |
| Zinc | 200 | NH | 0.13 | 0.16 | 0.19 | 0.26 |
| Water Soluble Boron | NH | NH | 2 | 2.5 | 3 | 4.2 |
| Asbestos Fibres | <0.001% | <0.1% | - | - | - | - |
| Sulphate | NH | NH | 400 | 510 | 600 | 840 |
| Nitrate[1] | NH | NH | 11 | 14 | 17 | 24 |
| Ammonium[1] | NH | NH | 0.77 | 1.3 | 2.6 | 7.8 |

Notes

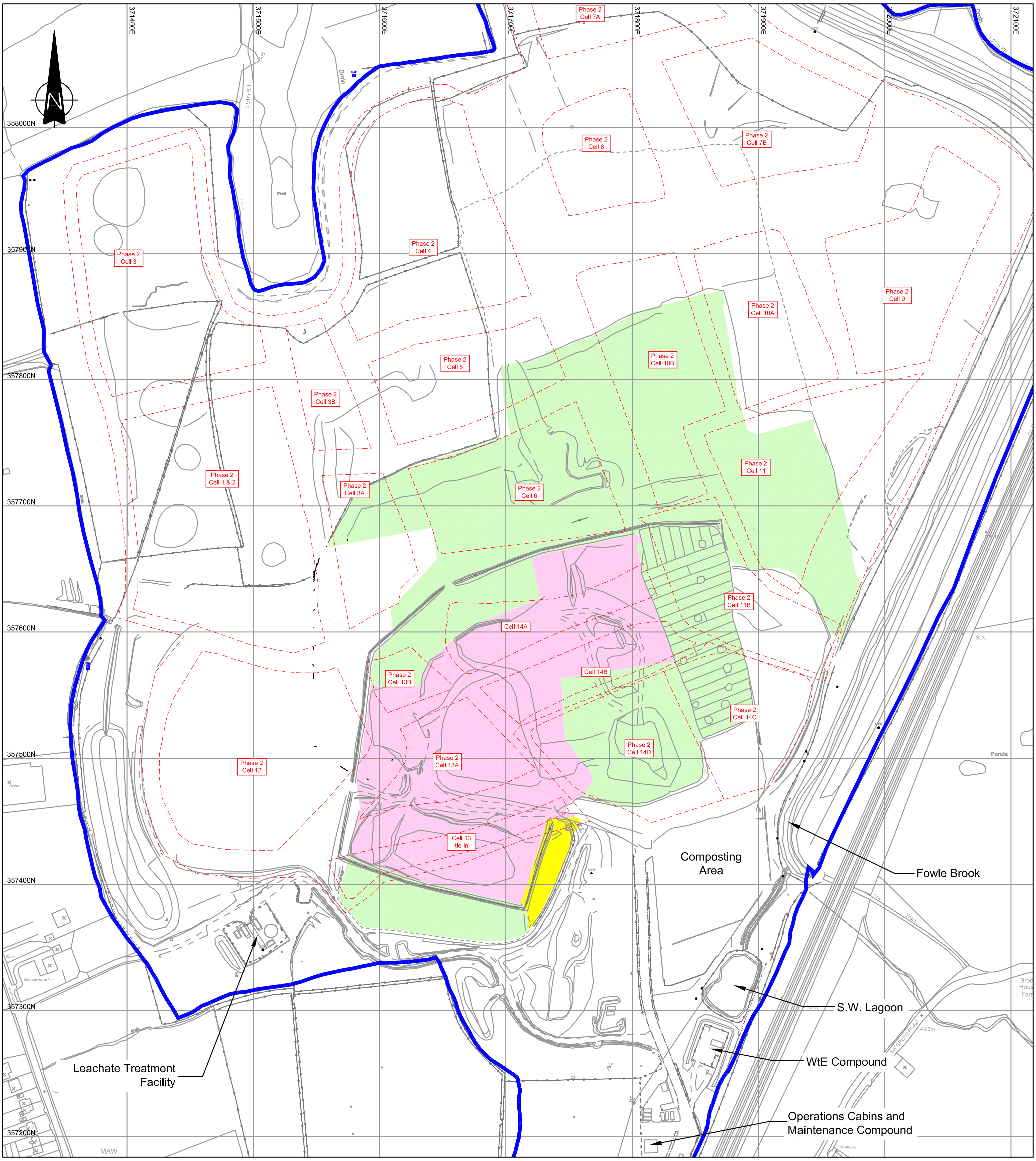
-: No restriction

NH: Non Hazardous

[1] for batches with 19 02 05, 19 02 06 and 20 03 03 wastes only

[2] where the soil leachate target is below the laboratory detection limit, the detection limit will be deemed the target for restoration

# APPENDIX A. RESTORATION AREAS




LEGEND:

| | |
|---|---|
| Ownership Boundary (blue line) | |
| 39,289m² | Operational Capping Area |
| | Catch Up Capping Area |
| 84,593m² | Top Up Capping Area |
| | Other Flanks Area |
| 1,833m² | Legacy Capping |
| | As-built Cell Footprint |
| | Proposed Cell Areas |

NOTES:

1. ALL DIMENSIONS IN MILLIMETRES AND ALL LEVELS IN METRES ABOVE ORDNANCE DATUM.

2. DO NOT SCALE FROM THIS DRAWING.

3. ANY ANOMALIES IDENTIFIED WITH THE DETAILS SHOWN ON THIS DRAWING ARE TO BE BROUGHT TO THE ATTENTION OF FCC ENVIRONMENT (UK) LIMITED PRIOR TO CONSTRUCTION WORKS COMMENCING.

| Revision: | Date: | Description: | By: | Chk: |
|---|---|---|---|---|
| - | - | - | - | - |
| - | - | - | - | - |
| - | - | - | - | - |

Reference files:
Information taken from plans;
Site Survey: 124W1867_W2 5TH JUNE 2020
Capping: 124C1875
Cell Footprints: 124A1799



FCC Environment

FCC Environment (UK) Limited
6 Sidings Court, White Rose Way, Doncaster, DN4 5NU

Site: **MAW GREEN** LANDFILL SITE

Drawing Title: **Capping Liability Q3 2020**

| Drawn By: | Checked By: | Date: | Scale: | Paper Size: |
|---|---|---|---|---|
| BS | LH | 11.11.20 | 1:3000 | A3 |

| Status: | Revision: | Drawing No: | Plan Number: |
|---|---|---|---|
| FINAL | - | 124C331 | PLAN 19 |

## APPENDIX B. LEAP ENVIRONMENTAL REPORT

# Human Health Quantitative Risk Assessment for Restoration Soils

## Maw Green Landfill

## For: Provectus Soil Management Ltd

Report Reference: LP2290/HHQRA

Report Date: 16th September 2020

Leap Environmental Ltd
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Registered in England No 6552502

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| | |
|---|---|
| Signed : | Kate Baker BSc MIEnvSc CSci ASoBRA |
| Countersigned : | Helen Smith MSc BSc CGeol DIC SiLC |
| Date : | 16 September 2020 |
| Revision: | Issue 1 |

# A INTRODUCTION AND BACKGROUND

## 1 Authority

Provectus Soils Management Ltd. (hereafter referred to as 'Provectus') appointed Leap Environmental Ltd (hereafter referred to as LEAP) to produce a set of soil restoration criteria for the Maw Green landfill site located on the outskirts of Crewe in Cheshire.

A site location plan is provided in Figure 1 and the boundary of the landfill is provided in Drawing ESID2 which is reproduced from reference 4D-197-178/ESID (see Section 4).

## 2 Client Aims

Provectus and the landfill operator (FCC Environment (UK) Ltd., hereafter referred to as 'FCC') have formed a strategic alliance at Maw Green landfill whereby Provectus treats contaminated soils which are then used by FCC as restoration cover for completed areas of the landfill. It is a requirement of an improvement condition within the FCC Environmental Permit for the site that an updated restoration plan is agreed with the Environment Agency. The soil quality criteria will be used as one of the parameters for determining when soil treatment has been successfully completed. The materials that have been treated by Provectus will be used as the subsoil layer of the restoration cover and criteria are required that are protective of the final use of the site. LEAP understands that criteria designed to be protective of controlled waters are being calculated by a third party consultant and are therefore excluded from this report.

## 3 Scope of Works

In order to provide suitable restoration criteria for soils that are protective of the intended future land use the following scope of works was undertaken:

- Review of relevant documentation provided by Provectus and publicly available information.
- Review of the restoration plan for the site.
- Derivation of a conceptual site model (CSM) through the identification of potential sources of contamination, potential receptors and potential pathways of exposure.
- Evaluation of potentially suitable published quantitative criteria.
- Generation of site-specific restoration criteria.

# 4 Sources of Information

Provectus has provided the following documents which are relevant to the production of this report:

- SLR '*Maw Green Landfill, Crewe, Cheshire: Hydrogeological Risk Assessment Review*' Draft report, ref. 402-0197-00720. April 2009.
- SLR '*Maw Green Landfill: PPC Application Section A – Environmental Setting and Installation Design*' ref. 4D-197-178/ESID. October 2003.
- SLR '*Maw Green Landfill: PPC Application Section B - Hydrogeological Risk Assessment*' ref. 4D-197-178/HRA. October 2003.

The reports listed are the basis of the summary information provided in Sections B and C of this report. Further details are provided in each of the original documents. The following sources of publicly available information[1] were also reviewed:

- British Geological Survey (BGS) *Geology of Britain* online viewer accessed on 22 August 2020.
- BGS 1:50,000 Series Geological Map Sheet 110 '*Macclesfield*' Solid ed. 1997.
- BGS 1:50,000 Series Geological Map Sheet 110 '*Macclesfield*' Drift ed. 1968.
- Defra *MAGIC* website accessed on 22 August 2020.
- Interrogation of the internet on 22 August 2020 for general information pertaining to the site.

[1] As such, this report contains British Geological Survey materials ©NERC 2020 and public sector information licensed under the Open Government Licence v3.0.

# B SITE CONTEXT

## 5 Site Details

The boundary of the landfill is a whole is provided in Drawing ESID2. The area that is currently being restored and forms the basis of this report is the pink area on Drawing 124C328. This comprises parts of Cells 13, 13A, 13B, 14A, 14B and 14D and is the final active area of this landfill, the remainder having already been completed and largely restored.

No site walkover was carried out as part of this assessment. On the basis of a review of the available reports (see Section 4) and a review of publicly available information, a summary of the site details for the currently operational landfill area is provided in Table 1:

**Table 1: Summary of Site Details of Currently Operational Landfill Area**

| Information | Details |
|---|---|
| Name and Address | Maw Green Landfill, Maw Green Road, Coppenhall, Crewe, Cheshire, CW1 5NG |
| Location and National Grid Reference (NGR) | Southern boundary is c.350 m north-east of the outskirts of Crewe.<br>NGR SJ 717 575 |
| Site Area | Operational area that requires capping – 45,656 $m^2$ |
| Topography | Previous natural topography of the landfill as a whole was low lying ground c.45 mAOD within a gently sloped valley. |
| Current Use | Landfilling of non-hazardous waste. |
| Site History | Originally low lying marshy agricultural ground. Reclamation of the area as a whole through land raising commenced in 1986 although in some areas up to 8 m of clay was extracted to provide engineering materials for the cells of Phase 1 of the landfill to the south.<br>The wider landfill was originally licensed for co-disposal of hazardous and non-hazardous waste until July 2004. |

## 6 Surrounding Area

The currently operational landfill area is part of the wider Maw Green landfill which covers an area of around 66 ha. It is surrounded to the north, east and west by completed and restored lined landfill cells. To the south, an older phase of landfilling (Phase 1) has been completed and restored to open land.

Further afield, the surrounding land uses and notable features are as follows:

- North – further completed landfill cells for around 500 m.
- East – Fowle Brook at c.180 m, railway line c.200 m and agricultural land beyond.

- South-east – landfill infrastructure including a composting area, site accommodation, a waste to energy compound and a lagoon; a railway line at c.200 m; and agricultural land beyond.
- South – new residential housing at c.275 m.
- South-west – leachate treatment facility at c.60m with agricultural land beyond. Farm buildings including residential are located c.250 m.
- West – a residential dwelling at c.185 m.
- North-west – a car dealership at c.200 m.

# 7 Environmental Setting

## 7.1 Geology and Hydrogeology

### 7.1.1 Regional Mapping

The BGS online viewer and regional 1:50,000 BGS map (Sheet 110) indicate that the landfill is underlain by superficial deposits of Till – Diamicton which comprises a heterogenous mixture of clay, sand, gravel and boulders varying widely in size and shape. The 1:50,000 map indicates that a small area of peat may be present in the valley bottom largely beneath Phase 1 of the landfill. The underlying bedrock is recorded as Triassic Mudstone, Siltstone and Sandstone on the online viewer. The 1:50,000 map records it as the Wilkesley Halite Member (formerly the Upper Keuper Saliferous Beds) of up c.90 m thick and which is undergoing dissolution, with Mercia Mudstone (formerly Middle Keuper Marl) of c.365-580 m thickness below. Approximately 250 m to the west of the operational landfill area is the King Street Fault, downthrown to the east. The Mercia Mudstone (Middle Keuper Marl) outcrops to the west of this.

The superficial deposits in the region are designated by the Environment Agency as a Secondary Undifferentiated aquifer and the Wilkelsey Halite Member bedrock as unproductive strata. The underlying and adjacent Mercia Mudstone is designated as a Secondary B aquifer.

### 7.1.2 Encountered Geology and Groundwater

The 2003 Environmental Setting and Installation Design (ESID) and 2009 Hydrogeological Risk Assessment (HRA) Review documents state that up to 8m of clay was excavated prior to landfilling commencing in Phase 2. Summaries of intrusive investigations for the whole landfill area provided in these documents indicate that the site was underlain by a thick deposit of occasionally silty and pebbly clay, probably till/boulder clay but possibly glacio-lacustrine deposits which ranged from 5.5 to >26.4 m thick. Sandy water-bearing horizons were encountered at around 19 m below the ground level which was current in 2003 or earlier. Alluvial and peat deposits were encountered up to 5 m thick on the former course of the Fowle Brook in the valley base.

Groundwater monitoring determined a northerly groundwater flow in the sandy water-bearing horizons with a hydraulic gradient of 0.003 to 0.005.

## 7.2 Surface Water

The nearest surface water to the site is the Fowle Brook. It originally flowed south to north through the site but was diverted to the eastern boundary of the landfill (c.180 m from the subject area) prior to the commencement of the landfilling operations. Provectus reports that the watercourse flows within an unlined ditch.

## 7.3 Designated Environmentally Sensitive Areas

The nearest statutory designated sensitive area is the Sandbach Flashes Site of Special Scientific Interest (SSSI) which is located c.400m to the north-west of the subject area of the landfill at its nearest point. The SSSI is a series of fresh and saline water bodies created by the dissolution of the underlying salt deposits[2] and subsequent subsidence which has created rare inland ecological habitats.

## 7.4 Landfill Construction

The landfill cells within the current operational area are lined at the base and sides with an engineered low permeability liner. Drawing WR7624/01/02 provides details of the proposed capping for the cells. A 300 mm regulating layer of suitable non-hazardous soil material, either from the soil treatment facility or imported from off-site, will be placed on top of the waste over which a 1 mm thick geomembrane liner and then a protector geotextile/drainage composite will be laid. The restoration soils will be placed above this protector layer and will comprise 1000 mm of soils as follows:

- 300 mm of low permeability material comprising clays or screened material derived from the soil treatment facility.
- 400 mm of general subsoil material from the soil treatment facility.
- 300 mm of restoration topsoil provided by a third party.

The remainder of Phases 1 and 2 of the landfill are complete and have been restored. However, additional cover may be required in these areas to achieve the final restoration contours of the site as the waste settles over time.

It is understood that the landfill cap will be restored with largely grazing land, some woodland areas and footpaths. The most recent scheme that has been made available to LEAP is Drawing ESID5.

[2] https://en.wikipedia.org/wiki/Sandbach_Flashes

## 7.5 Soil Treatment Facility Operations

The Provectus soil treatment facility is located on the former composting pad at the Maw Green landfill. The facility biologically treats hydrocarbon impacted soils using an ex-situ biopile.

It is understood that following an enquiry to take soils for treatment, Provectus determines the treatability of the material and ensures that inorganic contaminants are not present at hazardous concentrations prior to accepting the soils. Soils are received at the facility and treated on the biopile for 12-16 weeks before being subject to validation sampling and any further physical treatment, such as soil screening. Analytical testing of these samples is undertaken at a laboratory with suitable UKAS and MCERTS accreditation, where available for the following suite:

- Metals (As, Cd, Cr, CrVI, Cu, Pb, Hg, Ni, Se, Zn)
- Speciated USEPA 16 polyaromatic hydrocarbons (PAH)
- Speciated petroleum hydrocarbons (TPH CWG method)
- Phenol
- Sulphate
- Asbestos

The contaminant concentrations will be compared to the restoration criteria and then a full validation report submitted to FCC for their approval. Once the soils are approved by FCC, treated soils will be used in the restoration area of the landfill.

# C CONCEPTUAL SITE MODEL

## 8 Introduction

This Section of the report draws on the information provided in Section B to derive a conceptual site model (CSM) for the site. The CSM is a series of plausible source-pathway-receptor contaminant linkages determined in line with industry good practice (principally CLR11[3] and R&D66[4]) and is used, in this case, to determine a suitable set of quantitative acceptance criteria for the landfill restoration soils. The focus of the CSM is the current operational capping area. However, the previous areas of landfilling may also require additional restoration.

## 9 Potential Sources of Contamination

Given that the assessment is focused on the quality of the restoration soils, the underlying landfill wastes and localised potential off-site sources of contamination are discounted from this assessment. As such, the key potential source of contamination is the restoration soils.

LEAP understands that the topsoil will be sourced from a third party whose origin is to be determined. The source of this topsoil may contain contaminants.

The soils that are accepted at the treatment facility are derived from a wide range of contaminated sites and as such, a wide range of metals, inorganic and organic contaminants, may be present in the soil prior to treatment. The risk assessment is limited to the suite of analysis and contaminants of concern that Provectus analyses for to validate that treatment has been completed (see Section 7.5). It is understood that Provectus aims to ensure that volatile organic compounds (VOC) will be non-detect at the completion of treatment.

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[3] Environment Agency (EA) '*Model Procedures for the Management of Land Contamination*', CLR11 (2004).

[4] NHBC, EA and CIEH '*Guidance for the Safe Development of Housing on Land Affected by Contamination'* R&D66 (2008)

# 10 Potential Receptors

Based on the proposed final use of the landfill cap, the potential receptors of any contaminants that may be present in the soils are:

- Future site users
- Workers during the placing of the restoration cover and the planting of trees and hedgerows
- Surrounding residents
- Grazing animals
- Trees, hedgerows and grasses planted within the restored cap

Controlled waters receptors (the aquifers and Fowle Brook) and the SSSI have been excluded from this assessment because they have been assessed separately by a third party consultant.

No buildings are expected to be constructed on the site so below ground structures and utilities are discounted from this assessment.

# 11 Plausible Contaminant Linkages

Table 2 provides an evaluation of the potential contaminant linkages on the basis of the currently available restoration plan. In general, the potential for significant exposure of the end users is considered to be low.

The site will be covered with grasses, some woodland and footpaths. Disturbance of the soil is required to generate the airborne dusts or asbestos fibres with which receptors are subsequently exposed via inhalation and direct contact and these ground coverings will greatly restrict this from occurring. Exposure to workers planting trees and hedgerows within the restoration soils would be greater because the soil will be dug through, but this would occur for a short duration only. It is likely that the introduction of restoration soils will be carried out using machines and as such, their exposure would be greatly limited.

Inhalation of vapours generated from soils contaminated with volatile organic compounds (VOC) is not expected as previously stated but, in any case, would be restricted to outdoor exposure on the site for both human users and grazing animals because no buildings will be constructed. Dilution in the atmosphere would reduce any such exposure to a minimum and this is not considered to be a plausible exposure pathway. Due to the distance of the nearest off-site residential properties, exposure through inhalation of vapours within buildings is not considered to be plausible. In addition, the presence of a low permeability cap would minimise the migration of any vapours that were generated by any volatile contaminants within it.

The trees and hedgerows, along with the grasses planted on the restored cap have the potential to take up contaminants via their roots. This could both affect the plants themselves as well as any grazing animals/livestock.

**Table 2: Assessment of Potential Contaminant Linkages**

| Potential Contaminants in Soil | Potential Pathways | Potential Receptors | Discussion | Plausible Contaminant Linkage? |
|---|---|---|---|---|
| Free asbestos fibres | Inhalation of asbestos fibres | • Future site users<br>• Grazing animals | Very low frequency and duration of exposure expected. Exposure will be reduced by the presence of grass which will prevent the disturbance of the fibres, and would be limited to near-surface soils.<br>Below the 300mm of topsoil, no exposure pathway. | ✓<br>× |
| | | • Workers when placing restoration soils and planting trees and hedges | Placing of restoration soils will be a largely mechanical operation.<br>Exposure to workers when planting hedges would be more significant and to deeper depths, but for a short duration. | ×<br>✓ |
| | | • Off-site residents | Limited opportunity for soil to be disturbed. Distance to residential properties not expected to transport windblown fibres. | × |
| All other contaminants | Dermal contact, ingestion and inhalation of soil particles.<br>Ingestion of contaminated vegetation. | • Future site users<br>• Grazing animals | Very low frequency and duration of exposure expected. Exposure will be reduced by the presence of grass which will prevent the disturbance of the soil particles, and would be limited to near-surface soils.<br>Below the 300mm of topsoil, no exposure pathway. | ✓<br>× |
| | | • Workers when placing restoration soils and planting trees and hedges | Placing of restoration soils will be a largely mechanical operation.<br>Exposure to workers when planting hedges would be more significant and to deeper depths, but for a short duration. | ×<br>✓ |

| Potential Contaminants in Soil | Potential Pathways | Potential Receptors | Discussion | Plausible Contaminant Linkage? |
|---|---|---|---|---|
| | Inhalation of soil particles | • Off-site residents | Limited opportunity for soil to be disturbed. Distance to residential properties not expected to transport windblown fibres. | × |
| | Uptake of contaminants | • Vegetation | There is potential for plants to draw up contaminants through their roots. | ✓ |
| Volatile organic compounds | Outdoor inhalation of vapours | • Future site users<br>• Workers when placing restoration soils and planting trees and hedges<br>• Grazing animals | Treated soils will not contain VOCs at detectable concentrations. Vapours emitted outdoors will be diluted in the atmosphere. | × |
| | Indoor and outdoor inhalation of vapours | Off-site residents | Treated soils will not contain VOCs at detectable concentrations. Vapours emitted outdoors will be diluted in the atmosphere.<br><br>Migration of vapours through the cap will be limited by the presence of low permeability clays. | ×<br><br>× |

# D GENERATION OF ACCEPTANCE CRITERIA

## 12 Introduction

This Section provides justification for the selection of suitable soil acceptance criteria for each of the identified plausible contaminant linkages. The contaminants assessed are those of Provectus's validation analytical suite.

The following provides a discussion on relevant and available quantitative criteria, an evaluation of the exposure scenarios and assumptions for each of the sensitive receptors that have been identified, and a discussion on any differences between topsoil and subsoil.

## 13 Criteria for Topsoil

The sensitive receptors considered in the derivation of acceptance criteria for the restoration topsoils are:

- Future site users
- Site workers involved in the restoration of the landfill
- Grazing animals
- Vegetation (grassland, hedgerows, trees)

A number of sources of possibly appropriate topsoil acceptance criteria were reviewed for these receptors and are discussed below. Where a range of possible values were available for a potential contaminant, the lowest value was selected and is presented in Table 3.

The Environment Agency has published guidance on the application of sewage sludge on agricultural land[5] which includes a set of reference and maximum permissible concentrations (MPC) of potentially toxic elements (PTE) for both arable farming and grassland. The PTEs are protective of the health of plants, animals and people. In the absence of published quantitative criteria specific to protect grazing animals from contaminants in soil, these PTEs are considered to appropriate to use.

Where available, these PTEs are considered to be protective of all the receptors that were identified in the CSM. Given that the restored site will be used as grazing land, it is most appropriate to use the PTE limits for grassland. Some of the PTEs are dependent on the pH

[5] Environment Agency Guidance: Sewage sludge in agriculture: code of practice for England, Wales and Northern Ireland. Published 23 May 2018.

of the material which is to be applied to the land. For the purpose of deriving acceptance criteria it has been assumed that the pH of the restoration topsoil will be 6-7. Should the topsoil applied be more acidic than this, then lower acceptance criteria would be required.

BS3883:2015[6] provides maximum acceptable concentrations for three potentially phytotoxic metals (copper, nickel and zinc) in topsoil. The concentrations are those of the arable PTEs and have therefore, been rejected as acceptance criteria in this instance in favour of the PTEs for grassland.

The PTEs are only available for metals and do not include any organic substances or asbestos. The acceptance criteria for asbestos has been set as 'not present'. For practical purposes, the commonly achieved laboratory detection limit of 0.001% by weight should be applied.

For organic substances, the risk-driving receptor is considered to be a child visiting the site for recreational purposes. In the absence of PTEs, the CLEA approach was adopted. LEAP reviewed the Category Four Screening Level (C4SL) Project Report[7] and determined that the most appropriate generic land use scenario was Public Open Space Park (POSpark), the key assumptions for this scenario being:

- The critical receptor is a female child who is exposed between the ages of 0 and 6.
- Exposure frequency is 85 days per year for ages 0 to 1 and 170 days per year for ages 1 to 6.
- Visits last for an average of 2 hours with light activity for 2/3 of that time and moderate activity for 1/3.
- Exposure pathways are direct soil ingestion, skin contact and inhalation of vapours and dusts outdoors.
- The land is predominantly grassed (75%) and not in close proximity to housing so tracking back of soil to the home is not a significant pathway.
- There are no buildings.

A number of assessment criteria have been derived for a POSpark landuse by LQM. These values are known as Suitable for Use Levels (S4ULs)[8] and have been endorsed by the

[6] British Standards Institution (BSI) *Specification for topsoil* BS3883:2015.

[7] Contaminated Land: Applications in Real Environments (CL:AIRE) '*SP1010 - Development of Category 4 Screening Levels for Assessment of Land Affected by Contamination'* Final Project Report (Revision 2), 24 September 2014.

[8] The LQM/CIEH S4ULs for Human Health Risk Assessment, Nathaniel P et al, 2015. Copyright Land Quality Management Ltd, reproduced with permission: Publication Number S4UL3509

Chartered Institute of Environmental Health (CIEH). S4ULs are available for a range of soil organic matter (SOM) contents. It is considered that a SOM of 6% would be most appropriate for topsoil given the organic nature of this material. Theoretical soil saturations have not been considered in the evaluation of organic compounds.

S4ULs are available for PAHs that have been calculated using two approaches; the surrogate marker approach and the Toxic Equivalent Factor (TEF) approach. Public Health England (PHE) guidance[9] indicates that the TEF approach is likely to underpredict the true carcinogenicity of genotoxic PAHs, so the surrogate marker approach has been selected to derive the acceptance criteria for this risk assessment. Threshold PAHs have been assessed similarly, by using naphthalene as a marker compound due to its high volatility relative to other PAHs.

A S4UL has not been produced for lead so the C4SL was used as the acceptance criteria, noting that exposure assumptions are largely equivalent between the two sets of values.

Workers involved in the restoration works including placing of cover soils and planting of vegetation have the potential to be exposed to contaminants in the topsoil. However, exposure would be short in duration. Most human health risk assessment criteria focus on chronic risks arising from long term exposure which usually occur at lower doses than short term acute risks. Therefore, the acceptance criteria which are presented in Table 3 are considered likely to be protective of restoration workers.

**Table 3: Acceptance Criteria for Restoration Topsoil (pH 6-7, SOM 6%)**

| Contaminant | Value | Units | Source |
|---|---|---|---|
| **INORGANICS** | | | |
| Arsenic | 50 | $mgkg^{-1}$ | Sludge on Grassland |
| Cadmium | 3 | $mgkg^{-1}$ | Sludge on Grassland |
| Chromium | 600 | $mgkg^{-1}$ | Sludge on Grassland |
| Hexavalent Chromium | 250 | $mgkg^{-1}$ | POSpark |
| Copper | 225 | $mgkg^{-1}$ | Sludge on Grassland |
| Lead | 300 | $mgkg^{-1}$ | Sludge on Grassland |
| Mercury[1] | 1.5 | $mgkg^{-1}$ | Sludge on Grassland |
| Nickel | 125 | $mgkg^{-1}$ | Sludge on Grassland |

[9] HPA, Contaminated Land Information Sheet. Risk Assessment Approaches for Polycyclic Aromatic Hydrocarbons (PAHs). Public Health England, 2017.

| Contaminant | Value | Units | Source |
|---|---|---|---|
| Selenium | 5 | $mgkg^{-1}$ | Sludge on Grassland |
| Zinc | 200 | $mgkg^{-1}$ | Sludge on Grassland |
| Asbestos | Not present (<0.001%) | % | Reasonably achievable detection limit |
| **PETROLEUM HYDROCARBONS** | | | |
| Aliphatic EC5-6 | 180,000 | $mgkg^{-1}$ | POSpark |
| Aliphatic EC6-8 | 320,000 | $mgkg^{-1}$ | POSpark |
| Aliphatic EC8-10 | 21,000 | $mgkg^{-1}$ | POSpark |
| Aliphatic EC10-12 | 24,000 | $mgkg^{-1}$ | POSpark |
| Aliphatic EC12-16 | 26,000 | $mgkg^{-1}$ | POSpark |
| Aliphatic EC16-35 | 490,000 | $mgkg^{-1}$ | POSpark |
| Aromatic EC5-7 | 92,000 | $mgkg^{-1}$ | POSpark |
| Aromatic EC7-8 | 100,000 | $mgkg^{-1}$ | POSpark |
| Aromatic EC8-10 | 9,300 | $mgkg^{-1}$ | POSpark |
| Aromatic EC10-12 | 10,000 | $mgkg^{-1}$ | POSpark |
| Aromatic EC12-16 | 10,000 | $mgkg^{-1}$ | POSpark |
| Aromatic EC16-21 | 7,800 | $mgkg^{-1}$ | POSpark |
| Aromatic EC21-35 | 7,900 | $mgkg^{-1}$ | POSpark |
| **OTHER ORGANICS** | | | |
| Phenol | 1,300 | $mgkg^{-1}$ | POSpark |
| Benzo(a)pyrene[2] | 21 | $mgkg^{-1}$ | POSpark |
| Naphthalene[3] | 3,000 | $mgkg^{-1}$ | POSpark |

Notes to table

1. *As inorganic mercury.*
2. *Surrogate marker for all genotoxic PAHs.*
3. *Indicator compound for all non-genotoxic PAHs.*

It should be noted that the restoration area is on a non-hazardous landfill site and as such the soil must be classified as non-hazardous under waste guidance. This means that hydrocarbons within the restoration area will be limited to 0.1% or other criteria as substantiated by Environment Agency guidance WM3[10].

# 14 Criteria for Subsoil

The subsoil will be placed below 300 mm of topsoil and will extend to a minimum of 1m below final ground level.

All the plausible contaminant linkages that have been identified are via direct exposure with contaminants of potential concern and as such, it is considered highly unlikely that future site users or grazing animals will be exposed to contaminants within the restoration subsoil which will placed below 300 mm of topsoil.

The roots of grasses and hedgerows are unlikely to extend below the top 300 mm of topsoil and would therefore, also not be exposed to any contaminants present within the restoration subsoil.

It is possible that the roots of trees could extend into the subsoil and take up contaminants through their root system. There is also potential that, during the excavation of tree pits and the planting of trees that workers could be exposed to contaminants within the subsoil at these locations. As such, the acceptance criteria for tree pits should be the same as the topsoil criteria provided in Section 13.

Notwithstanding the acceptance criteria that have been derived, because the site is a licensed waste facility as a minimum, the subsoil restoration cover must not contain substances that would render the material as hazardous waste.

[10] Environment Agency '*Guidance on the classification and assessment of waste'* Technical Guidance WM3, Ist Edition v1.1. May 2018.

# E CONCLUSIONS

The likelihood of unacceptable exposure of site workers, future site users, grazing animals and vegetation to contaminants within the restoration cover of Maw Green landfill is considered to be largely very low. A set of acceptance criteria were derived for topsoil and tree pits based on published guidance. No acceptance criteria were derived for subsoils below 300 mm of the final restored ground surface because no plausible contaminant linkages were identified.

The site is a licensed waste facility so waste legislation is the primary driver rather than contaminated land legislation. For this reason, the Definition of Waste Industry Code of Practice (DoWCoP)[11] would not apply for any natural soils that may be imported onto the site for restoration cover, including topsoil. As such, the acceptance criteria that have been derived are, in some instances, higher than would be acceptable under DowCoP.

Notwithstanding the acceptance criteria that have been derived, because the site is a licensed waste facility, as a minimum the restoration cover must not contain substances that would render the material as hazardous waste.

[11] CL;AIRE '*The Definition of Waste: Development Industry Code of Practice*', Version 2. 2011.

## *LIMITATIONS*

This report is confidential to the Client, and Leap Environmental Ltd accepts no responsibility whatsoever to third parties to whom this report, or any part thereof, is made known, unless formally agreed by Leap Environmental Ltd beforehand. Any such party relies upon the report at their own risk. Unless explicitly agreed otherwise in writing, this report has been prepared under LEAP's standard terms and conditions, as included in the quotation for this works.

This report has been prepared by Leap Environmental Ltd on the basis of information received from a variety of sources which Leap Environmental Ltd believes to be accurate. Nevertheless, Leap Environmental Ltd cannot and does not guarantee the authenticity or reliability of the information it has obtained from others.

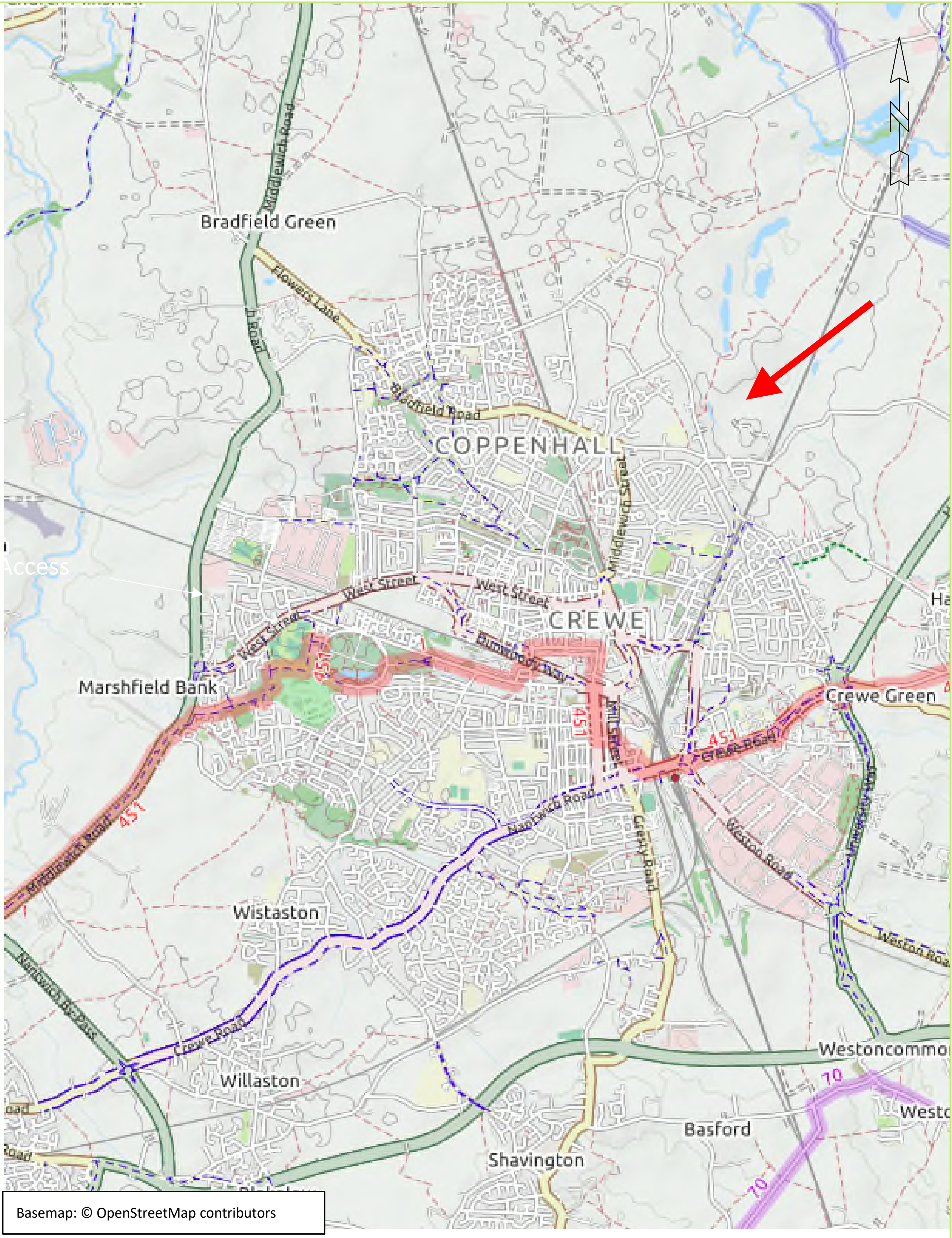
Leap Environmental Ltd has used all reasonable skill, care and diligence in the design and execution of this report, taking into account the manpower and resources devoted to it in agreement with the Client. Although every reasonable effort has been made to obtain all relevant information, all potential contamination, environmental constraints or liabilities associated with the site may not necessarily have been revealed. LEAP cannot be held responsible for any disclosures or changes in regulation that are provided post production of this report, and will not automatically update the report.

The conclusions reached in this report are necessarily restricted to those which can be determined from the information consulted, and may be subject to amendment in the light of additional information becoming available. These conclusions may not be appropriate for alternative schemes.

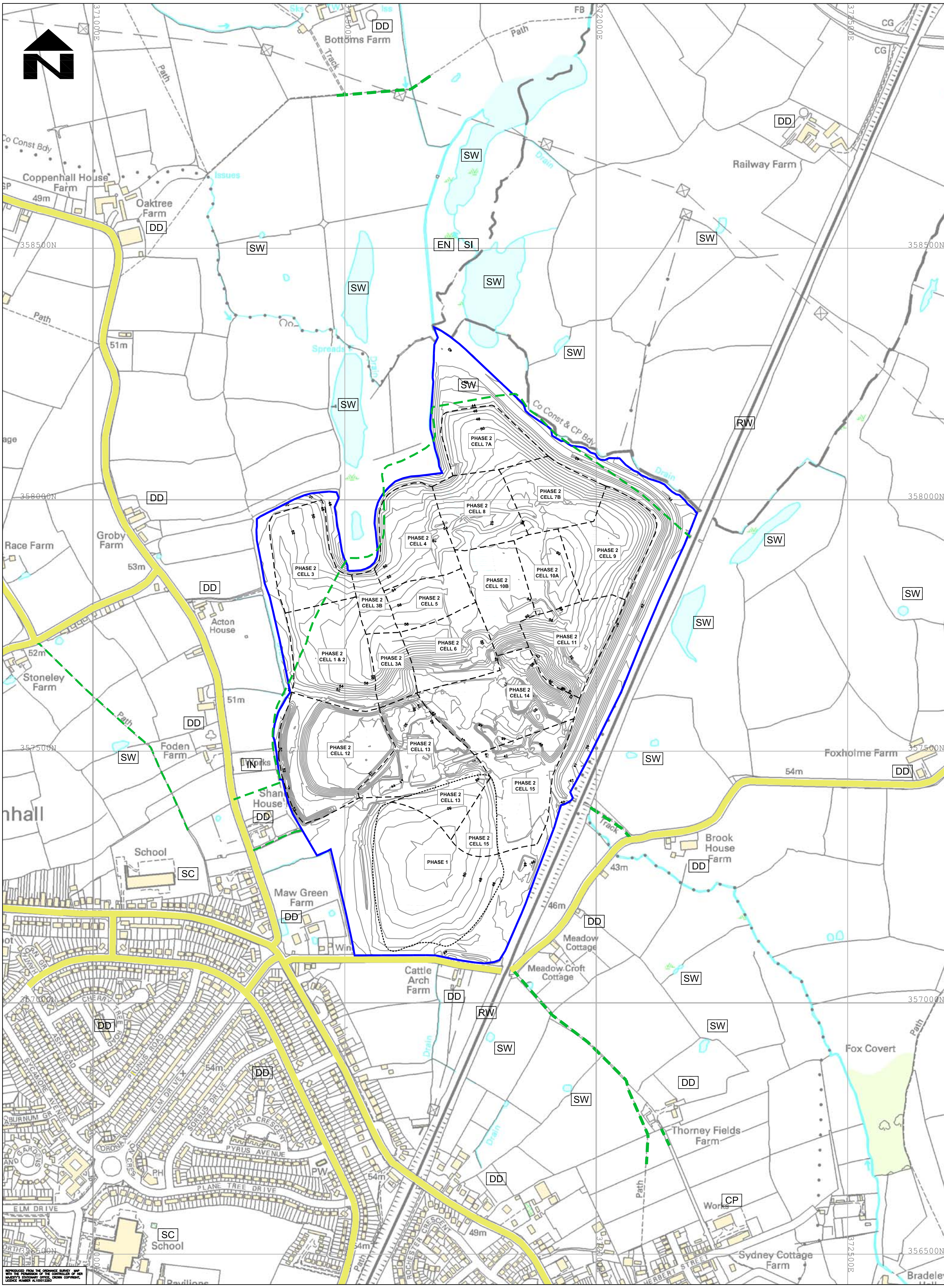
The extent of the exploratory holes, laboratory testing and monitoring undertaken may have been restricted due to a number of factors including accessibility, the presence of buried or overhead services, current development and site usage, timescales or client's specification. The exploratory holes only assess a small proportion of the site area with respect to the site as a whole, and as such may only provide an overall assessment of ground conditions on site. The presence of hotspots of undisclosed contamination or exceptional and unforeseen ground conditions cannot be discounted.

The presence of asbestos may be noted during the site walkover survey, intrusive investigations and/or from the results of contamination testing. However, this report does not constitute an asbestos survey. On this basis, the presence of asbestos on site cannot be discounted.

# Figures & Drawings




| | | | | | | |
|---|---|---|---|---|---|---|
| leap environmental | Client: | Provectus Soils Management | Date: | 16 September 2020 | Project ID: | LP2290 |
| | Project: | Maw Green Landfill | Title: | Site Location Plan | Fig. No. | 1 |




REPRODUCED FROM THE ORDNANCE SURVEY MAP WITH THE PERMISSION OF THE CONTROLLER OF HER MAJESTY'S STATIONARY OFFICE, CROWN COPYRIGHT, LICENCE NUMBER AL100012293

**NOTES**

1. SEE ESID3 FOR WIDER SITE SETTING AND ESID13 FOR SOURCE, PATHWAY, TARGET LINKAGES.
2. THE INSTALLLATION DOES LIE IN AN INDICATIVE FLOOD PLAIN.
3. SURVEY INFORMATION PROVIDED BY MAY GURNEY, REF:MAWW236.
4. NOTE PROPOSED CELL BOUNDARIES ARE INDICATIVE AND MAY CHANGE.

**LEGEND**

- INSTALLATION BOUNDARY
- CELL BOUNDARIES
- 46 INTERNAL SITE SURVEYED CONTOURS (mAOD)

LOCAL FEATURES

- DD DOMESTIC DWELLINGS
- SC SCHOOLS
- HO HOSPITALS
- SI SSSI
- BE BEACHES
- OF OFFICES
- IN INDUSTRIAL UNITS
- CP COMMERCIAL PROPERTIES
- FOOTPATHS
- SW SURFACE WATER BODIES
- EN LOCAL ENVIRONMENTAL AREAS
- MINOR ROADS
- RW RAILWAY

| Revision | Issue Date | Issue By | Comments |
|---|---|---|---|
| 0 | OCT. 2003 | SW | . |

waste recycling GROUP

Site: MAW GREEN LANDFILL
Project: PPC APPLICATION REF: BS 7722
Drawing: Environmental Site Setting
Date: OCTOBER 2003
Scale: 1:2500
Drawing No.: ESID2

4D.197.178 ESID2

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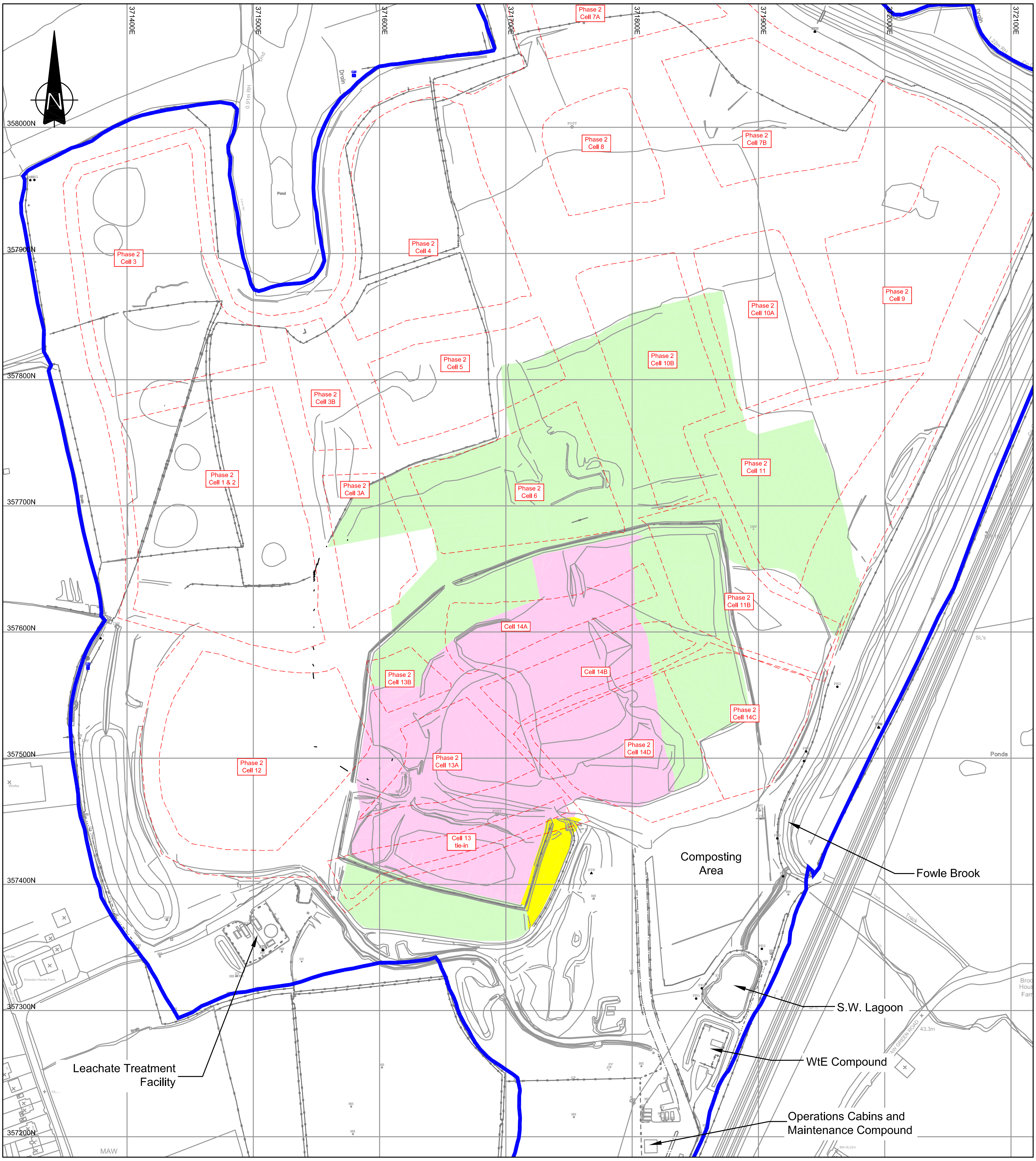



**LEGEND:**

| | |
|---|---|
| (blue line) | Ownership Boundary |
| 45,656m² | Operational Capping Area |
| | Catch Up Capping Area |
| 77,538m² | Top Up Capping Area |
| | Other Flanks Area |
| 1,833m² | Legacy Capping |
| (red dashed line) | As-built Cell Footprint |
| (light blue line) | Proposed Cell Areas |

**NOTES:**

1. ALL DIMENSIONS IN MILLIMETRES AND ALL LEVELS IN METRES ABOVE ORDNANCE DATUM.
2. DO NOT SCALE FROM THIS DRAWING.
3. ANY ANOMALIES IDENTIFIED WITH THE DETAILS SHOWN ON THIS DRAWING ARE TO BE BROUGHT TO THE ATTENTION OF FCC ENVIRONMENT (UK) LIMITED PRIOR TO CONSTRUCTION WORKS COMMENCING.

Reference files:
Information taken from plans;
Site Survey: 124W1861
Capping: 124C1864
Cell Footprints: 124A1799



FCC Environment
FCC Environment (UK) Limited
6 Sidings Court, White Rose Way, Doncaster, DN4 5NU

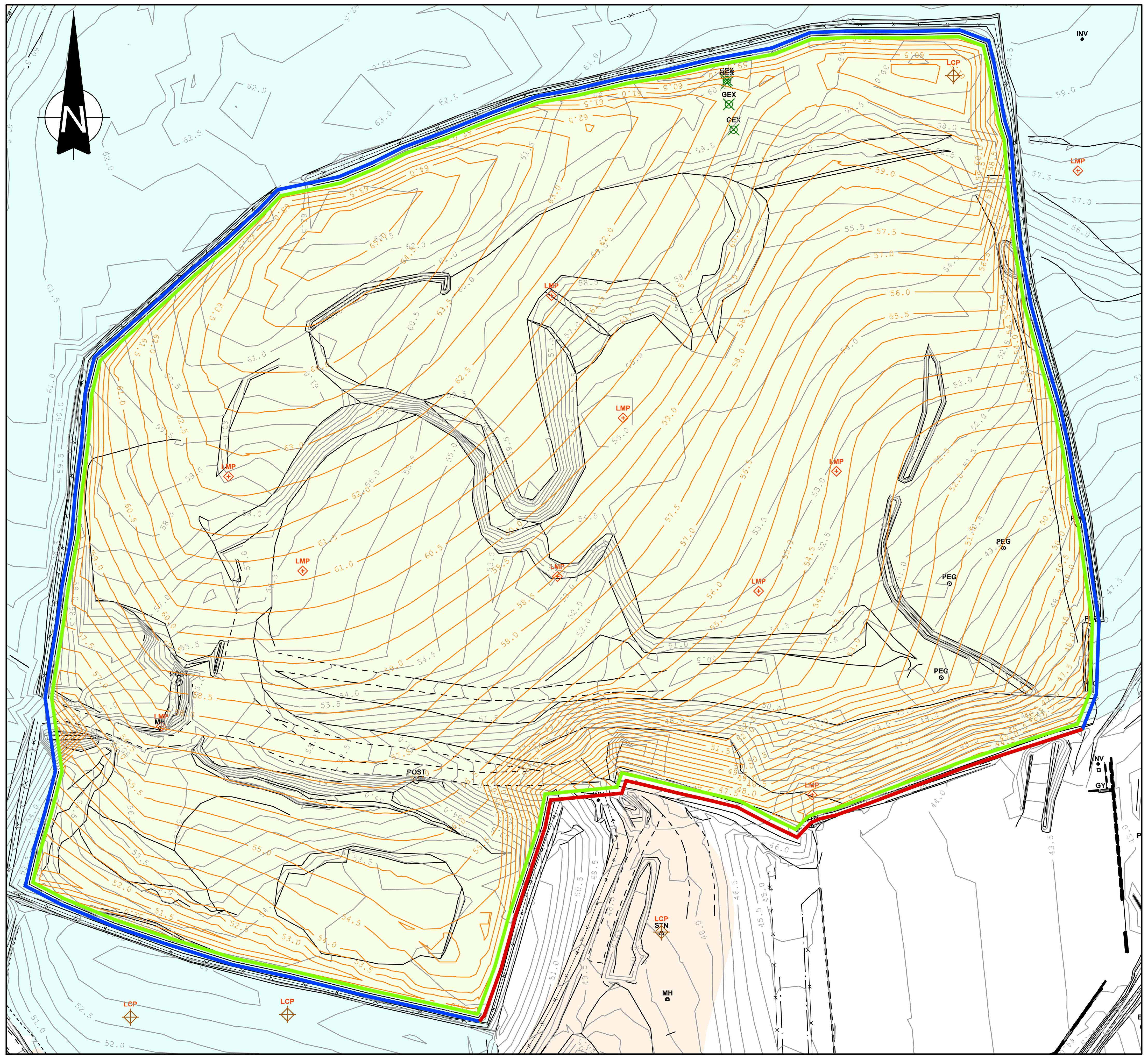
| Revision: | Date: | Description: | By: | Chk: |
|---|---|---|---|---|
| - | - | - | - | - |
| - | - | - | - | - |
| - | - | - | - | - |

Site: **MAW GREEN**
LANDFILL SITE

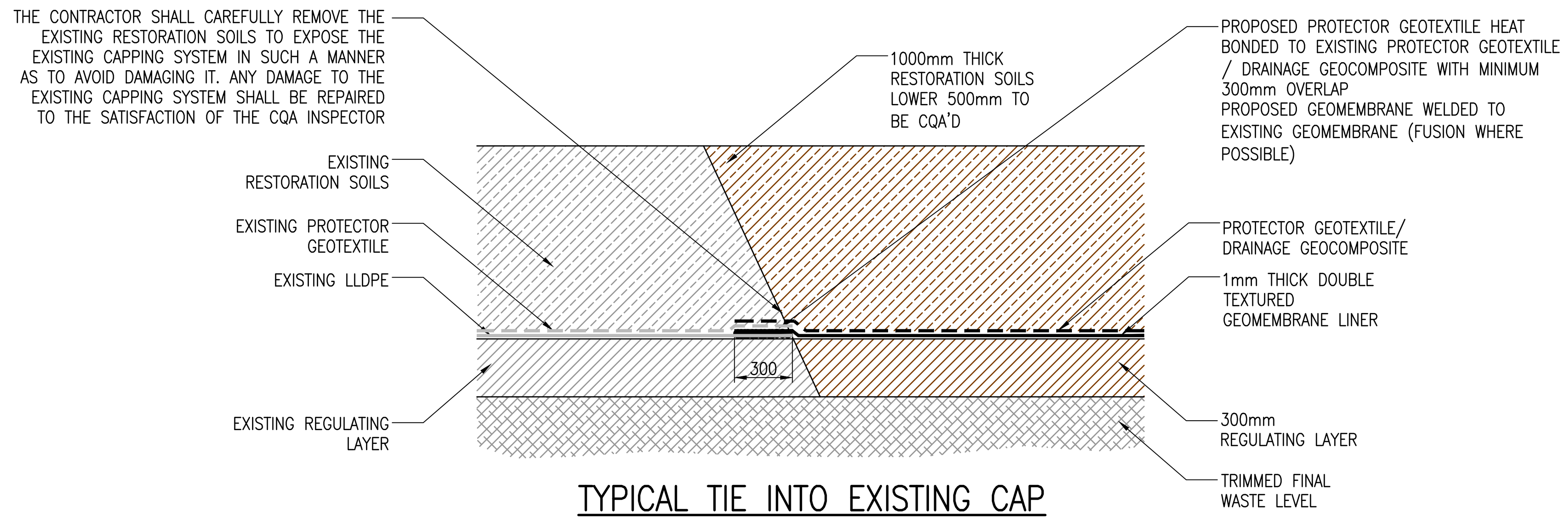
Drawing Title: **Capping Liability Q1 2020**

| Drawn By: | Checked By: | Date: | Scale: | Paper Size: |
|---|---|---|---|---|
| BS | LH | 29.05.20 | 1:3000 | A3 |

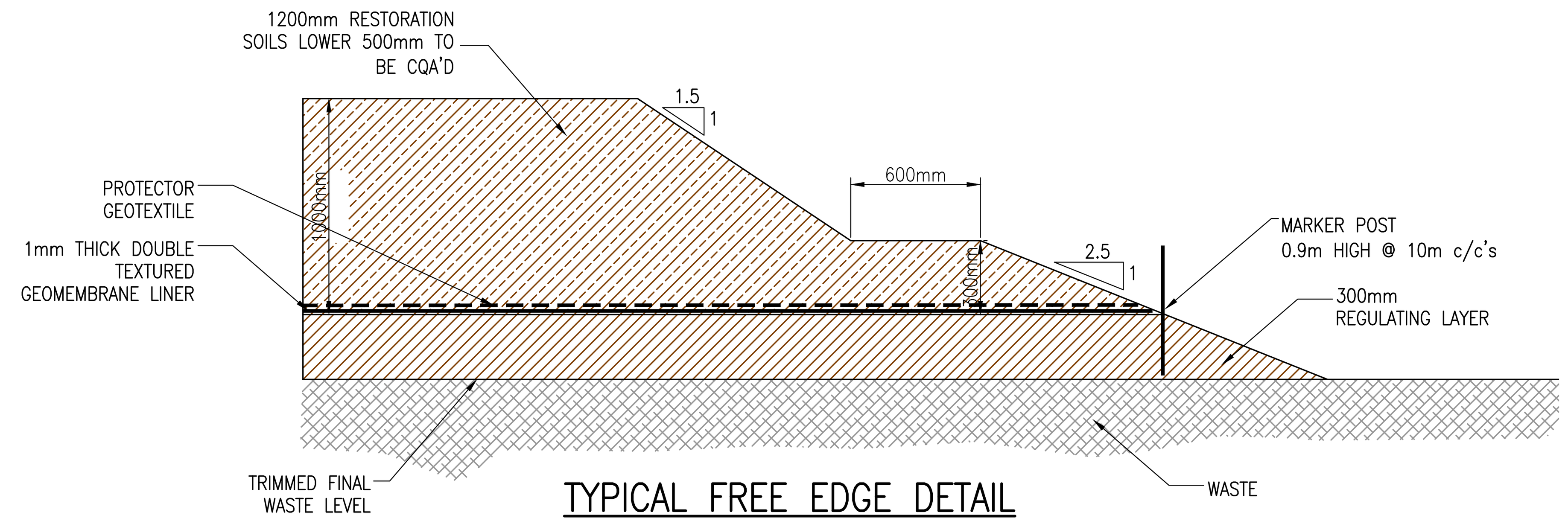
| Status: | Revision: | Drawing No: | Plan Number: |
|---|---|---|---|
| FINAL | - | **124C328** | **PLAN 19** |



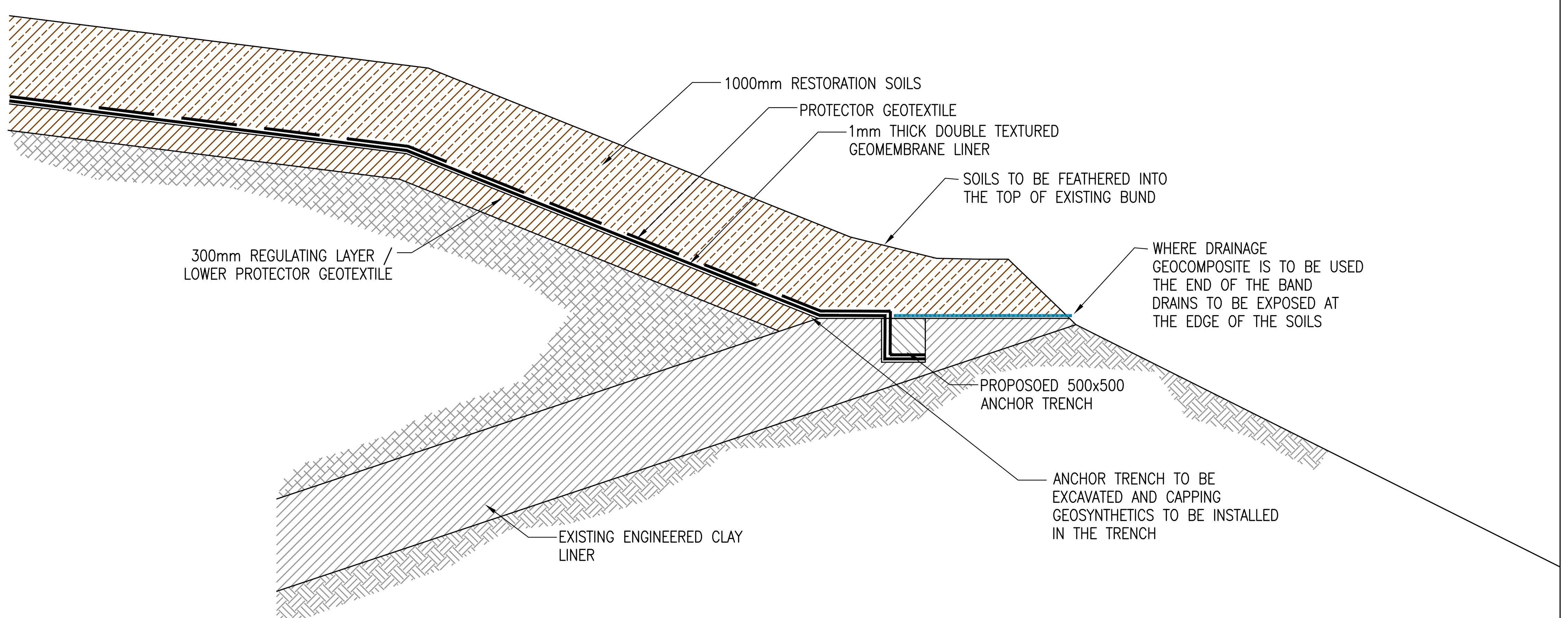

PLAN SHOWN EXTENTS OF REMAINING SITE CAPPING
SCALE 1:1000



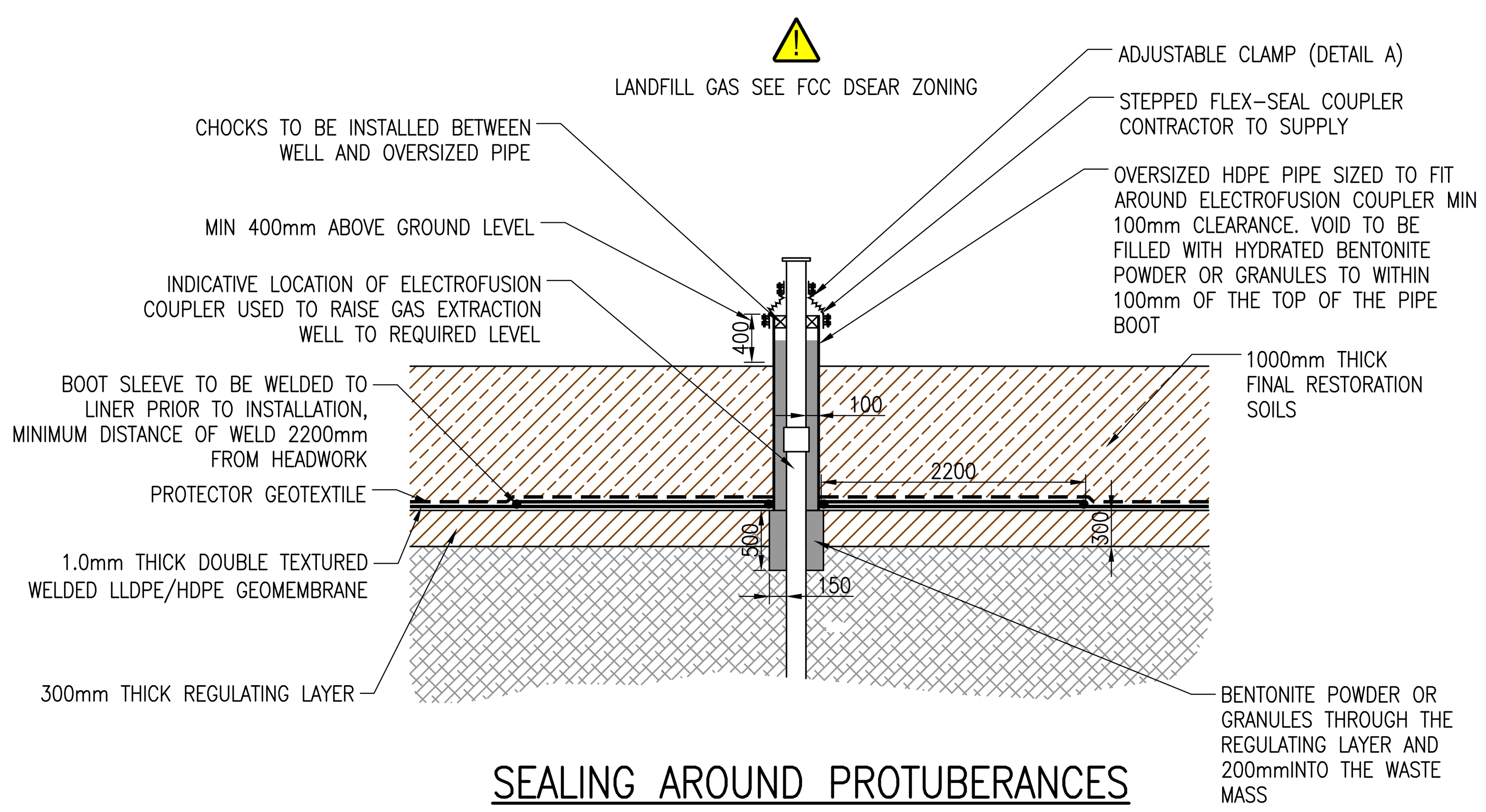

TYPICAL TIE INTO EXISTING CAP
SCALE 1:25



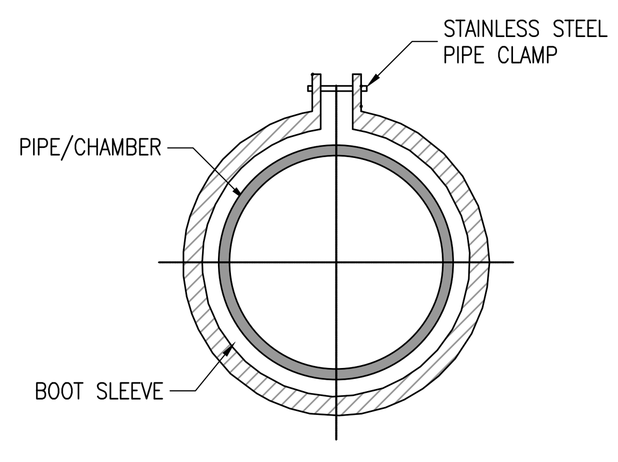

TYPICAL FREE EDGE DETAIL
SCALE 1:25




TYPICAL TIE IN TO EXISTING SIDEWALL LINING
SCALE 1:50




SEALING AROUND PROTUBERANCES
SCALE 1:50




DETAIL A
NOT TO SCALE



## NOTES

1. ALL DIMENSIONS IN MILLIMETRES AND ALL LEVELS IN METRES ABOVE ORDNANCE DATUM.

2. DO NOT SCALE FROM THIS DRAWING.

3. ANY ANOMALIES IDENTIFIED WITH THE DETAILS SHOWN ON THIS DRAWING ARE TO BE BROUGHT TO THE ATTENTION OF SIRIUS ENVIRONMENTAL PRIOR TO CONSTRUCTION WORKS COMMENCING.

4. THE CAPPING SYSTEM SHALL NOT BE PLACED ON ANY SLOPE STEPPER THAN 1(V):3(H).

## KEY

- SITE SURVEY
- PROPOSED WASTE CONTOURS
- PROPOSED REST OF SITE CAPPING AREA - 67,516m$^2$
- COMPLETED GEOMEMBRANE CAP
- COMPLETED CLAY CAP
- TIE INTO EXISTING SIDEWALL
- TIE INTO EXISTING GEOMEMBRANE

| REV | DESCRIPTION | DATE | BY |
|---|---|---|---|

CLIENT

FCC Environment

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sirius Environmental

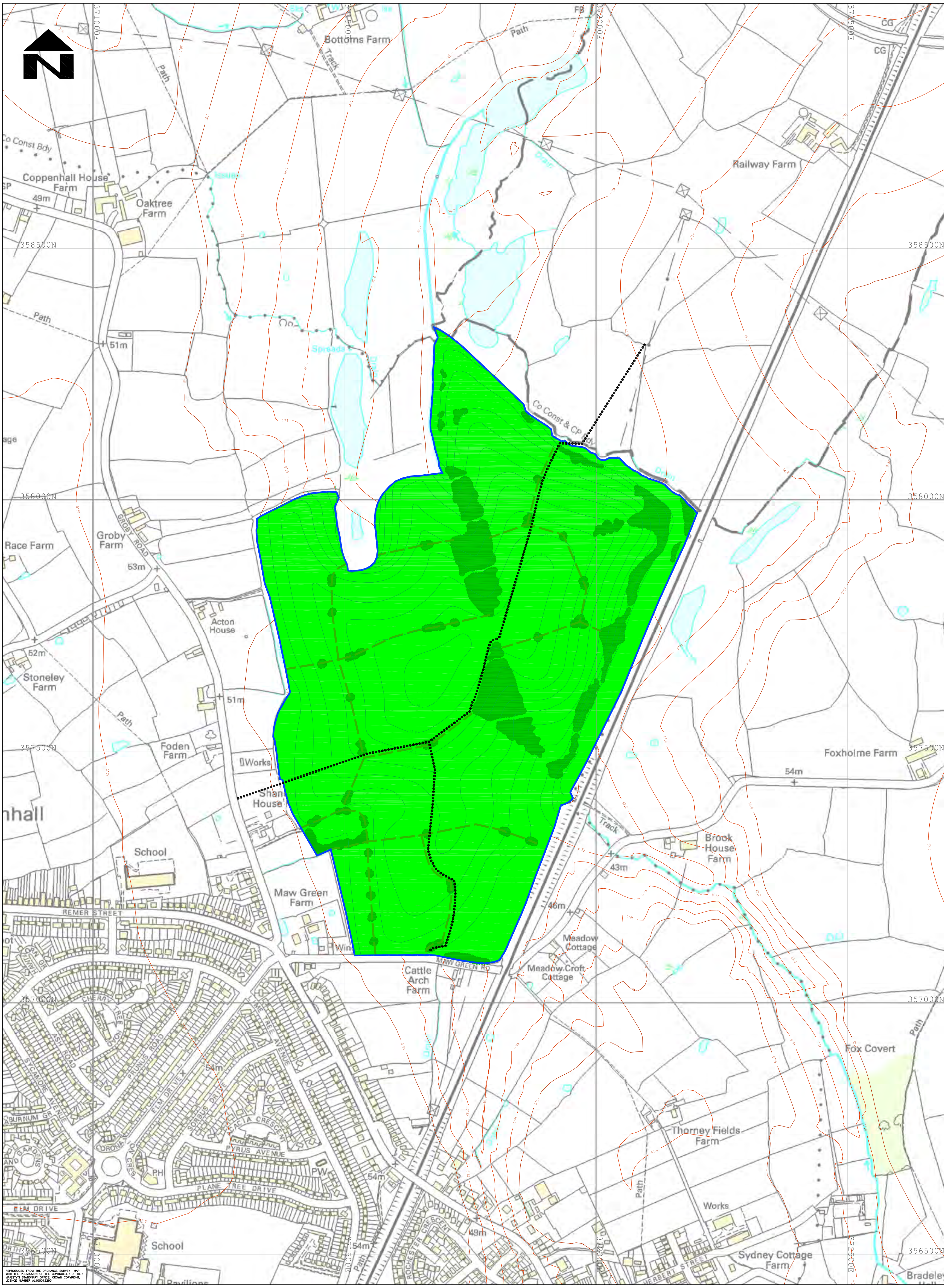
4245 Park Approach, Thorpe Park, Leeds. LS15 8GB. 0113 264 9960

JOB TITLE
MAW GREEN LFS
2019 Capping Works

DRAWING TITLE
Capping Construction Details

| DRAWN | DATE | APPROVED | DATE |
|---|---|---|---|
| M.C | 16/09/2019 | A.K | 16/09/2019 |

| SCALE | SHEET | DRAWING NUMBER | REVISION |
|---|---|---|---|
| As Shown | A1L | WR7624/01/02 | 0 |






NOTES

1. SURVEY INFORMATION PROVIDED BY MAY GURNEY, REF:MAWW236.

LEGEND

- INSTALLATION BOUNDARY
- SURROUNDING TOPOGRAPHIC CONTOURS (mAOD)
- POST-SETTLEMENT CONTOURS (mAOD)
- PROPOSED PLANTING
- HEDGEROW
- PROPOSED FOOTPATH

| Revision | Issue Date | Issue By | Comments |
|---|---|---|---|
| 0 | SEPT. 2003 | SW | . |

waste recycling GROUP

Site: MAW GREEN LANDFILL

Project: PPC APPLICATION REF: BS 7722

Drawing: Restoration

Date: OCTOBER 2003

Scale: 1:2500

Drawing No. ESID5

4D.197.178 ESID5

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# APPENDIX C. SLADEN ASSOCIATES REPORT

SLADEN ASSOCIATES

# CONTROLLED WATERS RISK ASSESSMENT
# MAW GREEN LANDFILL
# RESTORATION SOILS

**Prepared for**

**Provectus Soils Management Ltd**

**Date : August 2020** **Report No : 20 2218**

# CONTROLLED WATERS RISK ASSESSMENT
# MAW GREEN LANDFILL
# RESTORATION SOILS

**Prepared for:** **Provectus Soils Management Ltd**

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**REPORT No 20 2218**

# CONTROLLED WATERS RISK ASSESSMENT MAW GREEN LANDFILL RESTORATION SOILS

**CONTENTS**

## LIST OF FIGURES

**REPORT No 20 2218**

# CONTROLLED WATERS RISK ASSESSMENT
# MAW GREEN LANDFILL
# RESTORATION SOILS

## 1 INTRODUCTION

The present report documents derivation of leachate targets with respect to protection of controlled waters for restoration soils to be used as part of the final cover system at Maw Green Landfill.

This report describes modelling of flow patterns and potential contaminant migration within the restoration system. This modelling was undertaken to assist in development of the conceptual model and in order to allow predictions to be made as to the likely degree of dilution and attenuation of potential contaminants and their likely fate in the cover, drainage and groundwater systems. As such it assists in the quantification of the risks to controlled waters that may be associated with migration of any potential contaminants remaining within the restoration soils used.

The present report does not consider potential risks to human health, suitability of restoration soils to support vegetation or geotechnical stability. Final selection of acceptance criteria should also address those issues as well as pragmatic considerations.

## 2 THE SITE

### 2.1 SITE LOCATION

Maw Green Landfill is located in a low lying area, within the valley of the Fowle Brook, some 2 km north north east of Crewe Town Centre, on the fringe of the urban area at National Grid Reference 3718 3575, see Figure 1. The operational part of the site consists of a number of engineered cells. The landfill is being reclaimed progressively and it is proposed to use treated soils as part of the cover system for some areas. Figure 2 shows the area potentially being restored partly with treated soils.

Details of the landfill construction and site geology and hydrogeology are included in the following reports:

Maw Green Landfill, PPC Application Section A - Environmental Setting and Installation Design, prepared for Waste Recycling Group by SLR Consulting Ltd. Report No:4D-197-178/ESID, October 2003. ('ESID Report')

Maw Green Landfill, PPC Application Section B - Hydrogeological Risk Assessment, prepared for Waste Recycling Group by SLR Consulting Ltd. Report No:4D-197-178/HRA, October 2003. ('HRA Report')

and

Maw Green Landfill, Crewe, Cheshire. Hydrogeological Risk Assessment Review. Prepared for Waste Recycling Group by SLR Consulting Ltd. Report No: 402-0197-00720, April 2009. ('HRA Review Report')

Assumptions adopted in the present study are generally consistent with those made in the HRA Report.

### 2.2 PROPOSED LANDFILL RESTORATION SYSTEM

The capping will be covered by a minimum thickness of 1 m of restoration soils.

The construction would be as follows:

- A basal regulating layer of suitable material of 300 mm thickness.
- A Lower Protector Geotextile
- The cap sealing layer, which will comprise a 1mm thick welded double textured LDPE Geomembrane.
- An overlying Protector Geotextile.
- Restoration soils will be placed over the protector geotextile to achieve a total minimum thickness above the sealing layer of 1.0 m. The upper 0.3 m would be a 'growth layer' of imported agricultural soil.

Some of the earlier landfill areas were provided with a 1 m thick engineered clay cap in place of the sealing geomembrane.

It is expected that the general restoration soils will comprise soil forming materials and soil conditioners, including compost, in order to achieve the standard required for restoration to agriculture. Depending on such factors as post construction settlement the thickness of restoration soils could be significantly thicker than 1.0 m in some areas.

Ditches may be provided within the restoration soils to reduce the risk of soil erosion due to surface run-off. It is anticipated that any such ditches would be lined to prevent erosion or water loss and would be designed to take only surface run-off, rather than discharge of pore water from within the restoration soils. As the cover system is expected to be generally in an unsaturated condition, discharge of pore water to the drains would, in any case, not be anticipated.

## 3 INITIAL CONCEPTUAL MODEL OF POTENTIAL POLLUTION LINKAGES

### 3.1 ANTICIPATED PATTERN OF FLOW WITHIN THE RESTORATION SYSTEM

A proportion of the long term average precipitation falling on the restoration system will result in run-off. This would likely be greatest during significant storm events and would typically be expected to represent less than about 5 to 10 % of total precipitation unless the cover system became saturated. The completed restoration will be vegetated and evapotranspiration will represent a significant part of the water balance.

The climate data for this area indicates that the long term annual rainfall is in the range 734 to 822 mm/yr and the effective rainfall 270 mm (ESID Report).

The restoration system will be entirely above the groundwater level, indeed the entire landfill is above the groundwater table, and therefore would be expected to be operating normally in an unsaturated condition. It would be anticipated therefore that the net infiltration within the restored landfill areas will enter the restoration soils and result in a profile of unsaturated moisture content within the restoration soils that would comply with the moisture retention characteristics of the soils present.

A small proportion of the overall net infiltration would be expected to permeate through the sealing system into the landfilled wastes. However, the primary flow direction in the restoration/protection soils would be expected to be in a generally sub-horizontal downslope direction.

The proportion of flow through the seal into the wastes would be dominated by any imperfections or damage that may be present. The restoration soils could potentially become saturated during periods of relatively high infiltration, i.e. particularly in winter months, which could potentially increase surface run-off and reduce infiltration. Apart from periods when the restoration soils become saturated, and assuming the leakage through the sealing layer is small, flow volume within the restoration soils will be controlled primarily by the net infiltration and would not be influenced greatly by the absolute value of saturated hydraulic conductivity of the restoration soils. All else being equal, the degree of saturation of the restoration soils would be expected generally to increase in the downslope direction as the volume of water flow would increase with increasing upstream 'catchment' although local changes in gradient of the cover system could complicate this picture. In particular, relatively flatter areas would be expected to show a relatively higher degree of saturation.

For the present assessment, increased run-off due to saturation is a less critical condition than the unsaturated condition as it would result in less infiltration to the restoration soils and hence reduced average flow volumes and potential leachate generation in the restoration soils.

It is expected that both run-off from the restoration system and discharge of water from the restoration soils would be directed to a surface drainage system, which would itself discharge to surface water, in the case the Fowle Brook, Figure 3 shows the proposed arrangement. The condition of discharge to groundwater is also considered at the conceptual stage.

## 3.2 GROUNDWATER

The site is underlain by thick glacial sediments overlying Mercia Mudstone bedrock. The glacial soils are primarily clay but do include a deep sand horizon. Based on monitoring data, the site conceptual model assumes that the majority of horizontal groundwater flow would be within the sand horizon, assumed continuous with flow to the north. Flow within the overlying glacial clay is assumed to be near vertically downwards and to discharge to the sand unit, refer ESID and HRA Review Reports. The hydraulic gradient within the sand unit is in the range 0.003 to 0.005, the hydraulic conductivity to range from 2.0e-3 to 1.0e-5 m/s and thickness in the range 1 to 5.5 m. The thickness of the overlying clay is considered to range from 5.5 to 25.8 m, with a portion being unsaturated.

## 3.3 POTENTIAL CONTROLLED WATERS RECEPTORS AND CREDIBLE POLLUTION LINKAGES

The proportion of infiltration that passes through the geo-membrane or clay sealing layer will contribute to leachate within the wastes and will be controlled by the leachate collection system. As such its fate does not need further detailed consideration in the present study as the impact of leachate is addressed in the various hydrogeological risk assessments. Indeed for the present study it is conservative to assume that this component of the water balance is zero such that all net infiltration to the restoration results in discharge from the restoration soils to the drainage system.

Direct discharge to groundwater from the cap would be expected to be intercepted by a surface drainage system, the groundwater within the bedrock is included as a potential receptor at the preliminary assessment stage to address the potential for some leakage from the restoration and drainage system and any areas where the perimeter drainage system is absent or becomes ineffective. However, given the significant thickness of glacial clay above the sand aquifer, considerable attenuation would be expected to occur prior to discharge to the sand aquifer. Accordingly, it is not considered credible that that pathway would be more critical than direct discharge to surface water. Accordingly, with regard to any potential dissolved contaminants within the water emanating from the restoration soils, it is considered that, for the present site, more detailed assessment is only warranted with respect to the surface water receptor via direct discharge from the drainage system.

# 4 METHODOLOGY

## 4.1 ASSUMPTIONS

The present work is based on the following assumptions:

- Infiltration to the cap will equal the effective precipitation less run-off.
- Effective precipitation is 270 mm per year, it is anticipated that the restoration soils would be vegetated shortly after placement.
- Loss through the geo-membrane or clay sealing system to the wastes will be ignored, which is conservative.
- Direct surface flow run-off to surface drainage will be considered for completeness although a relatively low value will be assumed.
- There would potentially be some attenuation during flow through the restoration system, which would be expected to be greatest for areas of the restoration situated farthest from the surface drainage system.
- Degradation would be considered where appropriate but there would be no assumed loss of mass of contaminant due to volatilisation etc, within the surface drainage system.
- For the drain to surface water pathway, dilution within the final receiving stream will be ignored. This is also conservative.

Generically, the leachate target has therefore been calculated as follows:

SLT = EQS x AFC x DFD

Where:
SLT = Soil Leachate Target (mg/l)
EQS = The relevant Compliance Criterion (Environmental Quality Standard) for the substance (mg/l)
AFC = Attenuation Factor during transport in the Restoration Flow System
DFD = Dilution Factor in Surface Drain System

DFD would be taken as unity for List 1 Substances.

## 4.2 POTENTIAL CONTAMINANTS OF CONCERN AND COMPLIANCE CRITERIA

As the critical receptor is considered to be the surface water system, the relevant compliance criteria will be assumed to be Annual Average Environmental Quality Standards (EQS) levels where these have been published. Where no EQS is available EQS values for similar compounds have been selected.

Where new EQS values have been proposed in the document 'The River Basin Districts Typology, Standards and Groundwater threshold values (Water Framework Directive) (England and Wales) Directions 2015, these have been adopted. Otherwise former EQS values for surface water have been adopted.

For TPH fractions, where no EQS is available, the former drinking water standard for oils and hydrocarbons (0.01 mg/l) has been adopted. There is reason to consider however, that for some THP fractions, the adopted compliance criterion is likely to be conservative with respect to protection of controlled waters, where the critical receptor is either a surface water feature or potential drinking water. The Massachusetts Department of Environmental Protection (MADEP) has published risk-based criteria that are protective of aquatic receptors (BATELLE,2007), see also SOBRA 2012. The approach involved estimating the acute and chronic toxicity of hydrocarbon fractions to aquatic organisms based on equilibrium partitioning theory. Criteria in pore water and sediment were derived for eight groupings (fractions) of petroleum hydrocarbons based on similar toxicological and chemical properties, are set out in the following table:

| **Hydrocarbon Fraction** | **Toxicity-based Water Criterion (mg/l)** |
|---|---|
| Aliphatics C5-C8 | 0.22 |
| Aliphatics C9-C12 | 0.0063 |
| Aliphatics C13-C18 | * |
| Aliphatics C19-C36 | * |
| Aromatics C6-C8 | 1.2 |
| Aromatics C9-C12 | 0.046 |
| Aromatics C13-C15 | 0.0052 |
| Aromatics C16-C24 | * |

*Note: These fractions are not likely to be toxic, toxicology-based pore water concentration exceeds mean aqueous solubility.

With regard to human toxicity, the World Health Organisation (2005) has developed the following guidelines for drinking water standards:

| **Hydrocarbon Fraction** | **Toxicity-based Drinking Water Criterion (mg/l)** |
|---|---|
| Aliphatics C5-C8 | 15 |
| Aliphatics C9-C16 | 0.3 |
| Aliphatics C17-C36 | * |
| Aromatics C6-C8 | 0.01 (benzene) 0.7 (toluene) |
| Aromatics C9 - C16 | 0.1 |
| Aromatics C16-C35 | 0.09 |

In the light of the above, absence of current regulatory guidance in the UK and as dilution in the receiving stream is being ignored, the former DWS (0.01 mg/l) was adopted as a relevant compliance criterion for each of the TPHCWG groupings where the expected solubility exceeds that value. Where solubility is less than 0.01 mg/l it is assumed that the fraction can pose no significant risk to controlled waters.

Details of the chemical characteristics of proposed restoration soils are not available but, based on experience from similar operations, target values will be required for a fairly wide range of potential contaminants and the following compliance criteria and solubility have been adopted (all in mg/l). The adopted organic carbon partition coefficient is also listed.

| Substance | Compliance Criterion | Comment | Water solubility | Koc | |
|---|---|---|---|---|---|
| | mg $L^{-1}$ | | mg $L^{-1}$ | Log ($cm^3$ $g^{-1}$) | Reference |
| Benzene | 1.00E-02 | | 1.78E+03 | 1.83E+00 | SR7 |
| Toluene | 7.40E-02 | | 5.90E+02 | 2.31E+00 | SR7 |
| Ethylbenzene | 2.00E-02 | | 1.80E+02 | 2.65E+00 | SR7 |
| m-Xylene | 3.00E-02 | | 2.00E+02 | 2.69E+00 | SR7 |
| o-Xylene | 3.00E-02 | | 1.73E+02 | 2.63E+00 | SR7 |
| p-Xylene | 3.00E-02 | | 2.00E+02 | 2.65E+00 | SR7 |
| Naphthalene | 2.40E-03 | | 1.90E+01 | 2.81E+00 | SR7 |
| Benzo[a]pyrene | 1.70E-07 | | 3.80E-03 | 5.11E+00 | SR7 |
| Phenol | 7.70E-03 | | 8.41E+04 | 1.46E+00 | SR7/LQM |
| TPH Aliphatic C5-C6 | 1.00E-02 | Former DWS | 3.60E+01 | 2.90E+00 | LQM |
| TPH Aliphatic C6-C8 | 1.00E-02 | Former DWS | 5.40E+00 | 3.60E+00 | LQM |
| TPH Aliphatic C8-C10 | 1.00E-02 | Former DWS | 4.30E-01 | 4.50E+00 | LQM |
| TPH Aliphatic C10-C12 | 1.00E-02 | Former DWS | 3.40E-02 | 5.40E+00 | LQM |
| TPH Aliphatic C12-C16 | 1.00E-02 | Former DWS | 7.60E-04 | 6.70E+00 | LQM |
| TPH Aliphatic C16-C21 | 1.00E-02 | Former DWS | 2.50E-06 | 8.80E+00 | LQM |
| TPH Aliphatic C21-C34 | 1.00E-02 | Former DWS | 2.50E-06 | 8.80E+00 | LQM |
| TPH Aliphatic C35-C44 | 1.00E-02 | Former DWS | 2.50E-06 | 8.80E+00 | LQM |
| TPH Aromatic C8-C10 | 1.00E-02 | Former DWS | 6.50E+01 | 3.20E+00 | LQM |
| TPH Aromatic C10-C12 | 1.00E-02 | Former DWS | 2.50E+01 | 3.40E+00 | LQM |
| TPH Aromatic C12-C16 | 1.00E-02 | Former DWS | 5.80E+00 | 3.70E+00 | LQM |
| TPH Aromatic C16-C21 | 1.00E-02 | Former DWS | 6.50E-01 | 4.20E+00 | LQM |
| TPH Aromatic C21-C35 | 1.00E-02 | Former DWS | 6.60E-03 | 5.10E+00 | LQM |
| TPH Aromatic C35-C44 | 1.00E-02 | Former DWS | 6.60E-03 | 5.10E+00 | LQM |
| TPH Aromatic C44-C70 | 1.00E-02 | Former DWS | 1.00E-04 | 5.70E+00 | LQM |
| Arsenic | 5.00E-02 | | | | |
| Cadmium | 2.50E-04 | | | | |
| Copper | 2.80E-02 | | | | |
| Chromium | 2.00E-02 | | | | |
| Lead | 7.20E-03 | | | | |
| Mercury | 5.00E-05 | | | | |
| Nickel | 2.00E-02 | | | | |
| Zinc | 3.40E-02 | | | | |
| Water Soluble Boron | 2.00E+00 | | | | |
| Sulphate | 4.00E+02 | | | | |
| Nitrate | 11.3 | | | | |
| Ammonium as NH4 | 0.77 | | 8.99E+05 | Kd = 1 $cm^3$ $g^{-1}$ | Buss et al |

For the pathway associated with discharge of perimeter drain water to the surface water system, no dilution within the surface water following discharge will be considered, which is conservative. Compliance criteria will be assumed to apply to drain water prior to discharge.

# 5 DEVELOPMENT OF EXTENDED CONCEPTUAL MODEL

## 5.1 GENERAL

The patterns of water flow within the restoration system are important to the assessment of risks to controlled waters. The flow system in the, generally unsaturated, cover system can be relatively complex and in order further to develop the conceptual model of water flow conditions, a numerical model was developed to simulate flow and contaminant transport in the restoration system. The model simulates 2 dimensional flow and contaminant transport in a vertical section through the restoration system.

## 5.2 MODELLING SOFTWARE

Numerical modelling undertaken as part of the present study has made use of the SEEP/W program developed by Geo-Slope International Ltd. This was chosen as it allows rapid parametric studies to be undertaken and the implications of various assumptions to be graphically displayed. The program has been specifically formulated to allow accurate simulation of unsaturated as well as saturated flow systems. The program is based on the well-established finite element method for continuum analysis. Although similar analysis may be undertaken using finite difference based methods, the finite element approach offers some advantages; in particular the method is less sensitive to such factors as node spacing as conditions are not assumed to be linear within elements. In this process the study geometry is divided into a number of elements. Potential patterns of contaminant transport may be mapped on the results of the SEEP/W analysis with the use of a companion program CTRAN/W.

## 5.3 VERTICAL SECTION MODEL

### 5.3.1 GEOMETRIES ANALYSED

The presently proposed restoration area, Figure 2, is of a somewhat complex shape and with varying surface gradients. For the presently considered site areas, a maximum plan distance from high to low points on the proposed covers is about 220 m and a typical section has been adopted for analysis. The geometry modelled is shown in Figures 4 at five times vertical scale exaggeration. In some areas the treated soils would be placed 'upstream' of previously completed cover areas that have been completed using clean imported soils. This has been ignored in the analysis, which is conservative as attenuation would occur within the previously placed soils.

The upper surface was modelled as an infiltration boundary with a review such that if water pressure at the surface exceeds atmospheric, infiltration does not occur, i.e. run-off would be expected. The right hand boundary, which represents the topographic high point and which was assumed to be a water divide, was modelled as a no flow boundary. The lower boundary, representing the cap sealing layer, was modelled as a no-flow boundary. The left hand basal boundary was modelled as a zero (atmospheric) water pressure boundary/potential seepage face, as conditions at the downstream surface drain are assumed to be atmospheric.

The cover was modelled as a single layer system, representing the restoration soils (base case assumed 1000 mm thick).

With this system, the overall volume of groundwater flow is controlled by the infiltration rather than hydraulic properties of the soil layer, unless the system becomes saturated and then the saturated hydraulic properties would control the degree of run-off and the volume of flow within the cover soils.

In the normal, unsaturated, condition, effective conductivity of the unsaturated soils will depend on moisture content, which will depend upon the degree of negative pore pressure in the pore fluid. This will be constrained to come into equilibrium with the rate of infiltration. It follows that the solution to the flow problem must be iterative and this is accommodated by the software.

It is necessary to assume a relationship between negative water pressure and both volumetric water content and hydraulic conductivity. However, as the flow volumes are controlled by infiltration, unless the system becomes saturated in which case there would not be negative pore pressures, selection of these relationships is less critical than would otherwise be the case. Accordingly literature relationships were selected, for the shapes of the water content and conductivity relationships with negative pore pressure, from the software library functions of soils expected to be generally similar to the restoration system:

| Unit | Saturated Hydraulic Conductivity (m/s) | Saturated Volumetric Water Content (Porosity) |
|---|---|---|
| Restoration Soils | Base Case 1.0e-4<br>Low Value 1.0e-5 | 0.3 |

It is anticipated that the above base case saturated conductivity is likely to be greater than the field conditions, as previous experience has shown that the restoration soils include significant proportions of silts and clays. However, adoption of lower saturated conductivities results in increased run-off and less flow in the cover and would therefore not be conservative. Once the assumed conductivity is high enough to prevent saturated conditions under average infiltration conditions, the absolute value of assumed saturated hydraulic conductivity does not greatly influence predicted rates of attenuation as flow volumes is controlled by volume of infiltration.

Analysis was therefore run for both the base case and lower saturated conductivity case and the condition showing the lower rate of attenuation, the higher saturated conductivity condition, was adopted for evaluation of leachate targets.

Figure 5 shows the soil moisture retention and conductivity curves adopted.

### 5.3.2 PREDICTED FLOW CONDITIONS FOR STEADY STATE INFILTRATION

Figure 6 shows the predicted base case flow conditions within the restoration soils as contours of total head.

### 5.3.3 IMPLICATIONS FOR CONTAMINANT TRANSPORT

During transport through the system, the effective velocity of dissolved phase potential contaminants will be retarded by adsorption and the processes of dispersion, downstream dilution and, for organic compounds, bio-degradation will lead to potential attenuation through dilution and loss of mass of contaminant. Although mechanical dispersion and dilution would be expected to be independent of the nature of the dissolved substance, both adsorption and potential bio-degradation would be strongly dependent on the contaminant present. As such the analysis requires additional compound specific parameters. However, if bio-degradation is ignored, as would be appropriate for example for potential metal contaminants, although retardation will affect the rate of transport, and will delay attainment of ‘steady state’ conditions, it will not affect the predicted long term ‘steady state’ distribution of potential conservative contaminants in which the source concentration is not reducing with time as eventually desorption will come into equilibrium with adsorption. For the present purposes, therefore, considering long term conditions and no source reduction, discussion of adsorption and bio-degradation parameters is only warranted for organic compounds. The assumption that the source concentration remains constant implies that there is no depletion of the source, which is very conservative.

For organics, partitioning is assumed to be proportional to the organic matter content of the soil. The relevant material parameters for this analysis are the Organic Carbon Partition Coefficient (Koc) and the half life of biodegradation. The assumed values of Koc are based on the Environment Agency Report SR7 (2008) and have been tabulated in Section 4.2, above. For compounds not included in that document, data are based on LQM (2009) or Buss et al (2004). The values of fraction of organic carbon was assumed to be 0.01 (1%) for the restoration soils, which is likely very conservative, particularly where compost materials are introduced.

For the present study, adopted degradation rates are based primarily on EA P2 228 (2002). The data presented in EA P2 228 for shallow sand and gravel aquifers under aerobic conditions have been adopted. These are considered very conservative for the present case as the flow system within the restoration soils is expected to be mainly unsaturated and will always be at very shallow depth and therefore with ready availability or air. In fact, data for near surface soil are potentially more relevant. Biodegradation rates in soil are generally much more rapid than in groundwater. For example Howard et al 1991 suggest half lives for benzene may be 2 to 45 times shorter in soil than in groundwater.

It is generally found that for TPH compounds, rates of degradation in the field reduce with increasing molecule size. For TPH fractions where no guidance is given in EA P2 228, approximate half lives have been estimated based on the guidance given in EA P2 228 for BTEX and scaling half lives based on the general relationship between half life and molecule size proposed in New Zealand Guidance. With the exception of naphthalene, EA P2 228 (2002) does not report degradation rates for PAH compounds. Other PAH compounds are not generally critical with respect to the water environment. This is because of low solubility and generally high partition coefficients. Data presented by Surampalli et al (2004), based on field studies, suggest typical half lives in unconfined shallow aquifers for PAH compounds of less than 2 years. For the present study arbitrary but relatively high half-life of 10 years has been adopted for PAH compounds other than naphthalene. More detailed assessment is not considered warranted as these compounds are not highly mobile in the groundwater environment and rarely are critical.

The adopted values are summarised in the table below:

| Substance | Half Life (days) | Source |
|---|---|---|
| Benzene | 350 | Upper Limit EA Report P2-228/TR |
| Toluene | 200 | Upper Limit EA Report P2-228/TR |
| Ethylbenzene | 200 | Upper Limit EA Report P2-228/TR |
| m-Xylene | 200 | Upper Limit EA Report P2-228/TR |
| o-Xylene | 200 | Upper Limit EA Report P2-228/TR |
| p-Xylene | 200 | Upper Limit EA Report P2-228/TR |
| Benzo[a]pyrene | 3650 | High value based on literature, e.g. Surampalli et al 2004 |
| Naphthalene | 300 | Upper Limit EA Report P2-228/TR |
| Phenol | 100 | Upper Limit EA Report P2-228/TR |
| TPH Aliphatic C8-C10 | 700 | Upper Limit for BTEX EA Report P2-228/TR scaled according to NZ Practice |
| TPH Aromatic C8-C10 | 700 | As TPH C8-C10 scaled according to NZ Practice |
| TPH Aromatic C10-C12 | 1750 | As TPH C8-C10 scaled according to NZ Practice |
| TPH Aromatic C12-C16 | 2450 | As TPH C8-C10 scaled according to NZ Practice |
| TPH Aromatic C16-C21 | 3500 | As TPH C8-C10 scaled according to NZ Practice |
| TPH Aromatic C21-C35 | 3500 | As TPH C8-C10 scaled according to NZ Practice |
| Ammonia | 730 | Buss et al 2004 |

As noted above, some PAH compounds and higher level TPH fractions have very low aqueous solubility. Where the aqueous solubility is less than the adopted compliance criterion, more detailed analysis of potential fate and transport is not warranted. Where the EQS depends on the carbonate content of the receptor, the highest reported value has been adopted. This is considered justified as no dilution within the receptor has been assumed.

The restoration soils will be placed at varying distances from the surface water drains. Infiltration water with dissolved phase contaminants leached from the restoration soils placed further from the surface drainage will take considerably longer to reach the discharge than from areas closer to the drain, with consequent varying attenuation potential. In order to accommodate this aspect, the restoration soils were divided into four zones, Zone 1 corresponding to: 0 to 20 m from the discharge drainage, Zone 2: 20 to 50 m, Zone 3: 50 to 100 m and Zone 4 (Greater than 110 m). Analysis was undertaken for each of the four zones for a range of partition coefficients and half-lives, to reflect the range of organic compounds potentially present in the restoration soils. Figure 7 shows an example of the Zone 3 area as source for benzene. This analysis assumes unit concentration within the source zone. Based on this and similar analyses for other potential contaminants and source zones, the potential attenuation associated with each zone can be estimated. Figure 8 shows the predicted discharge concentration vs time for benzene and for conservative compounds, sources assumed in Zone 3, for the condition of constant infiltration and base case conductivity. Note that for this analysis potential retardation of conservative substances has been ignored. Although retardation due to adsorption is likely to occur and would affect breakthrough times, as discussed above, for a constant source, the final steady state concentration distribution downstream would be the same.

The modelled overall distance from crest to discharge (220 m) is essentially the maximum present. Lesser distances would be less conservative as flow volumes and velocities would be less and hence rates of attenuation greater.

The restoration system attenuation factor is defined as the ratio of the source concentration to concentration at discharge. The following table gives examples of the derived restoration system attenuation factors:

| Compound | Attenuation Factor for Restoration Zone | | | |
|---|---|---|---|---|
| | Zone 1 | Zone 2 | Zone 3 | Zone 4 |
| Conservative Compound (No Degradation) | 1 | 1.10 | 1.29 | 1.83 |
| Benzene | 1 | 1.54 | 3.18 | 14.8 |
| Toluene | 1 | 4.81 | 67.8 | >10,000 |
| Naphthalene | 1 | 16.6 | 1810 | >10,000 |
| Benzo(a)pyrene | 1 | >10,000 | VH | VH |

VH = Very High

### 5.3.4 EFFECT OF TRANSIENT INFILTRATION CONDITIONS

In reality infiltration to the cover system will be variable with time. In addition to daily variations reflecting varying short term weather conditions, there would be expected to be a seasonal effect where a relatively high proportion of total infiltration occurs during winter months, primarily due to lower potential evapotranspiration during the winter. Under steady state conditions, assuming average infiltration, predicted horizontal 'Darcy' groundwater velocities are of the order of 1e-6 m/s near the centre of the cover. This suggests that in a single year, the advective transport distance within the cover system would be in the order of about 100 m. Seasonal fluctuations in infiltration would not therefore be expected to significantly affect the impact of sources remote from the perimeter but may lead to variations in discharge rates of leachate originating as infiltration nearer the perimeter of the cover.

To study the effect of seasonal variations on flow conditions within the cover, a transient model was developed. A simplified seasonal infiltration function was adopted in which the entire year's infiltration was assumed to occur in six months with no infiltration for the remaining six months. The model simulated a period of 10 years. This simulation showed some seasonal variation in the degree of saturation of the cover system such that during winter months, at times of highest potential infiltration, the cover materials would be expected to be in a more saturated condition, which implies a higher proportion of run-off and consequently a somewhat lower flow through the cover soils. Following the winter period, flows may increase somewhat as water comes out of storage when degrees of saturation reduce.

Figure 9 shows the potential effect of seasonally varying infiltration on predicted contaminant concentration at discharge. Sources of benzene of assumed concentration unity, within Zone 2 and within Zone 3 are illustrated. As discussed above, one effect of seasonal variation in potential infiltration is that during periods of highest potential infiltration the restoration soils are more likely to reach saturation, possibly leading to increased run-off and reduced actual total annual infiltration even though the rate of infiltration in winter is higher than in summer. For the simplified model adopted, which includes yearly variations but does not include shorter term infiltration variations, the model suggests that average concentration at discharge to the drain will not be higher than predicted assuming uniform infiltration throughout the year. As annual average EQS values have been adopted, it is therefore considered reasonable to adopt the uniform infiltration condition for assessment purposes.

### 5.3.5 EFFECT OF DEPLETING SOURCE CONCENTRATION

As noted above, for most substances a constant source zone concentration was assumed, which is conservative. It follows that the predicted maximum concentrations will correspond to long term ‘steady state’ conditions. For ammonium however, this assumption is considered unduly conservative as the source is considered to be decay of organic matter. Accordingly it was assumed that the source concentration of ammonium would reduce with time. The rate of decomposition would depend upon the nature of the organic material present and generally occurs exponentially. For the present model it is assumed that the source would decay to negligible within a period ten years, which is consistent with the source concentration reducing to half of its original level each year. For this assumption the peak concentration does not correspond to the long term ‘steady state’ condition. The further the source from the discharge, the longer will be the time to peak concentration but the lower the peak value. Figure 10 shows the predicted discharge concentration with time for each of the assumed ‘source’ zones for ammonium. As may be seen, the further the source from the discharge, the longer to peak concentration but the lower the peak value. The peak values were used for derivation of attenuation factors.

### 5.3.6 EFFECT OF INCREASING THICKNESS OF RESTORATION SOILS

The base case modelling assumes a minimum thickness of restoration soils of 1.0 m. In practice the thickness is likely to be significantly greater. The effect of increasing thickness is to reduce average flow velocities and increase rates of contaminant attenuation. This is illustrated in Figure 11 for assumed benzene sources in Zone 2 and in Zone 3, where predicted discharge concentrations for 1 m and 2 m restoration soil thicknesses are compared.

### 5.3.7 EFFECT OF REDUCING RESTORATION SOIL SATURATED HYDRAULIC CONDUCTIVITY

As discussed above, provide the saturated hydraulic conductivity is sufficient to maintain unsaturated conditions within the restoration soils, flow velocities and volumes and hence potential rates of attenuation will be governed by the infiltration. Should the saturated hydraulic conductivity be such that saturated conditions develop, flow volumes would reduce below infiltration due to run-off and rates of attenuation would be expected to increase. This is illustrated in Figure 12 for an assumed benzene source in Zone 3, where the saturated hydraulic conductivity of the restoration soils is reduced by one order of magnitude compared to the base case. As may be seen, predicted attenuation increases. In addition to the increased attenuation, dilution within the perimeter drain would also be increased as a result of increased run-off.

# 6 DEVELOPMENT OF LEACHATE TARGETS FOR POTENTIAL CONTAMINANTS IN RESTORATION SOILS

## 6.1 GENERAL

Leachate Targets are required to ensure protection of controlled waters through the restoration to perimeter drain to surface water pathway.

As discussed above, the restoration to groundwater pathway was judged, for the present site, to be non-critical at the conceptual model stage. It is conservative to assume that all flow may be to the surface drainage system. Any intermediate condition, which would see some fraction of discharge to surface water and the remaining fraction to the groundwater, would lead to lower potential impact on the receptor being considered.

As Annual Average EQS values are being adopted as compliance criteria, the analysis will consider average conditions. It should be noted therefore that derived leachate targets relate to annual average concentrations leaching from the placed soils rather than maxima.

## 6.2 RESTORATION TO PERIMETER DRAIN TO SURFACE WATER PATHWAY

As noted in Section 4.1 above, in general the Soil Leachate Target is given by:

SLT = EQS x AFC x DFD or,
SLT/AFC = EQS x DFD

The factor DFD will be controlled by the ratio of direct surface run-off to water discharge through the restoration soils. Average surface run-off is expected to be less than about 5 to 10 % of total precipitation, estimated to be on average 822 mm/year. The average effective rainfall has been estimated at about 270 mm/year, i.e. about 33% of total precipitation. If run-off is assumed to be a nominal 5 % of total precipitation, a first order estimate of DFD would therefore be (0.05 + 0.33)/0.33 = 1.15. Note that DFD is assumed unity for List 1 substances.

The factor AFC is not constant but depends upon distance of the source soils from the perimeter drain and average values have been determined for three zones as follows:

AFC1: Zone 1, 0 to 20 m from downstream drain
AFC2: Zone 2, 20 to 50 m from downstream drain
AFC3: Zone 3, 50 to 100 m from downstream drain
AFC4: Zone 4, More than 100 to 220 m from downstream drain

If we consider separate leachate targets for each area (SLT1, SLT2 etc), compliance will be achieved provided that:

SLT1.Q1/AFC1 + SLT2.Q2/AFC2 + SLT3.Q3/AFC3 + SLT4.Q4/AFC4 <= EQS.DFD.QT

As the zones are of different lengths this leads to the following for 220 m case from crest to drain:

Q1 = 0.091 QT
Q2 = 0.136 QT
Q3 = 0.227 QT
Q4 = 0.546 QT

There is no unique solution to the above expression. It would, for example, be acceptable to specify a high SLT for any one zone and relatively low values for each of the others. However, one acceptable solution would be to set SLT1 = AFC1.EQS.DFD, SLT2 = AFC2.EQS.DFD etc. This has the intuitive advantage of resulting in higher leachate targets with increasing distance from the perimeter drain, as well as simplicity and is therefore the recommended approach.

## 6.3 DERIVED LEACHATE TARGETS

Leachate targets are therefore derived as follows:

SLT = EQS x AFC x DFD

Derived leachate targets for pore water (leachate) are summarised in the following table. These should be used within the overall assessment in conjunction with pragmatic considerations, human health issues and vegetation support issues to develop appropriate overall leachate targets.

| Substance | Compliance Criterion (mg/l) | Derived Leachate Targets (mg/l) | | |
|---|---|---|---|---|
| | | Zone 2 | Zone 3 | Zone 4 |
| Benzene | 0.01 | 0.015 | 0.032 | 0.15 |
| Toluene | 0.074 | 0.36 | 5 | No Restriction |
| Ethylbenzene | 0.02 | 0.37 | 48 | No Restriction |
| m-Xylene | 0.03 | 0.69 | 130 | No Restriction |
| o-Xylene | 0.03 | 0.5 | 55 | No Restriction |
| p-Xylene | 0.03 | 0.56 | 72 | No Restriction |
| Naphthalene | 0.0024 | 0.04 | 4.4 | No Restriction |
| Benzo[a]pyrene | 0.00000017 | No Restriction | No Restriction | No Restriction |
| Phenol | 0.0077 | 0.016 | 0.052 | 0.61 |
| TPH Aliphatic C5-C6 | 0.01 | 0.19 | 24 | No Restriction |
| TPH Aliphatic C6-C8 | 0.01 | No Restriction | No Restriction | No Restriction |
| TPH Aliphatic C8-C10 | 0.01 | No Restriction | No Restriction | No Restriction |
| TPH Aliphatic C10-C12 | 0.01 | No Restriction | No Restriction | No Restriction |
| TPH Aliphatic C12-C16 | 0.01 | No Restriction | No Restriction | No Restriction |
| TPH Aliphatic C16-C21 | 0.01 | No Restriction | No Restriction | No Restriction |
| TPH Aliphatic C21-C34 | 0.01 | No Restriction | No Restriction | No Restriction |
| TPH Aliphatic C35-C44 | 0.01 | No Restriction | No Restriction | No Restriction |
| TPH Aromatic C8-C10 | 0.01 | 0.18 | 24 | No Restriction |
| TPH Aromatic C10-C12 | 0.01 | 0.072 | 2.1 | No Restriction |
| TPH Aromatic C12-C16 | 0.01 | 0.14 | 2.7 | No Restriction |
| TPH Aromatic C16-C21 | 0.01 | No Restriction | No Restriction | No Restriction |
| TPH Aromatic C21-C35 | 0.01 | No Restriction | No Restriction | No Restriction |
| TPH Aromatic C35-C44 | 0.01 | No Restriction | No Restriction | No Restriction |
| TPH Aromatic C44-C70 | 0.01 | No Restriction | No Restriction | No Restriction |
| Arsenic | 0.05 | 0.063 | 0.074 | 0.11 |
| Cadmium | 0.00025 | 0.00027 | 0.00032 | 0.00046 |
| Copper | 0.028 | 0.035 | 0.042 | 0.059 |
| Chromium | 0.02 | 0.025 | 0.03 | 0.042 |
| Lead | 0.0072 | 0.0091 | 0.011 | 0.015 |
| Mercury | 0.00005 | 0.000055 | 0.000065 | 0.000092 |
| Nickel | 0.02 | 0.025 | 0.03 | 0.042 |
| Zinc | 0.13 | 0.16 | 0.19 | 0.26 |
| Water Soluble Boron | 2 | 2.5 | 3 | 4.2 |
| Sulphate | 400 | 510 | 600 | 840 |
| Nitrate | 11 | 14 | 17 | 24 |
| Ammonium | 0.77 | 1.3 | 2.6 | 7.8 |

* Note: Zone 1 Target set at Compliance Criterion (EQS)

## 7 PARAMETER UNCERTAINTY AND SENSITIVITY

Although there are a number of assumptions inherent in the present analysis, in so far as possible these have been chosen to be consistent with design assumptions for the overall facility. The approach to management of parameter uncertainty has been to incorporate a significant number of conservative assumptions into the analysis, in particular:

- Apart from for ammonium, the source of potential leachate within the restoration soils has been assumed to be constant with time. This is considered to be particularly conservative for potentially more soluble mobile contaminants.
- Evaporation to the atmosphere has been ignored but would likely be significant for volatile, relatively mobile, organic compounds.
- The potential leakage to the waste mass has been assumed to be zero.

- Degradation half lives have been assumed to much higher than would likely be observed in aerobic near surface soil conditions.
- The hydraulic conductivity of the restoration soils has been assumed to be significantly higher than would be anticipated.
- The organic matter content of the restoration soils has been assumed to be relatively low.
- A proposed minimum thickness of restoration soils has been adopted as the base case.

Analysis has been undertaken to illustrate the sensitivity of the analysis to seasonal variance in infiltration, variation in cover thickness and variation in restoration soil saturated hydraulic conductivity. In view of the significantly conservative assumptions outlined above, more detailed analysis of sensitivity it is not considered warranted.

# 8 SUMMARY CONCLUSIONS

The restoration system will comprise a cap sealing layer which will in turn be overlain by the restoration soils. The restoration soils will have a minimum overall 1.0 m thickness above the barrier layer. However, depending on such factors as the magnitude of post construction settlements, the overall thickness of the restoration soils is likely to be significantly greater in some areas.

The restoration system will be entirely above the site groundwater level and analysis suggests that it will remain unsaturated during average conditions if the saturated conductivity of the restoration soils is relatively high. For lower conductivities saturated conditions may develop, particularly in winter months, which would tend to increase run-off and reduce infiltration and hence reduce potential leaching. Any infiltration into the restoration soils that permeates through the barrier will contribute to leachate within the waste mass and be treated accordingly. It is expected, however, that this will be a small component of the overall water balance and that most of the infiltration will travel laterally within the restoration system and discharge to a surface water drain, which would discharge to the Fowle Brook.

Analysis has been undertaken to derive defensible leachate targets for the treated soils that will be protective to surface water. For some potential contaminants there is the potential for significant attenuation within the restoration system prior to discharge. Numerical modelling of the flow system in the restoration soils has been undertaken to quantify potential levels of attenuation. Based on the site conceptual model, for the present site, the discharge to groundwater pathway is considered to be less critical than the discharge to perimeter drain and thence to surface water pathway.

For site management, the cover area has been divided into four zones representing different distances from the surface water drainage system.

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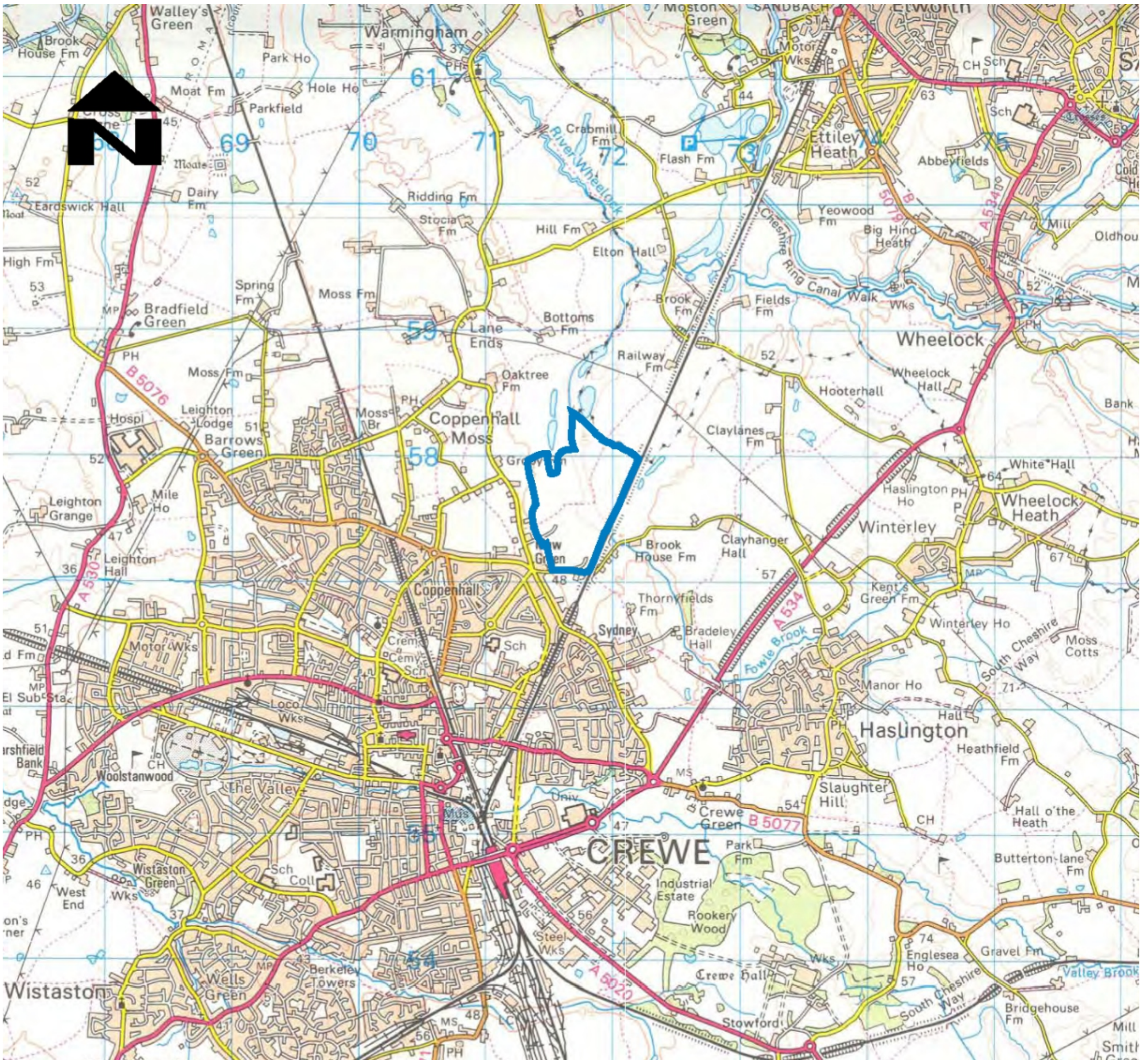
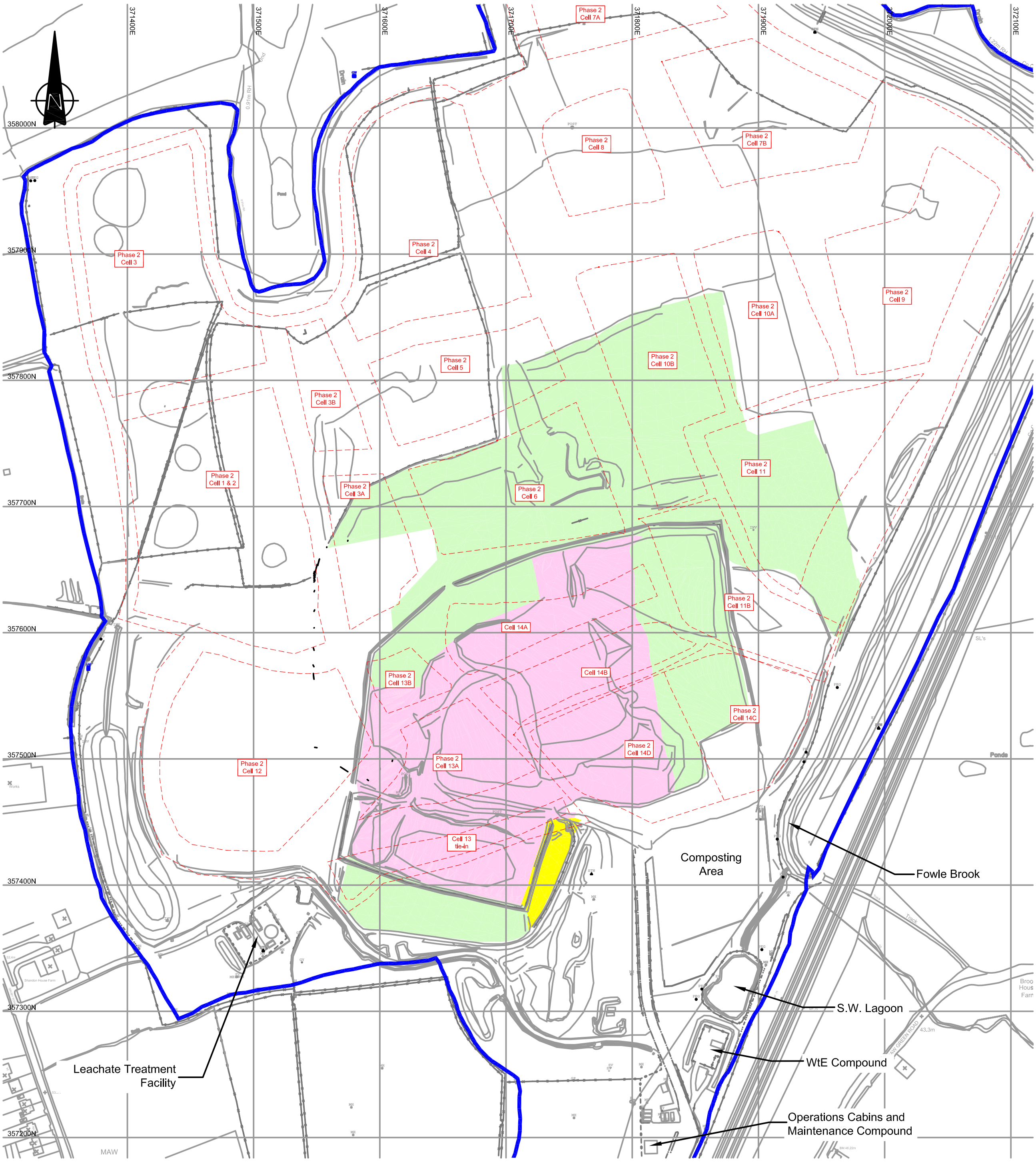
# FIGURES






SITE LOCATION PLAN

| SLADEN ASSOCIATES | Report No<br>20-2218 | Project<br>Maw Green Landfill<br>Crewe | Figure<br>**1** |
|---|---|---|---|




Green and pink shaded areas would accept treated soils



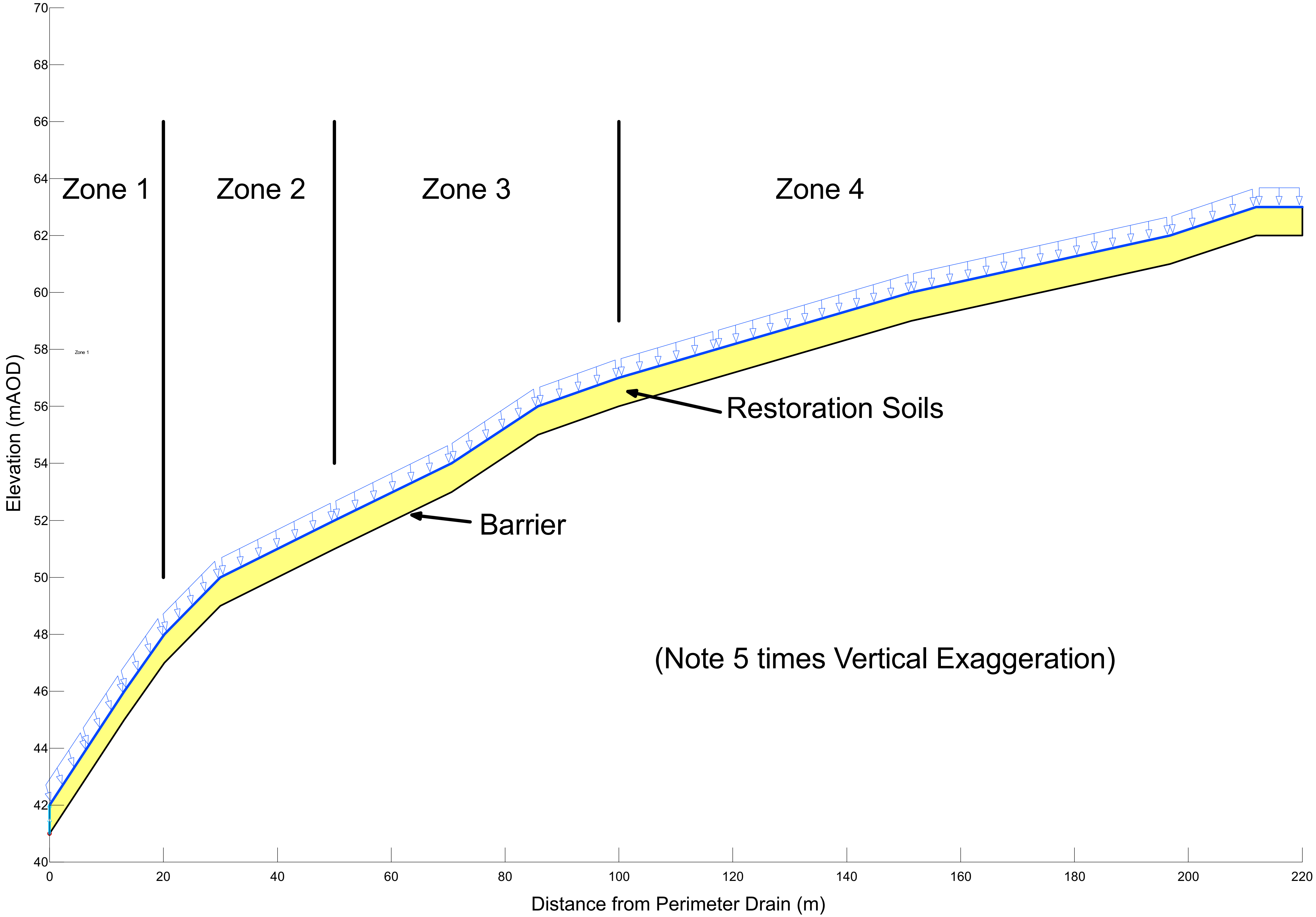
PROPOSED TREATED SOIL RESTORATION AREA

| SLADEN ASSOCIATES | Report No<br>20-2218 | Project<br>Maw Green Landfill<br>Crewe | Figure<br>2 |
|---|---|---|---|




PROPOSED RESTORATION LAYOUT

| SLADEN ASSOCIATES | Report No<br>20-2218 | Project<br>Maw Green Landfill<br>Crewe | Figure<br>3 |
|---|---|---|---|




GEOMETRY MODELLED - VERTICAL SECTION MODEL

| SLADEN ASSOCIATES | Report No<br>20-2218 | Project<br>Maw Green Landfill, Crewe | Figure<br>4 |
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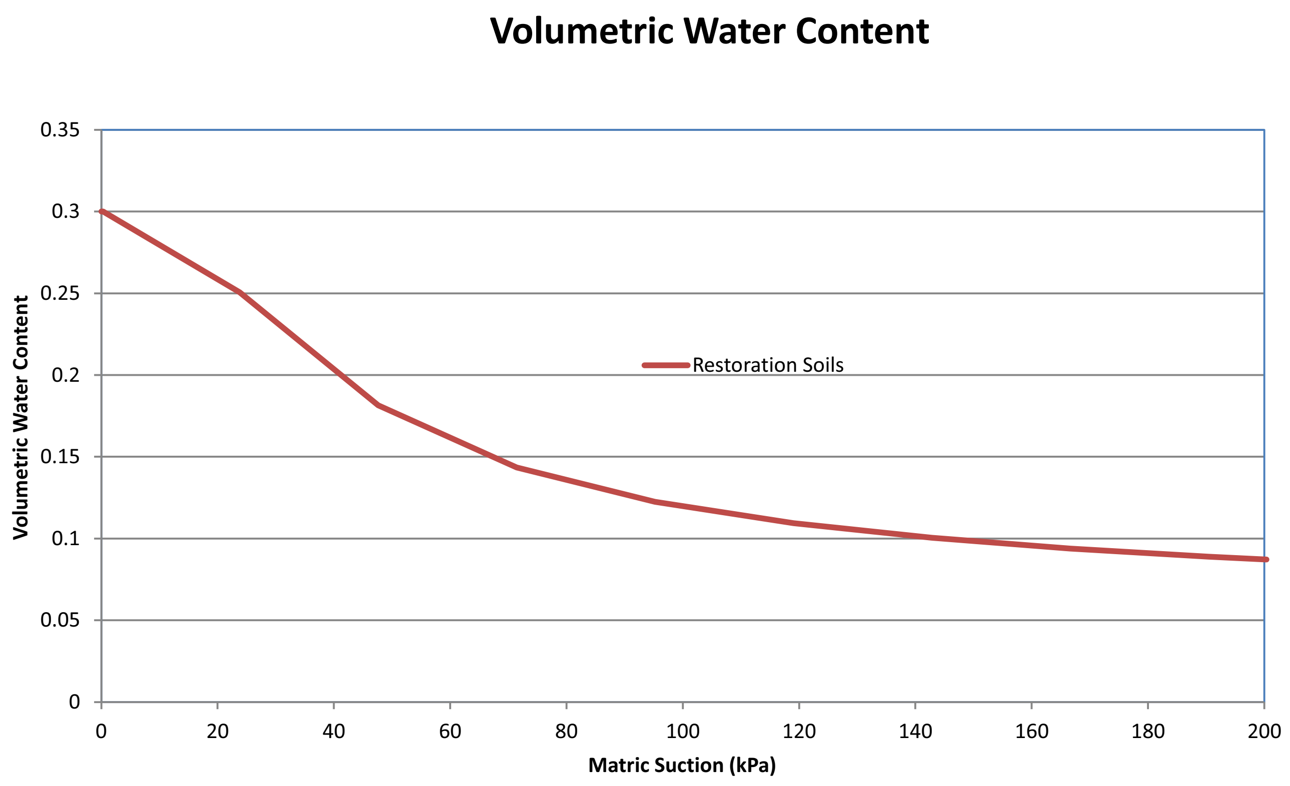
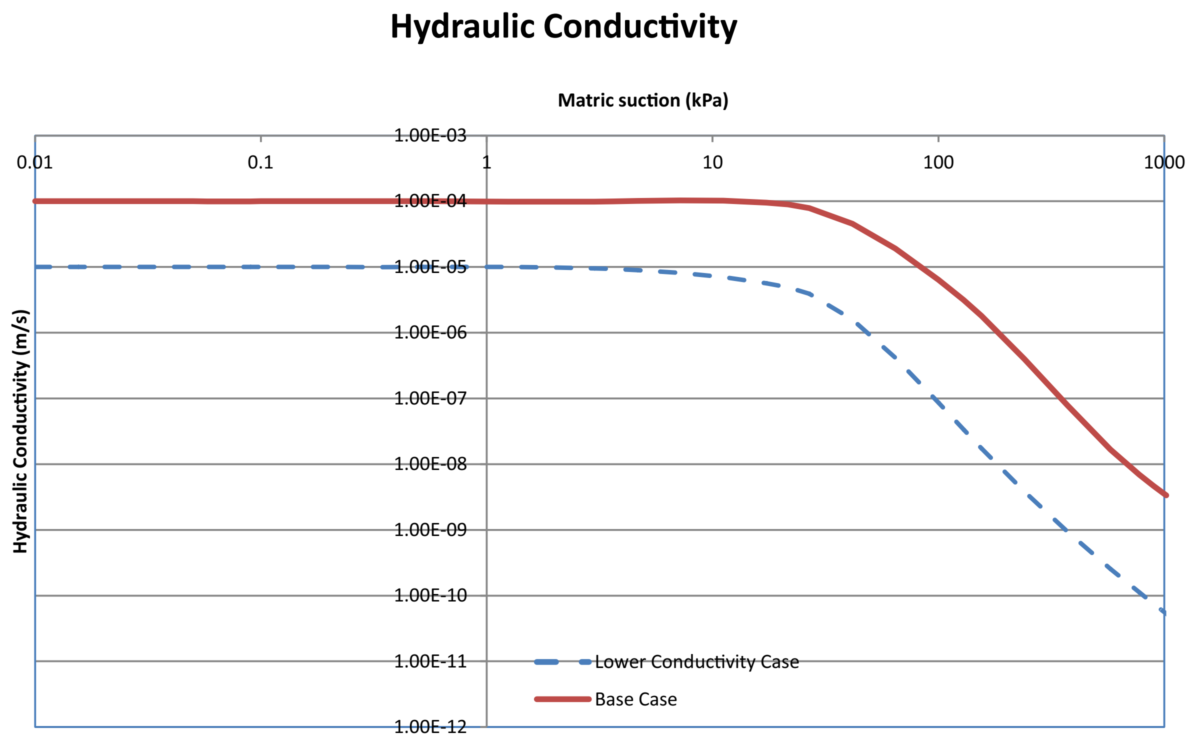
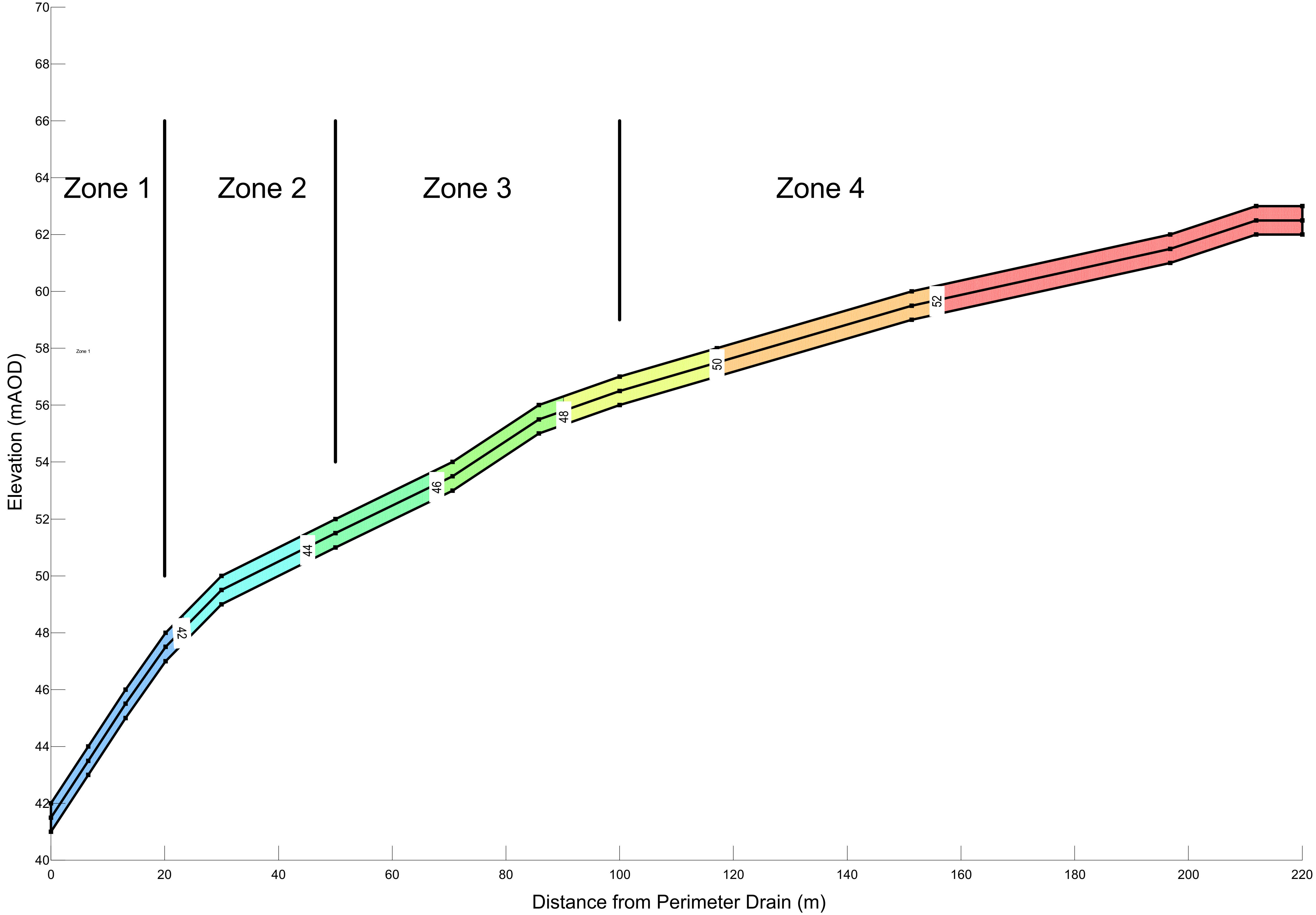


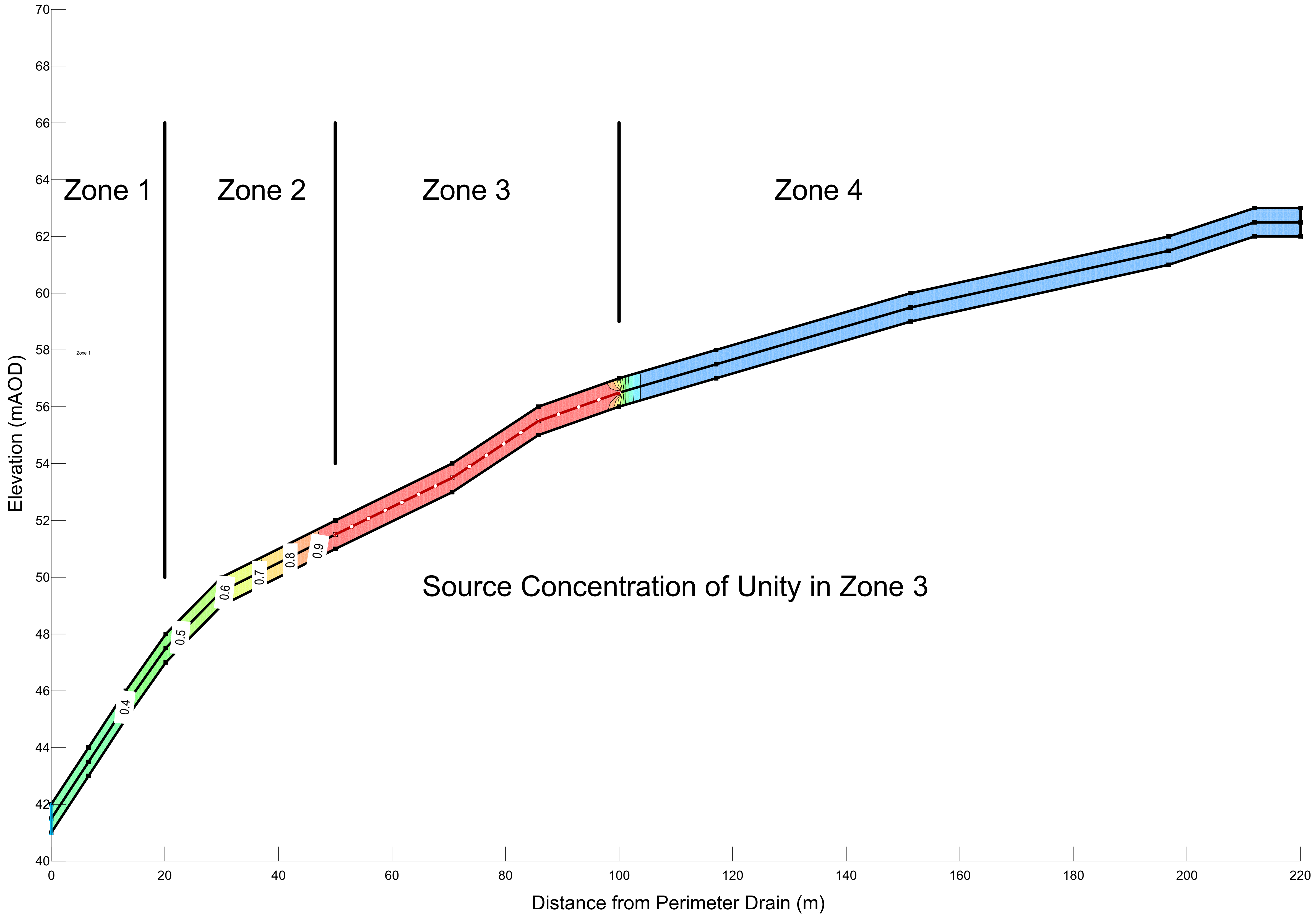

SOIL WATER RETENTION/CONDUCTIVITY CURVES

| SLADEN ASSOCIATES | Report No | Project | Figure |
|---|---|---|---|
| | 20-2218 | Maw Green Landfill, Crewe | **5** |



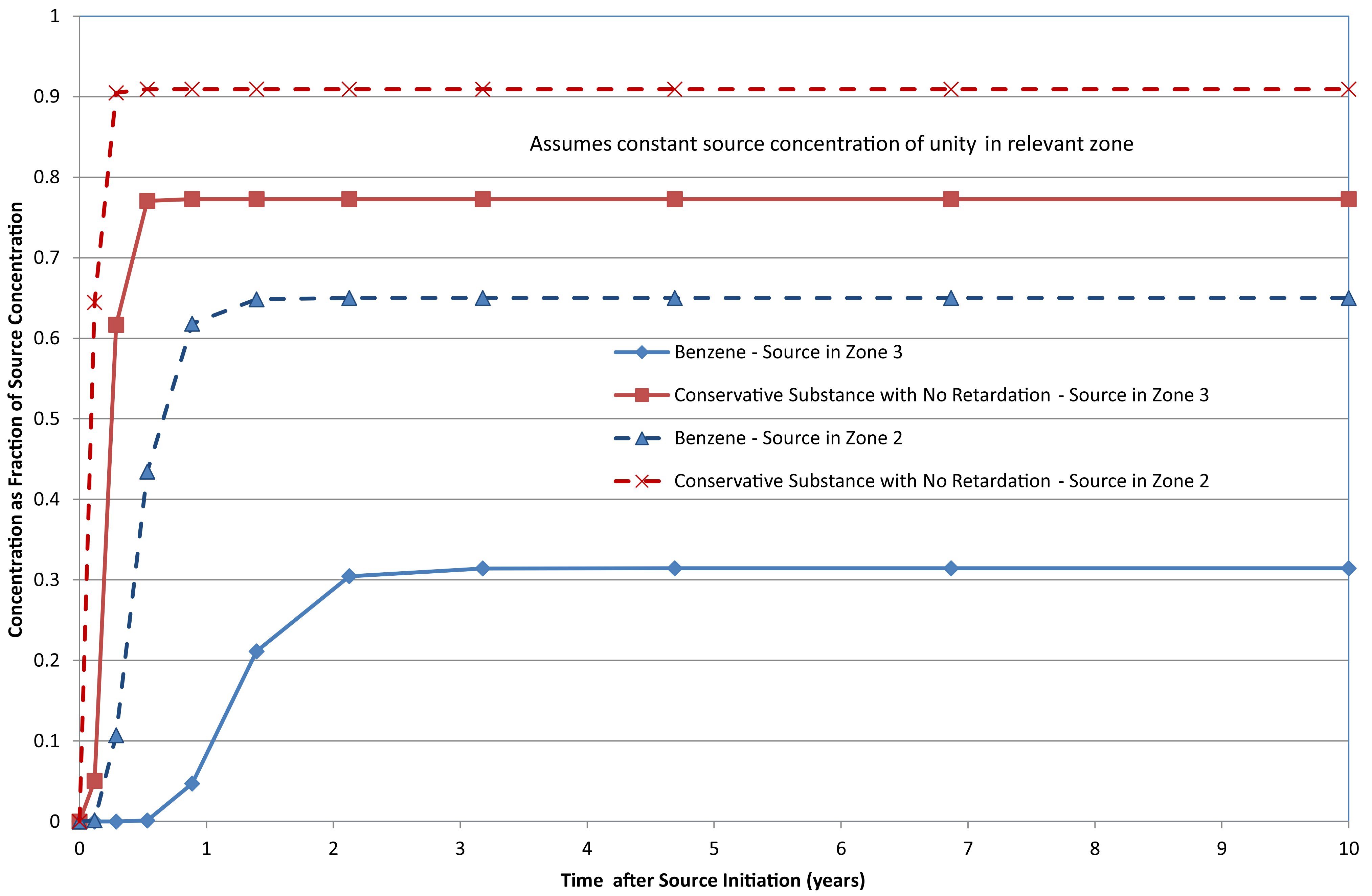

PREDICTED TOTAL HEAD CONDITIONS IN COVER SYSTEM

| SLADEN ASSOCIATES | Report No<br>20-2218 | Project<br>Maw Green Landfill, Crewe | Figure<br>**6** |
|---|---|---|---|



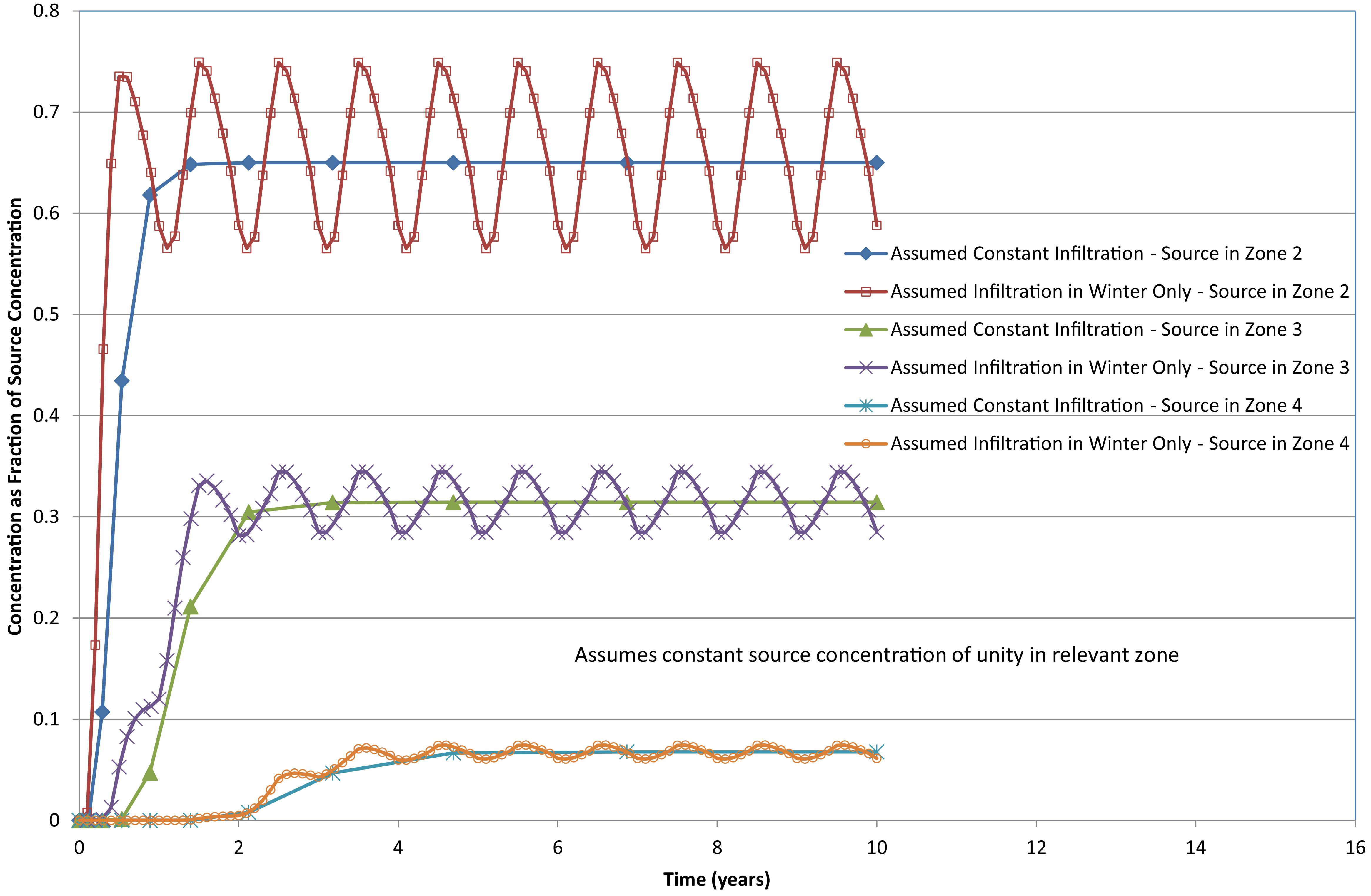

PREDICTED LONG TERM CONCENTRATION CONTOURS FOR BENZENE, SOURCE IN ZONE 3

| SLADEN ASSOCIATES | Report No<br>20-2218 | Project<br>Maw Green Landfill, Crewe | Figure<br>**7** |
|---|---|---|---|



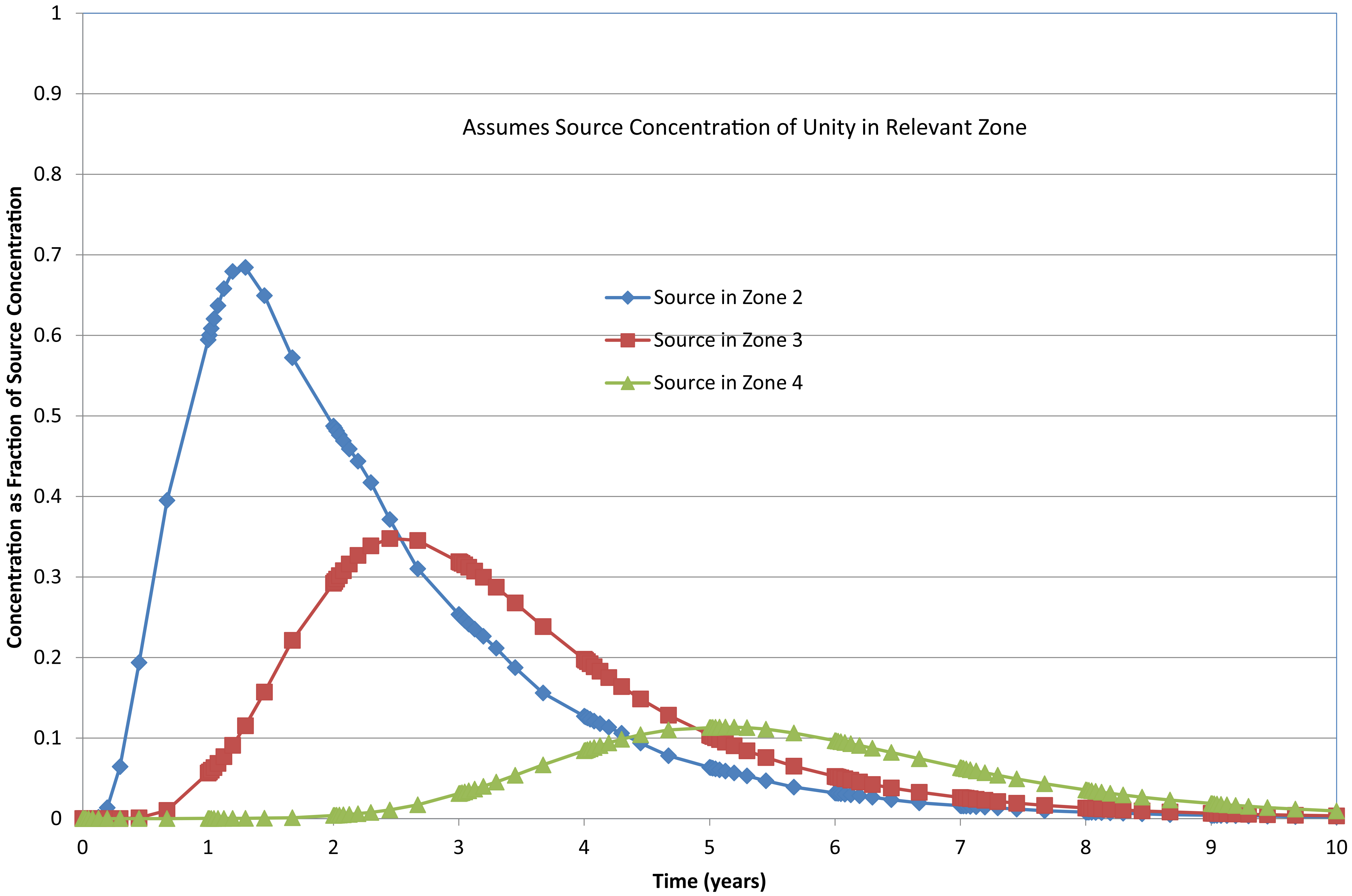

VARIATION IN PREDICTED DISCHARGE CONTAMINANT CONCENTRATION VERSUS TIME FOR BENZENE AND CONSERVATIVE COMPOUND - ASSUMED STEADY INFILTRATION

| SLADEN ASSOCIATES | Report No<br>20-2218 | Project<br>Maw Green Landfill, Crewe | Figure<br>**8** |
|---|---|---|---|



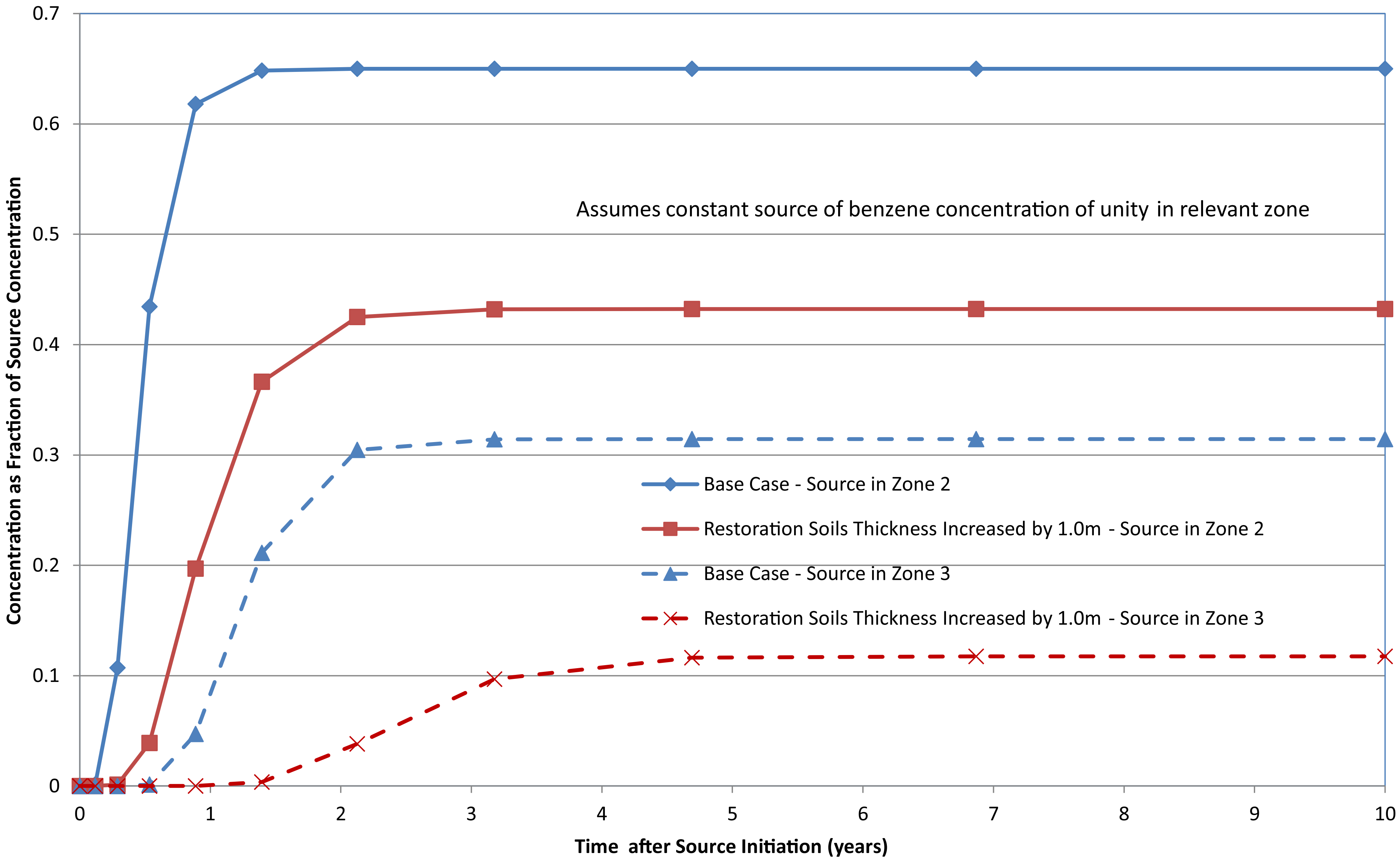

VARIATION IN PREDICTED DISCHARGE CONTAMINANT CONCENTRATION VERSUS TIME FOR BENZENE – ASSUMED SEASONALLY VARYING INFILTRATION

| SLADEN ASSOCIATES | Report No<br>20-2218 | Project<br>Maw Green Landfill, Crewe | Figure<br>**9** |
|---|---|---|---|




PREDICTED DISCHARGE CONCENTRATION OF AMMONIUM VERSUS TIME FROM SOURCE PLACEMENT

| SLADEN ASSOCIATES | Report No | Project | Figure |
|---|---|---|---|
| | 20-2218 | Maw Green Landfill, Crewe | **10** |




EFFECT OF INCREASING THICKNESS OF RESTORATION SOILS ON PREDICTED DISCHARGE CONCENTRATION

| SLADEN ASSOCIATES | Report No<br>20-2218 | Project<br>Maw Green Landfill, Crewe | Figure<br>**11** |
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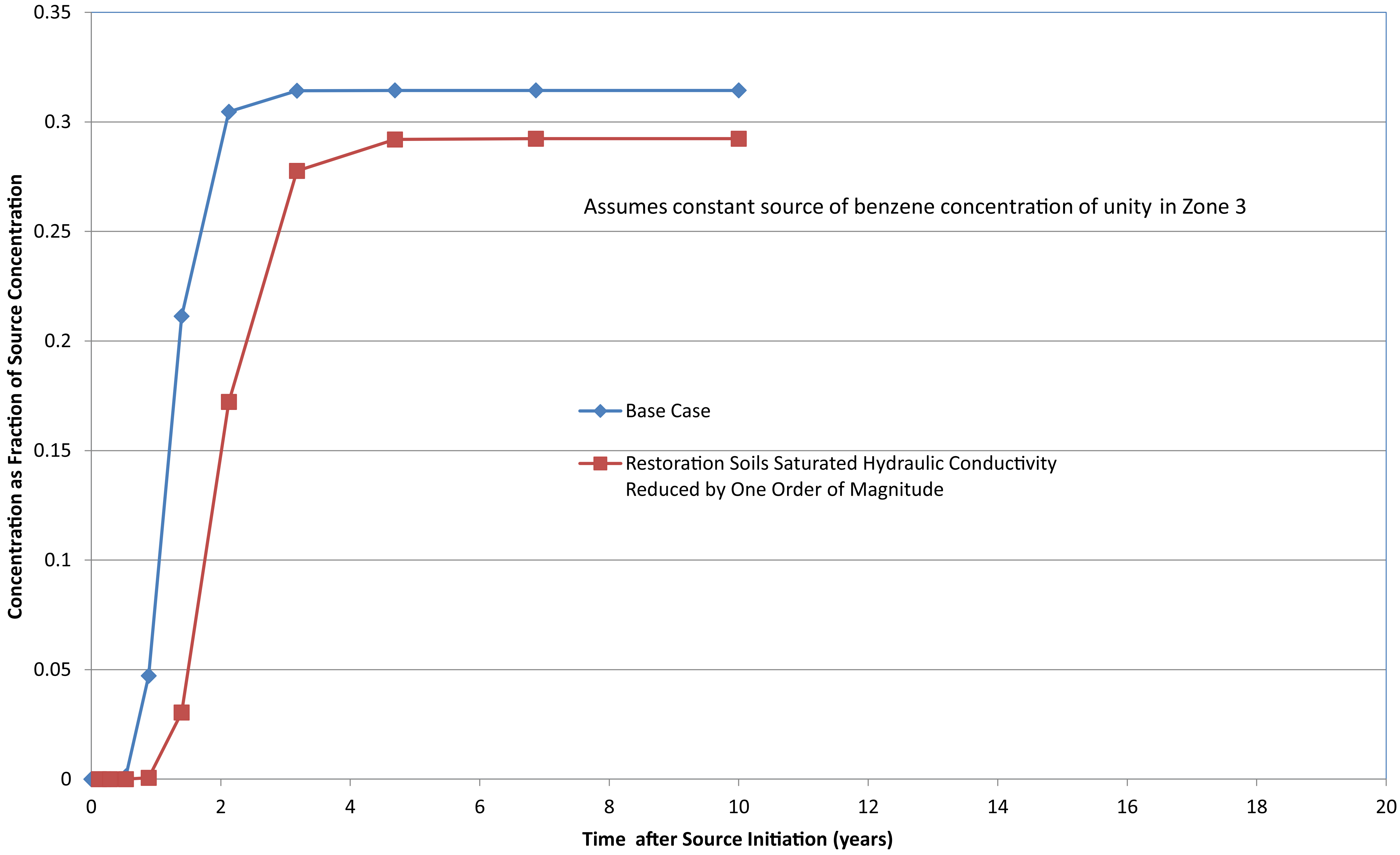


EFFECT OF REDUCING SATURATED CONDUCTIVITY OF RESTORATION SOILS ON PREDICTED DISCHARGE CONCENTRATION

| SLADEN ASSOCIATES | Report No<br>20-2218 | Project<br>Maw Green Landfill, Crewe | Figure<br>**12** |
|---|---|---|---|