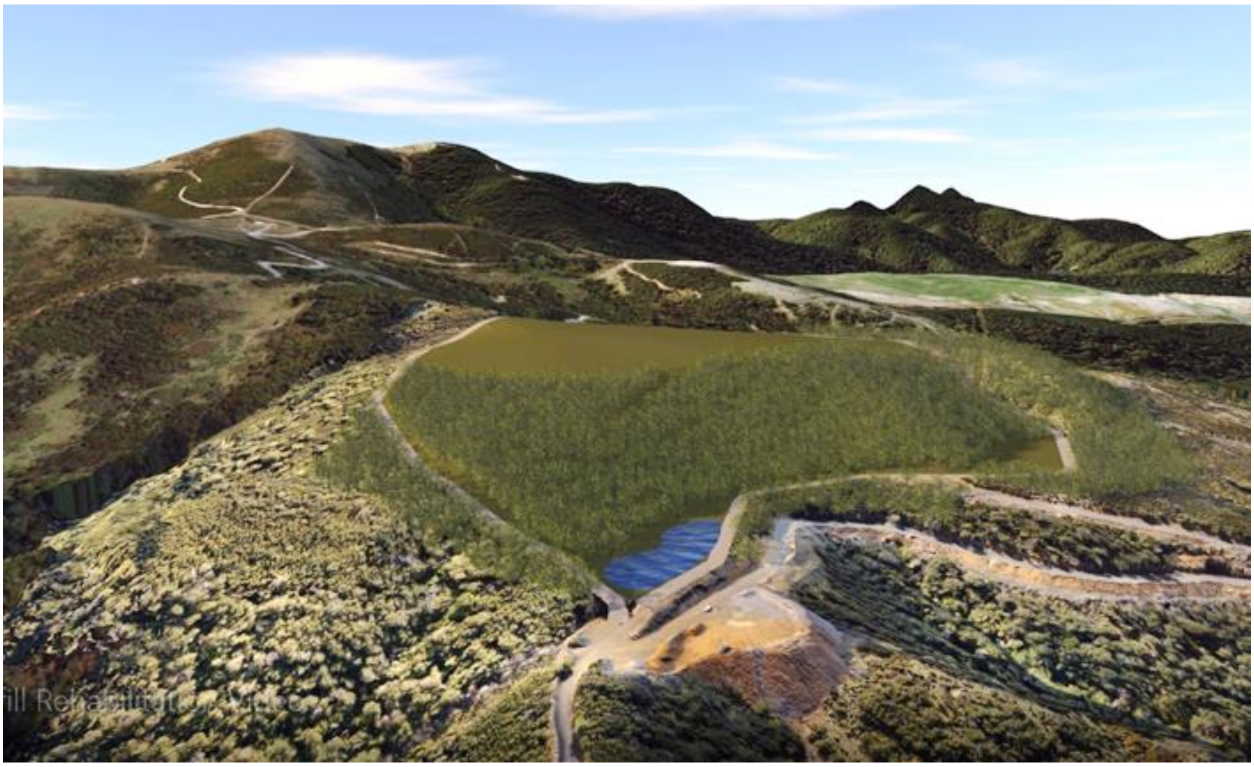
Appendix 5

Woodstock Landfill

Engineering Technical Report Issue 2



INDIGENOUS REGENERATION *through* **INNOVATIVE LANDFILL PRACTICE**

June 2022

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DOCUMENT CONTROL

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1	27/4/21	Martin Pinkham		Darryn Shepherd
2	10/6/22	Martin Pinkham		Darryn Shepherd

Contents

This updated report incorporates the contents of Addendum 1 to Engineering Report issued in February 2022, and further information. The subsequent additions to this report are shown as blue coloured text.
Where there is a reference to a Drawing it refers to a drawing in Attachment 8 Appendix 2 Drawings Issue 3.

1 Introduction

This engineering concept design report is to support resource consent applications for a new landfill located at Woodstock, North Canterbury. The Woodstock Landfill will provide a new solid waste management and disposal facility to provide an alternative facility for the disposal of C&D waste and contaminated soils to the existing Kate Valley Landfill.

This report describes the engineering concept design of the proposed landfill. The design has been undertaken to a level to provide a basis for all specialist assessments of potential effects associated with the landfill development, and to clearly define the general works proposed. The consent design will be developed into a detailed design for construction purposes, where the concepts described will be further developed and may change in detail from those presented.

However, it is not anticipated that the overall concepts will change, other than to incorporate technology and practice developments that may occur over the relatively long life of the project. Any changes made will be within the scope of the resource consents or other approvals that have been given for the project.

This report covers the following aspects of the project:

- The proposed formation of the landfill, staging, finished fill profile and airspace volume provided;
- Construction of the landfill, including toe bund requirements, operational soil requirements and other construction aspects;
- The key environmental containment measures including the lining and capping systems.
- Leachate management systems;
- Stormwater management systems;
- Landfill gas management; and
- Ancillary works and infrastructure required for the landfill including access roads, the bin exchange area, staff facilities, water supply and wastewater disposal.

The description of these aspects is supported by a series of concept level drawings that are bound separately in Appendix 2 Drawings Issue 3.

The design of the landfill and associated infrastructure is generally in accordance with the WasteMINZ WasteMINZ Guidelines: 2018 (WasteMINZ Guidelines).

2 Site description

The proposed landfill is located the Woodstock area, approximately 16 km west of Oxford and 70 km northwest of Christchurch. The landfill is to be constructed on a south facing ridge, which is currently operated as a hard rock quarry. The landfill is slightly to the east of the head of the upper end of the catchment of the Woodstock Stream, which flows into the Eyre River.

Access to the existing quarry, and proposed landfill, is on a private road approximately 2 km in length commencing at Trig Road and climbing up a valley before crossing the Woodstock Stream into the main quarry site. The predominant vegetation along this access road valley is a pine plantation forest.

Small portions of an adjacent area will be utilised, as required, for the long-term stockpiling of soils needed for landfill operation, and as a source for obtaining materials suitable for liner and capping construction.

A plan showing the overall site is shown Drawing A1 in Appendix 2, and an aerial photograph of the existing quarry is shown on Drawing A2. A full description of the site can be found in the AEE.

The site geology comprises Rakaia Terrane greywacke bedrock.

3 Project description

The project comprises the construction of a landfill with a capacity of approximately 3.2 Mm^3 to provide for the safe disposal of solid waste for a period of approximately 35 years. The landfill will be designed to accept solid waste in accordance with acceptance criteria described in the Application and in Appendix 10 Proposed Conditions of Consent.

The overall project will comprise:

- All works associated with the development of an operating landfill on the identified footprint area including:
  - Earthworks from the quarry operation to construct the required basegrades;
  - Construction of an underdrainage system to collect any groundwater under the liner;
  - Construction of a lining system including an impermeable lining system to prevent leachate seepage into the surrounding environment;
  - Construction of a leachate collection system above the impermeable lining system;
  - Stormwater control around the constructed landfill and ultimate treatment of stormwater before it leaves the site;
  - A landfill gas (LFG) collection system to collect LFG from the placed waste (if required);
- A leachate management system, including leachate storage, and possibly leachate treatment facilities;
- LFG treatment initially by flaring, but possibly later by a LFG to energy plant, with any excess being flared;
- Provision of water supplies for operational (non-potable) and staff (potable) requirements;
- A bin exchange area where road vehicles will deposit bins for site vehicles to transport them to the landfill tip face;
- All other roads required to access the various parts of the site;
- Operational infrastructure;
- Facilities for site staff;
- Maintenance facilities for site plant and equipment;

The details of these works are described in subsequent sections of this report.

Development of a landfill is essentially a long-term construction project. The landfill will be developed in stages, with one stage being filled with waste while the next stage is being constructed as the result of the quarry operation.

4 Landfill design

4.1 Geotechnical design

The geotechnical design for the landfill is detailed in the Engineering Geological Assessment (EGA) enclosed in Appendix 3. The concept level design for all works associated with the Woodstock Landfill have been developed in accordance with the recommendations of the Engineering Geological Assessment.

The geotechnical investigations show that the proposed landfill footprint and access road alignment are underlain by Rakaia Terrane greywacke bedrock. The upper layers of the bedrock are highly weathered. Overall, the EGA concludes that the land within the proposed project area is suitable for landfill development in accordance with the WasteMINZ Guidelines. In general, the landfill footprint overlies very low permeability rock, which will provide good natural containment, and is not close to any active faults. Suitable soils are available on site for liner and capping construction and landfill operation.

4.1.1 Formation stability

Slope stability analyses for the proposed cut design slopes of the quarry indicate adequate slope stability for the proposed design. The details of the slope stability analysis are provided in Attachment 2 Letter from Geology Consultant Issue 2. The analyses has shown that there should be slightly different designs for the south facing and east facing slopes. These are also shown on Details E and F of Drawing C02 in Appendix 2.
The practicalities of the construction of the sidewalls has also been considered and the following has been incorporated into the design to ensure a stable and safe quarry wall can be constructed and lined:

- The top of the quarry wall has been set back a minimum of 25m from the site boundary.
- The top of the quarry wall 25m setback area provides practical access for construction and maintenance activities
- The benches are graded towards to the rock face to mimimise water flowing over the near vertical faces and to retain any minor rock failures from the walls above them
- The benches are graded away from the operational landfill areas
- The shotcreting and polyurea application is to be constructed from the bottom up to minimise the time that the wall lining system is exposed to the weather.

The constructability of the quarry walls, and the safety of the staff undertaking the work is a matter that the operator needs to factor into the preparation of the site management plan, and site safety plan. For the proposed design of the quarry walls it is considered that the construction of the shotcrete and polyurea waterproofing is best completed from the floor up, in 2.5 to 3.5m lifts, using equipment and labour working from the waste as a platform.

It is also recommended that no staff or equipment work on the benches unless suspended by approved and certified lifting equipment.

During the detailed design of each stage of the works additional investigation, slope stability modelling and hazard and risk assessment will be required as the quarry wall formation moves in a westerly direction.

4.1.2 Landfill stability

The overall form and design of a landfill must be such that the landfill is stable over its lifetime. For a landfill, as proposed for Woodstock Landfill, the sides of the old quarry contain the fill so that once filled across the valley (in an east west direction) the overall landfill is stable on any cross section through the landfill.

However, consideration needs to be given to the long-term stability of the landfill well after the landfill is filled along the south face of the landfill.

Overall stability of the landfill along the south face is maintained by:

- Providing a toe bund at the toe of the landfill to act as a buttress for the landfill refuse during operations where in situ rock cannot provide such support. The bund is proposed to be a minimum of 6 m high, 10 m wide at the top and sloping at 3H:1V on either side of the bund. Most of the length of the bund will be approximately 12m high. The details of the bund are shown on Detail M of Drawing C04 in Appendix 2.
- Constructing a fill face above the toe bund at a stable slope, in this case selected to be 1V:3H flattening on the upper surfaces to match into the existing landforms;
- Providing materials with appropriate interface friction angles at the base of the landfill to protect against a base sliding failure or a potential circular slip failure through the base.

In addition, there will be temporary faces of active landfilling that generally face to the west and these need to be stable for periods of potentially up to ten years as the landfilling process moves from the east to the west.

Both of these situations have been modelled by a geotechnical engineer using a modern computer software system and these outcome of the modelling is included in Attachment 12 Stability Analysis.

4.2 Landfill formation and airspace

4.2.1 Landfill footprint

The footprint has been selected to maximise the fill potential of the existing and future quarry operation, the estimated total airspace being approximately 3.2 Mm^3, of which 3.1 Mm^3 will consist of waste, daily cover, and intermediate cover, and 0.1 Mm^3 will be capping.

The key considerations in determining the footprint were:

- The downstream extent was determined to allow sufficient area to construct the toe bund, construct a long-term stormwater drain and associated treatment facilities, leachate handling and other operational requirements;
- The upper perimeter of the landfill was determined to allow for a perimeter road and diversion drains. This requirement dictates the maximum extent of the northern side of the landfill footprint, with a high point on the northern ridge;
- The eastern perimeter was determined by being able to construct an eastern perimeter road and ensure that drainage off the landfill was to the southeast of the site through the sediment control ponds;
- The western perimeter was determined to fit closely to the existing contours, above an existing steep face, and to facilitate access along the perimeter road.

The landfill footprint and overall site layout is shown on Drawing B2 in Appendix 2.

4.2.2 Basegrades

Soil is required for landfill operation throughout the life of the landfill, to be used for construction of the lining system, daily cover, intermediate cover and to form the final capping layer. Over the life of a landfill soil requirements amount to approximately 20 % of the total airspace volume. Therefore, an airspace volume of 3.2 Mm^3 requires approximately 0.7 Mm^3 of soil for operation of the landfill over its lifetime. Ideally the soil required for operation of one stage of the landfill will come from excavation within the footprint of the next stage to be constructed. However, this is not always possible over the life of a landfill and some excavated soil needs to be stockpiled for later use. In the case of the Woodstock Landfill, most of this material will come from the highly weathered material in the upper levels of the quarry that are not able to be processed and sold.

The greatest soil requirement comes at final closure of the landfill when a significant quantity of soil is required for the landfill capping system, so some soils need to be held for a long period of time to meet this need.

In the case of the Woodstock Landfill, soils for operation of the landfill will be able to be found from within the landfill footprint for the first half of its life, but during the second half of the life the soils for daily operation will need to be brought in from stockpile, or other parts of the site.

The following have been taken into consideration for establishing the basegrade geometry for the development:

- Minimum slopes within the footprint to facilitate leachate flow to the leachate collection pipe system;
- The proposed geocomposite lining system incorporates impermeable geosynthetic components. While experience shows that lining system construction can be constructed on slopes up to 1V:3H this can be difficult and requires specialist equipment. In the case of the Woodstock Landfill the basegrade is almost flat and construction plant be able to safely operate placing, compacting, and trimming materials, and allows for safer deployment and installation of the geosynthetic liner components;
- The basegrade formation should be as planar as practicable. This is to facilitate forming the specified layer thicknesses, and for installation of the geosynthetic components;
- The Geology investigation has concluded that all the excavation for the basegrade is likely to be in very low permeability rock. The actual form of the basegrades may be modified during detailed design based on more detailed geotechnical information available at that time;
- In most locations a layer of compacted fill will be placed over the excavated rock to ensure that the basegrade shape meets the geometric specification.
- A toe bund will be constructed at the base of the landfill. This allows for containment of leachate at the toe, and stability of the landfill.
- The perimeter road, in combination with other access roads, will provide access for landfilling operations at some locations.

The proposed concept level final basegrade, designed to meet the above requirements, is shown on Drawing B1 in Appendix 2. In summary the basegrade design comprises:

- Minimum longitudinal floor slope of 2 %.
- Inter-bench vertical height of 10 m;
- Longitudinal bench slope of approximately 2 %;

4.2.3 Final fill profile

The function and construction of the landfill final cap is described in Section 5.5 below, while the overall form of the final fill profile, which includes the final cap, is detailed below.

The final landfill profile has been designed to maximise filling in accordance with the following parameters:

- The maximum overall slope after settlement will be 1V:3H. This is selected for overall stability of the landfill and to minimise potential erosion of the cap surface by overland flow;
- The minimum slope at any point of the landfill will be 1V:20H. This is selected to provide for stormwater runoff without ponding, even if some differential settlement has occurred.

Contour drains will be installed on the finished cap surface to divert stormwater to the landfill perimeter drains. These will typically be installed at intervals of 50 to 75 m down the slope to collect stormwater from the surface at regular intervals to avoid large sheet flow over the surface potentially causing erosion. These drains will be formed on benches, resulting in local steepening of the cap slope, while maintaining the overall post-settlement slope of no greater than 1V:3H.

After waste is placed in a landfill it undergoes settlement due to biodegradation of the organic fraction, consolidation because of new layers of waste placed above old, physical-chemical changes occurring within the waste and other changes that occur over time and as a result of additional loads (mechanical changes, ravelling, etc.). A large part of the overall settlement occurs during the operational life of a landfill. Typically, once fill has been placed to the final fill level, it could be expected that the final surface will settle by around 5 to 15 % of the landfill depth over the aftercare period of typically 20 to 30 years. The actual settlement will depend on:

- The nature of the waste material placed, particularly the organic fraction;
- The extent of the compaction achieved in the placement phase;
- The time taken to reach the final fill profile;
- The staging of the filling, and time delays between vertical stages.

The expected final contours after settlement are shown on Drawing B2 in Appendix 2. To achieve these contours, the final lifts of waste will be placed above these levels to allow the surface to settle to approximately the levels shown. This will be achieved by most of the waste filling on the front face having a slope of 1V:2.5H.

4.2.4 Overall volumes and areas

The key overall physical parameters for formation of the landfill are:

- Airspace volume including capping: 3.2 Mm^3
- Airspace volume excluding capping: 3.1 Mm^3
- Landfill footprint (liner area): 9.3 ha
- Area affected by landfill (incl perimeter road and stockpiles): 50.15 ha

4.3 Landfill phasing

The phasing has been designed to provide significant capacity in the stormwater treatment system in the early stages of the landfill operation, with the proposed stormwater pond design providing well in excess of the volumes typically required by good practice but will meet the needs of the quarry and the landfill for its full life.

Detail C on Drawing C1 shows the expected phasing of development of the landfill. The conceptual phase plan is based on:

- An operational life of each phase of approximately one year, although this varies to suit the actual layout of each phase. It is likely that the larger phases, in the central part of the landfill shown would be constructed as several sub-stages;
- A waste input of approximately 100,000 tonnes per annum (tpa). Assuming approximately a 0.9 t/m^3airspace utilisation rate (allowing for compaction and cover soil) this will occupy approximately 120,000 m^3 per year;
- The vertical height of each phase is generally based on filling up to each of the benches at 10 m height intervals;
- When waste filling and final finished capping is above the top of the quarry walls, all stormwater systems above the landfill level can be diverted around the landfill into the perimeter drains.

4.4 Lining system

4.4.1 Description

The purpose of a landfill lining system is to contain any leachate within the landfill and prevent it from entering the underlying soils or groundwater. It provides a low permeability containment system on which leachate is collected and removed from the landfill.

For a landfill, as proposed for Woodstock Landfill, the WasteMINZ Technical Guidelines describe the following two lining systems for a Class 1 landfill, comprising from top to bottom:

Type 1 lining system

- *Leachate drainage material, with underlying cushion geotextile to protect the geomembrane;*
- *1.5 mm HDPE geomembrane;*
- *600 mm compacted clay with a coefficient of permeability k < 1 x 10^{-9} m/s. Or*

Type 2 lining system

- *Leachate drainage material, with underlying cushion geotextile to protect the geomembrane;*
- *1.5 mm HDPE geomembrane;*
- *Geosynthetic clay liner (GCL);*
- *600 mm compacted clay with a coefficient of permeability k < 1 x 10^{-8} m/s.*

or

- *Leachate drainage material, with underlying cushion geotextile to protect the geomembrane;*
- *1.5 mm HDPE geomembrane;*
- *Geosynthetic clay liner (GCL);*
- *300 mm compacted clay with a coefficient of permeability k < 1 x 10^{-9} m/s.*

These two lining systems are considered to be equivalent to each other.

For the Woodstock Landfill it is proposed to use the Class 1 Type 2 Option 2 liner system for the base of the landfill and on the sidewall of the toe bund, comprising:

- Leachate drainage material, with underlying cushion geotextile to protect the geomembrane;
- 1.5 mm HDPE geomembrane;
- Geosynthetic clay liner (GCL);
- 300 mm compacted clay with a coefficient of permeability k < 1 x 10^{-9} m/s.

This system is considered to be at least equivalent to the liner systems detailed in the WasteMINZ Guidelines.

To protect the integrity of the leachate drainage material from clogging, which can occasionally occur when fine grained material migrates through the waste, a separation textile is to be placed on top of the drainage material prior to the deposition of waste. In addition, the first three metres of waste will be selected to minimise high levels of fine-grained materials near the liner system.

Details of the proposed liner are shown on Drawing C2 in Appendix 2.

All components of the lining system work together to contain leachate within the landfill and prevent leachate seepage. The combined system functions as follows:

- For there to be any leakage through a lining system there must be a driving head (depth) of leachate. An effective drainage system above the main containment layers drains the leachate away before a significant depth of leachate can form above the containment layers, thus limiting the potential for any leakage;
- The primary containment layer is one of the liner systems as detailed above. This primary layer is essentially impermeable. There is low risk that the sheet is damaged during construction, and this is mitigated by strict construction quality assurance (QA) procedures;
- The Geotechnical Report in Appendix 3 and Hydrogeological Report in Appendix 4 identify that the underlying geology is a very low permeability massive and competent greywacke.

- There is generally an inwards hydraulic gradient of the existing groundwater which would further reduce the potential for leakage.

Any potential seepage through a defect in the HDPE liner system, which sits directly on top of the GCL. would swell up in the event that moisture came through the HDPE. The seepage would then have to travel through the very low permeability 300 mm compacted clay layer before it flows out of the lining system.

The time of travel through the system depends on the actual permeability achieved for the compacted clay. During this slow travel time contaminants in the leachate adhere to the clay particles and are removed from the liquid that may eventually seep from the bottom of the liner system, thereby significantly reducing the contaminant concentration.

Soils investigations undertaken to date indicate that suitable clay soils are generally available on site, both within the general footprint area and elsewhere on the wider site, to meet the compacted clay liner objectives. The laboratory test results for these clays indicate a permeability of 2.5×10^{-10} m/s. The availability of these materials for the lining system construction will depend on:

- The amount of disturbance to potential low permeability soil layers near the surface during vegetation clearance operations;
- The degree of contamination of near surface clay soils by roots;
- The ability to stockpile low permeability soils excavated from the footprint for later use.

Drawing D5 in Appendix 2 shows the location and estimated quantities of readily available low permeability clay resources on the site, which is more than 60,000 cubic metres. It is understood that further deposits of clay are readily available in the local vicinity.

Figure 4.3 below are the test results from two samples of the low permeability clay resources on the site. During the construction phase an appropriate quality assurance programme will be developed to ensure that the clays used for the liner and the cap comply with the minimum permeability specifications.

It is recommended that for modelling and design purposes a minimum permeability of 1.0×10^{-9} m/s be adopted for the compacted clay layer (CCL).

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Reference No: 20/2802

Date: 22 November 2020

TEST REPORT – CONSTANT HEAD PERMEABILITY

Client Details:	Woodstock Quarries Ltd 39 Stott Drive, RD1, Darfield	**Attention:**	D. Shepherd
Job Description:	Woodstock Quarries Ltd – Lining Investigations		
Sample Description:	Clayey SILT with minor sand	**Client Order No:**	N/A
Sample Source:	Middle Quarry / New Road (cs)	**Sample Depth:**	≈ 2.0m (cs)
Date & Time Sampled:	3-Nov-20 (cs)	**Sampled By:**	D. Shepherd (cs)
Sample Method:	NZS 4407:2015, Test 2.4.2 (pit or bank) (cs)	**Date Received:**	5-Nov-20

CONSTANT HEAD PERMEABILITY TEST IN A TRIAXIAL CELL – ASTM D5084-16a			
Cell Pressure: (kPa)	570	**Compaction:**	NZ Standard
Saturation Back Pressure: (kPa)	500	**Solid Density: (t/m^3)**	2.65 (assumed)
Effective Confining Pressure: (kPa)	70	**Temperature During Test: (^{o}C)**	20.7
Saturation by Pore Pressure Response: (B Value)	0.99	**Permeant Liquid Used:**	De-aired Tap Water

Sample Status:	**Initial**	**Final**
Sample Dimensions: (mm)	104.9 ϕ x 115.5	104.9 ϕ x 113.6
Bulk Density: (t/m^3)	2.08	2.12
Water Content: (%)	17.1	17.1
Dry Density: (t/m^3)	1.78	1.81
Saturation By Calculation: (%)	93	98
Void Ratio: (*e*)	0.49	0.46
Constant Head: (kPa)	30 kPa	50 kPa
Hydraulic Conductivity: (k_{20})	2.7×10^{-10} m/s	2.5×10^{-10} m/s

General Notes:

- *Information contained in this report which is Not IANZ Accredited relates to the sample description based on NZ Geotechnical Society Guidelines 2005, the client supplied information (cs) and sampling.*
- *This report may not be reproduced except in full.*

Tested By: N.P. Danischewski **Date:** 11 to 20-Nov-20

Checked By:

Approved Signatory

A.P. Julius
Laboratory Manager

ACCREDITED IANZ TESTING LABORATORY №434

Test results indicated as not accredited are outside the scope of the laboratory's accreditation

Specialist Quality Assurance Service in Aggregate, Concrete and Soils Testing

The expected in-service life of the HDPE is in the order of 300 years, and that of the GCL is expected to be well in excess of 100 years. It is acknowledged that the life of the HDPE is extended, and the risk of damage to the HDPE is reduced, by the presence of a GCL under the HDPE geomembrane.

In addition to the liner system on the base of the landfill, and the sidewalls of the toe bund, the rock sidewalls will be sprayed with a polyurea waterproofing membrane over shotcrete.

The shotcrete will be applied to the excavated rock surface to create an even surface for the polyurea membrane. The shotcrete will be applied by a specialist shotcrete contractor. The details of this system are shown on Detail L of Drawing C03.

In some areas of the quarry wall there may be seeps that do not dry up between the time of excavation, and the application of the shotcrete / polyurea waterproofing system. If this occurs a geocomposite drainage material will be placed prior to the application of the shotcrete. A network of pipes will direct the flows from the geocomposite drainage material away from the operational landfill area, and if flows are significant they will be directed to connect to the next stage of the underdrainage system, providing a direct path from the sidewall to the perimeter drainage system.

The polyurea waterproofing system, which is applied using specialist spraying equipment by a specialist contractor, is used internationally for waterproofing rock walls of embankments, tunnels and building as well as landfills and water retaining structures.

There are well established techniques for constructing the interface between the HDPE / GCL liner system of the base of the landfill and the polyurea on the rockwalls. An example of this is shown in the photograph below (Figure 4.2) and shown on Detail P of Drawing C04.

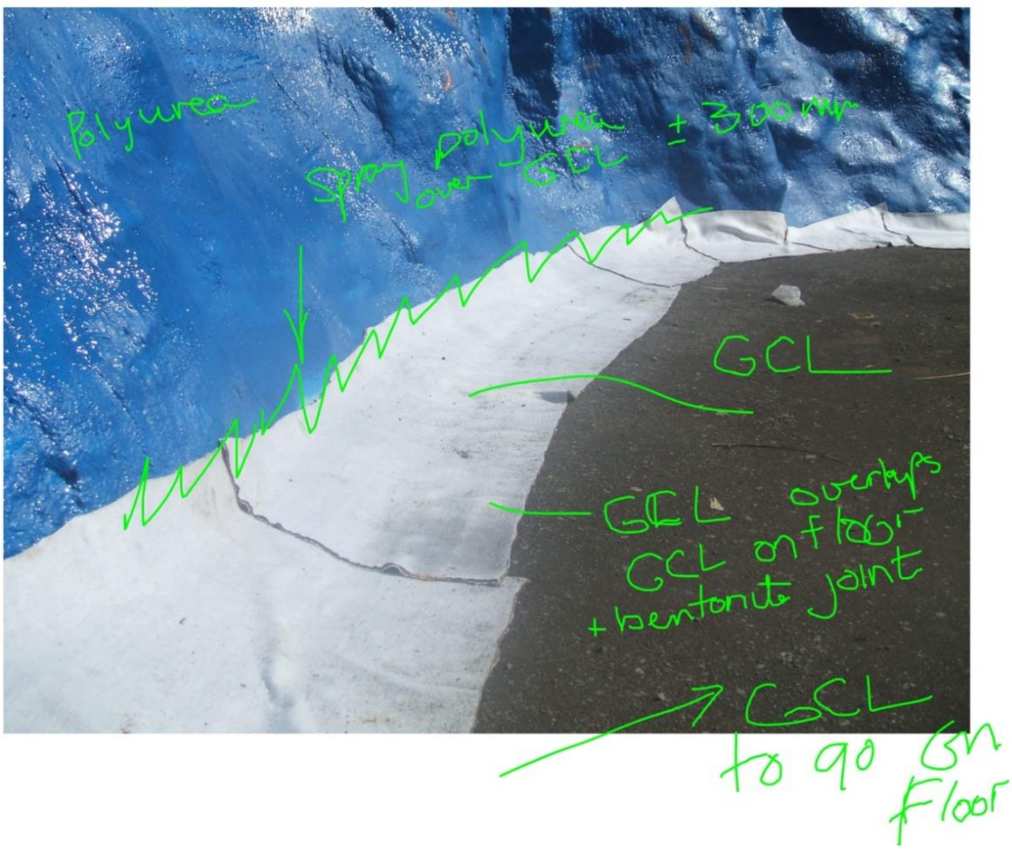

Figure 4.2: Interface between HDPE/GCL liner and polyurea membrane.

A key consideration in the construction of the sidewall lining is maintaining a high level of quality assurance (QA). Methodologies for the construction of the shotcrete are well established and the 2010 publication Shotcreting in Australia – Second Edition is widely used as the basis of the QA system for the application of

shotcrete.
There are no published quality assurance guides for the application of the polyurea but operators have developed their own methodologies for ensuring that an even layer of polyurea, generally 2.5mm, is applied to the shotcrete surface, prior to the laying of a protection geotextile. These techniques include:

- Measuring up of the area to be sprayed during a particular session and accurately calculating the amount of polyurea compound to be applied during that session
- Marking out a grid pattern over the area to be sprayed and calculating the number of polyurea pump strokes required for each part of the grid.
- Spraying test patches during the application process and checking the thickness of polyurea applied (the area of test patch is resprayed after the test patch is removed)
- Measuring the total amount of polyurea used at the end of each session which is cross checked against area sprayed.

As shown on Detail L of Drawing C03 and Detail P of Drawing C04 the waterproofing membrane is protected from the waste by the installation of a protection geotextile and the installation of a graded drainage material, which also has the dual purpose of draining the face of the quarry walls.

The installation of the graded drainage material needs to be carried out very carefully to ensure that the polyurea waterproofing system is not damaged by the waste. The sequence requires the waste to be placed well away from the quarry wall, the drainage gravel is then carefully placed in the space between the quarry wall and the waste, and then the next layer of waste can be placed. Detail L of Drawing C03 shows how this sequence of drainage material and waste placement ensures that the polyurea is protected and an effective drainage path is maintained down the face of the quarry wall.

4.4.2 Lining system potential leakage

While every attempt is made to avoid leakage of leachate from a landfill, some leakage may occur through defects that may be present in the lining system, from either the manufacturing process or installation.

However, to assess potential effects, it is standard international practice to assume that some defects will be present. In the case of the Woodstock Landfill, it is assumed that a high level of construction QA will be provided, and is discussed further below, resulting in no more than the following assumed defects in the geomembrane:

- Two to three manufacturing defects per hectare (pinholes 1 mm in diameter);
- Three to four installation defects per hectare (1 cm^2 in area).

The potential for defects is minimised by having a high quality assurance (QA) programmes in place, both for geosynthetic liner manufacture and for lining system construction. This assumes good field placement with a well-prepared smooth surface and geomembrane wrinkle control to provide good contact between the geomembrane and the underlying surface. In the case of the Woodstock Landfill, a high level of construction QA will be provided, resulting in no more than the assumed defects in the geomembrane. As most of the liner system is horizontal, apart from the toe bund, it will be easier to achieve a high level of construction quality assurance, as compared to landfills that have a high proportion of sloping sidewall. Having a high proportion of flat floor will make it easier to place the liner system without wrinkles, which can result in imperfect contact between the various layers of the liner system.

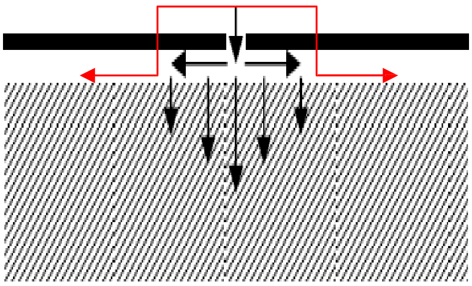

Figure 4.3: Diagram showing effect of imperfect contact between a geotextile and the underlying clay

The lining system will be installed with a high standard of QA, undertaken by a party independent from the lining installer, contractor, or landfill operator. The purpose of the QA process is to provide reliability that the lining system has been installed with no manufacturing or construction defects that may result in subsequent leakage.

The construction specification will specify the standards to be achieved and the quality control testing required by the contractor to demonstrate compliance with the specification. The QA process comprises an oversight of the testing undertaken by the contractor, regular or continuous observation of lining system placement and testing, and a review of all quality control documentation produced by the supplier and contractor.

Items that are observed and reviewed as part of the QA process include:

- All specified manufacturing QA documentation and/or independent testing of the geosynthetic materials supplied by the manufacturer;
- All compaction testing associated with installing the clay liner (strength, density, moisture content, air voids);
- Permeability testing of the placed clay layer by an independent accredited laboratory;
- Thickness of the compacted clay layer;
- Approval of the clay surface for placing any geosynthetic lining components;
- Approval of the geosynthetic liner placement methodology and panel layout;
- Observation of placing, welding, and testing of geosynthetic lining components to include:
  - Shear and peel testing of test weld samples at the commencement of each day;
  - Shear and peel testing of destructive test samples;
  - Air pressure testing of all dual track fusion welds;
  - Vacuum box or spark testing of all extrusion welds;
  - Visual inspection of the completed surface;
- Review of all construction records;
- Observation of placement of aggregate above the geosynthetic liner.

On completion of the construction of the liner system, a report is prepared to include all the test results, a description of the observations undertaken and certification that the lining system had been installed in accordance with the specifications. This report would be submitted to the Peer Review Panel (PRP) who would make recommendations to Environment Canterbury, prior to any waste being placed in that cell.

In Appendix 10 Proposed Conditions of Consent Issue 2 conditions that require the Applicant to adopt the QA as detailed above.

Methods have been developed for calculating leakage through defects in a composite lining system make due allowance for the contact between the HDPE geomembrane and the underlying clay or GCL. Field and laboratory measurements of actual leakage through different lining system have been undertaken by Rowe et al, and the results are shown in Figure 4.3 below. The figure clearly shows the incremental benefit between a geomembrane (GM). or compacted clay liner (CCL), liner alone compared to a composite HDPE / GCL lining system as shown in the bottom example, the same system that is proposed for the Woodstock Landfill.

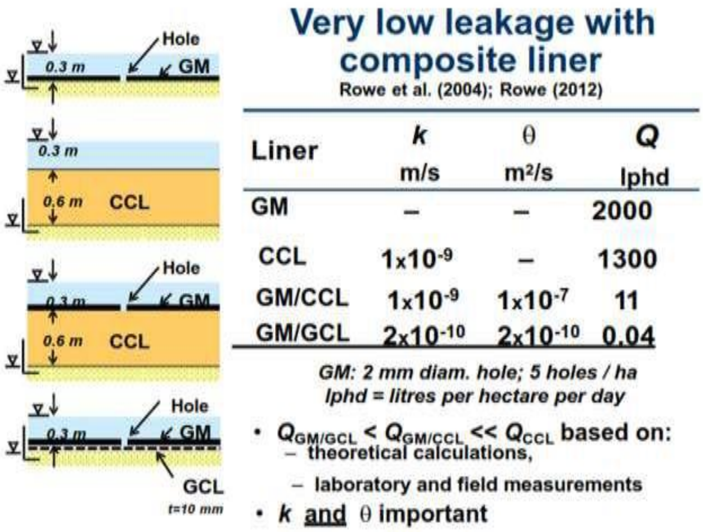

Figure 4.4: Laboratory and field measurements of liner seepage through known defects (Rowe et al, 2012).

This research suggests that leakage rates in the order of 0.04 litres per hectare per day could be expected from a composite GM (HDPE) / GCL liner as proposed for the Woodstock Landfill but in practice achieving perfect contact between all the layers over the whole liner is rarely achieved.

Also, previous methodologies often relied on a combination of formulae and charts to cope with variations in leachate head and struggled to model the use of GCLs under the GM (HDPE). Recent research from the University of Johannesburg has developed a methodology to assess leakage rates based on:

- variations in leachate head
- variations in contact between HDPE and GCL or CCL
- variations in CCL or GCL

The assessment of potential leakage rates were calculated for the 300mm layer of CCL, and for the layer of GCL. The assessment used two scenarios of liner contact ranging from good to average, and leachate levels ranging from a standard 300mm maximum depth through to a 1.5m maximum depth at the toe bund.

The assessment of the combined effectiveness of an HDPE / GCL / CCL liner is difficult to model as the primary purpose of the GCL is to expands, and plug any leak, in the event that liquid from a defect of the HDPE liner passes through the HDPE.

For this modelling an estimate of the worst-case leakage rate has been based on extrapolating the output of the individual models. Using this methodology is still very conservative for the reasons noted in the paragraph above. The outputs from the modelling are shown in Table 4.1 below.

Table 4.1 Worst Case Liner Leakage Scenario

Worst Case Liner Leakage Rates Calculated using 2017 methodology noted in Engineering Report Issue 2

Construction Scenario	Manufacturing Defects per ha (1mm diameter)	Construction Defects per ha (10mm diameter)	Liner Contact	Average Leachate Head (m)	300mm CCL Leakage Rate litres per hectare per day	GCL Leakage Rate litres per hectare per day	Recommended for Hydrogeology Modelling
Very good	2	3	Good	0.1	0.9	0.06	
Very good	2	3	Good	0.3	2.4	0.3	
Very good	2	3	Good	0.75	6.3	1.6	**1.5**
Average	3	4	Average	0.1	3.9	0.3	
Average	3	4	Average	0.3	11.3	1.5	
Average	3	4	Average	0.75	29.0	7.3	**6.0**

Appendix A provides further information on the methodology, and the selection of parameters used to assess the potential worst case of leakage through the liner.

It is recommended that for a conservative assessment of the impact of the potential leakage of leachate through the liner system a leakage rate of 6 litres per hectare per day should be adopted.

As shown on the Drawing C04, and described in Section 4.8, the Woodstock Landfill will also have an underdrainage system below the liner. While the primary purpose of this underdrainage system is to collect and convey any inflow of groundwater to prevent uplift of the liner, any leachate which may have travelled through the liner system would be collected by the underdrainage system.

With the proposed cell development programme each cell will have its own underdrainage system. Each section of the underdrainage system terminates at a manhole at the outside of the toe bund, before discharging into the perimeter surface drain at the most downstream manhole.

Each manhole will also be equipped with a valve on the inlet that can be closed when there is no more flow from the underdrainage system. The manholes will be linked together, and the downstream outlet manhole will also be fitted with a valve to prevent discharge into the surface water system, if required.

The outlet from the downstream manhole will be equipped with continuous pH and conductivity metering so any change in the chemistry of the discharge from the underdrainage system can be detected. In the event of a change in the chemistry of the discharge a more intensive testing programme of the discharge can be undertaken to ascertain whether this is caused by leachate leakage.

Further details on the methodology for assessing whether there is leachate in the surface water system is detailed in Appendix 4A Hydrogeology Report 2 (Attachment 1). In addition, appropriate conditions are detailed in Appendix 10 Proposed Condition of Consent Issue 3 (Attachment 7).

4.4.3 Construction quality assurance

Because of the importance of the lining system to the overall environmental performance of the landfill, as outlined above the lining system will be installed with a high standard of QA, typically undertaken by a party independent from the lining installer, contractor, or landfill operator. The purpose of the QA process is to provide reliability that the lining system has been installed with no manufacturing or construction defects that may result in subsequent leakage.

The construction specification will specify the standards to be achieved and the quality control testing required by the contractor to demonstrate compliance with the specification. The QA process comprises an oversight of the testing undertaken by the contractor, regular or continuous observation of lining system placement and testing, and a review of all quality control documentation produced by the supplier and contractor.

Items that would be observed and reviewed as part of the QA process would include:

- All specified manufacturing QA documentation and/or independent testing of the geosynthetic materials supplied;
- All compaction testing associated with installing the clay liner (strength, density, moisture content, air voids);
- Permeability testing of the placed clay layer;
- Thickness of the layer;
- Approval of the clay surface for placing any geosynthetic lining components;
- Approval of the geosynthetic liner placement methodology and panel layout;
- Observation of placing, welding, and testing of geosynthetic lining components to include:
- Review of all construction records;
- Observation of placement of the liner protection geofabric and drainage aggregate above the

geosynthetic liner.

On completion, a report is prepared to include all the test results, a description of the observations undertaken and certification that the lining system had been installed in accordance with the specification. This report would be submitted to Environment Canterbury who would approve the liner placement/cell construction prior to any waste being placed in that cell.

4.5 Leachate collection

Leachate is the liquid produced when rainwater percolates through the waste to the landfill lining system, collecting dissolved and/or suspended matter from the waste as it passes through. A landfill is managed to minimise the volume of leachate that is produced. This is achieved by:

- Minimising the size of the active tip area where waste is exposed to rainfall;
- Covering areas with intermediate or final cover as soon as is practicable so that as much water as possible is shed into the stormwater collection system and minimising percolation of water through these layers into the underlying waste;
- Providing professionally managed stormwater systems to separate all stormwater flow from areas where waste is placed and ensuring all site stormwater is diverted away from rubbish.

All stormwater that meets waste will be treated as leachate and will not be discharged to the stormwater system.

Leachate generated within the landfill will flow to the leachate collection system at the base of the landfill from where it will be removed for treatment and disposal (refer Section 6.4 of Appendix 5 Engineering Report).

The general layout of the proposed leachate collection system is shown on Drawing C1 in Appendix 2. The system will be designed so that the leachate head on the liner does not exceed a selected target value, typically in the order of 300 mm. The leachate pipes will be HDPE PE100 for durability and strength. A non-woven cushion geotextile will be placed beneath the aggregate layers to protect the geomembrane from puncturing as a result of the loads, i.e., weight of waste, on the aggregate.
The leachate collection system will comprise:

1. All landfill/lining system surfaces having a grade of no less than 2.0 % falling to leachate collection drains;
2. A high permeability aggregate layer on the floor areas of the landfill to collect leachate and direct it to the main collector drains. This will be a poorly graded (uniform size) aggregate nominally 20 mm particle size (or larger), in a layer with a minimum thickness of 300 mm;
3. A primary leachate collection drain at the centre of the floor with a grade of at least 2%. This would comprise an HDPE perforated leachate collection pipe sized for the expected maximum leachate flows, with some redundancy. It would be surrounded by a coarse aggregate layer, typically with a 40 mm minimum particle size. This is shown on Detail B on Drawing C01.
4. Leachate collection drains at the toe of all slopes, on the benches and on the floor, detailed similarly to the primary leachate drain;
5. Secondary leachate pipes on floor areas (if required) so that the drainage path through the drainage layer does not result in excessive hydraulic head over the liner system.
6. An overflow leachate pipe will be installed parallel to the toe bund as shown on Detail A on Drawing C1. This pipe will allow for the lateral movement of leachate between each of the cells should there be a buildup of leachate in a particular cell. This pipe is capped when first installed and then connected up when the adjacent cell is constructed.

7 The leachate pipes will convey leachate to a common point next to the toe bund, as shown on Detail A on Drawing C1. An additional layer of HDPE geomembrane will be installed beneath any leachate sumps within the landfill for additional security against potential leakage. At this point a large diameter HDPE riser pipe is laid on the side slope of the toe bund, and a specialist submersible pump is installed inside the riser. Pressure transducers on the pump control the pumping process and enable the landfill operator to monitor the depth of leachate in the landfill.

Leachate will be pumped from this point out of the landfill to a leachate storage facility. Pumping is preferred rather than a gravity discharge because:

- It avoids a pipe penetration through the lining system on the toe bund;
- It allows greater options for storage of leachate, allowing for pond/tank water levels to be above the base of the landfill.

Initially, the leachate collection / storage facility will be located within the landfill footprint as shown on Detail A of Drawing C1. As the landfill construction progresses from east to west the storage facility will be progressively moved. The leachate storage facility has capacity for at least 5 days of leachate generation. In the final stages of the landfill construction the leachate will terminate in a large sump and a permanent leachate storage facility constructed. A resource consent for this facility will be required.
Provision will be made for access to the ends of leachate pipelines for cleaning the pipes. Access to the downstream ends, when the leachate pump is removed, provide for cleaning using flushing hoses, which would have a practical reach limit of up to 200 m going up the pipe. Access to the upstream ends (where practicable) will provide for flushing the leachate lines and launching inspection / monitoring equipment.

There is a high level of redundancy in the leachate collection system as summarised below:

- The drainage blanket is continuous over the whole floor, sides, and side slopes of the toe bund
- The slopes of the floor are high
- The capacity of the leachate collection pipes have a high factor of safety
- Each cell has its own leachate collection system, but leachate will be able to migrate from cell to cell in a westerly direction
- An overflow pipe connects each cell

A leachate drainage layer/liner protection layer on the side slopes to convey leachate to leachate collection pipes on the floor and bench areas. The methodology for installing this drainage layer is shown in Figure 4.4 below.

As noted in Section 6.1.4 it is expected that most of the leachate will be recirculated back into the landfill to assist with compaction of the waste and dust control.

4.6 Final cap

The purpose of the final cap on the landfill surface is:

- To control the seepage of water into the waste, thereby minimising leachate generation;
- To minimise the escape of LFG;
- To provide a separation between the waste and any future uses for the site;
- To provide a suitable growth medium for the covering vegetation, typically grass or shallow rooting shrubs, such as manuka.

Deep rooting trees could compromise the integrity of the landfill cap but depending on the quantity of the weathered recovered from the quarry operation it may be possible to thicken the cap significantly in many areas to produce a more natural looking landform and allow the planting of deeper rooting indigenous forest species.

Typically, landfill cap systems that are used throughout the world comprise one of two overall types:

- Barrier caps; or
- Evapotranspiration caps (ET caps)

ET caps can provide an effective solution in low rainfall/arid climates. However, they are unlikely to be effective for the moderately high rainfall experienced in the Woodstock area and are not considered further.

Barrier caps generally fall into two categories. Those based on a low permeability soil layer and those incorporating a geomembrane or geosynthetic clay liner. The latter essentially excludes water from entering the landfill, resulting in a "dry tomb" landfill with little ongoing degradation of the waste. This approach is not commonly adopted in New Zealand, the preference being to allow some water to enter the landfill, at a controlled rate, to allow for ongoing biodegradation of the waste so that, ultimately, the waste will become benign. This approach has been adopted for the Woodstock Landfill.

The WasteMINZ Guidelines provide two options for a final cover design based on a soil barrier layer. These are described as, from top to bottom:

Minimum:

- 150 mm topsoil;
- 600 mm compacted soil ($k < 1 \times 10^{-7}$ m/s);
- Intermediate cover. or

Enhanced minimum:

- 100 to 150 mm topsoil;
- 300 to 450 mm growth layer;
- 600 to 1000 mm compacted soil layer ($k < 1 \times 10^{-7}$ m/s).

WQL will adopt the minimum standard for the final capping layer but plans to apply additional capping up to 2 m thick, to provide an effective barrier and to provide adequate thickness for a wider range of plantings on the final cap surface.

It has been found that better cap performance is achieved with a reasonable thickness of higher porosity soil placed above the barrier layer. This allows for the storage of water entering the capping system and later evapotranspiration when conditions allow, resulting in less overall seepage through the capping system. It also ensures that the vegetation can thrive and is less susceptible to drying out in times of low rainfall.

The capping options are shown in Drawing C02.

As described in Section 8, the soils for construction of the final capping system will generally be soils obtained from excavation within the landfill footprint, stockpiled for later use. Careful separation of soils within stockpile areas may be required to provide for suitable soils to construct both the barrier layer and the growth layer.

4.7 Stormwater control

4.7.1 Overall stormwater management

Stormwater systems are required as part of a landfill operation to ensure that:

- Suitable diversion systems are in place to separate stormwater from waste to avoid contamination. With all stormwater that comes into contact with waste being treated as leachate;
- Practicable steps are taken to minimise erosion of soil and transport of sediment from earthworks areas. This is achieved through minimising exposed soil surfaces, installing cut-off drains to minimise flow over exposed earth surfaces, installing temporary measures where practicable to minimise the transport of sediment from earthworks areas, and stabilising these areas with vegetation or by other means as soon as practicable;
- Suitable conveyance systems (channels, pipes) are in place to carry the stormwater to suitable

treatment to remove any sediment carried with the stormwater. These systems may comprise permanent systems (e.g., perimeter channels) or temporary systems as each stage is developed;

- Adequate treatment systems are in place to remove sediment from stormwater at all stages of development and operation of the landfill.

On this site, due to where the stormwater treatment systems will be constructed, it is not possible to separate “clean” stormwater from vegetated catchments from stormwater from active areas, apart from the runoff above the perimeter road. All stormwater from the site will be combined into a common system. However, much of the site where earthworks are to be undertaken consists of greywacke rock with considerably reduced opportunity for sediment laden stormwater to be generated.

4.7.2 Landfill stormwater systems

The stormwater collection and conveyance system at the landfill is based on:

- Open channel stormwater drains will be provided above the landfill to prevent stormwater from entering the active quarry and landfill activities. These will direct water to the existing flow paths on the west and east sides of the landfill.
- Open channel stormwater drains will be provided to the west of the landfill to prevent stormwater from entering the active quarry and landfill activities. These will direct water to the existing flow paths on the west side of the landfill.
- Within the operational quarry and landfill area benches will divert stormwater from active waste filling areas. These bench drains will divert stormwater to the sedimentation ponds.
- A system of temporary stormwater drains within the operational quarry area, as required to suit the stage of operation, diverting all stormwater to the landfill perimeter drain. Where required to maintain water quality temporary sedimentation ponds would be constructed. These would the drain to the perimeter drainage system.
- In the upper areas of the landfill bench drains on the final cap will discharge runoff to the perimeter road and it will flow into the existing flow paths to the west and east of the landfill site.
- In the lower areas of the landfill site permanent stormwater drains on the outside of each side of the landfill will collect runoff and direct it to the perimeter stormwater system, with all this stormwater passing through the sedimentation ponds for removal of sediment prior to discharging from the site.
- The stormwater is proposed to be discharged onto the existing slopes above the true left bank of the Woodstock Stream through a stormwater dissipater.

The preliminary assessment indicates that approximately 8 hectares of catchment would be directed into the permanent stormwater system.

Preliminary sizing of the primary sedimentation pond is that will need a capacity of approximately 2400 cubic metres. The pond will be constructed with a primary decant system that would discharge to the dissipator, as does the overflow. The ponds and decant system will provide considerable attenuation of the stormwater flows into the Woodstock Stream.

An overflow weir is proposed to be constructed on the south side of the sedimentation pond. In the event of a significant storm that resulted in an overflow of the main stormwater system an overland flow path will direct stormwater into the gully directly to the south of the sedimentation ponds. At the base of this gully a secondary sedimentation / attenuation pond would be constructed.

Sediment control ponds will be constructed downstream of the stockpile areas that are outside the primary stormwater catchment.

The general layout of proposed stormwater systems is shown on Drawing B2. Details of the perimeter drain, and sedimentation ponds are shown on Drawing C4.

As noted in the proposed conditions of consent the quality of the water in the Woodstock Stream will be monitored at the location SW01 as shown on Drawing E2.

Stormwater systems will be designed for the following events:

- Temporary systems: 20 % Annual Exceedance Probability (AEP)
- Sedimentation pond: 10% AEP
- Sedimentation pond overflow: 1% AEP
- Permanent systems: 1% AEP

The ponds, and other sediment control structures, will be designed and maintained in accordance with Environment Canterbury Erosion & Sediment Control Toolbox for Canterbury.

Where the Environment Canterbury Erosion & Sediment Control Toolbox for Canterbury does not cover a particular situation GD05 Erosion and Sediment Control Guide for Land Disturbing Activities in the Auckland Region will be utilised.

During the post closure the site will still be subject to meeting conditions of any remaining resource consents and will still be required to have a Management Plan that will include details of maintenance and monitoring of the stormwater systems.

4.8 Subsoil drainage

As noted in Appendix 4 Hydrogeological Report Woodstock Landfill (prepared by Verum) it is expected that there will be an inward hydraulic gradient into the landfill over some of the site, and it is expected that there will be several groundwater seepages exposed within the site when excavation to basegrade levels has been completed. These artesian seepages remaining beneath a lining system can result in uplift pressures and cause a local failure of the lining system, and therefore they must be controlled and drained away.

To control groundwater beneath the landfill a network of subsoil drains will be constructed beneath the lining system to be available to drain groundwater seepage under all stages of the landfill development. However, as subsoil drains provide a potential pathway for any leachate seepage through the lining system the drains will be progressively sealed when they are no longer required, i.e., when sufficient waste fill has been placed within each filling phase such that uplift pressures are no longer of concern, or groundwater flows cease.

The proposed subsoil drain system will comprise:

1. A main subsoil drain laid approximately 50 to 60m apart running approximately in a north-south direction, terminating near the perimeter stormwater drain.
2. Lateral subsoil drains will be installed in a herringbone pattern in an east-west direction
3. The subsoil main drains will pass through a manhole that is equipped with continuous pH and conductivity monitoring.
4. The subsoil manholes will also be configured to be able to be closed off in the event of a suspected breach of the liner system.

The main subsoil drains will be installed with trench dams at regular intervals along the drain so that the gravel surround does not provide a flow path after the drains are sealed. Where possible the last 30 m of drain upstream of the outlet will be a non-perforated pipe backfilled with clay to cut off this potential flow pathway.

5 Landfill gas management

The NES for Air Quality is the only NES to contain specific requirements in respect of landfills, and only applies to Class 1 and Class 2. It requires landfills with more than 200,000 tonnes of waste in place and a design capacity of greater than one million tonnes to collect landfill gas and either flare it (to minimum standards) or use it as a fuel to produce energy. The NES applies to landfills where the waste in or to be included in the landfill is likely to consist of 5% or more (by weight) of matter that is putrescible or biodegradable.

While the Woodstock Landfill will not be accepting putrescible or biodegradable waste there is a possibility that some of the wastes will decompose over time and produce LFG. Retrofitting an LFG system is a difficult and expensive method, and it is proposed that the Woodstock Landfill will install LFG wells progressively as the landfill is filled with waste.

The LFG collection system will be installed progressively as the landfill is developed. It will be based on a series of vertical wells at approximately 60 m centres, installed once the depth of waste is sufficient and extended vertically as waste filling progresses.

The intermediate and final capping surface will be tested for surface emissions every quarter to ensure that methane emissions of the surface do not exceed 0.5%.

The wells will be regularly monitored and if LFG of sufficient quantities are produced passive flares will be installed at each well, or for a group of wells.

If required, the proposed landfill gas (LFG) management system will incorporate the following elements:

- A system to retain LFG within the landfill site and prevent off-site migration, i.e., lining, and capping systems;
- An LFG collection system comprising a network of collection wells and pipework;
- A series of horizontal collection pipes will be extended out from the vertical wells as required to collect LFG between the wells as filling progresses;
- The wells will be connected to collection pipes to convey the LFG to a utilisation station where the LFG will be utilised to generate electricity or destroyed in a flare;
- A destruction system using flaring or electricity generation (or some other means of effective combustion); and
- Monitoring to confirm the effectiveness of the system, including regular surface methane emission monitoring on capped areas are less than 0.5%

If required, a blower installed at the utilisation station will apply a vacuum pressure to the well field to extract LFG from the landfill and convey it to the engines or flare.

Condensate traps (knock out pots) will be installed at any low points in the pipelines to remove potential condensate build-up in the pipelines.

Around the edges of the landfill, where the depth of waste is too shallow for the installation of a full well, pin wells (small diameter shallow wells) will be installed to provide additional coverage of the LFG collection system if required.

6 Leachate management

6.1.1 Leachate quantities

Leachate generation within the landfill has been estimated empirically based on leachate generation data for other landfill sites. Analysis of leachate generation data compared with rainfall over the life of these facilities shows that leachate generation varies approximately 2 to 6 % of rainfall.

The annual average rainfall for Oxford is 920 mm. For this average rainfall, and leachate generation of 5% of rainfall the expected annual leachate generation is 40 to 60 mm per year. Based on the recorded performance at other landfills, actual generation is expected to be less than this for most of the time, especially given the efficient geometry of the Woodstock Landfill.

Leachate generation is a function of the landfill footprint area and will increase as the landfill area increases. From a leachate management perspective, it is important to be able to manage peak flow and keeping the volume of leachate to be managed daily to a practical minimum requires balancing storage.

The design of the basegrade of a modern landfill, along with the drainage blanket, the spacing of the leachate collection pipes results in a very efficient leachate collection system, and investigations of operating landfills has shown that leachate depths are typically 50mm, with localised levels of 300mm, over most of the landfill footprint. On sidewalls leachate levels are likely to be lower.

There are a range of techniques that can be employed to minimise the amount of stormwater that enters the leachate system by diverting it to the stormwater system. This can include:

- The construction of temporary bunds upstream of the operational areas
- Installation of the liner system in stages
- The installation of HDPE flaps that are welded to the new HDPE liner and supported by sandbags to create a diversion channel.

However, from time to time leachate generation may be higher than the average, especially when a new cell has been established and there is a small amount of waste placed over the drainage blanket. From a contingency planning perspective, it is prudent to overestimate the quantity of leachate that could be generated, and for the Woodstock Landfill it is recommended that a peak leachate generation rate of 15% of rainfall be adopted.

There are also situations where a failure of a leachate pump or a temporary blockage of a leachate pipe, can result in the localised buildup of leachate behind the liner. At each of the leachate extraction points the leachate pumps are equipped with pressure transducers to control the pump operation but also provide the landfill operator with warning that there is a potential localised buildup of leachate.

While the geometry of the basegrades of the Woodstock Landfill, and the multiple leachate extraction points, will minimise the risk of leachate buildup it is possible that the leachate level could be as high as 2.5m against the bund sidewall. This is considered to be an extreme event that might happen only a few times over the life of the landfill, if ever.

For Woodstock Landfill it is proposed that the leachate be collected and stored in double skinned tanks with sufficient capacity to retain up to 5 days of generated leachate.

6.1.2 Leachate quality

Leachate quality varies significantly from one landfill to another, making leachate quality difficult to predict with any degree of accuracy for a new landfill. Leachate quality is influenced by the composition, age, and depth of the waste, as well as the local climate and landfill operation practices. A new landfill operating at shallow depths will firstly undergo aerobic decomposition before changing to anaerobic decomposition as depth and cover increases. The anaerobic decomposition goes through an acetogenic phase then a methanogenic phase. The percentage of the landfill decomposing methanogenically will increase, and over time will become the dominant form of decomposition.

Typically, over time as the proportion of "older" leachate increases, the strength of the leachate will decrease and particularly the ammonia concentration and the BOD/COD[1] will decrease.

The Woodstock Landfill will not be accepting municipal household or putrescible waste and it will be difficult to estimate leachate quality when referencing older leachate quality data. A paper published by the USEPA in 2015 analysed data from 91 C&D landfills in Florida and found that leachate from these facilities was significantly different from municipal waste landfills with the biggest differences being:

- Higher pH
- Lower NH_4-N
- Higher levels of sulphates

The parameters of interest when considering leachate quality are typically BOD/COD, pH, ammoniacal nitrogen and colour. The leachate will also contain a wide range of dissolved metals. Depending on where the leachate is to be discharged to, or whether it is to be treated on site, there may be other parameters to consider.

In section 9 of Appendix 5 Engineering Report several contingent events are described, some of which may result in the discharge of leachate into the environment. An additional Hydrogeology Report, Appendix 4A of the Application, has been prepared and includes an assessment of the impact of any such discharges.

In order that Appendix 4A Hydrogeology Report can assess the impact on the receiving environment it is necessary to provide an assessment of the characteristics of the leachate that are most likely to be generated at the Woodstock Landfill.

There are numerous publications of leachate characteristics from various sites, but there is also considerable variability in the reported characteristics. The composition of leachate varies significantly from landfill to landfill and varies over time due to many factors including:

- The source of the waste, particularly whether it is municipal waste or not
- The climate at the landfill site, particularly rainfall
- The waste acceptance criteria in operation, particularly in relation to heavy metals.

In order to provide a realistic, and most probable, data set for the Woodstock Landfill the leachate data sets from sites that may be relevant have been collated. The attached Table 6.1A Woodstock Landfill Leachate Composition Sources provides details of the background to the data set, a summary of the waste profile for the site, and commentary on the characteristics of the leachate at each of the sites.

The data sets have been summarised onto the attached Table 6.1B Expected Woodstock Landfill Leachate Composition. Table 6.1B includes projected Mean and 95 percentile values for the key contaminants that may impact on the environment.

[1] BOD – Biological Oxygen Demand, COD – Chemical Oxygen Demand

Table 6.1A Woodstock Landfill Leachate Composition Data Sources

Name	Source and Background	Waste Profile	Commentary
Burwood BH7	An historical data set was provided for the application to extend the landfill in 2012. It is not clear what period the data set covered.	The Burwood Landfill has been the primary landfill for the greater Christchurch area since 1984 until its closure as the municipal landfill in 2005. In addition to being the primary municipal landfill (for residential and commercial waste) it also received large amounts of treated wood waste, contaminated soils, and sewage treatment biosolids. From 2005 until 2012 it also received large amounts of contaminated soils and biosolids for capping purposes.	BH7 is a borehole immediately downstream of the historic Burwood Landfill. BH7 is the closest monitoring bore to the historic landfill but as the landfill was not lined it is possible that the leachate at BH7 is partly diluted and there has been some attenuation of contaminant levels as it passes through the underlying strata prior to reaching the borehole.
Redvale	Three data sets of leachate collected from the Redvale (Auckland) Landfill were provided as part of the 2019 Application for the proposed Auckland Regional Landfill at Riverhead. The data set is reported as starting in the late 1990's until 2018.	Redvale has been the largest landfill in the Auckland Region since 1992. In addition to receiving most of Auckland's municipal waste it has received very large quantities of contaminated soils (up to 40% of total waste received) and other industrial wastes.	The leachate at Redvale is collected at three points around the perimeter of the landfill. While this landfill is not lined the underlying mudstone strata is of extremely low permeability. There is a comprehensive leachate collection and removal system with the leachate being disposed of in a leachate evaporator. The quality of this data set is likely to be good. The characteristics of the leachate at Redvale will be significantly affected by the large quantities of green waste and food waste, and the high rainfall of approximately 1500mm per year. This will result with very fast degradation of the waste in an acidic environment resulting in very high Ammoniacal N concentrations.
WasteMINZ Class 2	This data set is included in the 2018 WasteMINZ Guideline and reported as being from 2 Waikato sites from 2007 to 2012, and from C&D Landfill (USA)	The WasteMINZ Guideline reports that the Waikato waste is at consented and lined sites that accepted C&D waste proposed for Class 2 landfills. There is no detail of the waste characteristics from the C&D (USA) study by Melendez.	The quality of the data from this source is suspect and it may be that some has been reported in mg/l and some reported in ug/l. It is noted that the data set attributed to Melendez (1996) noted below reports some data as being in mg/l whereas the original report quotes concentration in ug/l.
Fairfield	This data set is an historical record of leachate composition reported from twice yearly sampling of leachate reported to the Otago Regional Council in the site's Annual Report. The record runs from the year 2000 to 2015. This landfill is now closed.	The waste disposed at this site was a mixture of municipal waste from private collectors (with the majority of the municipal waste going to the Dunedin CC Green Island Landfill), commercial wastes, demolition waste, and some contaminated soils.	The leachate collection system encloses the whole site and while the site is not lined the basegrade is of very low permeability marine sediments. The quality of the data is very high. The rainfall at this site is approximately 800mm per year. The characteristics of the leachate from this site are likely to be the closest to that which could be expected at Woodstock Landfill.
C&D USA	This data set is summarised from a 1996 paper by Melendez, that analysed leachate data from 20 C&D sites in the USA. Not all sites measured all parameters but on average most parameters were measured at 10 to 12 sites.	The report notes that while the C&D sites primarily receive C&D waste there were often large quantities of grass and other vegetation. The report notes that many of the sites receive quantities of contaminated soils, and that the waste acceptance processes varied considerably from state to state.	The quality of this data set is generally good as it comes from many sites. However, the variability in waste acceptance could result in some landfills being more like municipal landfills.

Note: Leachate composition for the Kate Valley Landfill at Waipara is not publicly available as it is not required to be reported to Environment Canterbury as a condition of consent.

Table 6.1B **Expected Woodstock Landfill Leachate Characteristics**

Data source	Burwood BH7		Redvale		WasteMINZ Class 2		Fairfield		C&D USA (Melendez)		Adopted for Assessment	
Determinand	**Lower**	**Upper**	**Mean**	**Upper**	**Lower**	**Upper**	**Lower**	**Upper**	**Lower**	**Upper**	**Mean**	**95 percentile**
pH					5.9	8.3	7.3	7.5	6.45	7.6		
COD												
BOD_5				150	1.4	38			5.7	920		
Ammoniacal-N	127	195	700	1300	0.86	99	290	340	140	480	150	350
Chloride					0.3	28			2.65	2.65		
Suspended solids												
BOD_{20}												
TOC					55	191			15	2100		
Fatty acids (as C)												
Alkalinity (as $CaCO_3$)					70	1930			38.2	6250		
Conductivity (µS/cm)					120	554						
Nitrate-N												
Nitrite-N												
Sulphate (as SO_4)					360	1900			11.7	1700	500	1900
Phosphate (as P)												
Sodium							1150	1900	773	1290		
Magnesium							180	350				
Potassium												
Calcium												
Aluminium											2	5
Chromium	0.0016	0.0153	0.452	1.4	0.027	0.64			0.0014	0.046	0.02	0.05
Manganese									0.076	0.258	20	20
Iron					0.0023	0.3	22	235	0.275	5.2		
Nickel	0.0023	0.0069							0.12	0.17	0.1	0.17
Copper					0.001	0.102			0.04	0.21	0.05	0.2
Zinc	0.0042	0.019			0.0025	5.5	0.13	0.27	0.049	1.5	0.1	1.5
Cadmium			0.0024	0.01					0.005	0.025	0.01	0.025
Lead			0.0248	0.28	0.001	103	0.03	0.1	0.04	0.8	0.05	0.3
Arsenic	0.029	0.18	0.1653	0.34	18	200			0.015	0.04	0.15	0.35
Mercury			0.0005	0.01					0.005	0.009	0.005	0.01
PCP												

Key Parameters for assessment

6.1.3 Leachate management options

Leachate management options potentially available for the Woodstock Landfill are:

1. Treatment on site and discharge to a watercourse;
2. Treatment and discharge by irrigation outside the landfill footprint;
3. Treatment and discharge by irrigation to the landfill cap;
4. Recirculation into the landfill;
5. Evaporation of leachate using landfill gas as a heat source;
6. Cartage to an off-site treatment plant;

Each of these options and their relevance to the Woodstock Landfill are described below. The potential solution could be a combination of two or more of these options.

Option 1: Treatment and discharge to surface water

For this to be viable a high level of treatment would be required, such as reverse osmosis (RO), to remove a high percentage of the contaminants in the leachate. RO produces a significant quantity of "reject water" which has a high concentration of contaminants. This is typically returned to the landfill. This option is not currently considered viable given the high standard that would be required to discharge directly to the Woodstock Stream downstream of the landfill.

Option 2: Treatment and discharge to adjacent land

For this option to be viable the treatment method needs to be able to reduce the nitrogen and COD concentrations in the leachate. This can be achieved through biological processes with sequencing batch reactors (SBR) having successfully been used for leachate treatment elsewhere. Some metals will be removed through this process as well. Following treatment, the treated leachate would be irrigated to land. Investigation of the soils in the vicinity would need to be undertaken to determine a site-specific irrigation rate. Greater land areas may be required based on acceptable nitrogen loading rates. Although this option is potentially viable it is not being considered at this stage given the significant level of treatment and the land area required.

Option 3: Treatment and discharge to the landfill cap

This option is preferable to Option 2 as potential effects on groundwater are controlled by the presence of the underlying landfill lining system. For this reason, less treatment is required, and an aerated lagoon system has successfully been used at other sites. The nature of the development of the Woodstock Landfill is such that it will be a long time after commencing operation until any significant areas of final cap are available for irrigation. Irrigation could occur on intermediate capped areas but similarly it will be some time until sufficient area is available. While this may be a possible option for the future it is not a viable option when the landfill first opens.

Option 4: Recirculation into the landfill

For this option leachate is discharged directly to the waste placed in the landfill, either through a series of trenches/distribution pipes in the waste or, more commonly, by irrigating onto newly placed waste each day. Waste, especially in Canterbury, typically arrives at the landfill well below its field moisture content so it can permanently take up moisture. Therefore, in the early period of a recirculation management approach the quantity of leachate will reduce. Flow through the waste also typically provides some treatment benefit to the leachate and will help production of landfill gas (LFG) by raising the moisture content to the optimum level for LFG production. However, in the longer term the storage capacity for leachate will reduce and more and more leachates will require managing.

Option 5: Evaporation

This can be achieved in a purpose-built thermal leachate evaporator using LFG as the heat source. This method of leachate management has been used by other landfill for many years. Again, this option is not available during the early period of operation of a landfill as it takes some time before decomposition of the waste changes from aerobic through to acetogenic and then methanogenic when LFG starts to be produced. It is also necessary for a reasonable depth of waste to be placed before an effective gas collection system can be installed. Overall, it is likely to be at least ten years before thermal evaporation could start to be implemented.

Option 6: Cartage off-site

For many sites leachate is carted off site to a municipal wastewater treatment plant or to some other treatment facility. In the context of the Woodstock Landfill potential off-site disposal/treatment options are at the sewage treatment facilities operated by Waimakariri District Council, Selwyn District Council, and Christchurch City Council.

6.1.4 Proposed leachate management

From an assessment of the above options the following approach to leachate management is proposed at the Woodstock Landfill:

- Leachate collected from the landfill will gravity feed into the primary storage tanks
- During the early stages of operation, the primary tanks will be in the operational landfill area. Leachate in these tanks can be loaded into tankers by pumping and transferred off site for disposal to an approved facility.
- As far as is practicable, leachate will be recirculated into incoming waste at the landfill to minimise the quantity that needs to be transferred off site;
- When the landfill expands to the west the leachate storage facility will need to be located outside the landfill footprint and will need to be located inside a bunded compound.
- If sufficient LFG is available at the Woodstock Landfill an evaporator, or new technology, would be installed on site. Once sufficient capacity is available, transfer of leachate off site will cease.

7 Ancillary works

7.1 Bin exchange area and weighbridge

7.1.1 Overview

A bin exchange area will be located at the end of the existing formed access road. This allows for standardised bins to be delivered full to the site and deposited in the bin exchange area. Road haulage trucks will deposit full bins and pick up empty bins, thereby allowing for immediate departure from the site. The full bins will be taken to the working face by site haulage/tipper vehicles (mules) for emptying, and subsequent return (empty) to the bin exchange area.

Through this approach the transport of waste from source to the site is disconnected from the landfill working face operating hours. This allows the landfill to operate efficiently and provides a high level of control over waste arrival at the working face. The system also avoids disruption back at the off-site Refuse Transfer Stations (RTS) after hours as well as during the rare occasions that the working face may be closed due to high winds or other weather-related reasons. With access to the working face limited to the mules and non-WQL customers, the working face can be kept to a minimum size. Safety is optimised at the face by avoiding the manoeuvring activity of road haulage vehicles. Transport of waste to the facility can also take place over much longer hours each day than the working face operating hours, thereby optimising truck numbers and transport efficiency. This approach also minimises the number of trips required to the site from the customers sites that are primarily located around Christchurch.

7.1.2 Bin exchange

Waste from the client's sites will be transported via a 2-bin or 3-bin hook truck and trailer. Each bin will be unloaded on to the ground by the road haulage truck or by the on-site mule and picked up by a mule truck that is permanently based on-site. The mule will take bins individually to the working face, discharge the waste, and return the empty bin to the bin exchange area to be swapped for a full bin.

Compatible bins owned by third parties will be immediately picked up by a mule and taken to the working face for emptying while the truck waits within the bin exchange area for their bins to be returned. As the bins will be standardised, the haulage truck is able to make an exchange with any available empty bins in the exchange area, without needing to wait for the mule to return the same bins. From time-to-time waste trucks that do not have the standardised bin system and provision will be made for them to go direct to the working face.

7.1.3 Proposed operations

The bin exchange area will operate during the operational hours of the quarry, for pre-approved vehicles. Full bins (covered) may need to be stored overnight.

The working face will be used by mule trucks transporting hook bins from the bin exchange area to the working face and non standardised vehicles that do not use hook bins. However, it is anticipated that nearly all haulage will be standardised using hook compactor bins.

7.1.4 Design

Key elements of the design include:

- A weighbridge, with an associated site office, will be provided at the bin exchange area which arriving vehicles will need to use prior to entering the bin exchange area.
- A one-way circulation system within the bin exchange area for trucks undertaking the bin exchange process, with up to five road-haulage vehicles at any time, with others waiting if needed;
- Separate access into the bin exchange area is provided for mule vehicles. Exclusive access will reduce traffic conflicts;

- Overnight parking is provided for the mule fleet, some haulage trucks, and tipper trucks;
- The bin exchange area will have provision for light vehicle parking for mule truck drivers, visitors, and some administrative staff.
- The facilities building at the bin exchange area will contain limited facilities mainly for drivers but will include a lunchroom, washrooms, and an office;
- The bin exchange area provides for manual/visual inspection of loads entering the landfill for compliance with the Waste Acceptance Criteria
- The entire surface will drain to a specific stormwater treatment device. No waste bins will be opened in this area so treatment requirements will be minimal.
- Lighting may be provided for night operation if required, and may include automatic sensor lights;
- The bin exchange area will be completely screened from the public by existing rolling landform between the area and Trig Road.

A preliminary concept plan for the proposed Container Transfer, which includes the bin exchange area, and the weighbridge is shown on Drawing F1.

7.2 Site roading

7.2.1 Access roading

7.2.1.1 Description

The access to the site and the location of the various access routes around the site are shown on Drawing F2. The labels on the drawing correspond to the headings used below.

Trig Road Intersection.

The existing entry where vehicles enter the site off Trig Road was installed under previous consents and has operated safely. The entrance has excellent visibility of over 400 metres to the west and approximately 50 metres to the east where Trig Road effectively ends with 90-degree bends to the left and to right into farm tracks. The gate at this access point is kept locked when there are no staff at the quarry or landfill.

The Applicant has offered a Condition of Consent to upgrade the Trig Road intersection to comply with WDC Standard Drawing 218.

Access Road (Right of Way)

The main access to the site is via the existing right of way off Trig Road. The section of accessway from Trig Road to the Container Transfer / Site Facilities Area, is approximately 1.6km long and can only be used by customers of the site, service workers and staff. Signage will clearly advise that the road is not open to the public. This section of road will be used by the following vehicles:

- Truck and trailers hauling quarry products from the site
- Truck and tailers hauling waste to the site
- Contractors service vehicles
- Staff vehicles
- Fuel delivery trucks

The right of way terminates at the physical entry point of the main Woodstock Quarries site. As noted in the AEE for this Application it is expected that the peak traffic generation would just over 200 vehicles per day. It is proposed that this right of way be upgraded to have a minimum carriageway width of 6.0 metres.

Site Roads.

The roads beyond the Container Transfer / Site Facilities Area will only be used by WQL staff, approved quarry customers, contractors that service on site vehicles and plant, the occasional fuel delivery truck, and specialist landfill construction contractors. All users of these roads will be fully inducted.

This section of road will be used by the following vehicles:

- Specialist off road trucks hauling quarry products to the Container Transfer Area.
- Specialist off road trucks hauling waste from the Container Transfer Area to the active landfill face.
- Approved quarry customers truck and trailer accessing the lower pit stockpile area
- Contractors service vehicles
- Company 4WD vehicles
- Fuel delivery trucks

All the Site Roads will be designed, and maintained, in accordance with Section 5 Planning for Roads and Vehicle Operating Areas of the Worksafe Good Practice Guideline Health and Safety at Opencast Mines, Alluvial Mines and Quarries.

In addition, WQL will be required to modify, and maintain, a Traffic Management Plan (TMP) that complies with the Health and Safety at Work Act 2015. This TMP is required to protect workers and visitors to the site and will be continually modified as the site is developed. The Applicant has offered a Condition of Consent requiring Site Roads to be constructed and maintained to this standard.

The gravel road will operate on a one-way system as shown on Drawing B2. This provides for safety and efficiency of access for all vehicles on this primary access route onto the landfill site. The design objective is for the grade not to exceed 8 % to be suitable for hauling full waste vehicles up- hill.

7.2.1.2 Access road stormwater

Stormwater management along the length of the road will comprise:

- Cut-off drains at the top of cut slopes (where required) to divert water to specific discharge locations at existing flow paths;
- Armoured channel or pipe down any cut slope to carry flow from existing flow paths to culverts under the access road;
- Inlets at the location of each existing flow path to divert flow into culverts beneath the access road, or armoured cross swales across the road, to discharge to the existing flow path on the downstream side of the road;
- Small collection drains on the upslope side of the access road to collect any runoff from the slopes above;
- The road surface will have a uniform cross-fall to shed all stormwater to a channel on the down-slope side of the road;

7.2.2 Perimeter road

A road will be constructed at the top of the landfill around the landfill perimeter, and shown on Drawing B2, as follows:

- Along the eastern side of the landfill, the road will be constructed for one-way traffic and will start in the general area of where the access road enters the landfill;
- Along the western end the road follows the alignment of the stormwater cutoff drain which terminates at the sedimentation pond. This road will be steep and will be used for maintenance purposes by 4-wheel drive or tracked vehicles;
- The perimeter road will typically be a gravel road.

Stormwater beside the perimeter road will be managed in the same manner as stormwater on the landfill benches, with an open channel drain on the outside of the road diverting stormwater to the stormwater treatment ponds.

7.2.3 Stage access

Landfilling will occur in the lower eastern side of the existing quarry for the first phase of operation of the landfill and then continue westward progressively to the west. To provide access for filling and operation over the life if the landfill the following is proposed:

- A road will be constructed from the landfill access road across the perimeter drain and the first section of toe bund. This will provide the main access route for waste vehicles entering the site. Access can continue over the waste fill or benches for filling at higher levels or for subsequent phase located to the west of Phase 1;
- As landfilling progresses, access for waste vehicles will be constructed as required over the landfill surface.

7.3 Site facilities

7.3.1 Office, workshop, and staff amenities

A building will be provided for offices for staff responsible for the operation of the landfill. Parking will be provided adjacent to this building for 10 cars (staff and visitors).

A workshop will be provided for plant and general maintenance. This will be a building with a footprint of approximately 150 m^2 (15 x 10 m). Hardstand area for plant of approximately 1,000 m2 will be provided outside the building.

Amenities would accommodate:

- Offices for supervisors (two staff)
- One lunchroom/ kitchen
- Two toilets, showers, and locker facilities

Additional small buildings will also be provided in this general area to house small plant, equipment, etc. The precise location for the building will be confirmed as part of detailed design.

7.3.2 Gas utilisation centre

If required, the gas utilisation centre would be located on a level platform just outside the eastern end of the toe bund. The platform constructed for this purpose would contain:

- LFG flare(s);
- Electricity generators;
- Leachate evaporator(s);
- Leachate storage tanks;
- Workshop facility for engine maintenance;
- Staff facilities.

7.3.3 Wheel wash

A wheel wash would initially be provided inside the main landfill footprint for cleaning the wheels of all vehicles leaving the area. The wheel wash will comprise as a minimum a ramp into a flooded basin with rumble bars through which vehicles drive, followed by a drip catcher pad at the outlet. It may also include fixed water jets and/or a handheld water blaster for manual cleaning of vehicles.

Sediment from the wheel wash will be removed from time to time by front-end loader and placed on the ground on the landfill to dry and/or be used as cover. Overflows from the wheel wash will be diverted to a sediment pond adjacent to the wheel wash for settling of any sediment. Water will be pumped from this pond to the wheel wash. Discharges from this sediment pond will flow into the landfill stormwater system and will pass through the landfill stormwater treatment system.

Due to the nature of the proposed waste stream the waste bins are unlikely to be required to be cleaned. If any bins were required to be cleaned this would be undertaken within the operational landfill area.

7.4 Water supply

7.4.1 Potable water supply

An existing water supply will be provided for staff facilities. Current indications are that the water is of suitable quality to not require any treatment. If shown to be required, under-sink UV disinfection units will be provided where water is used for human consumption.

This system would also be used for general water use in the office/workshop areas.

7.4.2 Dust suppression and road washing

The recirculated leachate will be the primary method of dust control in the active landfill area. The leachate is sprayed over the surface using a large droplet irrigation system. The irrigation of the active landfill area is crucial to ensure that the waste is well compacted. Moisture sensors are connected to the irrigation controller to ensure there is not excessive irrigation.

Water for additional dust suppression on the roads and wheel wash will be sourced primarily from the sedimentation ponds on site. The water for dust suppression will be pumped into a large water cart. This is expected to use approximately 10 cubic metres of water per day.

The only area where road washing is envisaged is at the Container Transfer Area. This may require washing a few times a year, mainly in the summer.

7.4.3 Firefighting water supply

The primary firefighting resource will be the large on-site water cart equipped with a spray pump system. This will be able to access most areas of the site, and be able to quickly respond to a fire, whether it be in the landfill or on adjacent land. The water cart will be always kept full of water.

It is proposed to install approximately five 25 cubic metre water tanks on the hill above the landfill that will be kept full for firefighting. A 100mm gravity water main, with fire hydrants at key locations, will be installed on the eastern perimeter road. A small water pump and rising main will fill these tanks when the sedimentation pond has live storage in it.

Any additional water required for firefighting will be drawn from the sedimentation ponds. They would also be available for filling monsoon buckets carried by helicopters. The dead water capacity of the proposed sedimentation pond is approximately 700 cubic metres.

Additional sources may be available from the Woodstock Stream. These sources could be used in emergencies to fill water tankers for fire-fighting purposes.

7.5 Wastewater treatment and disposal

There is no reticulated sewerage system local to the site so all wastewater generated at the landfill will be treated and disposed of on site at a location near the point of generation. A separate consent application will be lodged for this at the same time a building consent application is made.

The treatment and disposal system will be designed and installed in accordance with Sections 5 and 6 of New Zealand Standard AS/NZS 1547:2012 – On-site Domestic Wastewater Management.

At the Container Transfer Area, a three-stage oil separator will be installed at the outlet of the stormwater collection system.

At the facilities workshop a three-stage oil separator will be installed at the outlet of the stormwater collection system.

7.6 Services

Site telecommunications will use either mobile cell phone technology or a simplex radio system.

Data services will be from either a terrestrial wireless provider, or satellite provider.

Electricity will be sourced from the existing on-site generation plants. If constructed, electricity would be generated from the gas utilisation station, with the surplus exported to the local network at 11kV by pylons and wires.

7.7 Fuel, oil, and other Hazardous Substances

The current quarry operation has the following hazardous substances on the site, all of which are stored in approved facilities. Explosives are not kept on site.

- 10,000 litre double skinned self-contained fuel tank
- 5,000 litre double skinned self-contained fuel tank
- 1,500 litre mobile diesel tank
- Dangerous goods container for storing lubricants

For the combined quarry / landfill operation proposed under the Application the additional hazardous substances are likely to be added.

- 5,000 litre double skinned self-contained fuel tank at the Facilities area
- Dangerous goods container for storing lubricants at the Facilities area
- Certified explosive magazine at the upper quarry area

The location of these existing and potential hazardous substances is shown on Drawing A5.

8 Landfill construction, operation, and closure

8.1 Landfill construction activities

A landfill operation is effectively a long-term construction project, being predominantly an earthworks and stormwater management operation. The bulk of these works are carried out progressively in conjunction with waste filling as waste is received over the life of the landfill. The activities on a landfill site fall into three general categories:

- Initial construction activities;
- Ongoing operational and phase development activities;
- Closure and aftercare activities.

Initial construction activities occur prior to the landfill accepting its first waste.

Initial construction activities will include:

- Construction of permanent site stormwater controls downstream of the landfill and any other stormwater controls required for initial earthworks (e.g., at stockpile areas);
- Construction of the bin exchange area;
- Site access roading to the first stage for landfilling and to all stockpile areas;
- Construction of the main site office area and workshop facilities;
- Formation of basegrades for Phase 1 of the landfill, construction of the toe bund, impermeable liner system and leachate collection system.

Operational activities include:

- Waste filling;
- Winning and placement of daily cover and intermediate cover as required. This may also include stockpiling soils close to where they may be required;
- Stormwater management and maintenance works;
- Construction of the next landfill phase and other required construction work.

During the operational period construction activities will be undertaken as required to develop the next landfill stage so that it is ready to accept waste when required. Wherever possible, soils required for operation of a stage will be taken from the footprint of the next or subsequent stages to minimise earthworks movements and the need for stockpiling of soils.

Closure activities include placing the final capping layer on completion, establishing any final landscaping, and removing any facilities and infrastructure that is not required during the aftercare period, or modifying such infrastructure for the aftercare period.

Aftercare activities include maintenance of the cap and stormwater systems, management and maintenance of the leachate and LFG systems and ongoing site and environmental monitoring.

The following sections describe these activities in further detail.

8.2 Earthworks

8.2.1 General

The overall soil requirement for the operation of a landfill amounts to approximately 20% of the landfill airspace volume. Therefore, for a landfill airspace volume of approximately 3.2 Mm^3 a soil volume of approximately 0.6 Mm^3 is required for its operation. This soil is used for daily cover, intermediate cover, final cover, and incidental construction works on the landfill site. This material is made available by providing for a surplus cut over fill when developing the landfill footprint from the quarry operation, so that there is an overall soils balance over the life of the landfill. It is planned for Woodstock Landfill that the operational soils be obtained from the landfill footprint. Drawing B4 in Appendix 2 shows the quarry operation, creating the landfill airspace, followed by the landfilling operation.

Typically, any surplus soil from the construction of a stage or cell is carted to a stockpile on site. Soils required for the operation of a cell would be taken from the footprint of the next cell, to minimise double handling of materials and to optimise haulage distances. If there is no soil readily available from future development areas, it would need to be taken from the soil stockpiles. At the end of the landfill life, soils for construction of the final cap would be taken from the soil stockpiles.

Investigations on site have shown that the highly to moderately weathered rock is expected to be rippable with a large excavator. Such materials are expected over approximately 10 – 15 m depth from the surface. Greater depths of excavation are required in most areas for the proposed basegrade formation, and this will be completed progressively by the quarrying operation. It is anticipated that blasting may be required in this area and other deep areas of excavation.

8.2.2 Site clearing

As part of the ongoing quarry development moving to the west a small area of existing scrub and small trees will need to be removed.

8.2.3 Water management

Prior to any sediment generating works being undertaken on site the downstream sediment treatment ponds will be constructed.

For the first phase of construction temporary diversions will be established within the construction area in accordance with the Erosion and Sediment Control Plan (ESCP).

For further phase development, secondary stormwater diversion will be through surface drains on the benches around each phase of the landfill. These diversion drains will be established as early as practicable to divert stormwater to the main perimeter drain.

8.2.4 Topsoil stripping

Topsoil will be required for placing on the final cap for the establishment of vegetation. It is important that as much topsoil as possible be recovered during construction, to remove these weak/organic soils from the footprint and for the topsoil to be available for later use. There could be up to 60,000 m^3 of topsoil requiring removal. This material needs to be stockpiled for use in the cap.

Topsoil will be excavated from the stockpile areas and other earthworks areas as required to be stockpiled with the balance of the topsoil or re-used as part of the reinstatement of construction areas.

8.2.5 Unsuitables

It is possible that there are small quantities of plastic soils present in the floors of the quarry. However, this is not expected to be a large quantity. If these materials were to remain in place, they are likely to settle, causing unacceptable strains on the lining system. Therefore, these unsuitable soils will be removed. Depending on the nature of the materials they may be deposited in the main stockpiles or kept separate to allow them to dry or to allow a possible alternative use, for example as a growth layer in the final cap.

8.2.6 Underdrainage

The hydrogeological investigation has identified that there may be pockets of subsurface water, and over much the site there is an inwards hydraulic gradient. This will require drainage prior to the construction of the liner system. The extent of the underdrainage system is unknown at this stage, but it assumed that there would need to be an extensive drainage blanket constructed with good quality aggregate manufactured on site at the quarry. On the top of the drainage blanket a filter geotextile will be placed to ensure the drainage blanket is not contaminated with the overlying subliner.

Within this drainage blanket a network of welded HDPE subsoil pipes will collect the subsurface water and discharge it into the perimeter drain. The discharge from the underdrainage system will be required to be continuously monitored and be able to divert to the leachate system in the event that contamination of the underdrainage system was detected.

8.2.7 Subliner

The subliner material is the fill immediately under the lining system. The subliner layer consists of high strength controlled compacted fill, typically constructed by cutting to fill within the footprint of each cell.

This subliner is shaped to the profile required for the leachate drainage system that sits above the liner.

8.2.8 Liner soils

Based on the site investigations to date, it is expected that much of the low permeability clay will not be obtained from the footprint of each cell, but from other parts of the site where the low permeability material has deposited in gullies. As this material is likely to be near the existing ground surface, it will be carefully selected during the excavation phase and stockpiled on the footprint of the next phase to be constructed, or at another convenient nearby location, for subsequent re- use for lining system construction.

The 300 mm thick low permeability clay layer will be constructed below the GCL, which sits on the prepared lining system subgrade as the first of the lining system layers.

Any low permeability soils surplus to immediate requirements will be stockpiled in the clay borrow area, for use in subsequent phases where there is a shortfall in suitable materials.

8.2.9 Stockpiles

Soil stockpiles are required for:

- Surplus excavated materials, until they are needed for landfill operation or final capping;
- Low permeability (“clay”) soils;
- Topsoil;
- Unsuitables.

Stockpiles will be formed as follows:

1. Sediment control ponds will be constructed downstream of the stockpile areas.
2. Topsoil will be stripped from the portion of the site to be used for the works proposed;
3. Clay soils will be excavated from the stockpile area and transferred either directly to current construction or to the clay stockpile;
4. Filling with surplus excavated materials will commence, with compaction in accordance with the specification prepared as part of the detailed design, to ensure stability of the stockpiled soils;
5. Where practicable, filling will commence from the proposed final toe of the stockpile, with the front face formed and shaped as filling progresses. As soon as sufficient area is available remote from current filling works the surface of the front face will be vegetated. This will comprise covering with a layer of topsoil or other suitable growth layer and sowing grass seed, or hydroseeding the face;

6 On completion of filling at the end of each summer earthmoving season, all bare earth surfaces of the construction-related earth fills will be stabilised with grass, erosion mats or tarps.

Additional stockpiles will be used from time to time, typically on top of the waste surface, at a location convenient as a source for daily cover

Topsoil stockpile

The topsoil stockpile will be progressively added to as each cell is developed. This will be operated in a similar manner to the main stockpiles with appropriate sediment control in place prior to construction and revegetation as soon as is practicable after each seasonal episode of accumulation or depletion.

Clay borrow and stockpile area

Prior to any work in this area a sediment control pond will be constructed in accordance with the ESCP. Topsoil will be stripped and stockpiled nearby before any area is filled and/or excavated. Only sufficient area will be stripped as required for the activities being undertaken at that time, and the area will be progressively re-stabilised in accordance with the ESCP.

8.2.10 Operational activities

The operation of the landfill generally comprises receipt of the waste, placement and compaction within the landfill and covering. The operation of the landfill is described in the Assessment of Environmental Effects.

8.3 Closure and aftercare activities

8.3.1 Closure Management Plan

Prior to the end of the life of the landfill a Landfill Closure Plan will be prepared to detail the activities required for closure of the landfill and during the aftercare period. In general terms, the activities required for closure and aftercare are described in the following sections.

8.3.2 Closure

8.3.2.1 Landfill cap

The final capping system will be constructed progressively after filling in any area has been brought up to final level. This work will generally comprise:

- Excavating soils from the soil stockpiles and placing in layers on the landfill cap in accordance with the design;
- Placing an upper topsoil and/or growth layer from materials stockpiled on site;
- Constructing surface contour drains to manage stormwater falling on the landfill cap, including connections to the perimeter drainage systems;
- Establishing vegetation (grass/shrubs, etc.) in accordance with an established planting plan.

On completion the stockpile sites will be graded to conform to the adjacent topography and re- vegetated. The sediment ponds downstream of the stockpiles will be removed on completion of the works, unless it is determined that they should be remain because of any established ecology.

8.3.2.2 Site stormwater systems

Work will be undertaken to ensure that all remaining stormwater systems required for the long-term management of stormwater on site are in good working condition, any new works required constructed, and all stormwater infrastructure no longer required is removed.

Any excess sediment will be removed from the stormwater ponds and the ponds left in a condition whereby they can operate with minimal attention.

8.3.2.3 Site facilities

All facilities not required during the landfill aftercare period will be removed. Such facilities will include:

- Bin exchange area facilities;
- Site office;
- General plant maintenance workshop;
- Removal of any leachate storage or other facilities no longer required.

It is proposed that all site roading remain in place unless the adopted long-term use for the site requires some alteration to the roading system.

8.3.3 Aftercare

Aftercare activities comprise:

- Ongoing operation and maintenance of the LFG extraction and treatment system;
- Ongoing operation and maintenance of the leachate collection, treatment, and disposal system;
- Maintenance of the site stormwater systems;
- Maintenance of the landfill cap, including filling any areas that may have been subject to differential settlement, repair of any surface erosion and maintenance of vegetation as required;
- Maintenance of any remaining site infrastructure, including fences and the like;
- Ongoing environmental monitoring as required by consents;
- Any reporting required by consents;
- Responding to contingent events as set out in the Landfill Closure Plan.

9 Contingent events

A landfill is a large civil engineering project that continues over an extended period of time. As such, it may be subjected to possible extreme natural events that fall outside the range of anticipated design scenarios. Other potential "failures" could also occur. Such possible events are described below along with possible response actions.

In Appendix 7 a detailed Environmental Risk Assessment considers the possible range of events and circumstances that could affect the site and provides a summary of the precautions that are in place to ensure that the potential impacts are minimised.

9.1 Extreme weather

Extreme weather is considered in the context of an extreme rainfall event. Possible damage from such an event could comprise:

- Higher than expected erosion, resulting in high sediment loads to the treatment system and possible carry-over of sediment to the downstream environment;
- Erosion damage to site stormwater infrastructure;
- Flooding and/or erosion resulting in mixing of waste with stormwater;
- Erosion of surfaces not draining to the site stormwater treatment system.

In most cases the extensive stormwater treatment ponds will manage or limit potential environmental effects. In the event of a significant storm that resulted in an overflow of the main stormwater system an overland flow path will direct stormwater into the gully directly to the south of the sedimentation ponds where a secondary sedimentation pond would be constructed.

After such an event, some or all the following may be required:

- Immediately advise Environment Canterbury if there has been a breach of any consent condition;
- Take immediate action to prevent any discharges of waste or leachate to the stormwater system;
- Investigate whether there have been any downstream effects, and scope the extent of any remedial works that may be required;
- Repair site stormwater infrastructure, with a focus on areas that may cause further erosion and sediment transport to the ponds;
- Restore the treatment capacity of the ponds by removing excess sediment;
- Prepare a report to Environment Canterbury describing the event, its cause, environment effects and remedial action taken, or to be taken.

9.2 Earthquake

A large earthquake may result in:

- Instability of the permanent landfill face;
- Instability of any internal working face;
- Instability of the landfill toe bund;
- Lateral displacement of the waste pile;
- Possible excessive strains and/or rupture of the landfill lining system.

The USA EPA Seismic Design Guide provides a particularly good summary of the potential failure modes that could occur at a landfill under seismic forces and are depicted in Figure 9.1 below.

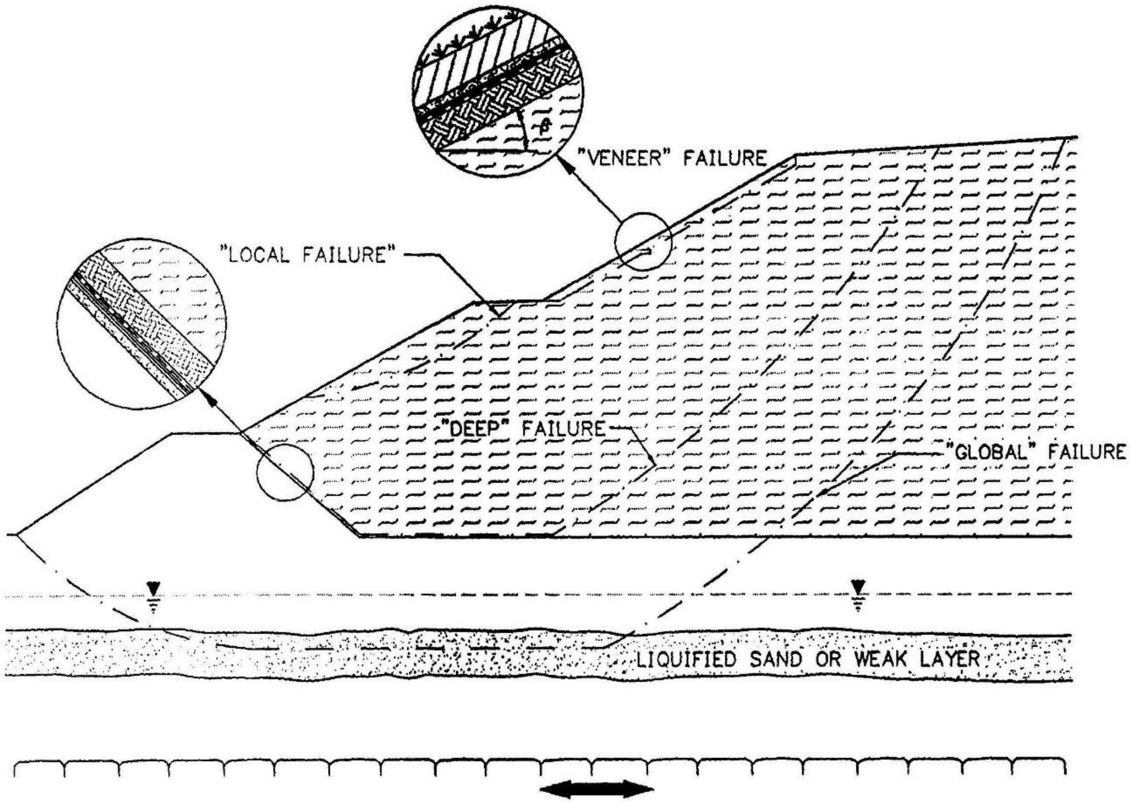

Figure 9.1: Potential Failure Modes of Landfills Subject to Seismic Forces

A description of these various failure modes could affect the Woodstock Landfill, the vulnerability to each mode, the potential consequences of failure, and the likelihood of the failure mode occurring are summarised in Table 9.1 below.

Table 9.1 Potential Failure Modes for Woodstock Landfill

Failure Mode	Vulnerability	Potential Consequences	Likelihood
Global	This type of failure is always due to an undetected weak layer, or layers that are susceptible to liquefaction. At Woodstock Landfill there is a dense, high strength layer of rock	Minor lateral movement of the full site	Very Low
Deep	A Deep failure, or lateral movement, could occur to the toe bund, and or waste pile. However, C&D waste is inherently strong due to the "reinforcing" effect of timber in the waste stream, and many of the soils will be good granular fill. At Woodstock Landfill the toe bund is minimum of 6m high, with a minimum width of 46 metres at the base, with a very low risk of a failure that would result in a release of leachate.	Failure, or lateral movement, of a section of the toe bund. Failure of part of the waste pile, especially the working face.	Very Low
Local	A local failure is one that can occur with fresh waste that has not been compacted properly or is very wet. At Woodstock Landfill there is minimal organic waste (which has	Minor slips of the front face of the waste pile.	Very Low

Failure Mode	Vulnerability	Potential Consequences	Likelihood
	the highest risk of failing), and wet wastes will not be permitted.		
Veneer	Veneer failure can occur when the capping layers are fresh, or there is a build-up of water under the capping. At Woodstock much of the landfill capping material has good drainage properties and there is a significant surplus of soils to ensure that the cap is thick.	Minor slips of the front face of the waste pile.	Low

As noted in Section 4.1.2 the stability of the long term and short-term slopes have been modelled by a geotechnical engineer using a modern computer software system. The output of the modelling is included in Attachment 12 Stability Analysis.

Following the 1994 North Ridge earthquake in California several researchers investigated failures of landfill liner systems. In almost all cases the failure of the HDPE liner occurred in the following locations:

- At the top of a slope adjacent to an anchor trench
- Along a longitudinal join of the HDPE liner, especially on side slopes
- Close to a defect in the liner, such as a scratch.

Of these failure modes the deep failure is of the most relevant to the Woodstock Landfill and could result in a failure of part of the toe bund. This failure is most likely to be over a short length of, say, 3 to 5 metres, and could result in a localised failure of the liner on the toe bund, probably along a longitudinal join. At Woodstock Landfill the toe bund is minimum of 6m high, with a minimum width of 46 metres at the base. As shown in Table 5 of the Attachment 12 Stability Analysis the failure to the full height of the bund that would result in a release of leachate is not the likely failure mode. This type of failure would be obvious and the work force on site would be able to respond and repair the failure quite promptly. There could be a short-term localised release of leachate that flows into the perimeter drain, and down into the sedimentation ponds.

Alternatively, a major earthquake event could result in a series of small failures of the toe bund and liner on the toe bund. These too are most likely to be short failures along a longitudinal join at 6 to 8m spacings, depending on the width of the HDPE rolls used for the construction. There could be a slower release of leachate at each of these failure sites, through the toe bund, which flows into the perimeter drain, and down into the sedimentation ponds. Any such failures would appear as a seep due to low head of leachate behind the toe bund. This failure may not be immediately obvious, and could occur over a few days before being identified, or triggering an alarm of the environmental monitoring system.

To enable an assessment of the potential worst-case scenario of a peak level of leachate in the leachate collection system, along with a failure of part, or parts, of the toe bund following a seismic event, resulting in a discharge into the surface water system the following methodology has been adopted.

- As noted in Section 6.1.1 above a peak leachate generation rate of 15% of rainfall has been adopted for contingency planning purposes.
- As noted above an undetected failure of up to 5m of toe bund has been adopted as a worst-case scenario
- The quantity of leachate that could be discharged to the surface water system as a worst-case scenario is summarised in the table below:

It is noted that this worst-case scenario could only result from the damage to the toe bund not being detected by the landfill operator, and a worst-case scenario would only occur for a few days before the landfill operator could repair the damage or divert the leachate to a temporary collection system.

Table 9.2 Worst case scenario of discharge of leachate to the surface water system

Landfill rainfall	920mm per year
Peak leachate generation rate	15%
Peak average depth of leachate	138mm
Landfill footprint area	9.3 hectares
Peak leachate generation rate	12,834 m3 per year
Landfill bund length	300m
Bund failure length	5m
Worst case leachate discharge per day	586 litres per day

Following a significant earthquake, the following should be undertaken:

- Inspect the landfill and surrounds for any visible sign of land damage, or damage to the lining system where exposed at the edge of any fill;
- If significant damage is observed, advise Environment Canterbury;
- If any evidence of damage is observed, scope a detailed investigation to determine the likely extent of any damage, and whether the lining system is likely to have been damaged. This investigation should also identify possible remediation works;
- Over the following months, carefully analyse groundwater monitoring results to identify any potential changes that may indicate new leakage through the lining system;
- Prepare a report to Environment Canterbury describing the event, its cause, environment effects and remedial action taken or to be taken.

9.3 Pipe blockage

Blockage of the stormwater pipe on the perimeter road above the landfill could result in water ponding against the landfill, additional leachate production and possibly a leachate spill. Blockage of other minor pipes or channels is likely to result in water flowing overland around the blockage and possible additional erosion. The potential effects of these events are generally described under “Extreme weather” and “Leachate spill”. As for all other contingent events it would be necessary to investigate appropriate remedial options and implement these as soon as is practicable.

9.4 Leachate spill

A leachate spill could occur as a result of:

1. A burst pipe or joint failure in the leachate rising main;
2. A leachate tank failure, with the tank contents overflowing from any bunded area;
3. Spillage at the tanker filling area, exceeding any containment in this area.

Any unintended discharge would be in the landfill stormwater catchment. Actions would include:

- Advise Environment Canterbury of the spill;
- Determine the extent of any discharge to the stormwater ponds and whether the concentration of any contaminants in the ponds are likely to cause any potential downstream environmental effects;
- If contaminant concentrations are unacceptable, hold any discharges from the pond system and develop a plan for emergency treatment of the contaminant(s) of concern;
- Clean up any surfaces impacted by the discharge;
- Continue to discharge from the ponds when safe;

- Prepare a report to Environment Canterbury describing the event, its cause, environment effects and remedial action taken or to be taken.

9.5 Landslip

A landslip, depending on where it occurs, may impede operations but may not create an environmental effect. It may have an effect if the landslip occurred to:

- Impede any major stormwater infrastructure;
- Result in the exposure of waste or leachate.

Actions to be taken in these instances are generally as described in other sections.

A landslip around the landfill perimeter may impact on unfilled sections of lining system (it is unlikely to extend into the landfill where fill buttresses the slope). This becomes an operational/construction issue whereby the lining system would need to be repaired before filling in the cell could proceed.

9.6 Dam burst (sediment ponds)

A dam burst, particularly the dam for the downstream sedimentation pond, is likely to result in the discharge of large water flow and large quantities of sediment, with the potential for significant downstream effects. The actions to be taken include:

- Immediately advise Environment Canterbury of the event;
- Take immediate action to prevent any ongoing discharges of sediment into the downstream environment;
- Investigate the extent of downstream damage and effects and identify remedial works that can be undertaken;
- Undertake the remedial works;
- Repair the dam to reinstate the required stormwater treatment on site.
- Prepare a report to Environment Canterbury describing the event, its cause, environment effects and remedial action taken, or to be taken.

9.7 Landfill fire

The landfill management plan will have a section on how to manage landfill fires. Landfill fires fall into two general categories: surface (associated with incoming waste) and underground fires.
Deliberate fires are not a part of landfill operation and management procedures are put in place to minimise the risk of landfill fires.

Surface fires can occasionally occur in recently placed waste. Typical causes of such fires include:

- A heat source within the incoming waste (e.g., hot embers);
- Spontaneous combustion of materials in the landfill when certain materials are mixed;
- Fire caused by human error or during maintenance work (smoking sparks from vehicles, etc.);
- A source external to the landfill (e.g., an adjacent forest fire). Surface fires can be managed by:
- Covering with soil to eliminate oxygen (soil stockpiles will generally be available adjacent to the working face resulting from cover soil stripped off at the beginning of each day, or stockpiles of fresh cover soil waiting to be used);
- Application of water (sourced from water tanks and ponds on site;
- Fire-fighting foams.

In all cases the Fire Service will be called to manage the fighting of surface fires.

Underground fires occur deep below the surface and are generally caused by an increase in oxygen in the landfill at depth, resulting in aerobic digestion of the waste that can occur at high temperatures, with resulting hot spots coming into contact with pockets of LFG. These can be difficult to extinguish and can result in damage to synthetic components of the lining system if close to the lining system. An underground fire is rare, particularly in landfills operated with appropriate use of daily and intermediate cover. Such fires are extinguished in a similar manner to surface fires but may also involve movement of quantities of waste to expose the fire.

In addition, there is a risk of fire spreading from an adjacent farmland and forestry land, especially in dry and windy conditions.

This can be mitigated by:

- Having a perimeter fire break road which is regularly maintained and kept free of vegetation.
- Covering the waste surface with soil to eliminate oxygen;
- Application of water sourced from water tanks and ponds on site;
- Ready access to fire-fighting equipment and water carts;
- Ready access to large earthmoving equipment.

10 Alternatives considered

10.1 Landfill footprint

The overall landfill site is based on the location of the existing quarry, and the proposed extension of the quarry to the west over the life of the site. While other potential sites are possible one of the main drivers for this project is to utilise waste material to rehabilitate a quarry and provide a long-term land use for the quarry.

The upper perimeter of the landfill is defined by a natural change of grade in the topography, to divert stormwater around the proposed quarry and landfill, and the need to provide access to the outer perimeter of the landfill.

10.2 Landfill access road

The landfill access road is an existing road that currently accesses the existing quarry. Due to the location of adjacent landholdings, there is no alternative access available.

10.3 Stockpiles

Large volumes of soil need to be stockpiled over the life of the landfill, requiring relatively large areas of land. Investigation of suitable stockpile areas recognised that there were limited areas that could be used as stockpile sites and provide appropriate prevention of adverse effects on the adjacent stream.

10.4 Leachate management

A wide range of options, described in Section 6.4.3, were considered for leachate management.

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- Does Disposing of Construction and Demolition Debris in Unlined Landfills Impact Groundwater Quality? Evidence from 91Landfill Sites in Florida, USEPA, August 2015
- Provisional Equations for Determining Leachate Leakage Rates Through Composite Barriers Arising from Compromised Geomembranes, presented to the International Conference Sustainable Material Processing and Manufacturing, January 2017.

Appendix A Methodology for the Assessment of Worst-Case Liner Leakage

The methodology for assessing the potential worst cost liner leakage scenario is based on a paper titled Provisional Equations for Determining Leachate Leakage Rates Through Composite Barriers Arising from Compromised Geomembranes, presented to the International Conference Sustainable Material Processing and Manufacturing, January 2017. The abstract of the paper is reproduced below.

Abstract

From years ago to present date the equations available for determining the rate of leachate leakage through composite barriers from geomembrane (GM) failures necessitated the use of graphs to attain the value of one of the terms of the equations for the case where the leachate head is larger than the thickness of the low-permeability soil medium of the composite barrier. This work reveals that the terms requiring graphs can be expressed analytically, which shows a new set of equations that leads to an entirely analytical approach of determining the rate of leachate leakage through composite barriers. The provisional set of equations is principally beneficial when the leachate level is large as against the thickness of the low-permeability soil medium of the composite barrier. This is usually the case when the low-permeability soil medium allied with the GM to form a composite barrier is a geosynthetic clay liner (GCL). Whether the failure in the GM is small or large or where the leachate level on top of the barrier is large as against the thickness of the low-permeability soil layer of the composite system, a provisional equation can be used to determine the leakage rate through the system. Although in such a scenario, graphs are essential in attaining the value of one of the terms of the equations. Therefore, this paper shows that the graphs can be replaced by equations, which proceeds to the generation and utilization of an entirely analytical method of determining the rate of leachate leakage through a failed composite waste containment barrier, irrespective of the leachate level overlying the system.

The authors of the paper have developed a formula, reproduced below, for assessing leakage rates for a range of values:

$$Q = 0.976\, C_{qo} \left[1 + 0.1\left(\frac{h}{t_s}\right)^{0.95}\right] d^{0.2}\, h^{0.9}\, k_s^{0.74}$$

Where:

Q	Leakage rate in m3/s
C	A value ranging from 0.21 to 1.2 that reflects the standard of contact between the layers
h	Average leachate head over the liner
t	Thickness of low permeability below the HDPE
d	Diameter of circular defects, ranging from 0.25mm to 25mm
k	Permeability of material under the HDPE

The selection of values for the key parameters used for this assessment are summarised in the table below:

Parameter	Range of values used
C	0.21 for Very Good contact, 0.7 for Average contact
h	Ranging from 0.1 to 0.75m.
t	300mm for the CCL, 7mm for the GCL
d	1mm for the manufacturing defects, 10mm for the construction defects
k	1.0×10^{-9} m/s for the CCL, 1.0×10^{-11} m/s for the GCL

The leakage rates for a CCL only under the HDPE, and the leakage rate for a GCL only under the HDPE are shown on the following three pages, with the first page being a summary.

The combined effectiveness of a GCL under the HDPE, along with a CCL under the GCL is difficult to model but the laboratory and field research noted in Section 4.4.2 shows that a combined HDPE / GCL / CCL to be the much more effective than a GCL or CCL alone.

In order for the hydrogeologist to be able to model the potential impact of leakage under the liner an estimate of the worst case leakage rate is necessary. It is recommended that for a conservative assessment of the impact of the potential leakage of leachate through the liner system a leakage rate of 6 litres per hectare per day should be adopted.

Worst Case Liner Leakage Rates

Calculated using 2017 methodology noted in Addendum to Engineering Report Issue 2

Construction Scenario	Manufacturing Defects per ha (1mm diameter)	Construction Defects per ha (10mm diameter)	Liner Contact	Average Leachate Head (m)	300mm CCL Leakage Rate litres per hectare per day	GCL Leakage Rate litres per hectare per day	Recommended for Hydrogeology Modelling
Very good construction	2	3	Good	0.15	1.3	0.11	
Very good construction	2	3	Good	0.75	6.3	1.6	
Very good construction	2	3	Good	1.25	11.2	3.9	3
Average construction	3	4	Average	0.15	5.8	0.5	
Average construction	3	4	Average	0.75	29.0	7.3	
Average construction	3	4	Average	1.25	51.4	18.1	12
Very poor construction	4	5	Poor	0.15	12.6	1.1	
Very poor construction	4	5	Poor	0.75	63.4	16.1	
Very poor construction	4	5	Poor	1.25	112.5	39.7	20

Worst Case Liner Leakage Rates

Calculated using 2017 methodology noted in Addendum to Engineering Report Issue 2

Compacted Clay Liner

CCL Thickness	**CCL Permeability**	**Hole Diameter (m)**	
0.3	0.000000001	0.001	0.01

Construction Scenario	**Leachate Status**	**Manufacturing Defects per ha**	**Construction Defects per ha**	**Liner Contact C**	**Average Leachate Head (m)**	**Leakage Man Faults**	**Leakage Construct**	**Leakage Rate per Hectare (m3/s)**	**Leakage Rate per Hectare (litres per day)**
Very good	Normal	2	3	0.21	0.15	4.29635E-09	1.02139E-08	1.45102E-08	1.3
Very good	High	2	3	0.21	0.75	2.15406E-08	5.12092E-08	7.27498E-08	6.3
Very good	Very high	2	3	0.21	1.25	3.82207E-08	9.08636E-08	1.29084E-07	11.2
Average	Normal	3	4	0.70	0.15	2.14817E-08	4.5395E-08	6.68767E-08	5.8
Average	High	3	4	0.70	0.75	1.07703E-07	2.27597E-07	3.35299E-07	29.0
Average	Very high	3	4	0.70	1.25	1.91103E-07	4.03838E-07	5.94942E-07	51.4
Very poor	Normal	4	5	1.20	0.15	4.91011E-08	9.7275E-08	1.46376E-07	12.6
Very poor	High	4	5	1.20	0.75	2.46178E-07	4.87707E-07	7.33885E-07	63.4
Very poor	Very high	4	5	1.20	1.25	4.36808E-07	8.65367E-07	1.30218E-06	112.5

Worst Case Liner Leakage Rates

Calculated using 2017 methodology noted in Addendum to Engineering Report Issue 2

GCL

CCL Thickness	**CCL Pemeability**	**Diameter (m)**	
0.007	1E-11	0.001	0.01

Construction Scenario	Leachate Status	Manufacturing Defects per ha	Construction Defects per ha	Liner Contact C	Average Leachate Head (m)	Leakage Man Faults	Leakage Construct	Leakage Rate per Hectare (m3/s)	Leakage Rate per Hectare (litres per day)
Very good	Normal	2	3	0.21	0.15	3.83934E-10	9.12743E-10	1.29668E-09	0.11
Very good	High	2	3	0.21	0.75	5.45914E-09	1.29782E-08	1.84374E-08	1.59
Very good	Very high	2	3	0.21	1.25	1.34762E-08	3.20374E-08	4.55136E-08	3.93
Average	Normal	3	4	0.7	0.15	1.91967E-09	4.05663E-09	5.97631E-09	0.52
Average	High	3	4	0.7	0.75	2.72957E-08	5.76811E-08	8.49768E-08	7.34
Average	Very high	3	4	0.7	1.25	6.73809E-08	1.42389E-07	2.0977E-07	18.12
Very poor	Normal	4	5	1.2	0.15	4.38782E-09	8.69279E-09	1.30806E-08	1.13
Very poor	High	4	5	1.2	0.75	6.23902E-08	1.23602E-07	1.85992E-07	16.07
Very poor	Very high	4	5	1.2	1.25	1.54013E-07	3.05119E-07	4.59132E-07	39.67