

Prepared for

RESOURCE MANAGEMENT (UK) LIMITED

by

Landfill Solutions Ltd

Withyhedge Landfill Site

Leachate Recirculation System Design
and Operation

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REFERENCES

Note. Under separate documents

WHAug1601-RESOURCE MANAGEMENT CQA Plan Aug 2016

Gas Management Plan (GMP)

Addendum to the GMP – Doc No. AGMP/WHAug16/02

Leachate management plan (LMP) containing the following:

07514290132.501_LMP Phase 1_A.1_19.05.08

07514290132.501_Withyhedge_LMP Phase 1_A.0_23.11.07

11514290005.501_Withyhedge Leachate Mgmt System Review_A.0_Sep11

ENV 62 Q1 11514290005.501_Withyhedge Leachate Management System Review_B.1_Sept11

WHAug1601-RESOURCE MANAGEMENT CQA Plan Aug 2016

Geophysics Resistivity report 23_05_16

Withyhedge HRA 2012 revision v2

Drawings:

LFS-00103-WH01 (RECIRC LOCATIONS)

LFS-00104-WH02 (GAS FIELD ENHANCEMENT)

LFS-00103-WH05 (RECIRC LOCATIONS & CAPPED AREA)

J4297-Survey lines and capping edge - cells 1,2,3,

LFS-00103-WH01 (RECIRC LOCATIONS & LEACHATE ABSTRACTION LINES)

LFS-0111- (Actual surveyed capping edge from geophysical data) Scale A

LFS=0012- (Surveyed Capping edge transposed onto recirc. locations) Scale A

1 Introduction

Resource Management (UK) Limited have engaged Landfill Solutions Ltd as their preferred contractor to provide a cost effective solution to the issues of leachate management, landfill gas management and production and movement towards landfill completion for the Withyhedge Landfill site via leachate recirculation. The drilling contractor will be Magpie Drilling who have extensive experience working on landfill sites throughout the UK and have recently conducted work at Withyhedge.

A review of the existing management documentation including gas management, leachate management, gas risk assessment and odour management has been done. A section for each of these sections has been included in this report and should be read in accordance with the original documents; copies of which are appended. Those documents are still current and the individual sections are intended to deal with the recirculation of leachate only.

This Leachate Recirculation Plan is written in a manner that integrates with the existing Gas Management Plan¹ (GMP) and Leachate Management Plan (LMP) and is intended to give direct management instructions on actions. The document also covers detailed actions that relate to odour management which are collectively intended to not only facilitate efficient recirculation but to also maximise landfill gas production and collection, maintain leachate compliance and prevent gas and leachate escaping.

The document has been written to enhance the existing management plans and should be read in conjunction with them. The plan is specific to the recirculation system and control of emissions.

Leachate recirculation is a way of managing leachate by reintroducing collected leachate back into the dry tomb waste mass therefore promoting early settlement and stabilization of the landfill, and enhancement of gas production. However, potential problems that can be caused as a result of leachate recirculation have to be managed. These include the possibility of contaminating surface water (outbreaks, overspray, leaks), creating nuisance conditions and the migration of landfill gas, increasing the leachate head at the bottom of the landfill (increasing the potential for leachate to leak out of the landfill and impact ground water), and decreasing the stability of the solid waste (saturated conditions). Therefore, this document has been developed to present these concerns and to aid in development and review of leachate recirculation proposals.

The underlying philosophy being applied to landfill management in this case is to minimise the generation of leachate. Although leachate is being reintroduced into the landfill, there will actually be a reduction in the total leachate volume generated if microbial respiration is increased. Therefore, this management option is not contrary to this philosophy.

Leachate will be sourced from cells 1, 2 and 3 within phase 2 which are non-hazardous cells and will only be re-introduced into non-hazardous wastes cells. Both the source area and the recirculation area can be seen in diagram A1 Appendix A. *See comments on the drawing.*

Another underlying philosophy is, that the risk of leachate migration must be managed and at Withyhedge the LMP manages leachate levels in accordance with the site Environmental Permit, this

means that the head on the liner is minimized, however the current removal of leachate from the site leads to moisture removal from the site and in turn this means that the gas generation rates decline with the elongation of the gas generation curve over time. This is exacerbated by the installation of a low permeability capping which reduces infiltration and changes the water balance in the site. Impacts of gas generation can be seen quite simply by altering the moisture content in the GasSim Model; by doing this the gas production rate reduces and the gas generation profile extends.

A consequence of this is that gas control and anti-migration can become difficult because of the design specifications for the collector system being outmoded with gas generation rates. In essence the gas collector will have been sized against peak gas production and this means that once waste has been capped the collector may be too large and that, over time, gas collection not only becomes difficult without either increasing gas generation rates or modification(s) to the collection system.

Over the landfill gas production cycle, it is easier to collect larger volumes of landfill gas and to divert to engines than it is to deal with small volumes; the latter can mean higher suction pressures are required to scavenge gas and that the risk of gas migration can increase if measures are not taken to prevent this.

2. Rational for Recirculation of Leachate

The leachate recirculation can result in benefits; however, it has to be managed to avoid adverse impacts.

The purpose of this document is to outline how leachate recirculation will be managed and how the existing Permit conditions will be complied with and how recirculation will impact on the existing LMP, GMP and Environmental Permit.

The basis to this leachate recirculation plan is to identify and conform with the following components:

- Location where leachate will be recirculated (this can be seen in Appendix 1 (doc No. LFS-00103-WH01)
- Leachate will only be recirculated in areas of the landfill with a composite liner and engineered capping and leachate collection system. Routine monitoring of the engineering for heave and leachate escape will be used as a line of evidence to demonstrate that leachate is not perching
- Leachate collection system design. The plan includes supporting assumptions, drawings, and calculations to demonstrate the leachate collection system will be able to handle the additional volume of liquid and still maintain no more than one metre of head above the liner
- A method to verify excessive head is not collecting above the liner. (This will be demonstrated in the data generated in data collected by routine monitoring in accordance with the existing LMP and continuous monitoring data collected in the recirculation process which adjusts entry of leachate
- Inclusion of a routine testing programme to monitor changes to leachate composition. This is already delivered via the LMP and compliance with Permit conditions

- Environmental Permit Conditions
- Leachate Recirculation System (LMS).
- Existing Gas Management Plan (GMP).
- Addendum to the gas management plan
- Gas Collection Infrastructure Review
- Existing Leachate Management Plan (LMP)
- Odour Management

2.1 Pre-Operational measures

The proposed leachate recirculation at Withyhedge Landfill will only proceed in capped and lined areas as identified in document - LFS-00103-WH05 (recirc. locations and capped area)
The Pre-operational measures stipulated in Table S1.4A on page 28 of variation EPR/BP3131SG/V004 requires:

"A review of the pre-treatment requirements of leachate, prior to disposal and / or recirculation (unless already undertaken and approved as part of the Improvement Programme)"

In response to this condition we have reviewed the Hydrogeological Risk Assessments for the site and in particular the most recent HRA "Withyhedge Landfill Site, Consolidated Hydrogeological Risk Assessment WH/CHRA/v2.0" dated February 2012.

On page 35 of the report it states that "All scenarios show that the Withyhedge Landfill is groundwater directive compliant with the exception of the predicted discharge from the unlined cells within Phase 1 for Hazardous Substances at the base of the unsaturated zone and for ammoniacal nitrogen at the down gradient compliance point." This is based on LandSim modelling for the site with site leachate data.

Current leachate conditions at the site mean that leachate would not require treatment. We have also considered the potential impacts of leachate recirculation and whether this will alter the current HRA and the impact on groundwater from List I and List II substances and whether pre-treatment will be required. The pre-treatment of leachate at Withyhedge Landfill is not considered necessary as recirculation will only take place in capped and lined areas where leachate quality is not expected to change adversely; this is supported in SC030144/R6 dated 2009 titled "Evidence" A technical assessment of leachate recirculation, in that document it states:

"7.2 Adverse impact on leachate quality a very small number of instances were reported where operators thought there was an adverse impact (i.e. leachate concentrations increased). However, there do not seem to be data to support this perception. At least as many operators thought from their own experiences that there was no detectable impact on leachate quality. Some anecdotal evidence has noted short-lived flushes of acetogenic leachate reaching the site base on uncapped areas, following extreme rainfall events, and it is possible that the same could occur with high rates of recirculation."

As previously stated, recirculation of leachate will not be carried out into unlined/uncapped areas and therefore the short term acetogenic flushing will not be a consideration.

During installation of the system, a recirculation point installed within an uncapped area will be disconnected both physically and electronically in the control system until such time that the capping has been completed and permission granted to reconnect the point(s) by Natural Resources Wales (NRW).

Wells expected to be affected but not limited to are:

LR-11

LR-12

LR-18

3. Management Overview

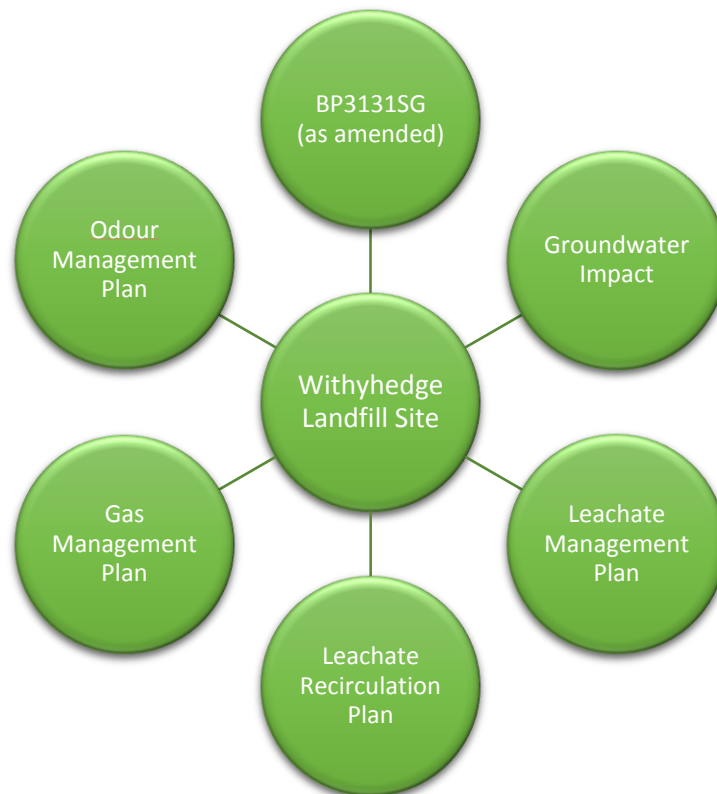


Fig. 1 The relationship between the permit, Leachate management, gas management, engineering, and emissions is shown.

4. LRS System Description

Landfill Solutions propose to carry out recirculation into an area of the site that has been suitably identified.

The area identified as having the necessary absorptive capacity has been subject to a geophysical survey with results confirming this areas suitability.

It is proposed that the sites legacy leachate will be introduced into the dry waste in systematically controlled process as a method of treating the leachate and the waste at source through anaerobic biological processes which leads to rapid waste stabilisation and settlement and shortening the sites liability and aftercare period. There is also the added benefit of a 20% to 100% increase in landfill gas production which can be harvested for means of renewable power generation.

Once installed the system will be capable of providing a complete leachate management solution to environmentally control and report all the necessary regulatory requirements for leachate, groundwater and perimeter borehole monitoring in-keeping with the regulatory requirements as contained in the permit for the site.

The theory is to gradually increase the moisture content to dampen not saturate the waste mass in order to avoid waste fracture through preferential pathways, this will bring the rate of waste degradation in the dry tomb back into line with that of the wet waste assumption that all the PPC risk assessments were originally based upon.

There is also the added benefit of creating a wetted waste barrier to help reduce the number of hot spots and landfill gas migration occurring, the wetted waste barrier also reduces the amount of oxygen ingress which can be troublesome when there are large fluctuations in atmospheric pressure.

The recirculation system design is based on the resistivity survey carried out at the site, waste depth, total height of waste, the area that has being filled and leachate seepage assessment. As leachate is recirculated through the pipe(s), it flows through the preferential pathways provided by the permeable media and disperses through the gravel, into the dry waste. The following considerations are taken into account during construction of the Leachate Recirculation System (LRS) piping network:

- There will be a separate system from that used for leachate collection or gas collection unless specifically designed as dual-purpose wells.
- Have well or injection point spacing based on leachate flow rates, waste mass permeability, and waste pore pressure.
- Distribute liquid uniformly within the zone of influence of each location and to prevent surface seeps.
- Be designed so that the leachate does not short circuit directly into the leachate collection system.
- The proposed leachate recirculation system will comprise of 30 injection points. Each leachate injection point will be fitted with a flow meter for measuring the amount of leachate delivered into the waste mass and two ATEX approved sensors to monitor level and internal

well pressure.

Whilst leachate is being introduced to each recirculation point, several criteria will be monitored:

- Volume of leachate introduced to each injection point
- The liquid level within each well. This is corrected for inaccuracies caused by fluctuations in well air/gas pressure.
- Duration of injection and period of rest
- Accumulative volumes
- Line pressure
- Valve status On/Off
- Leak detection
- Cycle number

As soon as one of the pre-set parameters is reached, injection will cease. The system will then move to the next available injection point. Operational data is saved automatically with regular data analysis carried out, with the resulting information, adjustments will be made to the delivery strategy.

Continuous monitoring will be used to monitor and control the leachate recirculation system, providing live and historical data for analysis and environmental and operational reporting.

In the event of an alarm, all leachate recirculation will cease and an alarm event log report will be produced identifying time, nature of fault, severity, actions, and down time incurred. The operator receives a copy of the report via email automatically with another once the fault has been rectified.

The system is maintained and operated by Resource Management (UK) Limited and remotely monitored by Landfill Solutions support and customer service, providing manned operations in normal working hours and 24 hour call out service/remote assistance in the event of an out of hours' alarm.

LRS. Performance - Objective

- The target volume for leachate recirculation is 24,000m³ per annum.
- Assuming a 5% per annum down time due to maintenance etc. and an adequate supply of leachate, the system will therefore treat up to 66m³ per day distributed across 30 injection points at 1.83m³ each.
- Initial configuration will be set such that 0.5 m³ will be injected into each well 4 times a day over 24hrs.
- The systems numerous built in safety devices will be monitoring and analysing on a continuous basis and system configuration reviewed periodically.

Performance Tracking:

Repeat geophysical studies will be conducted and compared to the previous data so that an accurate assessment of the life of the system can be determined and compared to the expected performance chart. Additional geophysical studies will be carried out as close to the anniversary to

the date the system is commissioned as possible, with results provided to NRW. It is understood that this frequency of these studies may at anytime be varied by NRW should the need arise.

This periodic insight into the moisture content of the waste mass is useful to predict the life of the system, in relation to its expected performance chart. This will determine any relocation and enhancements and prevent the waste from reaching saturation. An example of a Leachate Recirculation Performance system chart can be seen in Appendix D.

LRS Operational overview:

The system distributes leachate sequentially throughout the array moving from well to well once a set of parameters have been met. These being: -

- The main control system is functioning correctly
- The well in question has not been isolated in the main control system
- The leachate level in the well is below an acceptable level
- The tank capacity is sufficient
- The <T (time from fill to empty) is showing an increasing time.
- The leachate level in the base of the cell is below compliance limit
- There are no errors affecting the sequence (no failsafes)
- Temperature is above freezing
- Daily volume has not been reached

The sequence moves on to the next well when the current well leachate level reaches its maximum level or volume for that cycle/period has been reached.

During any cycle the introduced leachate causes pressure to rise in the well. These gas pressures act on the surface of the leachate to aid recirculation but also produce inaccurate readings from the level sensor at the base of each well.

By using an additional sensor in each well that measures these variations in pressure and subtracting these variations from the level sensor, each level reading is therefore corrected for changes in atmospheric and more importantly well pressure variations.

Each injection point can be set to automatic, manual or isolated from the main communication system from the main controller situated in the site office.

LRS Failsafes:

Immediate failsafes are triggered when out of range high/low pressures, levels and temperatures are detected. These parameters are monitored constantly and the system isolates the node and or closes the system down generating alarms and error messages immediately.

In addition to immediate failsafes, each injection well (node) has its own set of failsafes that monitor flow/pressure at the holding tank(s) and flow/pressure at the point of delivery. By constantly comparing these parameters the system uses this information to determine if there is a leak in the system or valve fault that will initiate a system shutdown and alarm.

Watchdog Timers

At each node there is an intelligent communication controller that operates each valve, reads sensors and sends indication to the system that the node is ready to receive leachate. These communication channels are connected using armour cabled wire and a license free radio transmission network as a backup. In the unlikely event of a communication failure, each watchdog timer would default its node to safe mode by closing all valves and disabling the supply pump until communication was established.

Actions: Any failures in the system will automatically notified to the Permit Holder with system prompts and email to Landfill Solutions Ltd who will liaise with the site manager to agree an action plan to include remedial actions and time scales.

Actions: Any failures in the LRS will be notified to the Permit Holder and an action plan agreed via e-mail to include remedial actions and time scales.

LRS - Visual Inspections

Actions: During start-up and routine operation, the landfill's surface will be examined daily by the site engineer and or the operator for:

- Seeps or excessive moisture on the side slopes at the elevation of the active recirculation lines and below caused by short-circuiting of leachate
- Ponding of surface water on the top and side slopes due to uneven settlement from the waste decomposition process
- Cracks or bulging regions on any surface, or and changes in slope indicative of geotechnical instability.
- Lateral heave can be caused by pressures created by leachate accumulation and by gases collecting under the leachate. In the case of heave this means that fugitive emissions also need to be assessed and gas pressures alleviated by elimination of perching and localised gas collection. Reference to the GMP and parts of this report that relate to landfill gas are essential.
- If an observed crack or bulge (lateral heave) continues to expand over 24-hour period, leachate recirculation should be immediately halted, and the site supervisor/engineer for the facility should be brought in to assess the situation before resuming recirculation activities. In addition, the above-grade piping network should be inspected weekly for damage.
- Odour observations will be made and recorded.
- Leachate holding tank bund liquid level will be observed by the operator at least once each week and more frequently in periods of heavy rainfall. The bund will be de-watered as necessary to maintain capacity in case of leakages or rupture of the holding tank.

5. Environmental Permit

Withyhedge Landfill is operated under an EPR Permit BP3131SG as amended.

6. Stability

The Stability Risk Assessment prepared by TerraConsult on behalf of Resource Management (UK) Limited, has been reviewed and in simple terms it appears that the factors of safety for slope stability at the site are acceptable in the areas where the leachate recirculation system is to be installed. The important factors that are identified as potential variables that could alter stability during recirculation are:

- Depth of leachate above basal liner
- Differential Settlement
- Pore water pressures (ru); and,
- Landfill gas pressures

The depth of leachate in this part of the site will be continually measured using sensors (discussed below in “System Design”). The differential settlement at the site will be no greater than already identified in point 52 of the report 0945/SRA which states that:

“The analysis indicates a maximum differential settlement across the subgrade of 250mm for a maximum height of 23.1m of waste placed on the basal liner. Strains were determined by assuming that the maximum calculated differential settlement occurred over the distance between the cell bunds. This maximum strain in the lining system / subgrade was calculated to be 0.01 %, which is less than 0.3% and is therefore considered acceptable.”

In this proposal we would expect to see some accelerated settlement as landfill gas production should increase and mass will be taken out of the site as a result of its collection. In this event we would anticipate that the control measures listed in Report 0945/SRA in 7.0 “MONITORING” are implemented as management controls (see pages 28 -29) and that the capping is visually inspected on a 6 monthly interval.

Landfill gas pressures should not alter as the aim is to collect the additional gas via the gas control system. Balancing of the gas field and requisite emissions monitoring will demonstrate gas is being collected and confirm gas pressures are acceptable.

Finally, pore water pressures in the layers above the cap’s membrane will be unaffected since introduction of leachate only occurs at 1m below the cap to a depth of 7m in total.

Internal pore water pressures at the water table will be controlled and even reduced by continuously monitoring the basal levels in accordance with the site permit. In order to achieve performance of the system it is expected that leachate in the designated area of recirculation be maintained below compliance. Our experience and the Environment Agency’s report SC030144/R6 titled “A technical assessment of leachate recirculation” show that recirculation has proved not to be detrimental to the stability of the waste and in most cases has contributed to early settlement and stabilisation if conducted in a controlled and calculated way as proposed in this document.

Management of Seep

A leachate seep involves the percolation of leachate from inside the landfill through landfill side slopes to the landfill exterior, typically at the toe. At Withyhedge Landfill inspection for seeps will occur on a daily basis. Seeps may occur during LRS operation due to the additional liquid introduced to the waste mass, which may be a result of the following:

- LCS not operating effectively to remove leachate from the cell
- Preferential flow pathways forming which cause leachate to concentrate in localised areas due to:
- Unequal compaction of waste
- Permeability variation between daily cover and deposited waste
- Excessive flow infiltrating into the waste mass via the LRS

The recirculation of leachate at Withyhedge Landfill in cells 1, 2 and 3 should not be an issue as recirculation will only occur in areas that are fully engineered, capped and lined. Also the mode of introduction is via vertical pipes and continually monitored for leachate volume introduction and hydraulic pressures and depths of leachate.

Actions - In the unlikely event that a seep does occurs the following steps will be taken by the Permit Holder:

- Leachate recirculation in the area of the seep will be ceased
- Inspection of the LRS to ensure it is functioning properly
- If necessary, the surface area of the seep will be excavated and the competency of the capping investigated and repaired to prevent future seepage in the area.
- Containment of seepage and routing to leachate collection areas such as the Leachate Pumping Storage Tank (LPST)

If leachate is discovered seeping from the engineered capping this may be accompanied with accumulated gas.

Actions: The seepage will be assessed for gas content and escape. In the event that gas is pressurised and leachate has accumulated, measures will be taken to alleviate leachate and gas accumulations.

Impact on Gas Control system - The introduction of additional leachate via the LRS could theoretically impact the operation of the landfill gas collection system and result in possible reduced performance. The LRS is designed with operational parameters that add moisture to the waste mass, but not at a rate or pressure that would lead to excessive introduction of liquid to the waste mass. However, waste heterogeneity could lead to short-circuiting of recirculated leachate into the gas control system.

Action: If the Permit Holder suspects that a gas well or horizontal collection pipe is being impacted by recirculation activities, a stepwise analysis will be conducted to identify specific gas

well(s) that may be impacted (which could be established through, for example, audible observation of the gas lines) and correlate the impacted wells with recirculation wells.

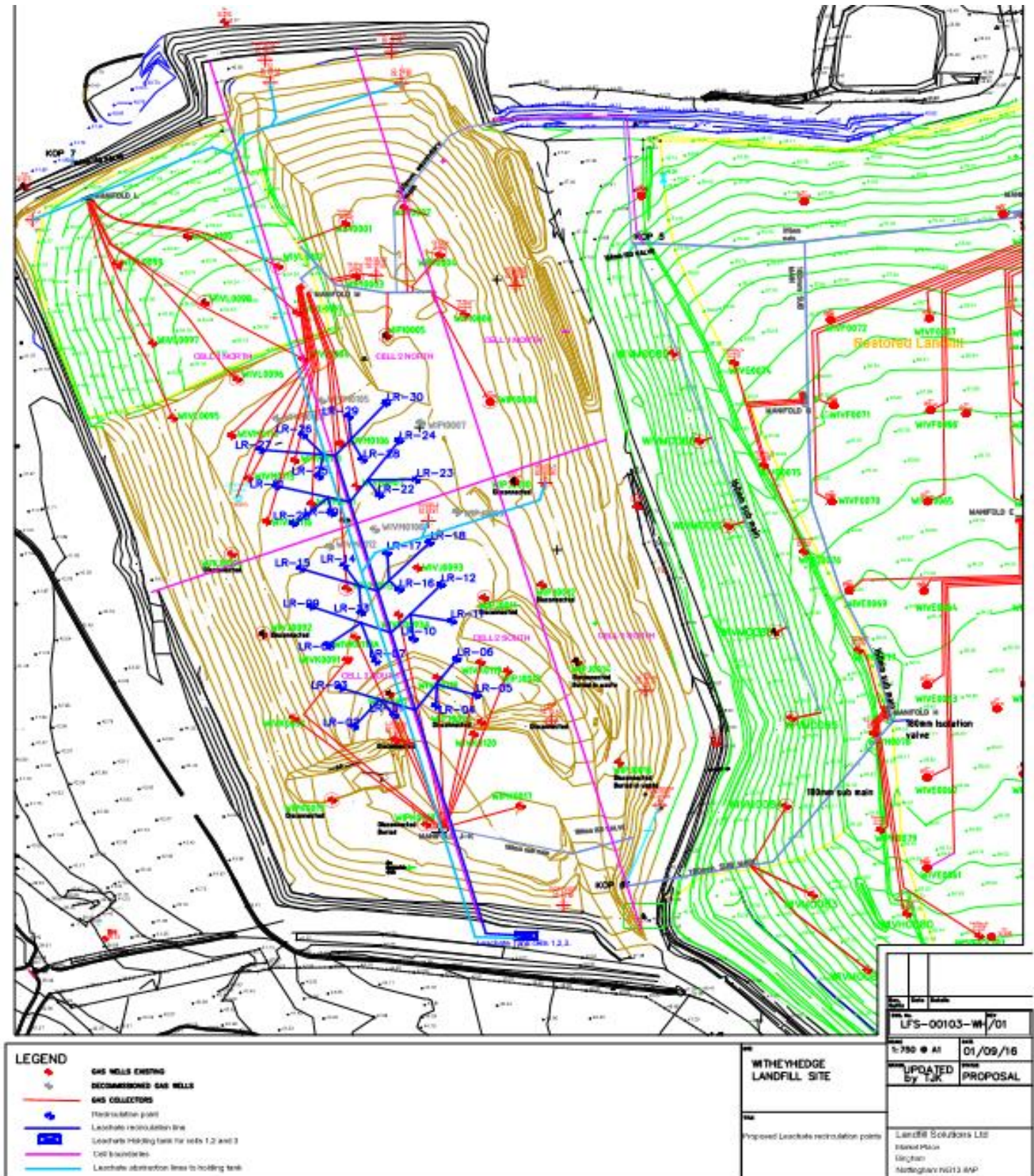
Action: Landfill gas field balancing will also be used to assess for blockages in pipe and wells with suction pressures at wells and manifolds being used routinely to consider blockages. High suction pressures at individual gas wells may be a consequence of leachate accumulation local to a well. Appendix B of the Gas Management Plan has an addendum that identifies additional procedures for assessing the operational gas collector for leachate/condensate blockages.

Action: The management of leachate will be in accordance with the Permit conditions and the requirement to maintain a leachate below compliance limit. In the event that perched leachate is identified as an issue and leachate recirculation is suspended in a localised area an action plan will be submitted to NRW to include measures to eliminate perching and to deal with accumulation of landfill gas below the leachate. This would typically include the installation of tiered landfill gas collectors, and/or the interception of perching via a borehole that drains the perching to base for collection via the Leachate Control System and in accordance with Permit Conditions.

Gas wells that are not fitted with leachate pumps may need to be retrofitted to accommodate the removal of excess leachate should it accumulate; however, the mode of introducing leachate is designed such to prevent saturation of waste.

APPENDIX A

Fig A1. Proposed recirculation area. Drawing ref - LFS-00103-WH01.dwg



APPENDIX B

Installation

1 Scope

The following procedure sets out the method of installation of the recirculation wells Withyhedge Landfill Site.

2 Prior to drilling into wastes

Well installation will be via the HDPE cap that has been welded and installed in accordance with a CQAP. In order to maintain the integrity of the cap outside of point of well entry the cover soils will be removed down to the capping and the HDPE will be carefully removed to expose the wastes. The area removed will be sufficient to drill down to the 7 metres (6 metres slotted) depth required to accommodate the LRS wells. A barrel auger will be used to create the orifice for well installation and sufficient clearance will be provided to avoid damaging the HDPE already installed. The location of each well will be fully surveyed for location and recorded.

3 After drilling into wastes

Landfill gas content will be measured will be assessed for methane, carbon dioxide, oxygen and pressure. A photographic record will be made to demonstrate the quality of the waste arising's and the quality of the installation. Once the hole has been drilled and the depth recorded the well will be installed to the specification in Appendix I. The HDPE capping will then be reinstated to the required standard and welded to the wells to achieve a seal.

4 Cells 1,2 and 3 Leachate abstraction

Drawing ref - LFS-00103-WH01 (RECIRC LOCATIONS & LEACHATE ABSTRACTION LINES) details the proposed connection of the leachate abstraction system (pale blue ident) to the 50m³ holding tank prior to recirculation.

The specification of the holding tank are:

A mild steel open bunded tank (horizontal cylindrical tank in a rectangular open bund).

Tank complete with:

- Tank capacity 50,000 litres
- Bund capacity 55,000 litres
- Access ladder and gantry
- 600mm manway
- Connections and isolation valves located within the bunded area
- 4" flanged inlet to flanged and but welded 63mm SDR11 pipe from leachate field
- 4" flanged outlet to flanged and but welded 63mm SDR11 pipe to leachate supply
- Tanker connection, if required, to be installed within the bunded area with a suitably sized external drip tray
- Sight glass located in bund area
- Finished in Mid Brunswick Green

This will be isolated physically from phase 1 abstraction system to ensure NO cross contamination of the recirculation system in cells 1, 2 and 3. (Included in CQA document.)

5 Health and safety

It is the responsibility of all personnel to ensure that their method of working is a safe method. Drilling contractors will provide their risk assessments to the Environmental Engineer for agreement prior to commencement of works.

Information to be provided by the site: A copy of the most recent trace gas analysis for the site that can be used for exposure risk assessment by all workers.

PPE Required: Reflective vest/jacket, hard hat, gloves, steel toe capped and mid soled boots. Personal monitor calibrated for Hydrogen Sulphide and Oxygen.

Useful Health and Safety Information

Methane is a colourless and odourless gas. When methane is mixed with air within its explosive range it can ignite or explode. The concentration limits are known as the lower and upper explosive limit. The flammable range for methane is 5-15% by volume. Ignition of such a mixture in a confined space may result in an explosion or a flash fire in open air. The risk of asphyxiation from landfill gas is present when persons have to enter a confined space or work in areas of inadequate ventilation. No one should enter or remain in any confined space where the oxygen content has fallen below 18% by volume. Minor constituents of landfill gas could have toxic effects if present in high concentrations. Trace gases do not usually represent a health hazard following normal atmospheric dilution – this assessment can be informed by using the trace component data provided by the site. Hydrogen sulphide is toxic at low concentrations hence the requirement for personal monitors; this is considered to be good practice.

APPENDIX C

Leachate Management Plan (LMP)

The existing LMP identifies measures for controlling leachate within the Withyhedge site. The recirculation of leachate will lead to some modifications in the way leachate distributes itself within the landfill, however the level of leachate within the landfill will remain in compliance with the permit.

Leachate levels will continue to be monitored in accordance with “2.4.2 Leachate Levels” of the LMP. Any changes in the cell, either positive or negative will be recorded and considered by the Permit Holder.

Actions: Resource Management (UK) Limited will carry out a continual review of leachate levels in the appropriate cell commencing when recirculation starts. Significant changes in control will be investigated and actioned.

In “3.2.4 Storage Capacity” the document cites absorptive capacity as potentially being between $0.02\text{m}^3/\text{tonne}$ to $0.24\text{m}^3/\text{tonne}$ based on literature values and it suggests the more use of the a more conservative value for assessing water balance.

In the Landfill Solutions Ltd system, the recirculation of leachate is stopped once drainable porosity is achieved and the recirculation is only carried out in capped areas. This means that no extra liquid is added to the system and the existing pumping system is still functioning and levels being measured.

Any preferential drainage pathways that lead to leachate passing to the base of the site will be investigated and actions taken to stop this happening. The intent of recirculation is to enhance gas generation and any bypass would be contrary to the intended outcomes.

Actions: In the event that leachate levels rise above compliance limits in the recirculation area recirculation will cease immediately (*controlled automatically by the LRS*) and an investigation will be carried out and appropriate actions taken to manage the situation.

The Resistivity Survey carried out at the site (2016) demonstrates that there are areas of waste that are dry. It is these areas where recirculation will take place with the intention of accelerating landfill gas production. The recirculated leachate will impact on the volume of leachate being tankered from the site. In the event that volumes of leachate taken from the recirculation cell do not fall this will be investigated by Resource Management (UK) Limited.

Actions: In association with the GMP the gas collection infrastructure should be checked once a week for liquid accumulation to ensure integrity is maintained. This includes well heads, collector lines, manifolds, gas main, KOP's and condensate discharging lines. This action will be required to ensure that recirculated leachate is not accumulating in the gas control system; this would have a negative impact on gas collection.

Odour Management

The OMP is currently being revised by the Permit Holder therefore odour will be managed in accordance with that revised document which will include the following detail as an appendix.

For the purposes of management odour will be managed initially via integrated control, meaning management of engineering, leachate and landfill gas. Observations of gas pressurisation, leachate leakage (seeps), lateral heave, are all related to odorous gas escape and therefore the primary mode of managing odour. In this case the management of odour is specific to the recirculation of leachate and not to the greater part of the site which is covered in the existing OMP.

With respect to odour management, the Actions cited within the LRP, LMP and GMP of this document are believed to be sufficient to intercept potential sources of odour. In the event that odour is verified as resulting from the Leachate Recirculation system the LRS will be turned off unless agreed with Natural Resources Wales.

Action: If an odour complaint is received or an odour (at levels likely to cause pollution outside the site) as perceived by the operator or an authorised officer of NRW then the leachate recirculation system will be shut down immediately as a default action until the issue is investigated unless otherwise agreed with Natural Resources Wales. A detailed olfactory assessment will be carried out along the leachate recirculation lines and injection wells. Associated flanks will similarly be assessed as will the gas control system where enhanced gas production could be the source of odour. If simple olfactory assessment does not confirm the location of the odour source, a more detailed assessment in accordance with the existing Odour Management Plan will be actioned.

Action: More detailed assessment will include:

- A specific methane survey using portable lasers to identify point source emissions of methane
- A hydrogen sulphide survey using an instrument calibrated to detect hydrogen sulphide down to ppb

Actions: In order to provide clarity on actions that need to be taken during recirculation they have been tabulated for simplicity in Table below:

Integrated Management Actions to be taken during recirculation

As soon as one of the pre-set parameters is reached, injection will cease. The system will then move to the next available injection point. Operational data is saved automatically with regular data analysis carried out, with the resulting information, adjustments will be made to the delivery strategy.
Continuous monitoring will be used to monitor and control the leachate recirculation system, providing live and historical data for analysis and environmental and operational reporting.
In the event of an alarm, all leachate recirculation will cease and an alarm event log report will be produced identifying time, nature of fault, severity, actions, and down time incurred. The operator receives a copy of the report via email automatically with another once the fault has been rectified.
The system is maintained and operated by Resource Management (UK) Limited and remotely monitored by Landfill Solutions support if required, providing manned operations in normal working hours and 24 hour call out service/remote assistance in the event of an out of hours' alarm.
The systems numerous built in safety devices will be monitoring and analysed continuously. System generated alarms will then need to be cleared before recirculation can proceed.
Repeat Geophysical studies will be conducted on each anniversary of the original study (<i>May 2016</i>) and compared so that an accurate assessment of the life of the system can be determined.
Immediate failsafe's are triggered when out of range high/low pressures, levels and temperatures are detected. These parameters are monitored constantly and the system isolates the node and or closes the system down generating alarms and error messages immediately.
In addition to immediate failsafe's, each injection well (node) has its own set of failsafe's that monitor flow/pressure at the holding tanks and flow/pressure at the point of delivery. By constantly comparing these parameters the system uses this information to determine if there is a leak in the system or valve fault that will initiate a system shutdown and alarm.
At each node there is an intelligent communication controller that operates each valve, reads sensors and sends indication to the system that the node is ready to receive leachate. These communication channels are connected using armour cabled wire and a license free radio transmission network as a backup. In the unlikely event of a communication failure, each watchdog timer would default its node to safe mode by closing all valves and disabling the supply pump until communication was established.
Actions: Any failures in the system will automatically notified to the Permit Holder with system prompts and email to Landfill Solutions Ltd who will liaise with the site manager to agree an action plan to include remedial actions and time scales.
During start-up and routine operation, the landfill's surface will be examined daily by the operator for:

Seeps or excessive moisture on the side slopes at the elevation of the active recirculation lines and below caused by short-circuiting of leachate

Ponding of surface water on the top and side slopes due to uneven settlement from the waste decomposition process

Cracks or bulging regions on any surface, or and changes in slope indicative of geotechnical instability.

Lateral heave can be caused by pressures created by leachate accumulation and by gases collecting under the leachate. In the case of heave this means that fugitive emissions also need to be assessed and gas pressures alleviated by elimination of perching and localised gas collection. Reference to the GMP and parts of this report that relate to landfill gas are essential. If an observed crack or bulge (lateral heave) continues to expand over 24-hour period, leachate recirculation should be immediately halted, and the site supervisor/engineer for the facility should be brought in to assess the situation before resuming recirculation activities. In addition, the above-grade piping network should be inspected weekly for damage.

In the unlikely event that a seep does occurs the following steps will be taken by the Permit Holder:

- Leachate recirculation in the area of the seep will be ceased
- Inspection of the LRS to ensure it is functioning properly
- If necessary, the surface area of the seep will be excavated and the competency of the capping investigated and repaired to prevent future seepage in the area.
- Containment of seepage and routing to leachate collection areas such as the Leachate Pumping Storage Tank (LPST)

Seepage will be assessed for gas content and escape. In the event that gas is pressurised and leachate has accumulated, measures will be taken to alleviate leachate and gas accumulations.

If the Permit Holder suspects that a gas well or horizontal collection pipe is being impacted by recirculation activities, a stepwise analysis will be conducted to identify specific gas well(s) that may be impacted (which could be established through, for example, audible observation of the gas lines) and correlate the impacted wells with recirculation wells.

Landfill gas field balancing will also be used to assess for blockages in pipe and wells with suction pressures at wells and manifolds being used routinely to consider blockages. High suction pressures at individual gas wells may be a consequence of leachate accumulation local to a well. Appendix B of the Gas Management Plan has an addendum that identifies additional procedures for assessing the operational gas collector for leachate/condensate blockages.

The management of leachate will be in accordance with the Permit conditions and the requirement to maintain a leachate head below 1 metre. In the event that perched leachate is identified as an issue and leachate recirculation is suspended in a localised area an action plan will be submitted to NRW to include measures to eliminate perching and to deal with accumulation of landfill gas below the leachate. This would typically include the installation of tiered landfill gas collectors, and/or the interception of perching via a borehole that drains the perching to base for collection via the Leachate Control System and in accordance with Permit Conditions. Gas wells that are not fitted with leachate pumps may need to be retrofitted to accommodate the removal of excess leachate should it accumulate, however the mode of introducing leachate is designed such to prevent saturation of waste.

The functionality of the Leachate Control System (LCS) is critical to successful LRS operation; the LRS actively adds liquids to the landfill and the LCS is the means by which liquid head on the liner is minimised via leachate removal from the landfill. The Environmental Permit for Withy hedge states “2.8.1 - The limits for the level of leachate listed in schedule 4 table S4.1 shall not be exceeded” – this level is set at 1 metre above the liner. Recirculation of leachate will assist in this compliance, however perching of leachate created by recirculation will be managed by elimination of the impact of low permeable layers in waste and leachate allowed to percolate waste increase moisture content as is the intention of the LRS.

Differential pressure readings will be considered at different points of the collector main, for instance at the well head and the manifold. This will identify disconnections in the pipe and blockages in a particular section. In the event of a blockage being discovered via this manner it will need to be reported immediately to the Permit Holder so that they can take appropriate action with respect to leachate recirculation. The requirements of the Gas Management plan will also need to be satisfied by EnerG.

A monthly assessment of the existing gas collection system’s efficacy in treating landfill gas will be undertaken by EnerG and reported back to the operator.

If the horizontal collector is intercepted it will be further decommissioned by chasing the pipe back one metre and sealing each end with a bentonite plug.

A photographic record will be taken of the decommissioned collector, the location given a unique reference and its location noted on the final CQA report

In the event that additional gas wells are required a review of gas collector main will be required to demonstrate the existing main has sufficient capacity to accept the maximum quantity of gas anticipated. There is potential to create a ring main from the existing gas collectors and this may be the most cost effective means of collecting additional gas. If needed.

Extra vigilance will need to be taken when the gas control system is being balanced especially where there is obvious uplift in gas production. Not only will field balancing be carried out but observations will be made that relate to accelerated settlement that may occur as a result of loss of mass as a result of landfill gas production.

Resource Management (UK) Limited will carry out a continual review of leachate levels in the appropriate cell commencing when recirculation starts. Significant changes in control will be investigated and actioned.

In the event that leachate levels are rising in the recirculation area an investigation will be carried out and appropriate actions taken to manage the situation.

In the event that leachate volumes being pumped from the recirculation area an investigation will be carried out and appropriate actions taken to manage the situation, this will need to include an assessment of gas production rates.

In association with the GMP the gas collection infrastructure should be checked at least once a week for liquid accumulation to ensure integrity is maintained. This includes well heads, collector lines, manifolds, gas main, KOP's and condensate discharging lines. This action will be required to ensure that recirculated leachate is not accumulating in the gas control system; this would have a negative impact on gas collection.

Action: More detailed assessment would include:

- A specific methane survey using portable lasers to identify point source emissions of methane.
- A hydrogen sulphide survey using an instrument calibrated to detect hydrogen sulphide down to ppb

Installations will be recorded in accordance with the appendices and a Construction Quality Assurance document presented to NRW.

Interaction Matrix

LRP	GMP and Design	LMP	GasSim	Appendix 2 of the GMP	Odour Management
Identifies there will be an impact on gas control system and gas production rates	The GMP identifies that the gas field will be balanced and managed to Impact on gas control system and gas production rates in a manner where fugitive emissions will not be an issue	Identifies there will be an impact on gas control system and gas production rates	The GasSim model for the site demonstrates that the Impact on gas control system and gas production rates is manageable via the Gas Management Plan.	Additional gas will be collected via field balancing techniques where Methane, Carbon Dioxide, Oxygen, Balance gas and differential pressure are managed to collect all gas safely. In any case the collection of gas will be managed in accordance with 4.1.1 of the GMP – Gas Field Balancing and the Addendum to the Gas Management Plan, Document No. AGMP/WH November	Additional gas will be collected in accordance with the GMP and Appendix 2 of that document and odour will be managed via the GMP and in accordance with the Odour Management Plan..
Efficacy for gas collection infrastructure to accommodate landfill gas volumes produced	A review of the gas management system plan shows that the existing gas collector is capable dealing with of 567m ³ gas per hour (velocity of 10m sec ⁻¹) being collectable via the northern 160mm 17.6 SDR collector and 720m ³ per hour via the Southern 180mm 17.6 SDR pipe. The Northern section of the cell has 24 gas wells, the southern section has 10 wells. The initial phase of leachate recirculation is expected to affect approximately 15 wells. The existing gas collector is capable of collecting 85% of 1400m ³ gas per hour which equates to 1190m ³		The GasSim model for the whole site suggests that the maximum volumes of gas being produced for the whole site would be 1400m ³ /hr. Page 13 of the Gas Management Plan states that the 50 percentile plot indicates gas production rate of approximately 720m ³ /hour in 2014.	Additional gas will be collected via field balancing techniques where Methane, Carbon Dioxide, Oxygen, Balance gas and differential Pressure are managed to collect all gas safely. In any case the collection of gas will be managed in accordance with 4.1.1 of the GMP – “Gas Field Balancing”	

			Landfill gas modelling has already demonstrated odour should not be a problem in terms of volumes of gas produced. This is conditional that LRP, LMP GMP and Appendix 2 of the GMP are followed.	Additional landfill gas produced as a consequence of recirculation will be intercepted via the existing field balancing protocols and in addition delivery of Gases to the GUP and changes in pressures. The primary reason for recirculation is to collect additional gas produced and diversion to the site engine/s. Additional gas wells will be introduced as soon as uplift	Odour issues that are suspected to originate from the recirculation area will initially be investigated in accordance with the existing OMP
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Key

- New/Existing Proposed Landfill
- Existing Landfill
- Existing Road
- Existing Watercourse
- Existing Foul Sewer

TerraConsult
Solid Waste Centre, Solid Lane,
Barnet, Herts AL4 4TX

Wetherhedge Landfill Site

Location Plan

Scale	1:500	1:1000
Author	TerraConsult	
Ref	Wetherhedge	
Date	10/01/2014	Wetherhedge Landfill Site
Rev	1.0	Wetherhedge Landfill Site

Wetherhedge Landfill Site
Wetherhedge Landfill Site
Wetherhedge Landfill Site

APPENDIX D

Recirculation system performance chart



Landfill Gas Performance

Recirculation commences	Waste volume in m3	Gas generation rate 3 months in m3	Gas generation rate 6 months in m3	Gassim peak generation rate in 2017 (m3)
2016				
Wet conditions	216,000	80	180	365
Average conditions	216,000	30	75	150

APPENDIX E

Withyhedge Landfill Site Geophysical investigation to map variations in moisture content within the waste mass

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Table 3:A – Proposed ERT data acquisition parameters

1. SITE INFORMATION

1.1 General

1.1.1 The requirement was for information relating to possible lateral and vertical variations in moisture content within Withyhedge Landfill site in Pembrokeshire.

1.1.2 From our discussions we understood that the landfill structures were capped with a MDPE membrane and covered with top soil to a depth of approximately 0.5-1m. The maximum depth of landfill is expected to be 25-30m bgl.

1.1.3 The area considered for investigation is shown as area 'B' along with surveyed capping edge in:
Drawing ref - J4297-Survey lines and capping edge - cells 1,2,3,

2. OBJECTIVES AND SCOPE

2.1 Objectives

2.1.1 The specific objectives of the investigation were to map lateral and vertical relative variations in moisture content within existing landfill material

2.2 Scope

2.2.1 The specific scope of the investigation is as follows:

- Site B comprising one area of 250 m x 80 m
 - 2 survey lines along the long axis in each area

Site	Area	Width	Length	Survey Lines	Total Length	Notes
Withyhedge	B	2	8	3 x 250	750	

Table 2:A – Geophysical investigation scope.

3. PROPOSED METHODS

3.1 Methods

3.1.1 We have previously provided a proposal below for a combined geophysical investigation using electrical resistivity tomography (ERT).

3.2 Rationale

3.2.1 The electrical resistivity tomography method provides a 2-D depth cross-section along each survey line of in situ resistivity distribution. Subsurface

material resistivity is primarily a function of porosity and in particular the nature of the pore fluid/gas.

3.2.2 Low porosity, dry materials will generally yield high resistivity values; high porosity, saturated materials will yield low resistivity values. By mapping lateral and vertical variations in resistivity along a survey line relative changes in moisture content can be inferred and interpreted. Whilst resistivity data cannot be used to determine absolute moisture content values it is a useful method for mapping relative changes within the survey area and can be semi-quantitatively correlated by carrying out survey over areas of known moisture content.

3.3 Electrical Resistivity Tomography (ERT)

3.3.1 The electrical resistivity data was acquired along each survey line using an Iris Syscal Pro multichannel resistivity system.

3.3.2 Data was acquired along the long axis of each site area along three survey lines each approx. 250 m in length. Lines were positioned roughly equidistant to cover the 80 m corridor width.

3.3.3 Survey data acquisition protocols are summarised in the table below. Specific data acquisition parameters were established on site by the lead geophysicist to optimise data quality with respect to the objectives. Optimisation was based upon a review of initial test or trial data acquired on site prior to commencement of the full survey. The initial test data suggested that the site conditions would not compromise achieving the objectives and the survey was carried out.

Parameter	Description
Equipment	Syscal Pro
Array Type	Wenner-Schlumberger
Max number of electrodes	96
Min electrode spacing	3 m
On time	0.5 sec
Off time	0.1 sec
Cycles	3
Depth of investigation	25-30 m

Table 3:A – Proposed ERT data acquisition parameters

3.3.4 The ERT equipment was configured to provide information to a maximum depth of ~30 m. Depth coverage increases as a function of offset from the

start and end of the survey line – in this case maximum depth penetration was reached within ~60 m of the start and end of each line.

3.3.5 Data was stored digitally in ASCII format to allow office based post processing. Positional information relating to survey line location and elevation was acquired using RTK equipment with topographic information incorporated into processing workflows.

3.4 Reporting

3.4.1 Data was processed using industry standard RES2DINV software. All data has been QC checked by an experienced geophysicist. Further to removal of any spurious data points, data was then subject to an iterative, least squares inversion process to provide a continuous colour cross-section of 'true-resistivity'.

3.4.2 Processed data is then presented as 2-D depth cross-sections. Interpretation was carried out based upon the geophysical data and available intrusive information – the position of any key layer boundaries defined by changes in resistivity are annotated onto the cross-sections as necessary along with any lateral or vertical changes in resistivity that are likely to be associated with relative changes in moisture content.

3.4.3 All features identified from the dataset are summarised on a base drawing of the site.

4. RELOCATION

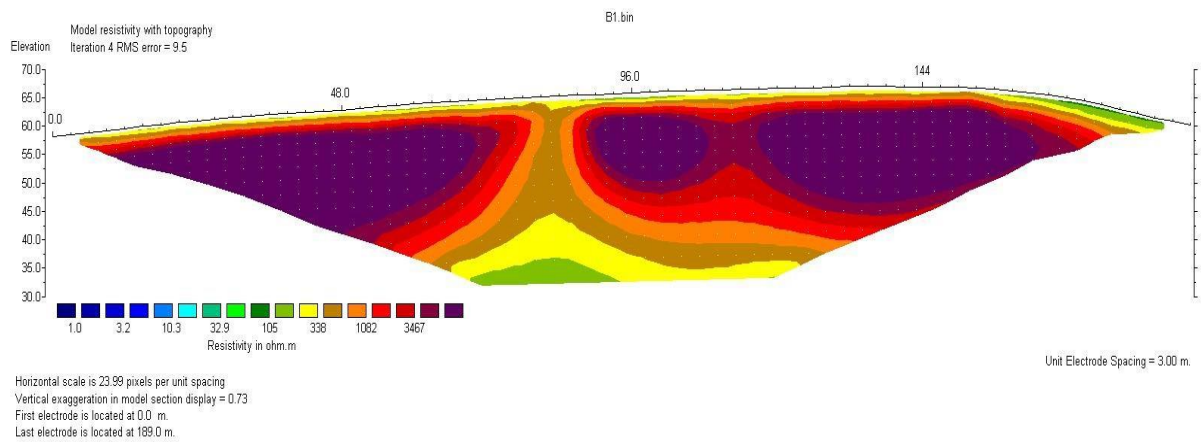
4.1. Results have been referenced to an agreed project coordinate system. Relocation of all survey data was done to within a tolerance of +/- 0.2 m).

5. EFFECTIVENESS

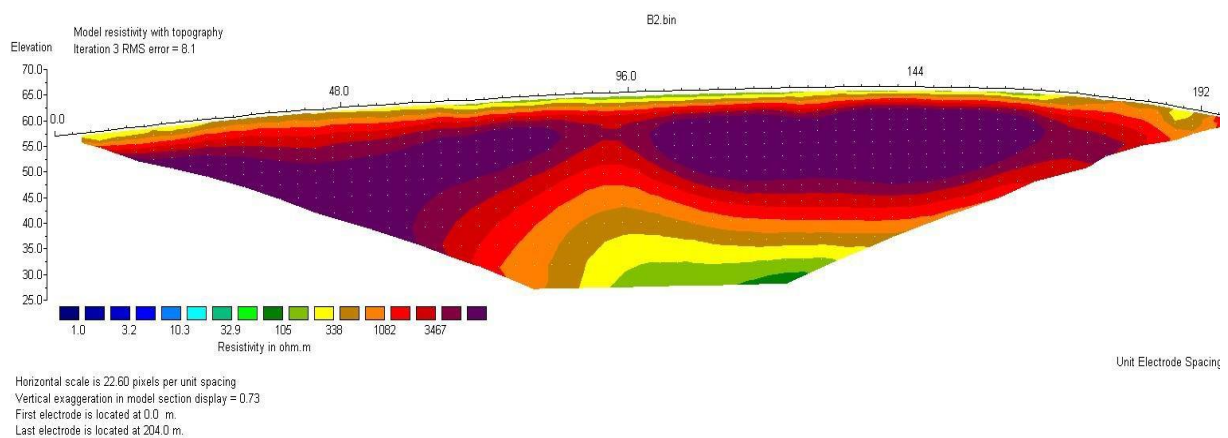
5.1 Generic

5.1.1 As with any geophysical investigation, the effectiveness of the proposed approach will be influenced by the characteristics of the ground, the target and site conditions. We cannot guarantee that we will locate all target features, or that all of the features reported will be of engineering significance.

6. RESULTS (Area B)



Line 1



Line 2

7. CONCLUSION

The results for area B show large areas of high resistivity indicating a large entombed waste mass almost to the base of the site with very little moisture present in the waste above 5m from pit base.

The inclusion rising to the surface was identified in the area of a gas extraction well that has deposited condensate around the well and would be avoided although still having 60% of its absorptive capacity remaining.

Area B is in our opinion the most suitable area for leachate recirculation yielding results equal to or better than the projected recirculation performance table.