University of Southern Queensland

Faculty of Health, Engineering and Sciences

An Investigation into design and construction of a leachate dam in Lismore

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Student Number: [redacted]

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i. Abstract

Societies have had to find methods to dispose of their waste for countless years. In recent times, local governments have allocated land that has been set aside to resolve this problem. In doing this there is now a highly concentrated volume of waste that is largely uncontained.

Testing of the waterways near the waste facilities highlighted that the toxins at the waste disposal centres are being transported into the surrounding environment by the formation of contaminated water known as leachate.

Local councils have been made aware of these problems by the Environmental Protection Agency and tasked to develop solutions to reduce the amount of toxic runoff released from the site.

The Lismore City Council's solution to this was to build a Leachate processing dam to collect, treat and release leachate in a state that would significantly reduce the harm done to the nearby waterways.

This will involve the design and construction on a dam onsite that will capture the leachate and withhold it until it is at predetermined levels that are considered safe to be in the surrounding environment.

One specific element of the dam's design is its waterproof lining system. It is this design feature that this report will focus on and give recommendations after thorough analysis.

This project was undertaken at a time when it was expected that the results would be able to be included in the report. Due to the covid situation that is not the case and as of the submission of this report, the final designs for the dam and the construction timeline have still not been submitted to council.

ii. Acknowledgements

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v. Glossary (only of provided)

CCL – compacted clay liner

EPA – Environmental Protection Authority.

GCL - Geosynthetic clay liner

HDPE – high density polyethylene

Leachate – Water that has passed through waste material and become contaminated

Landfill – Waste disposal facility. Usually, an engineered, in ground structure with a liner

Overburden – waste placed into landfill

POEO – Protection of Environment Operations Act. Legislation that governs the actions of the EPA.

Putrescible – material that is likely to decay

Runoff – water that has not evaporated or infiltrated the earth.

TDS – total dissolved solids

Trigger value – predetermined level which, if exceeded, ‘triggers’ a management response.

1. Literature review/introduction

1.1. What is leachate?

The definition for leachate given by the Macquarie dictionary (1997) is, *'A liquid that has percolated through and/or been generated by decomposition of waste material'*. It includes water that comes into contact with waste and is potentially contaminated by nutrients, metals, salts and other soluble or suspended components and products of decomposition of the waste.

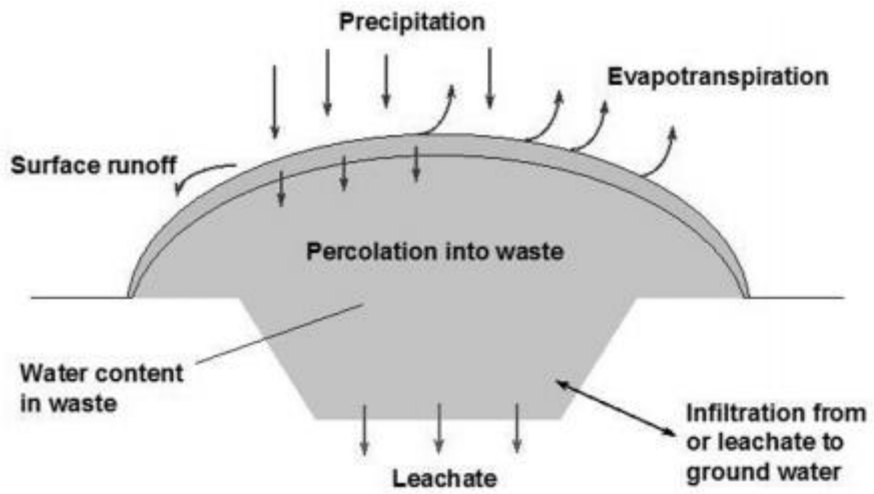

Figure 1. Schematic of creation of leachate.

Many issues are inherent with the operation of a landfill. Noise, dust and odour are among the more apparent problems however leachate is about the worst thing a landfill site can do to the surrounding environment. It's composition of numerous toxic substances, heavy metals, xenobiotics, aromatic hydrocarbons and phenols make it hazardous for the general environment as well as human health. There is also a large amount of organic material contained within the leachate. Nitrogen, organic salts, macro and micro nutrients and these are known to enhance soil quality, potentially increasing productivity for crops. Careful handling and correct treatment for leachate is the requirement of the EPA to ensure the health of the general public and the environment within the vicinity of waste facilities.

Liners provide a barrier between the leachate and the natural earth and ground waters surrounding the landfill. It is the primary objective of this report to highlight the natural pathway of the toxins created by landfill, identify the problems caused by its path and presence, and, make recommendations to reduce the harmful effect on the surrounding environment. The liners used in the capture of leachate are critical in ensuring that it follows the design pathway and does not infiltrate the ground before treatment. Liner design, thickness, materials used, site and ecological constraints will all have to be considered to determine the appropriate application.

Compliance with EPA standards is also a primary project outcome. Monitoring of the safe release of treated leachate into the surrounding waterways will be an ongoing task for the operators of the facility as well as the longer-term objectives of capping and revegetation of the dams and cells once the design life of the plant has been reached.

1.1.1. Composition of Leachate

LEACHATE COMPOSITION

Table 1: Landfill leachate classification vs. age

	Young	Medium	Old
Age (year)	<1	1-5	>5.0
pH	<6.5	6.5-7.5	>7.5
COD (g L^{-1})	>15	3.0-15	<3.0
BOD_5/COD	0.5-1	0.1-0.5	<0.1
TOC/COD	<0.3	0.3-0.5	>0.5
NH_3-N (mg L^{-1})	<400	400	>400
Heavy metals (mg L^{-1})	>2.0	<2.0	<2.0
Organic compound	80% VFA	5-30% VFA+ HA+FA	HA+FA

Figure 2. Composition of old vs young leachate. (Pravin, 2013)

- pH – is a measure of the acidity. It ranges from 1-14 where 1 is acidic and 1 is alkaline. As shown in this composition chart. The young leachate starts as slightly acidic and tends toward a neutral value'
- COD (chemical oxygen demand). This is also known as dissolved organic matter. When the BOD:COD ratio is high the leachate has a high proportion of organics that are easily biodegradable.
- BOD (oxygen demand for oxidation of organic matter by micro-organisms) COD also includes oxidation of non-biodegradable organic matter.
- TOC – (total organic matter),
- NH_3 – ammonium, this can be seen to be increasing as the leachate ages
- Heavy metals – elements such as nickel, zinc, copper and lead. Reducing over time.
- Organic compounds – pesticides and hydrocarbons are included in this category and are also decreasing over time.
- VFA – volatile fatty acids – their presence indicates a highly biodegradable substrate that can be easily converted into biogas.
- HA – Humic acid -Humic acids are an agent to immobilize heavy metals. They form the biological centre of humic substances, which are the result of decomposition and conversion processes of organic material in soil and water
- Barium – mineral deposits that are dissolved can potentially cause harmful effects in humans and animals. These include increased blood pressure, difficulty in breathing and damage to liver, kidney and heart.
- TDS – total dissolved solids, depending on the materials that make up the TDS will determine its level of concern. The EPA however considers that TDS levels 500mg/L safe and anything over 1000mg/L unsuitable for human consumption.
- TPH – total petroleum hydrocarbons

The leachate transforms through several stages as it ages. During the acid phase, the leachate tends to exhibit lower pH values and higher levels of organic, more degradable compounds such as volatile fatty acids. In the later, much more stable phase, the methanogenic phase, the pH increases and the BOD/COD ratio also rises indicating the degradability of the organic carbon is being reduced dramatically. Several other variations are expected throughout the leachate lifespan. Seasonal variations are often observed as well as changes in recorded levels due to higher or lower rainfall.

1.2. Leachate Capture and Storage

In the base of a modern landfill, liners are laid out to ensure leachate does not permeate the surrounding soil. Perforated pipes are then laid in the base that will allow the leachate to be collected underneath the waste as it is generated by precipitation falling on the site. It will then drain out into processing plants that will treat the leachate to a point that it can be released into the sewer. During the life of the landfill this process will continue until the landfill has reached its capacity. At that point the landfill will be capped with another liner, known as a phytocap which will include a vegetation layer. This final application will ensure no more liquid enters the landfill and continues the production of leachate. This phytocap is also designed to improve the aesthetics of the site to restore a natural as possible end to the life of the cell.

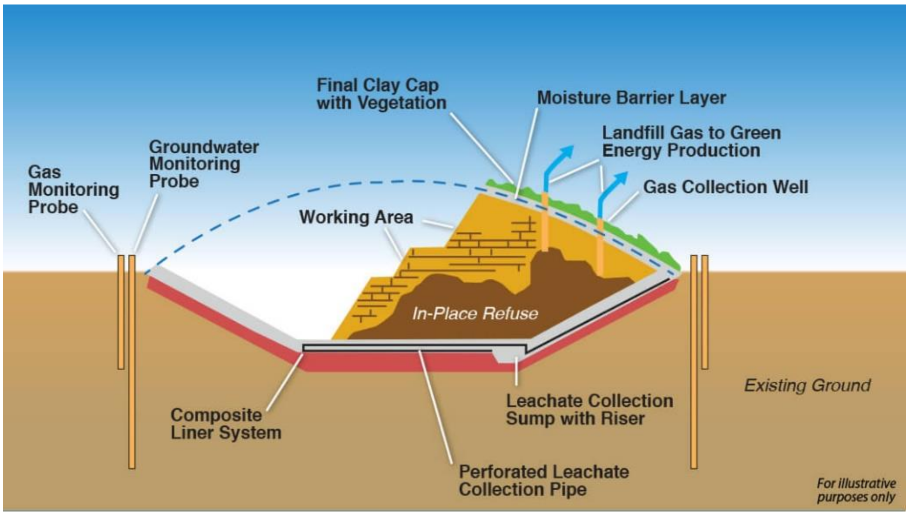

Figure 3. Landfill diagram indicating leachate capture. (Millennium waste Inc, 2021)

1.2.1. Dams

Several methods of leachate capture and storage are available to consider. Many sites employ dams for storage however, stainless steel tanks can also be used. Often the choice is made with ongoing costs considered. If the slope of the surrounding area is suitable then a gravity fed system would be a better choice than needing pumps to move the either feed the leachate into the plant or remove it back into the sewer. A dam's design must ensure it is capable of containing the runoff during the 25-year rain event. Calculations of runoff will be made followed by leachate percolation equations to determine the volume and size requirements of the dam. Due to the topography of the site at the Lismore waste facility, it has been determined that a leachate dam and a sediment dam are the best solutions for the initial design. The dam will use the process of reverse osmosis to treat the leachate before it is released.

1.2.1.1. Liners

One of the more problematic issues involved with leachate is its natural tendency to be absorbed into the ground and the ground water. Without treatment, this is likely to have a negative effect on the surrounding area so the need to contain this toxic runoff is critical. Before the realisation that toxic materials were leaching into the surrounding water systems, waste materials were placed in a location decided solely on convenience. When problems with the health of humans and environment were attributed to the toxins from the waste, attempts were made to contain these harmful substances by making a more concentrated effort to inhibit their movement.

In the past liners have generally been CCL's. Compacted clay liners were a simple form of barrier consisting of approximately 300-900mm of compacted clay in the base of the in-ground structure. They generally have a saturated hydraulic conductivity of 1×10^{-9} m/s which made the dam or landfill compliant with the standards however the process required a lot of earthworks and excessive amounts of material.

According to ASTM D4439, a geomembrane is defined as follows:

Geomembrane: A very low permeability synthetic membrane liner or barrier used with any geotechnical engineering related material so as to control fluid (or gas) migration in a human-made project, structure, or system.

Geosynthetic clay liners use a sandwich construction whereby bentonite clay (composed of greater than 70% montmorillonite or similar expansive clays) is placed between 2 layers of geomembrane. The bentonite is then restricted from movement once the moisture content increases thereby forming a more impenetrable layer than the CCL. The GCL's generally have a thickness of 6mm. This makes them make more cost effective due to the reduction in materials required and, in the labour required to place the liners into position. GCL's have a hydraulic conductivity of 5×10^{-11} m/s making them more effective than CCL's. although the GCL's are a more effective barrier than the CCL's, they are susceptible to leakage through compromised joints between the membranes. They are generally seamed together using tape or glue which can deteriorate over time and cause problems with the barrier's integrity.

HDPE geotextiles have been developed to overcome the issue with inadequate seals. They use a process of double seam welding to bond the membranes to form an impenetrable barrier that will resist leakage for a much greater lifespan. With the increased tear resistance and high tensile strength, the HDPE geotextile geomembrane also has the advantage of being able to deal with rougher terrains if the conditions are less favourable. By forming a double welded joint, the joint can then be inflated to check for any leaks in the barrier. Once these leaks are found that can be repaired before the barrier is covered over ensuring the integrity of the joints.

1.2.1.2. Freeboard

Freeboard refers to the height between the level of the water and the surrounding level of the dam. This is level will be important when considering the maximum rainfall events that will occur in the area. The freeboard level will need to be sufficient to allow the dam to contain the inflow for the duration of the event and not overflow. This inflow will be deemed to be a 1 in 25-year rain event.

In conjunction with freeboard is the need to identify any threat from erosion. By minimising the unvegetated area above the water level, the risk that suspended solids being generated is also reduced. The ongoing maintenance schedule will need to address this concept and include suitable measures to supress erosion.

1.2.2. Other pollutants

Due to the nature of the structure being a dam, it is prone to be polluted by many other materials. In windy conditions many other items are likely to be unintentionally captured by the dam. Branches and leaves would not pose any risk to the chemical/biological composition of the dam. These may need to be included in a maintenance schedule as possible threats to correct outflow design.

1.2.3. Treatment

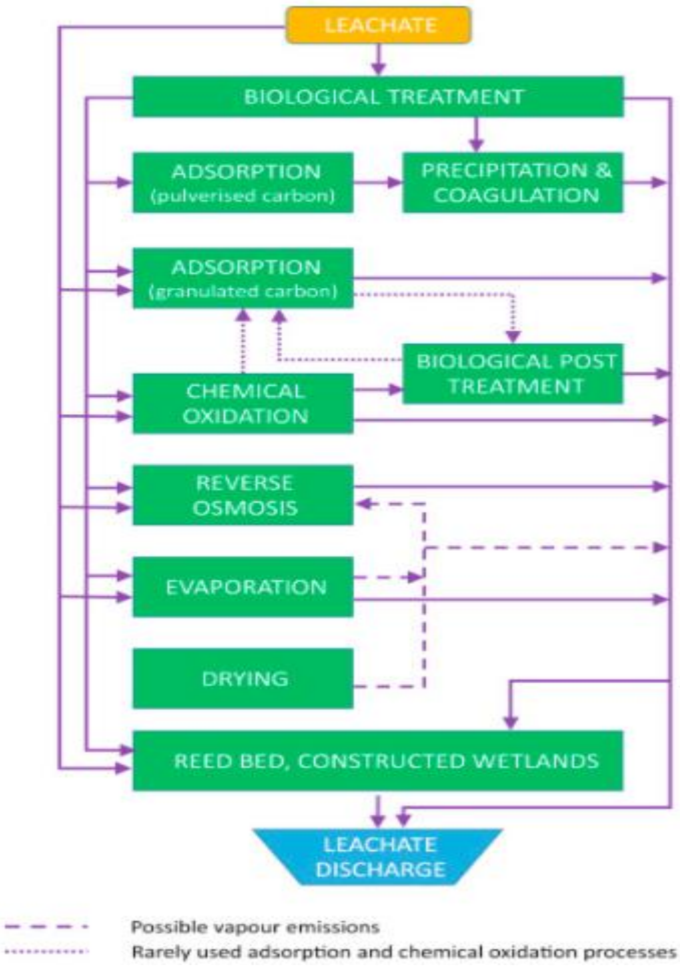

Figure 4. Diagram showing the process available to treat Leachate. (Ehrig, Stegmann, 2018)

It is difficult to judge the exact composition of leachate due to the contents of the landfill and the amount of water passing through. For that reason, the correct treatment of the leachate is determined and carried out with different processes at different facilities. These processes include aeration, chemical dosing, reed beds, sequencing batch reactors, filtration constructed wetlands and reverse osmosis. The ongoing monitoring of the leachate is critical in maintaining a functional treatment plant.

1.2.4. Release

Before release in the sewer system, the treated leachate is tested against EPA compliance figures. If the standards are met then the waste water is released, if not, then further treatment will be required. This standard is usually an agreement between the operators and the local water authority. The agreement would generally be reliant on the concentrations of pollutants that remain. BOD, barium, ammonia and TDSs are some of the contaminants that are interest to the water authorities.

Other options for disposal of leachate include off site transport, irrigation, evaporation and reinjection. In the case of off-site transport, only disposal facilities that can lawfully receive can be used. Often this is the only option with restricted waste cells. Irrigation may be a viable option provided certain criteria are addressed. Most notably that the process is managed in accordance with the Environmental Guidelines, '*Use of effluent by irrigation*' (NSW DEC, 2004b). The use of irrigation leachate is preferrable on rehabilitated landfill rather than any primary production land. The application must not exceed the lands capacity to absorb the nutrients carried by the leachate and it must not pose a threat to human or animal health either directly or into the future. As the level of contamination varies greatly from case to case, a determination would need to be made about the suitability of using leachate for irrigation. Evaporation can become an option in climates where evaporation exceeds precipitation. Dams with a large surface area may be used to promote leachate losses. This is often only a partial solution in most areas and would need to be complimented by other methods as well. Reinjection is also a method employed to break down the pollutants contained within the leachate. By recirculating the leachate through the waste mass, the moisture content is brought up to a level that is said to enhance anaerobic biodegradation of the organic materials contained within the waste. The other advantages of this process include accelerated water stabilisation. Long term maintenance and monitoring reduced and leachate strength is reduced sooner. The EPA however have guidelines that must be met for reinjection to used. Sustainable rates of absorption must be adhered to. Storage capacity must be sufficient and the cells must be constructed with leachate extraction systems and level control systems.

1.3. EPA legislation and compliance

As defined by the Protection of Environment Operations Act, the different classifications of waste are listed below.

• general solid waste (putrescible)

Putrescible waste refers to material that will decay. This includes all organic matter such as dead animals and food waste. This type of waste will generally give off unpleasant odours, gases and other generally objectional conditions

• general solid waste (non-putrescible)

Non-putrescible means items such as masonry, glass and plastics. These items would not generally decay within a short time frame

• restricted solid waste

Restricted solid waste isn't very common and must undergo chemical test to be classified as restricted. Specific contaminant concentration (SCC) and/or toxicity characteristics leaching procedure (TCLP) will determine if the waste is to be classified as restricted.

• special waste

Special waste has the potential to be harmful to humans or the environment. This category contains materials such as clinical waste, asbestos and tyres. These types of waste need to be properly managed to ensure contamination does not take place.

• hazardous waste

Hazardous waste includes oxidizing, corrosive or toxic substances. Also listed are explosives, gases, flammable solids.

• liquid waste.

Anything is a liquid if it has an angle repose of less than 5 degrees. That is to say that it will flow if tilted on an angle. Or if it is free flowing above 60 degrees.

All aspects of general waste management and landfill disposal are governed by 'The Protection of the Environment Operations Act 1997'. This legislative document is used by the EPA for anything from licensing for landfill occupiers to pollution incident reporting.

While a landfill is a necessary part of the safe and secure disposal of society's waste, there are still several adverse effects as a result. These include gases and odours, litter, dust and stormwater runoff. Another significant problem is leachate. This report is being prepared to offer a design for the waste facility at the Lismore city council depot in order to better manage the toxic levels in the surrounding waterways due to leachate.

Parameter		Trigger Values Leachate
Lab Parameters	pH	7.0 – 9.0
	Temperature	38°C
Nutrients	Ammonia (as N)	50 mg/L
	Total Kjeldahl Nitrogen	100 mg/L
	Total Phosphorus (as P)	20 mg/L
TPH	Total TPH	10 mg/L
PAH	Total PAH	0.01 mg/L
Oxygen Demand	Biological Oxygen Demand	300 mg/L
Metals	Arsenic	0.1 mg/L
	Cadmium	0.1 mg/L
	Copper	1 mg/L
	Chromium	0.1 mg/L
	Lead	0.1 mg/L
	Mercury	0.001 mg/L
	Nickel	0.5 mg/L
	Selenium	0.1 mg/L
	Zinc	5 mg/L
Anions	Sulfate (as SO_4)	100 mg/L
Phenols	Phenolic Substances	1 mg/L
	Chlorinated phenolic substances	0.01 mg/L
Oil and Grease	Oil and Grease	100 mg/L
Detergent	Detergent	NA- as Biodegradable

Table 1. Trigger values for leachate monitoring based on the trade waste agreement. This chart indicates the acceptable level for leachate being pumped into the sewerage treatment plant (STP). If the concentrations are exceeded, a penalty is imposed on the LCC (LCC, 2019)

In the following chapter, the concentrations are compared against local soils in the vicinity of, but not affected by the plant, to establish the level of contamination being caused by the waste facility. It is these values that are of concern to the EPA and that are the operational focus of leachate dam being designed.

1.3.1. Other leachate dams and examples

1.3.1.1. Hampton downs landfill. NZ

Figure 5. Example of liner for leachate dam, processing tanks and operational dam at Hampton Downs Landfill - North Waikato (IS Dam Lining, 2021)

- This project employed the use of geotextiles as well as geomembranes to improve durability and strength. During the deployment of GCL's, the liners are susceptible to damage from traffic above or rough surfaces below. The use of geotextiles mitigates this issue through the use of welded 1.5mm double textured HDPE.
- Owners, EnviroWaste operates this waste facility with modern, environmental awareness. Their focus is to operate the landfill with minimal negative impact but to also carryout remediation and regeneration services on the site once operations have ceased.
- The company contracted to carry out the works employed HDPE liners on the Hampton Downs project because of its ongoing integrity. By welding the geomembranes together, an uncompromised seal can be achieved. A double weld is created with a cavity between the welds, this is then inflated to check if it can maintain pressure. If the pressure drops, the leak can be identified and repaired. IS lining provides several options for their liner's dependant on the client's project. HDPE, geotextile, RPP and GCL can all be considered based on requirements such as tensile strength, UV durability, chemical resistance and geomembrane density

1.3.1.2. Kimbrikki resource recovery centre.

Figure 6. Stainless steel tanks at the Kimbrikki installation. (Kimbrikki news, 2019)

- The facility at Kimbrikki was commissioned in June of 2019 and within 4 months had processed one hundred million litres of landfill leachate. This system uses both aeration and chemical dosing to process the leachate before it is released into the sewer.
- Kimbrikki is located on the Northern Beaches in Sydney and is operated by the Northern Beaches council. It is another example of the current 're-use, reduce, recycle' mentality. It claims to have diverted 2.5 million tonnes of waste through resource recovery operations rather than into landfill. Many items are recovered through this process and the centre has a buy back initiative in order to create a self-sustaining facility. Everything from road base, aggregates and sand to building materials, household furniture and sporting equipment is available making this centre a popular alternative for the community.
- The Kimbrikki facility recognises that the future generations will be those most affected by the decisions made now. To this end, they have created an eco-shop, do school tours and have employed an ecologist to further educate the general public. By using these resources to change the way people think they are making substantial progress in the population's awareness.

1.3.1.3. Lucas Heights Waste Management Centre

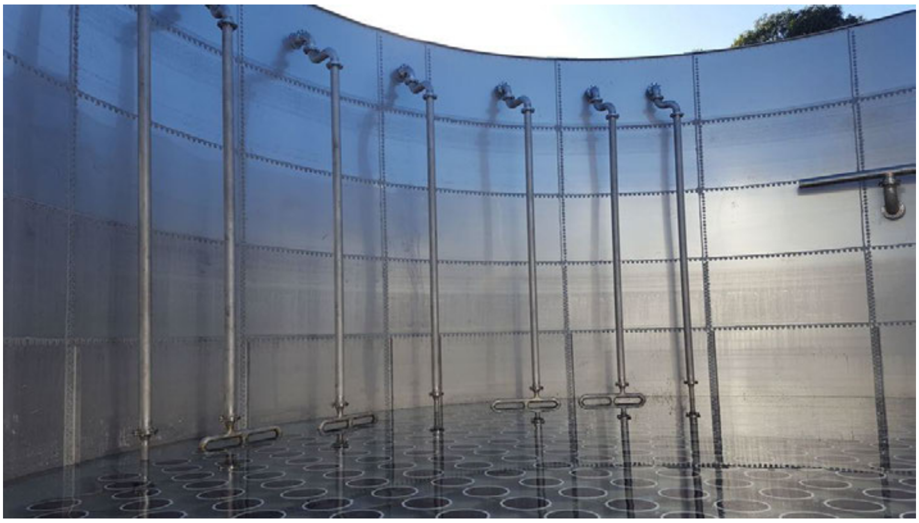

Figure 7. Lucas Heights stainless steel tank. (JPG Engineering, 2019)

- Lucas Heights waste management centre processes 630 000 tonnes of waste per annum. Of this 575 000 is placed into landfill while the remaining 55 000 tonnes is processed through the resource recovery facilities.
- As a council operated facility, it is, as with all other local government assets, subject to stringent boundaries regarding its operations. From community consultation to major stakeholder input, any alterations to the original strategy must undergo intense scrutiny.
- The design and construction of the leachate treatment facility was carried out by JPG engineering and it is currently operated by Suez Recycling and Recovery.

1.3.1.4. Eastern Creek

Figure 8. Landfill leachate treatment facility at Eastern Creek, Sydney. This plant uses ammonia oxidation to treat its leachate. (JPG Engineering, 2019)

- Currently treating approximately 400m^3 of leachate per day when the ammonia level is at 1500mg/L. this processing level can be increased if the monitored ammonia level is reduced.
- The volume of the leachate dam to spill level is 8500m^3. The average daily leachate inflow is 157m^3 and the maximum recorded daily volume was 5656m^3
- This pond currently services 7 cells. As stipulated by the EPA. The progressive capping and revegetation of the cells will reduce the level of contaminants as they are filled

Analysis of all factors at each site has revealed a different solution. Topography, ecology, community and precipitation all contribute to the outcome of the investigation. the operation of any facility however is going to be governed by the standards imposed by the EPA and the careful and accurate monitoring of the outflows are the final objective for the design and commission of any facility.

2. Background Investigation

The Lismore waste facility is located 3km from the Lismore CBD. It is in a sparsely populated area and surrounded by farmland with a small steep hill on the north side and a low gradient slope going away to the south. It operates as part of the Lismore city council's portfolio to process domestic and commercial waste and currently places into landfill approximately 35,000 tonnes of waste per annum.

In 2012 the site had constructed a leachate dam that was reliant upon an evaporation method as a means of processing the toxic runoff. The dams were not constructed with an effective liner and subsequent testing of the water in the immediate area showed that this was an ineffective process and changes were required to ensure the stream below the facility was not contaminated due to runoff from the facility.

Figure 9. Aerial photo for Lismore Waste Facility from 2012. (LCC, 2012)

2.1. Site specific Investigation

2.1.1. Water analysis from site and surrounding area.

The Lismore city council commissioned the environmental analysis laboratory to conduct an investigation into the water quality at the Lismore waste facility and the surrounding area. Groundwater and surface water samples were taken to determine the extent to which the water quality had been compromised by pollutants associated with leachate. These samples were taken in accordance with the council's environmental protection license (No. 5880) between august 2019 and June 2020.

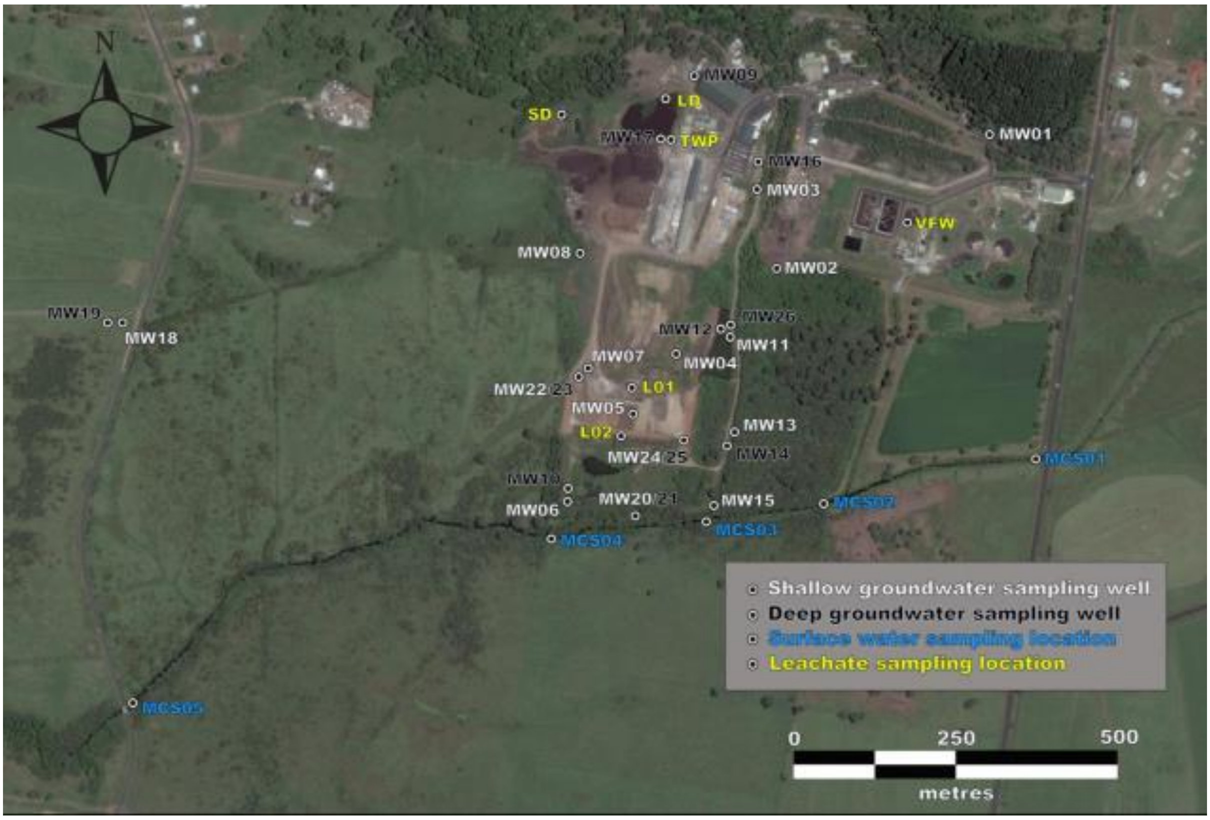

Figure 10. Aerial view of the well locations. (LCC 2019).

Figure 9 indicates the shallow and deep-water sampling wells in the vicinity of the waste facility. Surface water samples were taken from Monaltrie creek and most of the other points have both a deep and shallow wells.

Several guidelines were followed to ensure quality assurance of the data. Sampling equipment was decontaminated prior to collection of all samples as well as duplicate samples to ensure consistency of results. Samples were placed in eskies with ice bricks to maintain stable temperature and delivered to the EAL at Southern Cross University Lismore.

In order to establish a background level, two wells are located above the hydraulic gradient to ensure no possible contamination from the site. These wells are MW01 and MW09 at the northern end of the site. The samples from these wells will represent the baseline for the samples to indicate the level on contamination. Although these wells did not return ideal groundwater quality parameters, it is considered acceptable to use these figures as a reference for the other wells.

Several indicators in the water samples will cause concern if detected. Panno *et al*. (2006) identified sodium and chloride as indicators of potential leachate contamination. Sewerage effluent was also found to be a source of these ions. Ashrafi (2005), Kumar and Alappat (2005) and Scott et al. (2005) also name these Phosphorus and ammonia as indicators of leachate contamination. The list also includes hydrocarbons as an indicator.

Water Level	Standing Water Level
Field Parameters	pH, Conductivity, Redox Potential, Temperature, Dissolved Oxygen
Lab Parameters	pH, Conductivity, Total Dissolved Solids
Nutrients	Ammonia, Nitrate, Total Nitrogen, Total Phosphorus
TPH	TPH (C_6 – C_9), TPH (C_{10} – C_{14}), TPH (C_{15} – C_{28}), TPH (C_{29} – C_{36})
Carbon	Dissolved Organic Carbon
Oxygen Demand	Biological Oxygen Demand (BOD_5).

Table 2. key indicators of leachate for groundwater. (LCC, 2019)

Cations	Calcium, Magnesium, Sodium, Potassium
Anions	Alkalinity, Sulfate, Chloride, Fluoride
Metals	Arsenic, Manganese, Iron
Phenols	Total Phenolics
Pesticides	Organochlorine Pesticides (OCPs), Organophosphate Pesticides (OPPs)
Microbiological	Faecal Coliforms

Table 3. contaminates of concern in groundwater. (LCC, 2019)

Field Parameters	pH, Conductivity, Redox Potential, Temperature, Dissolved Oxygen
Lab Parameters	pH, Conductivity, Total dissolved Solids, Total Suspended Solids, Turbidity
Nutrients	Ammonia, Nitrate, Total Nitrogen, Total Phosphorus
TPH	TPH (C_6 – C_9), TPH (C_{10} – C_{14}), TPH (C_{15} – C_{28}), TPH (C_{29} – C_{36})
Carbon	Dissolved Organic Carbon
Oxygen Demand	Chemical Oxygen Demand (COD).
Microbiological	Faecal Coliforms

Table 4. key indicators of leachate in surface water (LCC, 2019)

Cations	Calcium, Magnesium, Sodium, Potassium
Anions	Bicarbonate (Alkalinity), Sulfate, Chloride, Fluoride
Metals	Arsenic, Manganese, Iron
Phenols	Speciated Phenolics

Table 5. contaminates of concern in surface water (LCC, 2019)

The trigger values were adopted by the United Registrar of Systems (URS) and are accepted under reserve by the EAL

Parameter		Trigger Values Surface Water	Trigger Values Groundwater	ANZG (2018)*
Lab Parameters	pH	8.56 pH	9.0 pH units	6.5-8.0
	Conductivity	2.200 dS/m	2.210 dS/m	0.125-2.2 dS/m
	Total dissolved Solids	573 mg/L	2195 mg/L	..
	Suspended Solids	221 mg/L	..	10 mg/L
	Turbidity	273 NTU	..	6-50 NTU
Nutrients	Ammonia	1.47 mg/L	0.9 mg/L	0.9 mg/L
	Nitrate	2.14 mg/L	0.7 mg/L	0.7 mg/L
	Total Nitrogen	7.8 mg/L	1.2 mg/L	0.35 mg/L
	Total Phosphorus	2.08 mg/L	0.53 mg/L	0.025 mg/L
TPH	TPH (C_6 – C_9)	20 µg/L	20 µg/L	..
	TPH (C_{10} – C_{14})	50 µg/L	169 µg/L	..
	TPH (C_{15} – C_{28})	212 µg/L	100 µg/L	..
	TPH (C_{29} – C_{36})	90 µg/L	50 µg/L	..
Carbon	Dissolved Organic Carbon	19 mg/L	24 mg/L	..
Oxygen Demand	Chemical Oxygen Demand	129 mg/L	189 mg/L	..
Cations	Calcium	30 mg/L	88 mg/L	..
	Magnesium	15 mg/L	113 mg/L	..
	Sodium	135 mg/L	223 mg/L	..
	Potassium	26 mg/L	3.4 mg/L	..
Anions	Alkalinity (as $CaCO_3$)	157 mg/L	579 mg/L	..
	Sulfate	94 mg/L	233 mg/L	..
	Chloride	117 mg/L	408 mg/L	..
	Fluoride	0.4 mg/L	0.55 mg/L	..
Metals	Arsenic	-	0.024 mg/L	0.024 mg/L
	Manganese	1.9 mg/L	1.9 mg/L	1.9 mg/L
	Iron	1.74 mg/L	6.12 mg/L	0.7 mg/L[#]
Phenols	Speciated Phenolics	320 µg/L	320 µg/L	320 µg/L
Microbiological	Faecal Coliforms	6 cfu/100ml	..	..
Pesticides	OCPs and OPPs	..	ID	ID

Table 6. Trigger values as adopted by URS. ANZG (2018) indicates levels that are required to provide a 95% protection for marine ecosystems.

Parameter		Shallow Groundwater Site								
		MW01	MW02	MW03	MW11	MW13	MW15	MW18	MW20	MW22
Lab Parameters	pH									
	Conductivity		✓	⊗	✓	✓	✓	⊗	✓	✓
	TDS		✓		✓	✓	✓		✓	✓
Nutrients	Ammonia				✓	✓	✓	⊗	✓	✓
	Nitrate	✓					✓ (blue)	⊗		✓ (blue)
	Total N	✓		✓	✓	✓	✓	⊗	✓	✓
	Total P				✓	✓		✓	✓	
TPH	$C_6 - C_9$									
	$C_{10} - C_{14}$				✓ (blue)					
	$C_{15} - C_{28}$	⊗	✓	⊗	⊗	⊗	✓	⊗		✓
	$C_{29} - C_{36}$	⊗	⊗	⊗	⊗	⊗	✓	⊗	⊗	✓
Carbon	DOC									✓
Cations	Calcium		✓	✓	✓	✓	✓		⊗	✓
	Magnesium		✓		✓	✓	✓			✓
	Sodium		✓	✓	✓	✓	✓		✓	✓
	Potassium				✓	✓	✓		✓	✓
Anions	Bicarbonate		✓	✓	✓	⊗				⊗
	Sulfate						✓			✓
	Chloride		✓		✓	✓	✓		✓	✓
	Fluoride						✓			✓
Metals	Arsenic									
	Manganese						✓ (blue)			✓
	Iron				✓		✓			✓
Phenols	Speciated Phenols									

Table 7. Summary of shallow groundwater parameters exceeding the specified trigger values. Black ticks indicate the trigger value was exceeded in both 2018-2019 and 2019-2020. Blue ticks indicate value was only exceeded in 2019-2020 period. Cross indicates trigger value was exceeded in 2018-2019 period.

Parameter		Deep Groundwater Site									
		MW09	MW12	MW14	MW16	MW17	MW19	MW21	MW23	MW25	MW26
Laboratory Parameters	pH		⊗		✓						⊗
	Conductivity		✓	✓			✓	✓	✓	✓	✓
	TDS		✓				⊗	✓			✓
Nutrients	Ammonia		✓	✓			✓	✓	⊗	⊗	✓
	Nitrate	✓		✓ (blue)		✓	✓ (blue)		✓ (blue)	✓ (blue)	
	Total N	✓	✓	✓		✓	✓	✓	✓	✓	✓
	Total P	✓		✓		✓	✓	✓	✓	✓	✓
TPH	$C_6 - C_9$										
	$C_{10} - C_{14}$										
	$C_{15} - C_{28}$		⊗			⊗	⊗	⊗			✓
	$C_{29} - C_{36}$	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗
Carbon	DOC					✓					
Cations	Calcium		✓			✓ (blue)	✓				
	Magnesium						✓				
	Sodium		✓	✓		⊗	✓	✓	✓	✓	✓
	Potassium		✓	✓		✓	✓	✓	✓	✓	✓
Anions	Bicarbonate			⊗		⊗	⊗				⊗
	Sulfate				⊗				⊗		
	Chloride		✓	✓			✓	✓	✓	✓	✓
	Fluoride			✓				⊗	⊗	⊗	
Metals	Arsenic										
	Manganese										
	Iron										
Phenols	Speciated Phenols										

Table 8. Summary of deep groundwater parameters exceeding the specified trigger values. Black ticks indicate the trigger value was exceeded in both 2018-2019 and 2019-2020. Blue ticks indicate value was only exceeded in 2019-2020 period. Cross indicates trigger value was exceeded in 2018-2019 period.

2.1.2. Geotechnical report

The geotechnical investigation was undertaken by Douglas Partners to assess the subsurface conditions for the design and construction of the leachate and sediment dams at the Lismore waste facility. The assessment was carried out to provide LCC with a report that would cover the following: -

- Stability and suitability of proposed dam design
- Remediation of the existing sediment dam
- Methodology of filling and lining design
- Stability of existing cell and proposed batter
- Methodology for fill placement and remediation of existing cell batters
- Suitability of fill sources.

The site consists of thick grass and scrubland and slopes moderately in an easterly direction.

The Department of Natural resources, Mines and Energy (2018) describes the site as located in an area of Pleistocene aged miscellaneous unconsolidated sediments which typically comprise of '*silt, sand and/or gravel with subdominant organic mud, peat or clay'.*

The report details conditions that are in general agreement with those described above.

During the assessment it was noted that the groundwater was encountered at depths below the existing site level however it was also noted that moisture conditions were affected by climatic conditions, subsurface and surface conditions and therefore may vary with time.

Any clay fill to be used in construction must comply with the following specifications.

- Maximum particle size 20mm
- Plasticity index >10%
- Liquid limit <50%

The following additional conditions are recommended for material to be used in leachate ponds.

- Dispersion low to moderate
- Permeability <1 x 10^{-9} m/sec
- Clay/silt content >30%

The report finds that the nearby Blakebrook Quarry contains clay material that will satisfy the both the previous and addition specifications. Given the high plasticity of the material it is expected that during drier periods that the material will experience shrinking and cracking. This material also contains a large percentage of coarser materials. It is expected that due to the reduced reactivity of the material the works will have improved resistance to erosion and rutting during heavy rain.

This report is only intended to recommend the material from Blakebrook Quarry for its physical properties only and not any chemical or environmental properties that may be required for design.

The report also includes a recommendation that geosynthetic clay liner or high density polychalene membrane be considered for use in construction. The reasons for this are not made clear however it is recommended that specialists in leachate dam construction be engaged in any final dam design.

2.1.3. Flora/fauna

On the eastern side of the proposed site, an external batter slope with 1V:4H would encroach on koala habitat trees. It is recommended that the external batters be of a 1V:2H slope.

2.2. Walls / Fill

A geotechnical report will need to be carried out in order to assess the level of the groundwater in the area. This level will need to be avoided in any excavation in order to avoid flooding the barriers from below and compromising the integrity of the barrier. On the recommendations of this report, a base RL of the dam can be established and the height of the walls calculated. The slope of the retaining walls will also be decided by any constraints due to the surrounding area and the stability of the material that will be used to construct the walls.

The fill to be used will be well graded structural fill. It is recommended that a local source be identified. This will reduce costs and inhibit any potential contamination from outside areas.

2.3. Design of the Leachate barrier system

As per the EPA Guidelines for solid waste landfills

The base and walls of a solid waste landfill cell needs to be lined with an enduring material of sufficiently low permeability so as to inhibit waste water from penetrating into the groundwater, soil and substrata below.

Included in this design will be a minimum of: -

- A compacted sub base, 200mm thick. The purpose of this is to provide a stable, high load bearing layer on which the liner will be constructed.
- A compacted clay layer. This layer will be a minimum of 1000mm thick with a hydraulic conductivity of less than 1×10^{-9} m/s. this liner must also include a geomembrane over the compacted clay. The base must have gradients of greater than 1% longitudinally and 3% transversely.
- A collection layer for the leachate. This will comprise of a gravel layer 300mm thick which will include pipework to remove the leachate from the bottom of the cell. Pipework should have an internal diameter of not less than 150mm and be placed at a maximum distance of 25m apart. The gradients of the pipework will match that of the compacted clay base.

To achieve the required hydraulic conductivity the clay should have a suitable particle size distribution and high plasticity. Laboratory testing of the material will be needed to confirm a particle size of no greater than 50mm in any direction.

A geosynthetic clay liner may be used as an alternative to compacted clay provided an overlying geomembrane is also used. This geomembrane must also be protected by a cushion geotextile to avoid damage from overlying materials and construction equipment.

A separation geotextile needs to installed above the drainage layer to inhibit fine particles penetrating the barrier from overlying waste.

Consideration also needs to be given to higher groundwater levels. This may affect the integrity of the barrier so a groundwater relief layer may need to be added.

Any elements of the barrier system that are constructed on slopes must have adequate slope stability. An analysis should reveal any factors that could lead to failure of the slope or the barrier. These factors will need to be considered in the design of the final landform to ensure the barrier performs to the requirements.

The outer perimeter needs to be at least 15m from the boundary of the property to allow for installation of monitoring systems and barrier systems if required.

Requirements for geomembranes: -

- Consist of a thin plastic film of high-density polyethylene or other material which has shown to be of a similar performance in terms of strength and durability. The film must also have a minimum thickness of 2mm. the geomembrane must also have adequate puncture resistance, tear resistance and be able to withstand the installation process.
- The material must also meet requirements due to degradation from chemical exposure, temperature fluctuations and stress cracking. These factors must be met for the operational life of landfill as well as the post closure time period. The relevant specifications for these performance parameters are contained within the Geosynthetic Research Institutes guides to high density polyethylene geomembranes and the linear low-density geomembranes. (GRI test method GM 13 and GM 17)

Requirements for Geosynthetic Clay liners.

- Consist of geotextiles with a thin layer of bentonite between them. The hydraulic conductivity of the barrier must not exceed 5×10^{-11} m/s. this sandwiched layer must also be reinforced by either stitching or needle punching in order to give the barrier greater internal shear strength.
- The barrier must have sufficient durability, flexibility and strength in order to withstand the entirety of the design life of the cell as well as beyond after it has ceased operations.
- The barrier must also comply with the standards outlined by the Geosynthetic Research Institute. (GRI-GCL3)

- The bentonite contained within the barrier must also be that which has been formulated for landfill applications. The specifications are listed in the table below.

Property	**Range or value**
Montmorillonite content	>70wt%
Carbonate content	<1 to 2 wt.%
Bentonite form	Natural Na-bentonite or >80wt% sodium as activated bentonite
Particle size	Powdered (e.g. 80% passing 75-micron sieve or granulated (e.g.<1% passing 75-micron sieve
Cation exchange capacity	>= 70meq/100g (cmol/kg)
Free swell index	>=24cm^3/2g

Table 9. Minimum bentonite specification. (EPA Victoria, 2015)
Note. Carbonate implies calcite, calcium carbonate or other soluble or partially soluble carbonate materials.

- Another issue that can arise with GCL liner is the occurrence of the liner drawing moisture from the surrounding soil. If this occurs then the barrier may not experience the required swell in the bentonite consequently increasing the hydraulic conductivity which will not meet the requirements of the design. If this is the case, this issue needs to be investigated in accordance with the method in *Hydraulic conductivity and swell of nonprehydrated Geosynthetic Clay Liners permeated with multispecies inorganic solutions* (Kolstad et al., 2004) or in an equivalent method.

2.3.1. Clay (CCL's)

Leachate breakthrough time will need to be calculated in order to determine if a clay liner is a viable option. As the cheapest option it will form a benchmark on which to measure the other alternatives against.

The standard that will need to be achieved is the breakthrough time. This is given by the formula.

$$\boldsymbol{t = \frac{T^2\eta}{K(H+T)}}$$

Where t = breakthrough time, y
T = thickness of clay liner in m
η = clay liner porosity
K = hydraulic conductivity, m/y
H = depth of leachate above liner (also known as head)

Example:

- Thickness of clay liner can be anywhere from 300mm to 900mm
- Clay liner porosity. Clay has a void ratio of between 1.06 and 3.34. using the formula n = e/(1+e) this gives porosity a value of between 0.51 and 0.77
- The standard hydraulic conductivity set out by the EPA is 1 x 10^{-9} m/s. (0.0315m/y)
- Depth of dam is expected to be 5m

$$t = \frac{0.3^2 0.51}{0.0351(5+0.3)}$$
$t =$ 0.247 years (≈3months)

$$t = \frac{0.9^2 0.77}{0.0351(5+0.9)}$$
$t = 3.012$ years

Considering the operational life of the dam is expected to be greater than 25 years, a compacted clay liner, even at a depth of 900mm would be unsuitable.
It is generally considered that a CCL is at the midpoint in price range between HDPE liners and GCL's

2.3.2. GCL

GCL’s (Geosynthetic clay liners) are usually composed of bentonite clay encased by a sheet of geotextile on the top and bottom. This is then needle punched to ensure the barrier stays together. This sandwiched layer forms a hydraulic barrier that has a very low hydraulic conductivity. This method of construction will be considered if the compacted clay liner is deemed to be insufficient for the requirements of the dam as its performance exceeds that of the CCL.

A GCL will likely be the most expensive option for the barrier. It is also considered to be the most effective and also less problematic than the CCL.

Figure 11. Installation of GCL in China. (MTTVS, 2021)

GCL liners are generally specified as having hydraulic conductivity values in the range of $1x10^{-11}$ m/s or approximately 100 times more effective than CCL’s. It is these factors that have clients making the extra capital investment to ensure the longevity of their facility.

2.3.3. HDPE

HDPE (High Density Polyethylene) is a thermoplastic made from petroleum. It is known for its high strength and is used in a range of other applications due to it's cost and simplistic manufacture techniques. HDPE liners are generally produced in large rolls 5-7m in lengths from 50 to 500m and in thickness's other between 1 and 2mm.

HDPE is generally the cheapest option with liners and very simple to install however the performance of the HDPE liner is much lower than the GCL.

Figure 12. Installation of HDPE liners (Copin, 2019)

2.4. Dam Sizing / Freeboard

Dam sizing will be reliant on the basin size from the catchment. It will also need to include a freeboard that would be able to contain a 1 in 25 year rain event without overflowing into the nearby waterway. The available documentation has placed the required volume at 15000m^3

2.5. Outlet Structure

A 'chute' or 'spillway' is a drainage channel incorporated into the design of the dam designed to manage overflows and control the bypass flows associated with the dam's operation. There are several critical design characteristics that will need to be followed in order to maintain effective and efficient operation of the dam. These include the flow entry into the chute, the velocity of the water as it travels down the chute and the management of energy at the base of the chute. The flow entry must remain unrestricted. The water must not be allowed to leave the chute excessively and there must be adequate control measures at the base of the chute. These components are necessary to ensure the water does not erode the surrounding soil causing the walls of the dam to fail.

Although the design of the outlet structure falls outside the scope of this project, the relevance of it's correct operation is critical due to the possibility of non-compliant leachate overflowing before acceptable toxic levels are achieved. For this reason, this component of the dam will be briefly included in the design process in the form of a basic outline of the structure.

3. Methodology

- The primary objective for this project is compliance with the EPA regulations relating to the release of leachate.
- The design and construct brief will include tracking of the leachate and monitoring of its composition and strength.
- Investigation into current methods of waste cell and dam construction will be carried out with particular attention on the liners used and their effectiveness.
- Based on other sites, the initial plan is to build a leachate dam with an impervious liner that will allow the leachate to be contained before treatment.
- This report will investigate other possible liner materials to assess whether they would be cost effective in improving the water quality in the stream below the waste facility.
- These investigations will involve the analysis of data from similar sites and the results they have produced with their methods.
- Recommendations will be made based the potential level of improvement for the stream.

4. Design process

4.1. Site constraints

4.1.1. Ecology

REF indicates that the surrounding trees are part of the local koala corridor. It is intended that the batters for the eastern wall of the dam do not encroach on these trees and so a batter slope of 1V:2H has been adopted.

The proposed site for the dam compromises of a small existing dam that will be decommissioned, dewatered and backfilled in accordance with the design shape of the new works. The only vegetation consists of thick scrub and long grass. This presents no issues with clearing this area.

4.1.2. Geotechnical

The Geotechnical report was carried performed by Douglas Partners, Geotechnics/environment/Groundwater. This report was undertaken to assess the conditions of the subsurface for the design and construction of the Leachate dam at the waste facility. The report also included comments regarding the landfill capping adjacent to the proposed dam and recommendations for the stability of these slopes.

The recommendations of this report conclude that the construction of the walls for the dam be carried out using locally sourced clay from nearby Blakebrook Quarry. This material has been used in previous landfill construction and has been found through laboratory testing to be suitable for this application as well.

The report indicates that the fill to be used, as well as the underlying soft clays, provides some issues with regard to stability. Removal of these underlying clays will reduce the settlement due to the placement of structural fill however the primary and secondary consolidation will need to be monitored in order to determine if further action is required.

Due to the settlement of the structural fill under self-weight it is expected that cracking may occur in the embankments. This would likely compromise the integrity of the dam walls and would therefore require ongoing maintenance. It is due to this condition that the report recommends the use of a HDPA or Geosynthetic liner and suggests a suitably qualified and experienced industry professional to be engaged to consult with the final design requirements.

4.2. Catchments

The catchment area is shown in figure 9. The aerial photo of the site gives an overview of the site layout and figure 10. gives the site of the proposed position of the dam.

Figure 13. Aerial photograph of site (Newton, Denny, Chapelle, 2020)

Figure 14. Proposed site of collection dam (Newton, Denny, Chapelle, 2020)

4.3. Position

The dam is proposed to be in a position between the landfill and the surrounding waterways. Due to the natural slope, this position is the most appropriate to fulfill the requirements of the EPA. Community consultation will be advised however the site in not in the immediate vicinity of any residential areas and is not expected to be an inconvenience to the general public.

4.4. Volume

Runoff will need to be calculated in order to predict a design rainfall scenario for the inflow. This will be done using data from the BOM. 2020 rainfall will be used as well as some average daily/yearly rainfall in order to cover design standards.

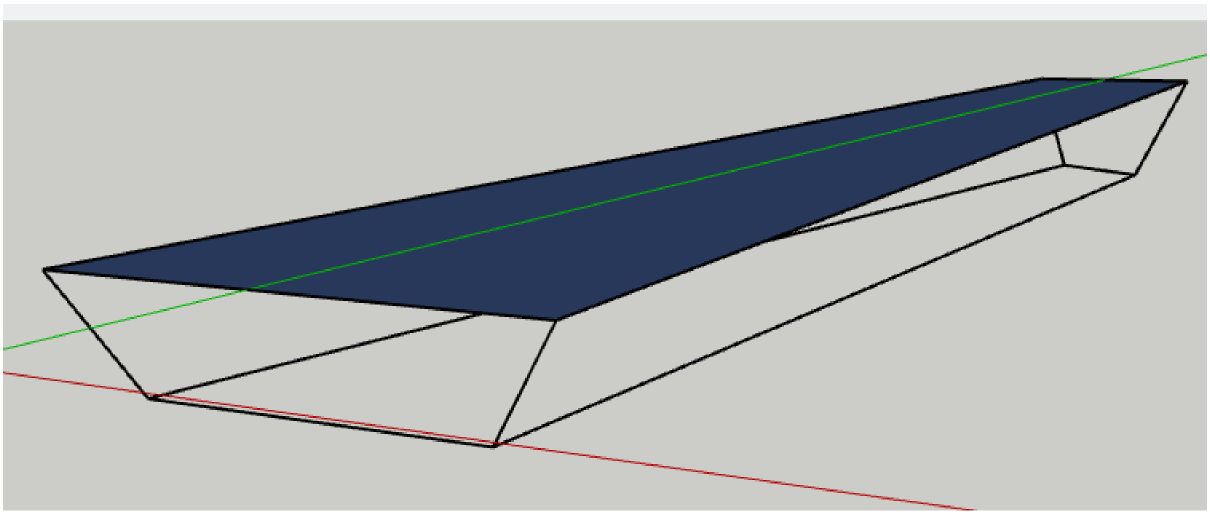

Figure 15. Approximate internal shape of dam.

Volume calculator included in appendix figure 14. Due to the ground water level being unable to penetrated, the dam walls will be extended vertically from the natural ground level to allow for the required volume.

Runoff for capture areas at Lismore waste facility				
area	size (m^2)	runoff coefficient	highest recorded (day)	discharge (m^3/day)
active face area	10000	0.3	258	774
hardstand	4640	0.7	258	837.984
MRF	11050	0.85	258	2423.265
compost	18120	0.245	258	1145.3652
south compost	4300	0.245	258	271.803
roads	4550	0.825	258	968.4675
			total discharge	6420.8847

Table 10. runoff calculations to determine dam volume requirements. (Michigan State 2015)

Table 10 indicates that in a 1 in 25 rain event approx. 6500m^3 will be discharged into the dam. A factor of safety of 3 will be applied giving a total required volume of 19500m^3. Dam sizing will note this figure and calculate dimensions to allow this volume of water to be stored.

Formula used Q = ciA (rational method equation)
Where Q = discharge
c = runoff coefficient
i = intensity
A = area

dam volume calculator				
surface				volume
width	39	freeboard	1.1	6435
length	150			
	base			
depth	width	length		volume
2.6	28.6	139.6		12795.33
2.8	27.8	138.8		13592.1
3	27	138		14364
3.2	26.2	137.2		15111.42
3.4	25.4	136.4		15834.75
3.6	24.6	135.6		16534.37
3.8	23.8	134.8		17210.66
4	23	134		17864
4.2	22.2	133.2		18494.78

Table 11. Dam volume calculator.

Initial size was assumed through measurements of the available space. Using the constraints placed on the dam by the location of the existing cell to the west and the wildlife on the east. A total width at the high-water level of the dam is given by 39m. The restrictions in a north south direction were less problematic and as such a length of 150m will be the initial figure. The dam is expected to be rectangular in shape with internal and external walls at a slope of 1V:2H. The depth calculator suggests that with the additional freeboard depth, an initial depth of 4m will be sufficient for the requirements of the dam.

Fill requirements will be as follows

Eastern wall and western dam walls

- Height – 5m
- Bottom width – 30m
- Top width – 4m
- Length – 150m
- Volume = 13125m^3 (26250m^3)

Southern and northern dam walls

- Height – 5m
- Top width – 4m
- Bottom width – 24m (1V:2H)
- Length – 39m
- Volume = 2730m^3 (5460m^3)

Total fill required 31710m^3

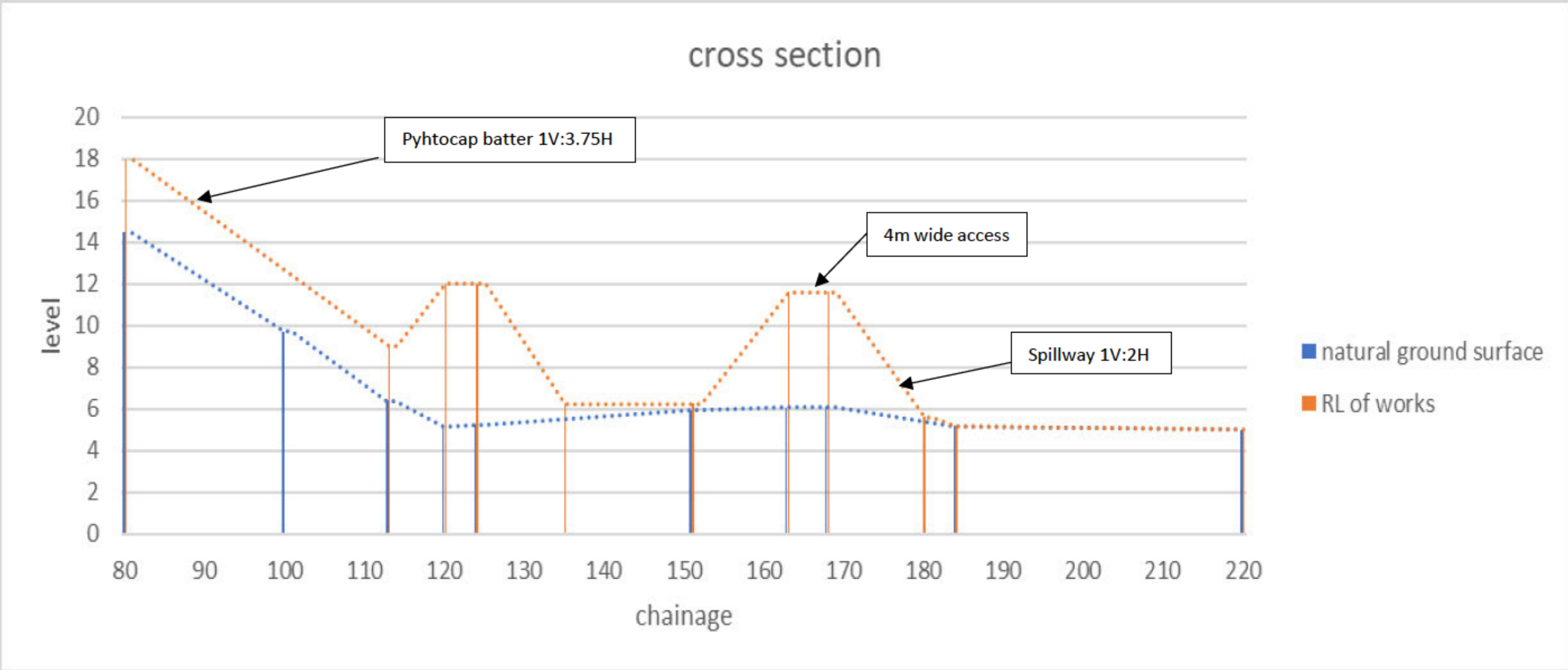

Figure 16. Cross section showing profile of dam walls.

Figure 11 illustrates the cross-sectional view of the dam's profile. The left side of the construction will be the stabilisation of the phytocap that will seal in cell 1. This is outside the scope of this project. The dams' walls will be constructed to RL 12.00 with batter slopes on either side at 2H:1V. there will be a 4m wide surface for vehicular access around the top. The base of the dam will not impede on the natural water table and will be at RL 6.28. The eastern wall will also have a 4m wide access at the peak of the wall at RL 11.60. The spillway will be positioned on the eastern wall.

4.5. Liner

All interior surfaces of the dam will be of a slope no greater than 1V:2H to ensure safe operation of earth moving equipment.

The sub-grade will be rolled to ensure a flat, dry, smooth surface with no rocks or vegetation that may cause damage to the liner during installation. If it is found that the subgrade is not able to be finished in this way, then a layer of sand or geotextile may be needed to create the smooth base required.

Installation of the rolls of GCL will require the use a front-end loader or other approved handling equipment. The process will begin at the lowest elevation end so that the following layers overlap the preceding layers in the direction that the water will flow. It is also recommended that once all layers are down, only low ground pressure devices be used on the site to avoid damage to the barrier. The GCL rolls should be installed in a relaxed condition, free from any folds or wrinkles.

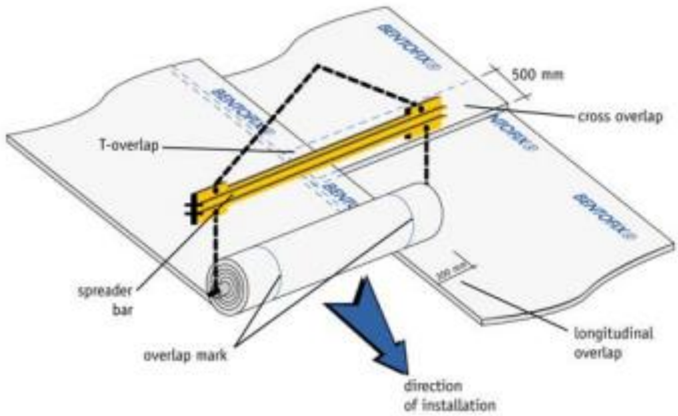

Figure 17. Use of spreader bar to deploy GCL rolls (Bentoxfix, 2005)

The GCL will require an anchor trench around the perimeter of the dam. Typical anchor trenches are placed 500mm from the crest of the dam and are 300mm wide x 500mm deep.

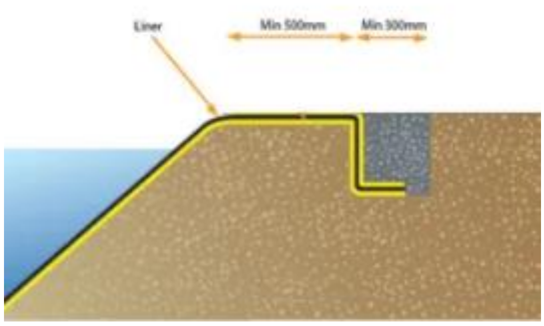

Figure 18. Anchor trench (Geoline, 2021)

Where the GCL rolls overlap, 300mm will be applied to the panel edges and 500mm to the panel ends. GCL's have several methods of joining from inflatable welds to panels that will fuse together after pressure is applied. Compliance with the GCL's manufacturers joining method will need to be closely monitored to ensure the effective operation of the liners throughout the design life. This will include logging the manufacturers numbers printed on each roll.

The required area of GCL is 5266.27m2. this figure has been obtained from a spreadsheet listed as table 18 in the appendix.

The chosen manufacturer will be given this figure during consultation to ensure the correct number of rolls can be obtained.

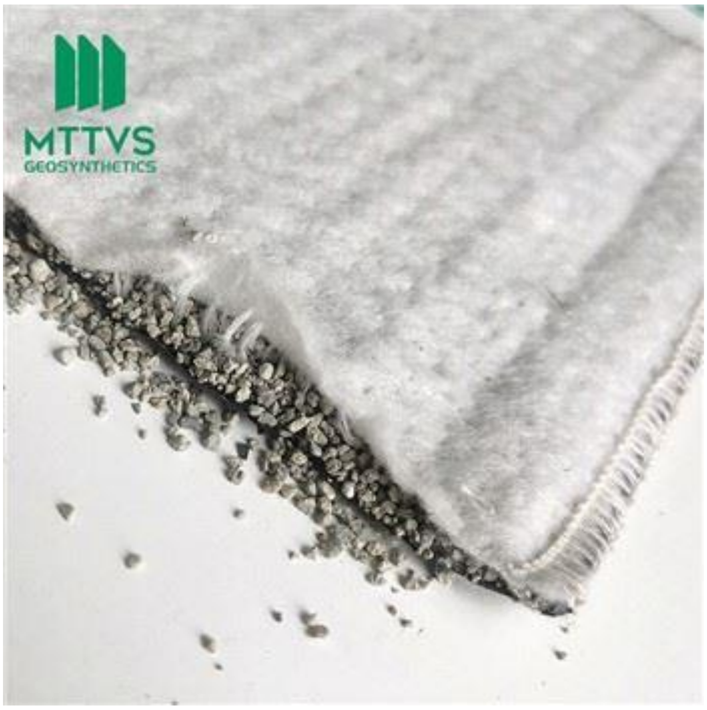

Figure 19. Example of a GCL before it's installation. (MTTVS, 2021)

Closer inspection reveals the small particles of Bentonite clay that will swell to form an impermeable layer once installed onsite. The two layers of Geomembrane are shown encasing the clay with the needle punched seam shown on the right side of the diagram.

4.6. Outlet

Outlet to be constructed will be a concrete weir, armoured with rock to provide scour protection. Measures to avoid erosion will included.

- Shaping of chute face to ensure as far as practicable that water follows design path to the base of the chute.
- Placement of rock on chute face to arrest water speed and reduce chance of erosion.
- Placement of rock at the base of chute to allow water to discharge at low velocity.

Design will be based off similar structures already in use. although the spillway is an important part of the facility, the main focus is on the liner.

Figure 20. Example of spillway design. (Catchments and creeks, 2011)

5. Conclusions

5.1. Implications

Without the use of liners and a collection dam, the leachate would naturally permeate the soil below the cell. Now that this has been prohibited that leachate becomes more evident. This means being exposed to the elements and therefore exposed to the general public. The most notable issue regarding the operation of the leachate collection facility will be the odour given off by the plant. Due to the position of the facility, it is expected that there will be the highest number of complaints during a south west wind direction. This will most likely occur during the months from march through till June.

5.2. Consequential Effects of the Project

The consequential effects of carrying out this project offer little in the way of negative outcomes. The expectation that the waste facility will not be releasing toxic runoff into the surrounding waterways is a positive result for the environment as well as the residents that situated downstream of the disposal site. The construction of the dam will also create short term employment for contractors involved in the initial process as well as longer term employment for ongoing monitoring and maintenance of the site.

5.3. Expected Project Outcomes

Compliance with EPA regulations regarding discharge from municipal waste centres is the primary objective for this project. The current levels of toxins being released into the surrounding waterways may be harmful to the community and the environment. The inclusion of monitoring systems into the design will ensure that the facility will operate effectively into the future and that the compliance guidelines are consistently achieved.

As this project hasn't reached the point of commencement, the results of testing will need to be obtained and entered as a matter of interest. This will be done in conjunction with the project manager, compliance officer (LCC) and the consulting engineers from Newton, Denny, Chapelle as well as Gilbert & Sullivan and Douglas Partners.

6. Risk assessment

The risk management plan adopted for this project is based on the Australian Standard Risk Management (AS/NZS ISO 31000:2009) on which the New South Wales EPA Licence Assessment guidelines (2010) have been based.

Rating	Indicator	Description	Frequency
5	Almost certain	Multiple occurrences recorded	Is expected to occur all the time
4	Likely	Several occurrences have been recorded	Occurs most of the time
3	Probable	Some occurrences recorded	Might occur
2	Not likely	Few recorded occurrences	Not expected to occur but might
1	Rare	No recorded occurrences	Very slight chance of occuring

Table 12. Measures of likelihood.

Rating	Indicator	Description
5	Severe	Deaths, off site impacts. extreme financial loss
4	Significant	Extensive human injuries, substantial off-site problems, major financial loss
3	Medium	Some human health issues, some external impacts, significant financial loss
2	Minor	First aid response, minimal off-site impacts, small financial loss
1	Negligible	No injuries, negligible off-site impact and financial loss.

Table 13. Measure of consequence.

consequence	likelihood				
	almost certain	likely	probable	not likely	rare
severe	V	V	V	V	H
significant	V	V	V	H	H
medium	V	H	H	M	M
minor	H	H	M	L	L
negligible	H	M	L	L	L

Table 14. Level of risk matrix

V – very high risk, immediate action required.

H – high risk, senior management to address

M – medium risk, supervisor to address

L – low risk, implement standard operating procedure.

Construction element	Description of risk	Potential impacts	Likelihood frequency	Consequence severity	Level of risk	Design control measures
			General			
General	Personnel travelling to and from site	Extensive injuries	2	4	high	Awareness of all staff and visitors on site. Appropriate signage and visibility gear. Clear communication between operators and contractors
General	Contamination of site from polluted water	Contamination of water source	2	2	low	Spill response procedures outlined in management plan.
General	Storm event	Erosion, overflow of leachate catchment	3	2	Medium	Design has been completed with storm event considerations. Adequate drainage culverts in design to manage storm events.
			Site preparation			
Site preparation	Tree felling	Serious personnel injury	2	4	High	Proficient plant operators
			Earthworks			
Earthworks	Machinery accidents	Injury or death of operator or bystander	2	4	High	Contractors responsible for safe operation of machinery. Adequate visibility PPO for all personnel on site.
Earthworks	Injury due to buried services	Rupture of gas lines or electricity cables may result in	2	4	High	Contractor required to contact relevant authorities before commencing any works.

		severe injury or death				Any underground works to be recorded as installed
Earthworks	Personnel falling into excavations	Injury due to falling	2	3	Medium	Appropriate warnings placed around any deep excavations. Contractor required to follow directions as required by occupational health and safety regulations
Site infrastructure						
Crane operations	Use of machinery to lift site facilities	Injury due to falling objects	4	4	Very High	All crane operations to be performed using correct sized equipment and lifting points. No personnel to be under lifting area.
Manual handling	Personnel injury when lifting objects	Injury or strains due to incorrect lifting techniques	4	2	High	Implement training regarding correct lifting techniques. Use of appropriate equipment or extra personnel.
Site traffic	Machinery/vehicle collisions	Personnel injury, plant damage	3	3	High	Traffic management plan developed prior to commencement of works. Adequate parking for vehicles. Induction process for staff. All roads designed with line of sight and road widths considered.
Dam construction						
Lifting geosynthetic rolls	Use of truck lifters to place rolls and pipework	Injury to personnel due to falling objects	3	4	Very high	Materials to be lifted using appropriately sized equipment. No personnel to be positioned under lifting area
Liner installation GCL’s	Personnel injury while deploying GCL’s	Injury due to tripping/falling or incorrect lifting technique	3	2	Medium	Contractor must comply with manufacturers guidelines. Good preparation of subgrade will reduce risk of minor falls.

						Correct orientation will reduce work required on sloped ground
Liner installation HDPE	Personnel injury while deploying HDPE membrane liner	Injury due to falling or incorrect lifting techniques	3	2	Medium	Liner not to be deployed in windy conditions. Installer must comply with manufacturers guidelines
Liner installation HDPE	Personnel injury while welding HDPE liner	Minor burns or cuts from knife use	4	2	High	Test welds required to test competency of operator. Minimise welding with panel layout.
Liner installation cushion geotextile	Personnel injury while deploying rolls of material	Minor burns from bonding panels together. Injury due to incorrect lifting technique	4	2	High	Ensure preceding liners are kept free from debris to minimise injury risk.
Leachate collection system HDPE pipes	Personnel injury during installation of pipes	Manual handling injuries. Burns from welding HDPE	2	2	High	Qualified personnel to perform welding activities. Pipes to handled in accordance with AS20:33 installation of polyethylene pipe systems.
Leachate collection system HDPE pipes	Use of power and hand tools required for drilling and installation of pipes	Power tool and manual handling injuries.	3	3	High	Employ suitably qualified personnel to undertake tasks. All power equipment to be assessed before use.
Leachate collection system-aggregate	Personnel injury while placing leachate drainage aggregate.	Struck by machinery. Slips trips and falls.	3	2	Medium	Effective communication between onsite machinery operators and ground staff. Employment of appropriately trained and experienced staff.

Separation geotextile installation	Personnel injury while deploying rolls of material	Minor burns from heat bonding panels together. Manual handling injuries due to poor lifting techniques.	4	3	High	Place aggregate as a smooth working surface. Design liner orientation reduces work required.
Subsurface drainage system	Personnel injury while placing sump	Being struck by sump	3	3	High	Correct machinery used for placing sump. No personnel within specified clear area. Suitable bunding or flagging around clear area

Table 15. Risk assessment and description.

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8. Appendix

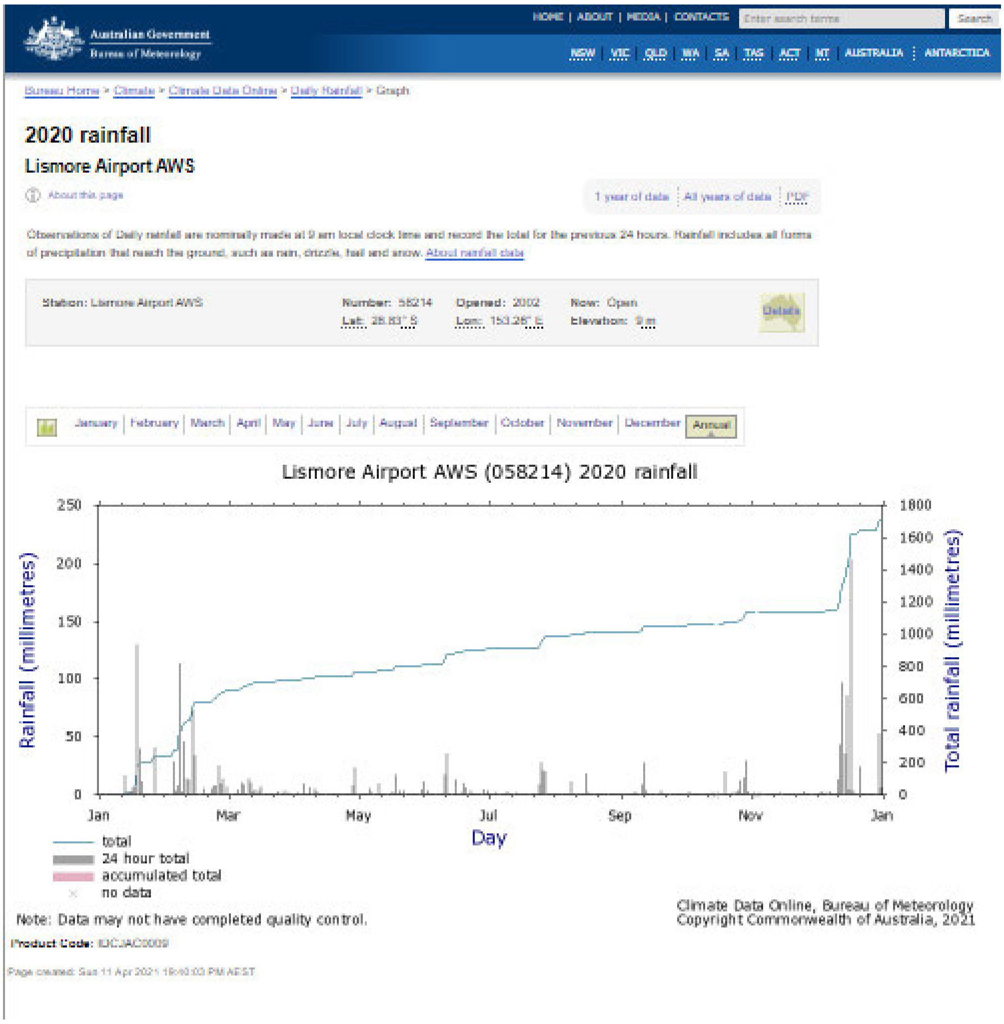
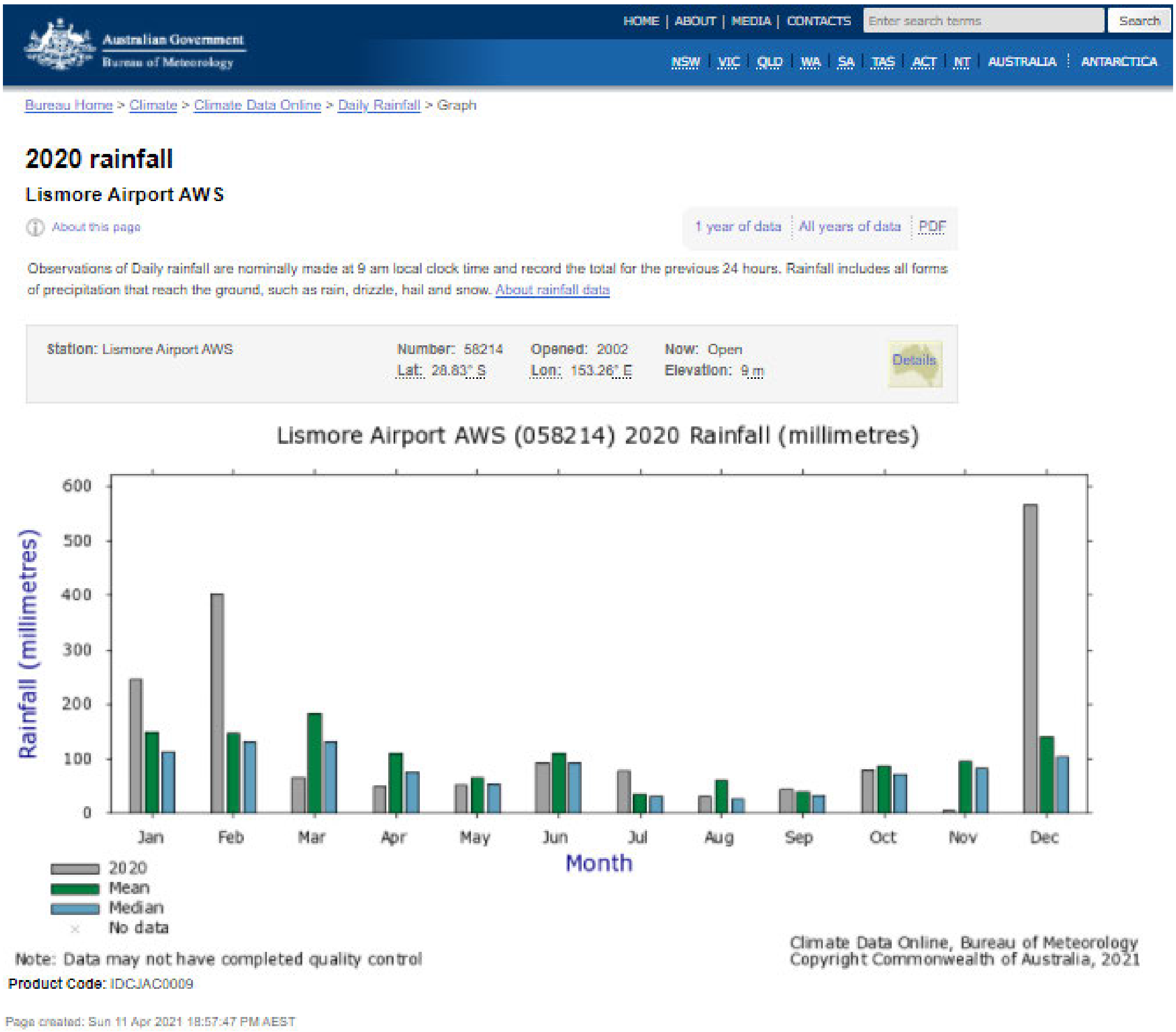


Figure 21. Graph of 2020 rainfall (BOM, 2021)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Bureau Home > Climate > Climate Data Online > Daily Rainfall > Graph

2020 rainfall

Lismore Airport AWS

About this page

1 year of data | All years of data | PDF

Observations of Daily rainfall are nominally made at 9 am local clock time and record the total for the previous 24 hours. Rainfall includes all forms of precipitation that reach the ground, such as rain, drizzle, hail and snow. About rainfall data

Station: Lismore Airport AWS Number: 58214 Opened: 2002 Now: Open
Lat: 28.83° S Lon: 153.26° E Elevation: 9 m
Details

Note: Data may not have completed quality control

Product Code: IDCJAC0009

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Figure 22. Graph of 2020 rainfall against all recorded data.(BOM, 2021)

Australian Rainfall and Runoff terminology

Frequency Descriptor	EY	AEP (%)	AEP (1 in x)	ARI	Uses in Engineering Design
Very frequent	**12**				
	6	99.75	1.002	0.17	Water sensitive urban design
	4	98.17	1.02	0.25	
	3	95.02	1.05	0.33	
	2	86.47	1.16	0.50	
Frequent	**1**	**63.2**	1.58	1.00	Stormwater/pit and pipe design
	0.69	**50.00**	2	1.44	
	0.5	39.35	2.54	2.00	
	0.22	**20.00**	5	4.48	
	0.2	18.13	5.52	5.00	
Infrequent	0.11	**10.00**	10.00	9.49	Floodplain management and waterway design
	0.05	**5.00**	20	20.0	
	0.02	**2.00**	50	50.0	
	0.01	**1.00**	**100**	100	
Rare	0.005	0.50	**200**	200	
	0.002	0.20	**500**	500	
	0.001	0.10	**1000**	1000	
Extremely Rare	0.0005	0.05	**2000**	2000	Design of high-consequence infrastructure (eg major dams)
	0.0002	0.02	5000	5000	
Extreme			PMP		

Table 16. Annual exceedance probability chart. This will be used to determine the design rainfall figures.

	Annual Exceedance Probability (AEP)						
Duration	**63.2%**	**50%#**	**20%***	**10%**	**5%**	**2%**	**1%**
1 min	2.43	2.72	3.65	4.27	4.87	5.67	6.27
2 min	4.06	4.55	6.10	7.16	8.21	9.72	10.9
3 min	5.69	6.38	8.56	10.1	11.5	13.6	15.2
4 min	7.20	8.08	10.8	12.7	14.6	17.1	19.1
5 min	8.59	9.64	12.9	15.2	17.3	20.3	22.6
10 min	13.9	15.6	20.9	24.5	27.9	32.3	35.6
15 min	17.6	19.8	26.4	30.8	35.1	40.6	44.7
20 min	20.4	22.8	30.5	35.6	40.6	46.9	51.7
25 min	22.6	25.3	33.8	39.5	45.0	52.1	57.5
30 min	24.4	27.4	36.5	42.7	48.7	56.6	62.5
45 min	28.6	32.0	42.9	50.3	57.5	67.2	74.6
1 hour	31.7	35.5	47.7	56.1	64.3	75.6	84.3
1.5 hour	36.3	40.8	55.2	65.3	75.3	89.1	100
2 hour	40.0	45.1	61.3	72.8	84.3	100	113
3 hour	46.0	51.9	71.5	85.4	99.6	119	135
4.5 hour	53.2	60.4	84.1	101	119	143	163
6 hour	59.4	67.6	94.9	115	135	164	187
9 hour	69.9	80.0	114	138	164	198	226
12 hour	78.9	90.6	130	158	188	227	259
18 hour	93.8	108	156	191	227	274	310
24 hour	106	123	178	218	258	310	350
30 hour	117	135	196	239	284	339	382

Table 17. Annual Exceedance Probability.

interior surface calulator			
lengths around crest		lengths around base	
depth	4		4
length	150		134
width	39		23
base corner to crest corner			11.2
area north/south wall			347.2
area east/west wall			1590.4
base			3082
crest before anchor (400mm)			75.76
plus anchor trench (500mm)			170.91
total area of GCL required (m2)			5266.27

Table 18. Excel spreadsheet used to calculate area of GCL required.