Memorandum

To:	Zoe Wood	**At:**	Arcadis Australia Pacific Pty Ltd
From:	Sam Butler	**At:**	SLR Consulting Australia Pty Ltd
Date:	7 December 2018	**Ref:**	610.15781.00000-M01-v0.3_edits.docx
Subject:	West Nowra Recycling and Waste Facility		

1 Introduction

Arcadis has engaged SLR Consulting (SLR) to determine suitable leachate management options for the West Nowra Recycling and Waste Facility (the Facility) as a result of Stage 4 landfilling activities.

1.1 Background

It is understood that the Facility is divided into several stages and leachate is managed as follows:

- Stage 1: "Old" unlined landfill, stockpile and irrigation areas, and landfill gas extraction comprising the northern portion of the Facility. It is understood that Stage 1 landfilling occurred in unlined trenches. A combination of gravel and concrete drains discharge leachate to the existing leachate dam.
- Stage 2: Completed lined landfill areas, are now used for stockpiling and landfill gas extraction. It is understood that Stage 2 leachate is currently discharged to the existing leachate dam.
- Stage 3: Active lined landfilling of solid waste and wet weather tipping areas, and future landfill gas extraction area. It is understood that Stage 3 leachate is currently discharged to the existing leachate dam.
- Stage 4: Proposed lined landfilling areas for solid waste, and future landfill gas extraction. Leachate management for Stage 4 is to be determined.

1.2 Site Leachate Management Infrastructure

Existing leachate management infrastructure at the Facility is detailed within Table 1.

Table 1: Existing Leachate Infrastructure

Parameter	Comment
Existing Irrigation System	On average since December 2015, Council has pumped 1257.84 m^3 of leachate to the irrigation area per year. (Shoalhaven City Council, 15/10/18)
Existing Leachate Storage Pond	Maximum storage capacity of Pond of 8.9 ML (Memorandum to David Hojem from Giordano Bianco 14/9/17)

2 Leachate Generation

2.1 Existing Site Data

Council provided leachate generation data from Landfill Stages 1 - 3 (2013 - 2014) for potential use within the Site leachate generation water balance. Council also notes that no data was available for landfill Stages 1 and 2 (old unlicensed areas, and prior to any record keeping). Several months within the historical data set were noted to be missing with other years not available.

It is considered that due to the historical and incomplete nature of the site leachate generation data, estimates of leachate produced by Stages 1 – 3 should instead be determined by the use of the Hydrologic Evaluation of Landfill Performance (HELP) computer program.

2.2 HELP Input Parameters

HELP input parameters developed for the Site leachate generation assessment is included within **Appendix A**.

2.3 Stage 1 - 3 Leachate Generation Summary

For the purposes of leachate generation modelling the HELP model conservatively incorporates 90th percentile annual rainfall volumes from historically wetter years. The monthly infiltration percentage rates are in accordance with associated capping arrangements (detailed within **Table 11**) and the monthly rainfall.

Where areas have been temporarily capped, an infiltration rate of 25 – 30% is typically attained and infiltration rates in restored (final capping areas) are typically in the range of 2 – 10% (Environmental Protection Agency, 2000).

Estimated leachate generation produced by Stages 1 – 3 is detailed Table 2.

Table 2 Leachate Generation Summary – Stages 1 - 3

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual Total (m^3)
	Monthly Precipitation (mm)	63.5	81.5	83.4	96.0	87.3	70.5	98.5	121.5	138.3	108.0	106.8	115.6	1170.9
Stage 1 Closure Area	Leakage (mm)	3.24	3.2	3.1	3.24	3.12	3.19	3.21	2.9	3.26	3.15	3.28	3.19	
	Monthly Infiltration Percentage (%)	4.8%	3.0%	3.2%	2.8%	2.6%	3.6%	2.3%	1.6%	1.7%	2.0%	2.4%	1.8%	
	Leachate Production (m^3)	92.34	91.2	88.35	92.34	88.92	90.915	91.485	82.65	92.91	89.775	93.48	90.915	1,085.28
Stage 2 Closure Area	Leakage (mm)	1.3	0.93	1.66	1.36	0.9	0.46	0.73	0.73	1.08	1.17	1.78	1.36	
	Monthly Infiltration Percentage (%)	2.0%	1.1%	2.0%	1.4%	1.0%	0.7%	0.7%	0.6%	0.8%	1.1%	1.7%	1.2%	
	Leachate Production (m^3)	115.7	82.77	147.74	121.04	80.1	40.94	64.97	64.97	96.12	104.13	158.42	121.04	1,197.9
Stage 3 Closure Area	Leakage (mm)	1.03	1.04	1.52	1.43	1.02	0.66	0.8	0.69	0.86	1.01	1.37	1.23	
	Monthly Infiltration Percentage (%)	1.6%	1.3%	1.8%	1.5%	1.2%	0.9%	0.8%	0.6%	0.6%	0.9%	1.3%	1.1%	
	Leachate Production (m^3)	91.67	92.56	135.28	127.27	90.78	58.74	71.2	61.41	76.54	89.89	121.93	109.47	1,126.7
Stage 3 Operational Area	Leakage (mm)	26.5	23.1	20.2	23.1	25.7	27.9	27.2	25.6	28.5	26	26.6	27.1	
	Monthly Infiltration Percentage (%)	41.73%	28.34%	24.22%	24.06%	29.44%	39.57%	27.61%	21.07%	20.61%	24.07%	24.91%	23.44%	

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	**Annual Total (m^3)**
	Leachate Production (m^3)	212	184.8	161.6	184.8	205.6	223.2	217.6	204.8	228	208	212.8	216.8	2460
Estimated Monthly Stage 1 -3 leachate production (m^3)		511.7	451.3	533.0	525.5	465.4	413.8	445.3	413.8	493.6	491.8	586.6	538.2	5869.96

2.4 Stage 4 Leachate Generation Summary

The monthly infiltration percentage rates vary in accordance with associated capping arrangements (detailed within **Table 11**) and the associated monthly rainfall. Estimated leachate generation produced by Stage 4 is detailed in Table 3.

Table 3 Leachate Generation Summary – Stage 4

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	**Annual Total (m^3)**
	Precipitation (mm)	63.5	81.5	83.4	96.0	87.3	70.5	98.5	121.5	138.3	108.0	106.8	115.6	
Closure 8.9 Ha	Leakage (mm)	4.75	4.73	4.57	4.72	4.54	4.65	4.63	4.23	4.68	4.55	4.75	4.6	
	Monthly Infiltration Percentage (%)	7.5%	5.8%	5.5%	4.9%	5.2%	6.6%	4.7%	3.5%	3.4%	4.2%	4.4%	4.0%	
	Leachate Production (m^3)	422.75	420.97	406.73	420.08	404.06	413.85	412.07	376.47	416.52	404.95	422.75	409.4	4930.6
Operational 0.8 Ha	Leakage (mm)	26.5	23.1	20.2	23.1	25.7	27.9	27.2	25.6	28.5	26	26.6	27.1	
	Monthly Infiltration Percentage (%)	41.73%	28.34%	24.22%	24.06%	29.44%	39.57%	27.61%	21.07%	20.61%	24.07%	24.91%	23.44%	

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	**Annual Total (m^3)**
	Leachate Production (m^3)	212	184.8	161.6	184.8	205.6	223.2	217.6	204.8	228	208	212.8	216.8	2460
Stage 4 monthly leachate production (m^3)		634.75	605.77	568.33	604.88	609.66	637.05	629.67	581.27	644.52	612.95	635.55	626.2	7390.6

3 Leachate Management Options

A summary of feasible leachate management options including typical advantages and disadvantages are listed within Table 4.

It should be noted that re-circulation is not considered a feasible leachate reduction option within this assessment, as once the absorptive capacity within the waste mass is reached, no source reduction of leachate is achieved.

Table 4 Leachate Management Option Summary

Option	Option Description	Advantages	Disadvantages
1	Leachate Storage Pond	**Simple** – A storage pond provides a relatively simple and effective method of managing leachate **Storage** - A leachate storage pond can be utilised in conjunction with other alternate leachate treatment methods such as physico-chemical treatment or thermal treatment.	**Cost** - Ponds are required to be lined to the equivalent performance standard as the landfill and are subject to the same landfill construction approvals and auditing requirements. **Odour** - If leachate ponds become anaerobic, or where odour is particularly critical due to surrounding sensitive land uses, leachate odours can become an issue. Where odour is an actual or potential issue, then the leachate pond may need to be covered or mechanically aerated. Other associated leachate measures such as irrigation will provide some source reduction, lowering the amount of leachate stored in the leachate storage pond, but should not be relied upon to reduce odour issues. **Pond size** – Large storage pond is necessary to ensure sufficient sizing in accordance with best practice NSW EPA requirements.
2	Reverse Osmosis (RO) Plant – leachate treatment	**Leachate reduction** – Can achieve moderate reduction in leachate for the site estimated at ~60%, dependant on leachate quality.	**Cost** – High capital expenditure and potentially requiring a separate approval from EPA. **Power** –High power consumption for operation **Maintenance** –Involves regular on-going maintenance **Leachate concentrate** – Moderate levels of by-product volumes of leachate concentrate produced (~40%) **Not a standalone system** - Must be utilised in conjunction with other leachate management measures, such as leachate pond storage
3	Direct Evaporation Treatment System - Leachate is evaporated by the combustion of landfill gas.	**Leachate reduction -** High reduction in leachate feed volume ~90%. Leachate treatment rate of 35m^3/day.	**Maintenance** – Maintenance required, albeit minimal. **Not a standalone system** - Must be utilised in conjunction with other leachate management measures, such as leachate pond storage.

Option	Option Description	Advantages	Disadvantages
	Leachate combustion machines can either be portable or placed in fixed locations for long-term service. The system can be operated on a variety of fuels – natural gas, methane, propane, fuel oil or waste oil.	**Leachate concentrate** – Low by-product levels of leachate concentrate produced (~10%) **Operational Area** – Minimal space requirements in comparison to other infrastructure, i.e. in comparison to an additional leachate storage pond	**Landfill gas use** –Consumption of landfill gas (180 m^3/hr of LFG consumption for $35m^3$/day of leachate reduction) **Leachate concentrate** – Further management measures may be required to deal with the high strength leachate concentrate. **Moderate Cost** – Moderate capital expenditure (~ $0.5M). Cost effective in comparison to an RO plant
4	Surface irrigation of leachate over suitable areas at the landfill	**Cost effective** – Low construction and installation cost in comparison to other treatment systems. **Leachate reduction** - Moderate levels of leachate reduction. Source reduction – Surface irrigation increases the level of evapotranspiration.	**Moderate application rate**- The irrigation application rate must not exceed the capacity of the land to absorb the nutrient, salt, organic and hydraulic loadings supplied by the leachate. It must not compromise any future use of the land or productivity of the soil. The application rate must minimise runoff. It should not cause spray drift of leachate. **Must be utilised in conjunction with other measures** - Occupiers must have contingency measures in place, should irrigation become unviable for any reason. This must include one or more of the other options discussed in this section, such as a leachate dam. **Effectiveness** - Spray irrigation over the active landfill surface may not be as effective in distributing the leachate throughout the waste mass in comparison to re-injection. It may also pose risks of increased odour impacts, surface runoff, and spray drift.
5	Solar system in conjunction with an RO Treatment Plant	**Leachate reduction** – High levels of leachate reduction achievable, leachate treatment rate of up to $100m^3$/day.	**Cost** – High capital expenditure for Reverse Osmosis Plant and potentially requiring a separate approval from EPA. **Power** –Moderate to high power consumption for operation **Maintenance** –Involves regular on-going maintenance of filtration units **Leachate concentrate** – Moderate levels of by-product volumes of leachate concentrate produced (~20-40%) **Not a standalone system** - Must be utilised in conjunction with other leachate management measures, such as leachate pond storage

Option	Option Description	Advantages	Disadvantages
6	Leachate Storage Tank	**Simple** – A storage tank provides a relatively simple and effective method of managing leachate **Storage** - A leachate storage pond can be utilised in conjunction with other alternate leachate treatment methods such as physico-chemical treatment or thermal treatment.	**Cost** – High capital expenditure required for the installation of suitably sized storage tanks. **Bunding** - Tanks and associated connection points must be surrounded by a bund with a capacity of at least 110% of the tanks. **No Evaporation –** If the storage tank is enclosed, no evaporation (source reduction) will occur.
7	Discharge to public sewer	**Low impact** – Sewer discharge typically has a low environmental impact for the landfill operation and does not have the same odour issues typically associated with leachate pond storage or irrigation.	**Approval** - requires the approval of the local sewerage authority and a Trade Waste Agreement, which may impose restrictions on the quality of leachate permitted to be discharged **Location** – Assessment of feasibility required **Cost** – Connection costs and sewer discharge rates may make sewer discharge unfeasible. **Treatment -** Sewer discharge and treatment at the wastewater treatment plant can encounter issues if the leachate contains high levels of contaminants.

3.1 Leachate Management Recommendations

The performance rating for each criterion is determined as detailed within Table 5. Each leachate management option is rated using an Ordinal scale: 5 (*Excellent*) to 0 (*Very Poor*). Each criterion is weighted evenly in this brief analysis.

Table 5 Leachate Management Multi-Criteria Analysis

Option		Criteria				Total Score
		Leachate Reduction	Capital Expenditure	On-going Maintenance	Energy Consumption	
1	Leachate Storage Pond	2	25	4	4	12
2	Reverse Osmosis (RO) Plant – leachate treatment	3	1	2	1	7
3	Direct Evaporation Treatment System - Leachate is evaporated by the combustion of landfill gas	4	2	4	3	13
4	Surface irrigation of treated leachate on suitable areas of the landfill subject to salinity management	3	4	4	4	15

Option		Criteria				Total Score
		Leachate Reduction	Capital Expenditure	On-going Maintenance	Energy Consumption	
5	Solar system in conjunction with an RO Treatment Plant	5	21	2	2	110
6	Leachate Storage tank	1	2	4	5	12
7	Discharge to public sewer	4	1	4	3	12

Based upon **Table 5**, it is recommended that the following leachate management measures are given further consideration in conjunction with Option 1 within a Site Water Balance:

- Option 4 - Construction of an Irrigation System (Constructed on-top of Cell 2)
- Option 3 - Direct Evaporation Treatment System - Evaporation by the combustion of landfill gas

4 Water Balance

A water balance is developed for the analysis of alternate leachate management scenarios at the Site. In accordance with NSW EPA Environmental Guidelines: Solid Waste Landfills, the water balance was conducted over a period of two consecutive wet years (90th percentile) to ensure that the proposed system has sufficient capacity to deal with all leachate generated during both the operational and closure periods of the landfill.

The site water balance considers the following scenarios, as described in Table 6.

Table 6: Scenario Summary

Scenario	Scenario Detail
1	Utilisation of the existing leachate storage pond (Option 1) and the construction of an irrigation system on the crest of Stage 2 (Option 4).
2	Utilisation of the existing leachate storage pond (Option 1) and the use of a direct evaporation treatment system (Option 3).

4.1 Design Parameters

The design parameters appropriate for this water balance assessment as defined within Section 2.3 of the NSW EPA Environmental Guidelines: Solid Waste Landfills, are summarised within Table 7.

Table 7 Water balance design parameters

Item	Requirement
General	Collected leachate must be stored in appropriately sized dams or tanks and disposed of so as not to cause environmental harm. There must be sufficient leachate disposal capacity to prevent the build-up of leachate and an increase in the risks of water pollution and offensive odours.
Water balance requirement	The model should account for all predicted leachate inputs and outputs from the leachate management system. The model should be run by using monthly time intervals, and it should estimate the changes in the cumulative volume with each month. The maximum cumulative volume may not be reached until many months into the landfill's operation.
Water balance duration	In deciding on any of the above management options, a water balance should be modelled over at least two consecutive wet years (90th percentile) to ensure that the proposed system has sufficient capacity to deal with all leachate generated over the operational life of the landfill.
Pan Coefficient	The evaporation from the leachate dam should be estimated by using a pan coefficient of 70%.
Storage	The dam must have a freeboard that can accept rainfall directly on the dam from a 24hour rainfall event with a 1-in-25-year average recurrence interval without overflowing.

4.2 Water Balance Scenarios

4.2.1 Scenario 1: Option 1 (Existing Leachate Storage Pond) and Option 4 (Proposed Irrigation Area over Stage 2)

An existing water balance is developed for Stages 1 – 4 to determine the sufficiency of the existing leachate storage pond and the construction of an irrigation system on the crown of Stage 2 to accommodate two consecutive wet years (90th percentile rainfall) and predicted leachate generation from Stages 1 - 4.

Parameters for the Scenario 1 water balance are provided within Table 8.

Table 8 Scenario 1 Water Balance Parameters

Scenario	Purpose	Assumptions
1	Determine the sufficiency of the existing leachate management system to accommodate two consecutive wet years (90th percentile rainfall) and predicted leachate generation from Stages 1 – 4.	1. Leachate management by the use of the existing leachate storage pond and a revised irrigation system constructed on Stage 2 (ie Option 1 and Option 4). 2. Irrigation system is able to dispose of 730mm/m^2 over the irrigation area per year at a rate of (851 m^3/month). 3. The clay cap where the irrigation system is proposed for Cell 2 requires removal and is to be re-instated with 1400mm depth of silty sand and 200mm of topsoil to allow for infiltration.

Input parameters for Scenario 1 are provided within Table 9.

Table 9 Water Balance Inputs

Inputs												
	January	February	March	April	May	June	July	August	September	October	November	December
Average Rainfall	396	719	339	343	178	427	322	265	249	376	316	403
90th Percentile Rainfall	427	547	560	645	586	474	662	816	929	726	717	777
Leachate from cell (m^3)	1151	1064	1109	1139	1082	1056	1080	999	1142	1110	1228	1171
Outputs												
Dam Evap (m^3)	908	724	642	483	376	316	358	488	604	749	800	953
Irrigation Use (m^3/month)	852	852	852	852	852	852	852	852	852	852	852	852

4.2.1.1 Preliminary Irrigation Area Sizing

The irrigation area was iteratively sized in accordance with the findings of the SEEP/W model. The irrigation modelling determined 730mm of leachate per m^2 can be applied over the irrigation area. The irrigation system to be constructed Stage 2 is required to be at least 14,000 m^2 in size. The findings of the preliminary irrigation modelling and conceptual sizing of the disposal area are included in **Appendix B**. The water balance (average and 90th percentile rainfall events) for Scenario 1 is depicted within Figure 1.

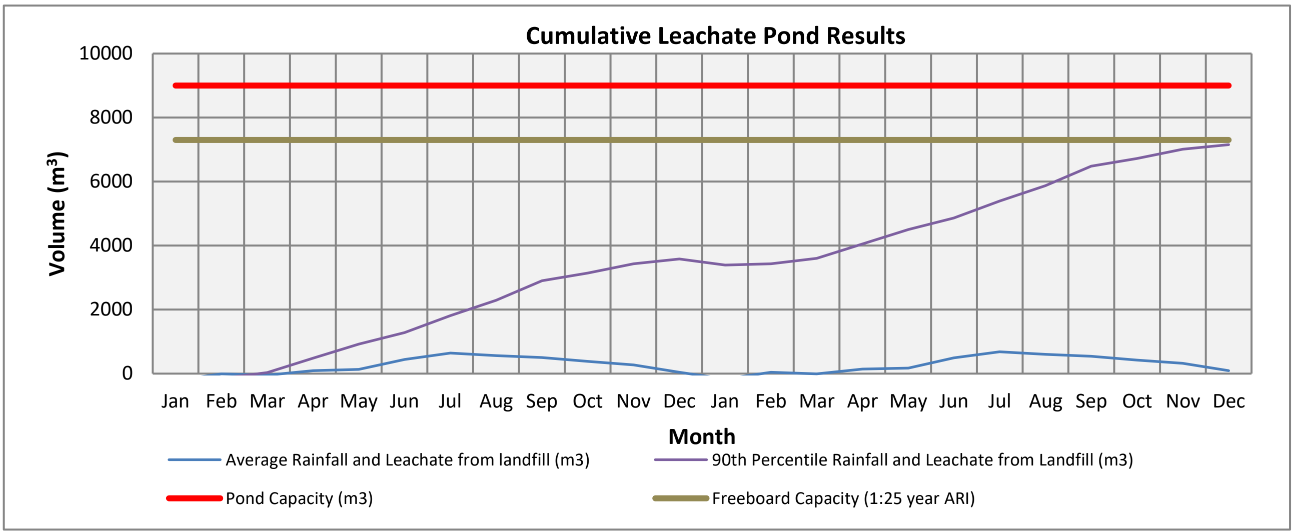

Figure 1 Scenario 1 Results

As shown in Figure 1, the water balance for Scenario 1 confirms sufficient capacity of the current leachate storage pond to accommodate two consecutive 90th percentile rainfall years and leachate generated by Stages 1-4 if a new irrigation area of 14,000m^2 is constructed

4.2.2 Scenario 2 Option 1 (Existing Leachate Storage Pond) and Option 3 (Direct Evaporation Treatment System)

As included within Table 6, a water balance is developed for Stages 1 - 4 including the use of the existing leachate storage pond and a direct evaporation treatment system. Parameters and assumptions used for the Scenario 2 water balance is provided within Table 10.

Table 10 Scenario 2 Water Balance Parameters

Scenario	Purpose	Assumptions
2	Determine if the evaporation treatment system in conjunction with the existing leachate storage pond is able to accommodate two consecutive wet years (90th percentile rainfall) and leachate generation from Stages 1 - 4.	1. Leachate management by the use of the existing leachate storage pond (Option 1) and a Direct Evaporation Treatment System (Option 3)- Evaporation of leachate by the combustion of landfill gas is included within this scenario. The evaporation rate of removal is 35m^3/day. 2. Disposal via irrigation not required in this scenario

Input parameters for Scenario 1 are provided within **Table 11**.

Table 11 Water Balance Inputs

Inputs	January	February	March	April	May	June	July	August	September	October	November	December
Average Rainfall	396	719	339	343	178	427	322	265	249	376	316	403
90th Percentile Rainfall	427	547	560	645	586	474	662	816	929	726	717	777
Leachate from cell (m^3)	1151	1064	1109	1139	1082	1056	1080	999	1142	1110	1228	1171
Outputs												
Dam Evap (m^3)	908	724	642	483	376	316	358	488	604	749	800	953
Direct Evaporation Treatment System (m^3/month)	1050	1050	1050	1050	1050	1050	1050	1050	1050	1050	1050	1050

Leachate generation for average and 90th percentile rainfall events for Stages 1 - 4 is depicted within **Figure 2**.

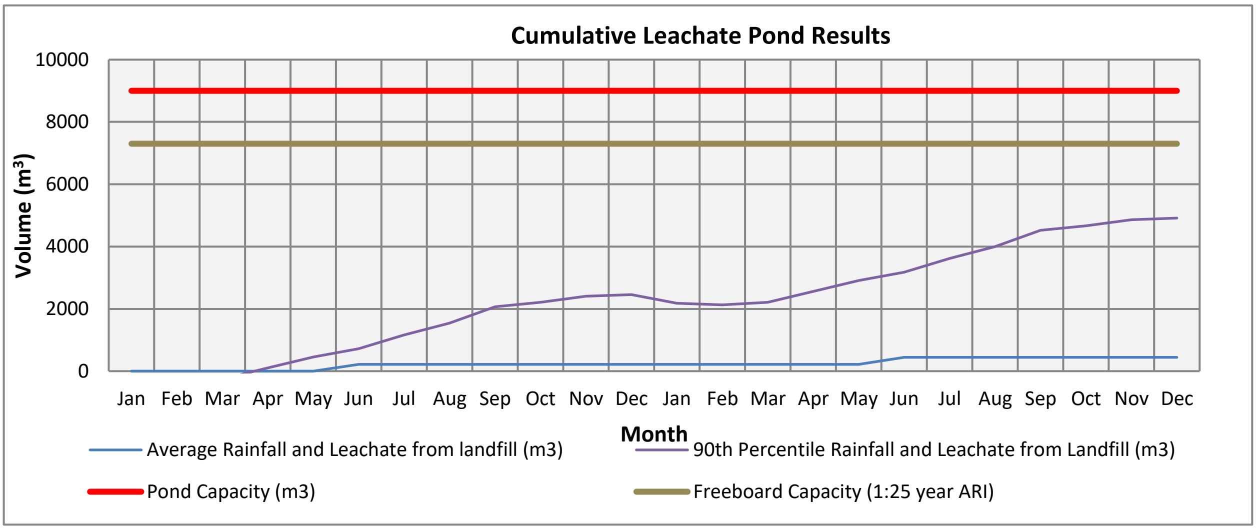

Figure 2: Scenario 2 Results

In this scenario, leachate generated by Stages 1 - 4 would be sufficiently dealt with via the direct evaporation treatment system and existing leachate storage pond.

5 Recommendation

Preliminary water balance modelling indicates that leachate volumes produced by Stages 1-4 is able to be managed by one of the following scenarios, as described in Table 12.

Table 12 Leachate Management Recommendations

Scenario	Description	Notes
1	Construction of an irrigation system on top of Cell 2. The irrigation system is to be utilised in conjunction with the existing leachate storage pond.	The clay cap where the irrigation system is proposed for Cell 2 will require removal and is to be re-instated with 1400mm of silty sand and 200mm of topsoil. The irrigation disposal area is required to be at least 14,000m^2 in size with a maximum annual leachate application rate of 730mm/m^2 at a rate of 851 m^3/month over the irrigation area per year. Refer to Appendix B for proposed irrigation area preliminary assessment and concept design.
2	Installation of a direct evaporation treatment system The evaporation system is to be utilised in conjunction with the existing leachate storage pond.	Evaporation treatment is recommended as an alternate leachate management measure to provide high levels of leachate source reduction and low levels of leachate concentrate.

6 Bibliography

Environmental Protection Agency. (2000). *Landfill Manuals: Landfill Site Design.*

NSW EPA. (2016). Environmental Guidelines: Solid Waste Landfills.

SLR Consulting. (2017). West Nowra Recycling and Waste Facility Proposed Stage 4 Landfill Extension Concept Design Report.

SLR Consulting. (2017). West Nowra Recycling and Waste Facility Proposed Stage 4 Landfill Extension Soil, Water and Leachate Assessment.

APPENDIX A

HELP INPUT PARAMETERS

HELP Input Parameters

A water balance was conducted over a period of two consecutive wet years (90th percentile) as recommended within the NSW EPA landfill guidelines, to ensure that the proposed system has sufficient capacity to deal with all leachate generated during both the operational and closure periods of the landfill.

The following section contains the input parameters used within the Hydrological Evaluation of Landfill Performance (HELP) model.

Capping Arrangements

The capping arrangements for Stages 1 – 4 for the purposes of HELP generation modelling are detailed within Table 13.

Table 13 Capping arrangements

Stage	Estimated Landfilled Area (ha)	Barrier Arrangement	Reference
1	9.5	Stage 1 Landfill is assumed to be covered with a compacted clay liner 600mm thick with a permeability of 10^{-9} m/s. Note: It is understood that Stage 1 landfilling occurred prior to regulatory licensing requirements, in unlined trenches. A combination of gravel and concrete drains discharge leachate to the existing leachate dam. It is estimated 30% of leachate produced is captured by the retro-fitted leachate system and discharged into the existing leachate storage pond.	Shoalhaven City Council (12th/10/18)
2	8.2	Stage 2 is assumed to be covered with a compacted clay liner with a permeability of 10^{-9} m/s and a geomembrane of 10^{-11} m/s.	
3	10	Stage 3 lining is a combination of clay lining and synthetic lining. For the purposes of this assessment, it is assumed the barrier layer comprises a permeability of 10^{-9} m/s.	
	0.8	300mm intermediate cover soils assumed to be a compacted liner with a permeability of 10^{-6} m/s.	
4	9.7	A seal bearing surface 300mm thick A sealing layer comprising: A 2mm low density polyethylene flexible membrane (i.e. LDPE) or approved alternative; and A Geosynthetic Clay Liner; A 1,000 mm revegetation layer	West Nowra Recycling and Waste Facility Proposed Stage 4 Landfill Extension Concept Design Report (SLR, 2017)
	0.8	300mm intermediate cover soils	

Climate Data

Climate data for the model was obtained from SILO (Scientific Information for Land Owners) which contains a database of historical climate records for Australia, hosted by the Science Delivery Division of the Department of Science, Information Technology and Innovation. SILO contains Australian climate data from 1889 to the present date of this assessment. SILO datasets are constructed from observational records provided by the

Bureau of Meteorology. SILO was utilized to process the raw data, which may contain missing values, to derive a dataset for the Site which is both spatially and temporally complete.

SILO data was obtained for, maximum and minimum temperature, pan evaporation, vapor pressure, and relative humidity at the times of maximum and minimum temperature.

Rainfall

A data set of over 25 years was obtained for this assessment, including solar radiation, daily rainfall and average temperature.

Evaporative zone depth

The evaporative zone depth is the maximum depth from which water may be removed by evapotranspiration. The value specified influences the storage of water near the surface and therefore directly affects the computations for evapotranspiration and runoff. Where surface vegetation is present, the evaporative depth should at least equal the expected average depth of root penetration. The depth specified should be characteristic of the maximum depth to which the moisture changes near the surface due to drying over the course of a year, typically occurring during peak evaporative demand or when peak quantity of vegetation is present. It is assumed that the evaporative zone depth for the purpose of this assessment is 10 cm.

Maximum leaf area index

Leaf area index (LAI) is defined as the dimensionless ratio of the leaf area of actively transpiring vegetation to the nominal surface area of the land on which the vegetation is growing. The LAI for this assessment is 1.0 (poor stand of grass, utilised for the operational landfilled areas) and 3.5 (good stand of grass, utilised for the closed/rehabilitated landfilled areas).

Growing Season

The growing season input parameter influences the evapotranspiration rate within the HELP model. The start of the growing season is based on mean daily temperature and plant species. Typically, the start of the growing season for grasses is the Julian date (day of the year) when the normal mean daily temperature rises above 10 to 13 degrees Celsius. For the purpose of this assessment, the growing season is considered to be year-round.

Other Climate Data Inputs

Other climate data properties incorporated into the HELP model include the average yearly average wind speed is 12.4 km/hr and average relative humidity for the area is described within Table 14.

Table 14 Average relative humidity

Quarter	Average Relative Humidity (%)
First Quarter	66
Second Quarter	62.7
Third Quarter	55.3
Fourth Quarter	58.0

APPENDIX B

PRELIMINARY LEACHATE IRRIGATION AREA ASSESSMENT

Introduction

Arcadis has engaged SLR Consulting (SLR) to determine suitable leachate management options for the West Nowra Recycling and Waste Facility (the Facility) as a result of the proposed Stage 4 landfilling activities. As part of this scope of work a preliminary assessment of the volume of leachate that can be applied to the proposed irrigation area over the existing Stage 2 area has been carried out.

The purpose of the desk based irrigation assessment was to determine a preliminary sizing of the required on-site leachate irrigation area to adequately manage irrigation waters and to inform the concept design for the EIS stage of the proposed landfill extension. This assessment has not included any site specific investigations and does not cover detailed irrigation system design, which shall be carried out in the detailed design phase, once approval has been granted.

Background

To assess the quantity of leachate that can be applied to an area without generating run-off a water balance of the soil system should be developed, which takes into consideration:

- Precipitation;
- Evapotranspiration;
- Surface runoff;
- Topography;
- Soil and vegetation characteristics; and
- Soil moisture storage.

The soil system is considered to be in balance when the precipitation entering the soil equals the amount leaving through evapotranspiration. In this case the irrigation volume will contribute to the water balance of the soil.

The area proposed to be utilised for irrigation is located in the central area of Stage 2, as shown in **Figure 3** below. This area was previously used for waste disposal and has a liner underlying the waste. The area has been capped with 200mm topsoil, 800mm silty sand, and 600mm clay.

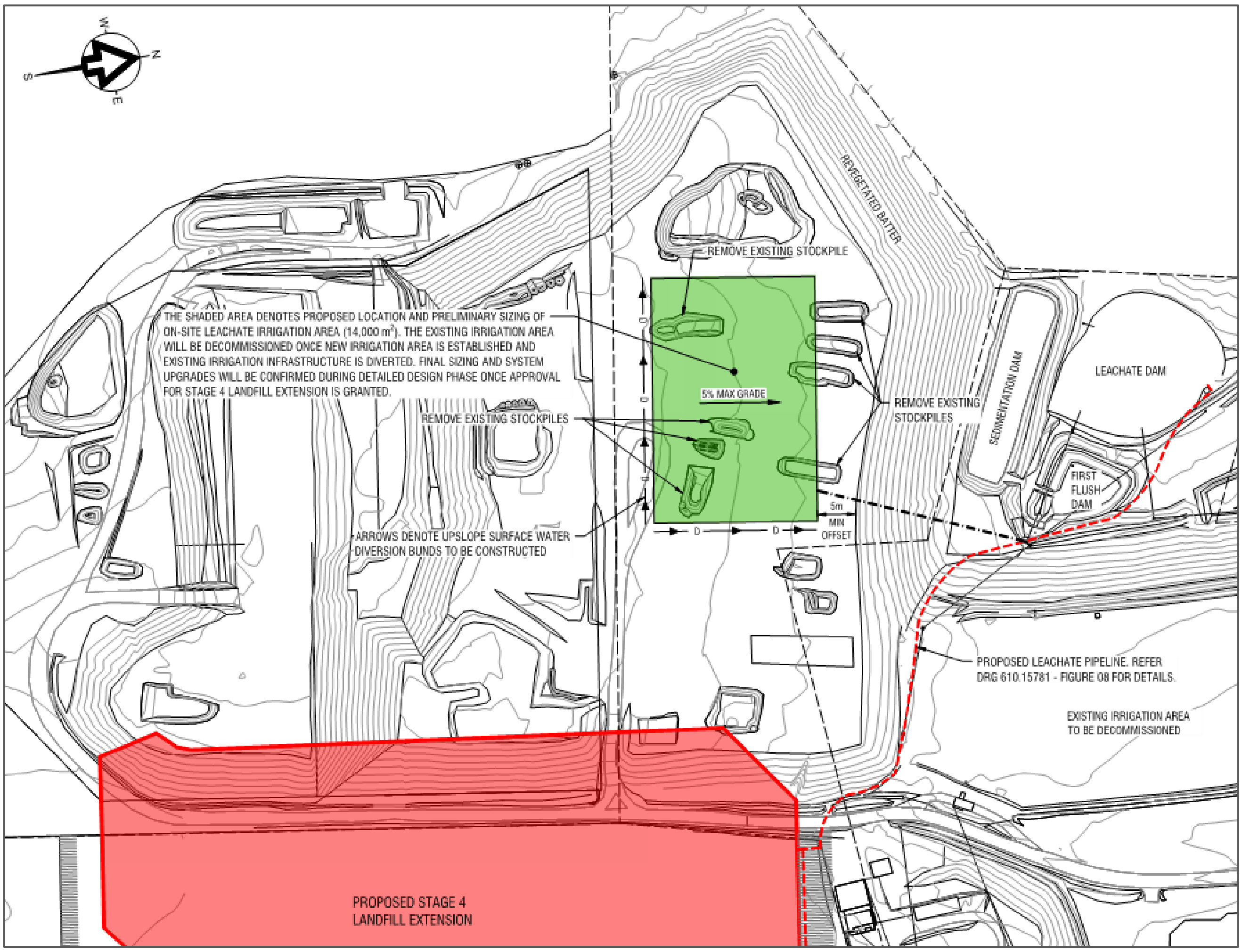

Figure 3 Proposed preliminary irrigation area

Climate

Climate data for the model was obtained from SILO (Scientific Information for Land Owners) which contains a database of historical climate records for Australia, hosted by the Science Delivery Division of the Department of Science, Information Technology and Innovation. SILO contains Australian climate data from 1889 to the present date of this assessment. SILO datasets are constructed from observational records provided by the Bureau of Meteorology. SILO was utilized to process the raw data, which may contain missing values, to derive a dataset for the Site which is both spatially and temporally complete.

SILO data was obtained for, maximum and minimum temperature, pan evaporation, vapor pressure, and relative humidity at the times of maximum and minimum temperature. SILO provides daily climate values which are required for input into the modelling programme.

Data for humidity, temperature, and solar radiation were obtained from the BOM website, with different stations providing different data sets:

- Humidity data was calculated quarterly using monthly percentages obtained for Nowra RAN Air Station AWS station (068072);
- Temperature data was obtained for Ulladulla AWS station (069138); and
- Solar radiation was obtained for Nowra Boat Shed station (068213).

Methodology

Geostudio is an integrated, multi-physics numerical analysis tool that has four components that simulate the flow of energy/mass. Geostudio SEEP/W coupled with thermal functionality has been utilised to simulate an average year of weather to the current layout of the Stage 2 capping profile. A 1D analysis of the soil profile can provide inputs to the evaporation potential of the system allowing for an estimate of additional loading to the system that can be undertaken. As this is a preliminary assessment to inform the concept design, no vegetation has been incorporated into this model, as it has been assumed that vegetation will not have been established at the outset of irrigation.

To ensure a conservative calculation of soil saturation potential prior to run off generation the profile utilised is shown in **Figure 2.2.1.** The current profile has an approximate slope of 3% and an approximate embankment slope of 23%. A land climate interaction boundary specifying the site specific climate data detailed in **Section 02,** has been applied to assess the evaporation potential of the soil system.

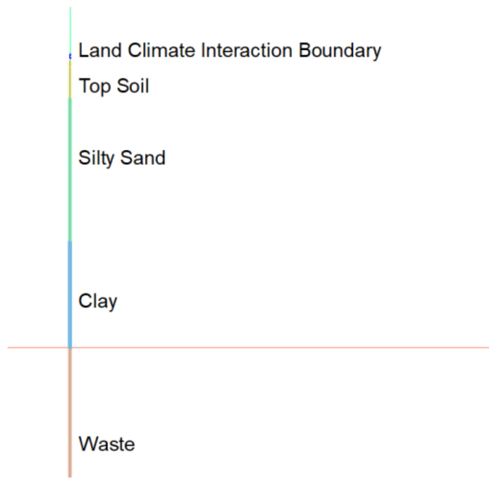

Figure 4: 1 Dimensional Analysis of the Capping Evaporation Potential

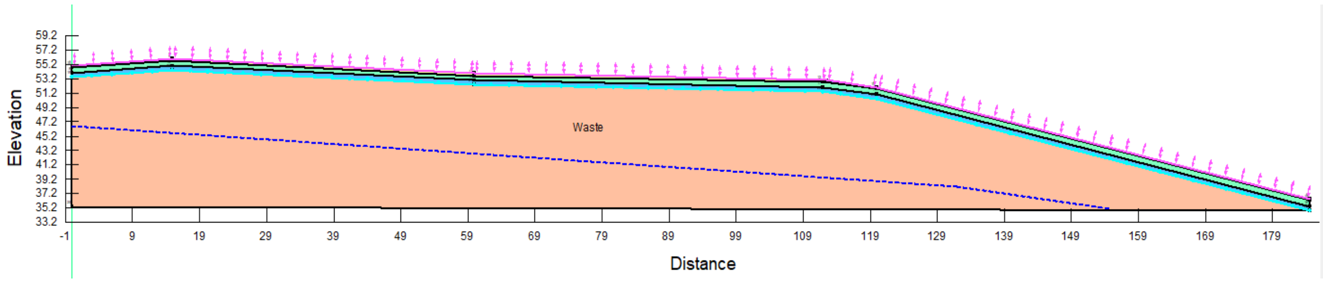

Figure 2.2 Shoalhaven Stage 2 landform profile modelled

It should be noted that site specific soil data for soil moisture curves were not provided and estimates established in literature have been used. Soil moisture curves provide the soil suction parameters of the model, which is the soils ability to retain water in an under unsaturated conditions. Confirmation of soil type and vegetation characteristics shall be carried out in the detail design phase.

Results

1D Soil Profile Analysis – Base Conditions

The cumulative runoff of the 1D soil column is indicative of the soil water balance, and whether the current system without additional irrigation would have any runoff generated. Based on the analysis the soil water balance the cumulative rainfall exceeds the cumulative evaporation; however, this does not mean that there is runoff generation as net percolation into the underlying soil layers contribute to the runoff potential and soil storage, **Figure 5**. Note that positive cumulative net infiltration is indicative of water moving into the soil and negative is indicative of water moving out of the soil.

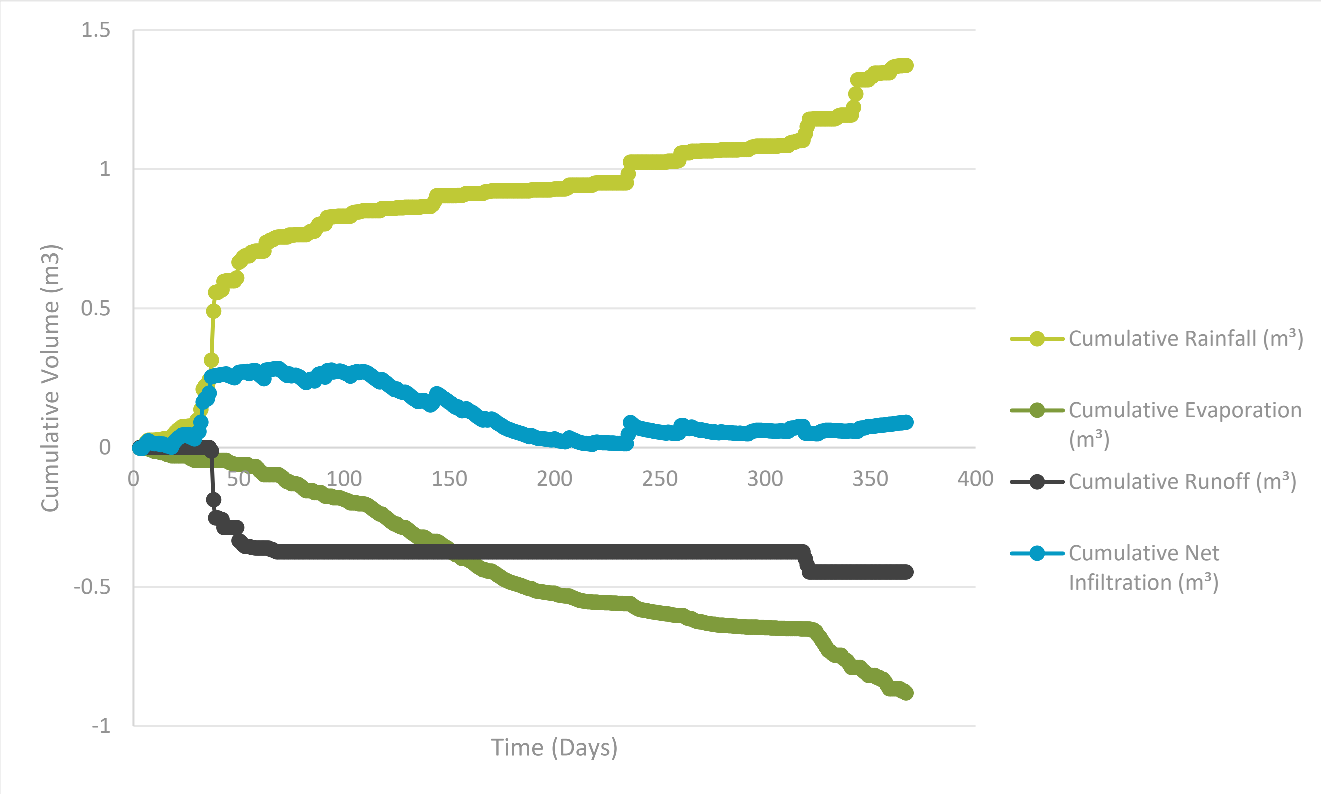

Figure 5 Cumulative climate and infiltration rates

The soil saturation degree is shown in **Figure 6** below. The soil saturation has been set at the top node of the analysis to determine when the system would generate runoff and be capable of taking additional leachate. As can be seen in the Figure 4, the system has periods where the soil is saturated and would generate some runoff as a result of rain exceeding the storage capacity and evaporation potential of the system. These instances are the result of rain events that are sustained over periods of 24 hours or greater.

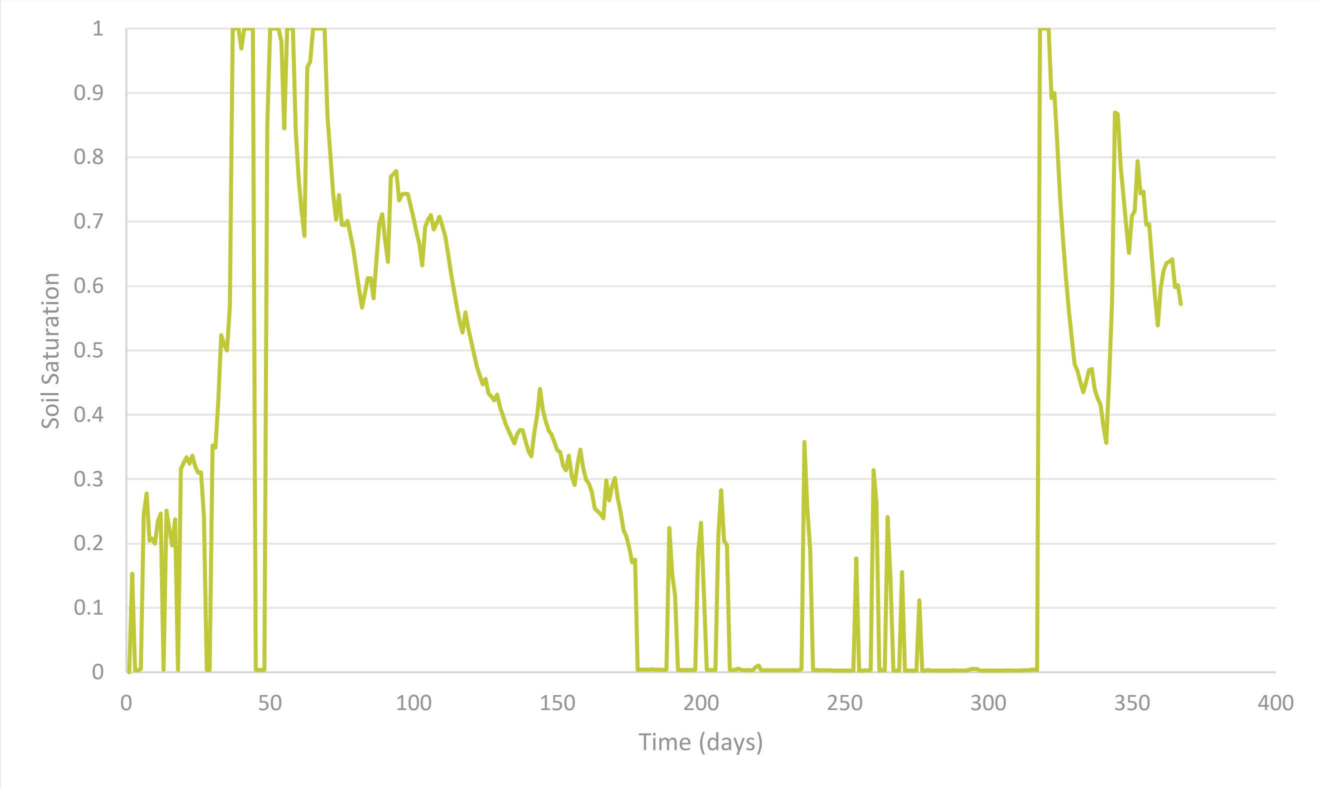

Figure 6 Soil Saturation over modelling period of 365 days

Application of leachate to the area at a rate 0.1mm per day over the course of the year, with days of precipitation excluded was modelled to assess the soil saturation with increased wetting. These results show that increasing the wetting of the soil horizon continually creates significantly greater soil saturation conditions, which are shown in **Figure 7**.

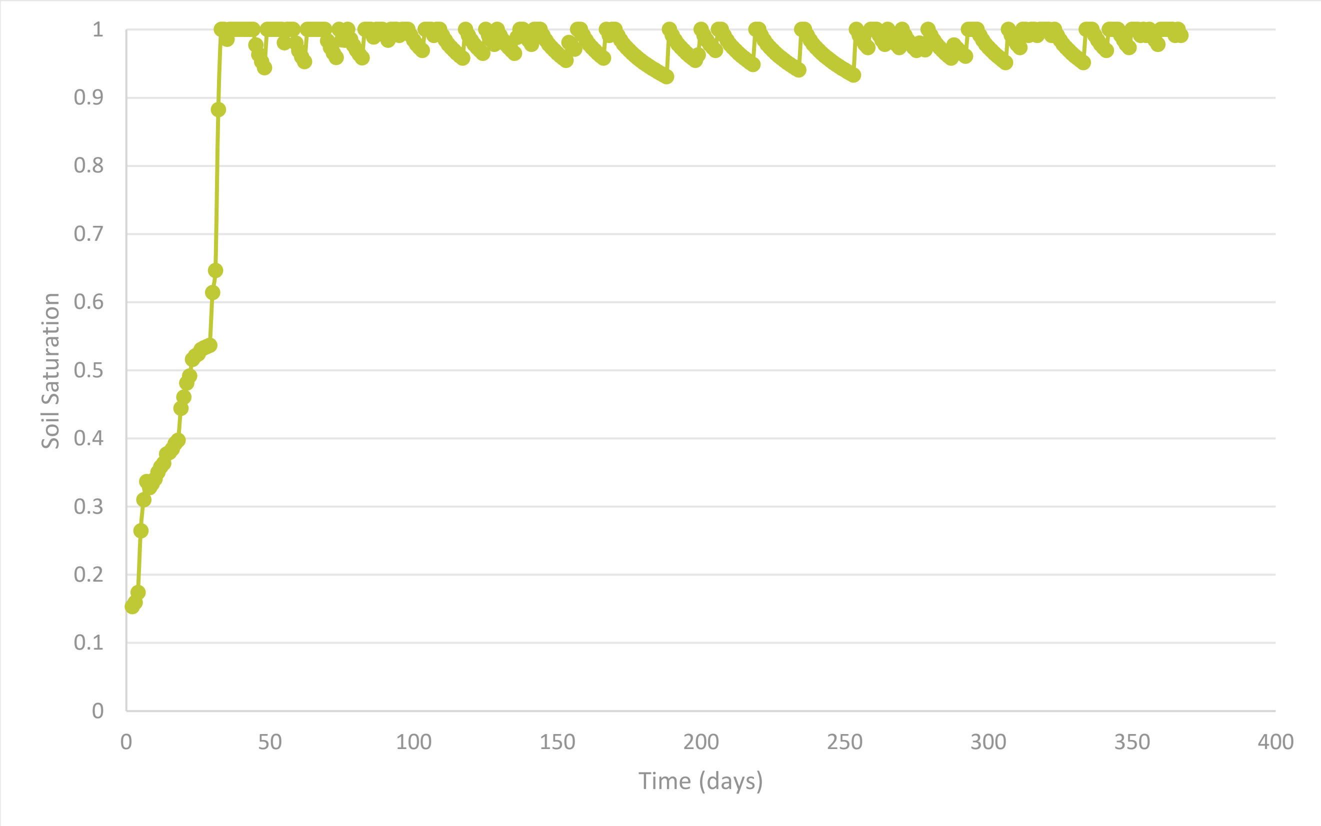

Figure 7 Soil Saturation at 0.1mm leachate application to the 1D column

The system was also modelled removing the clay liner component and replacing it with silty sand, the results of the degree of soil saturation running this simulation with just the environmental conditions are shown in **Figure 8** below. The simulation was also run with an application of 5mm of leachate applied to the area over each day that precipitation did not occur; these results are shown in **Figure 9** below. The results from the application of leachate at 2mm/day over 365 days show that run off is not likely to be generated.

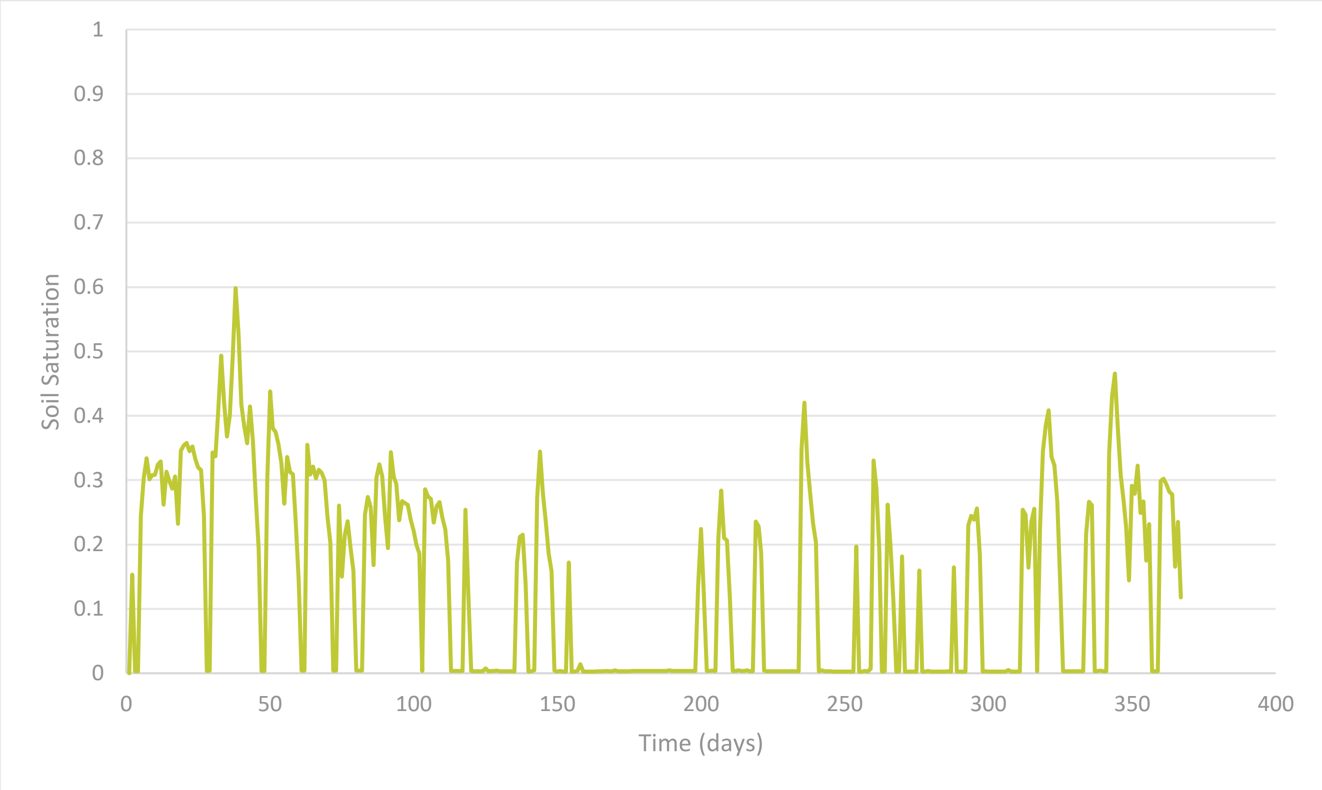

Figure 8 Degree of Soil Saturation with clay removed from capping system

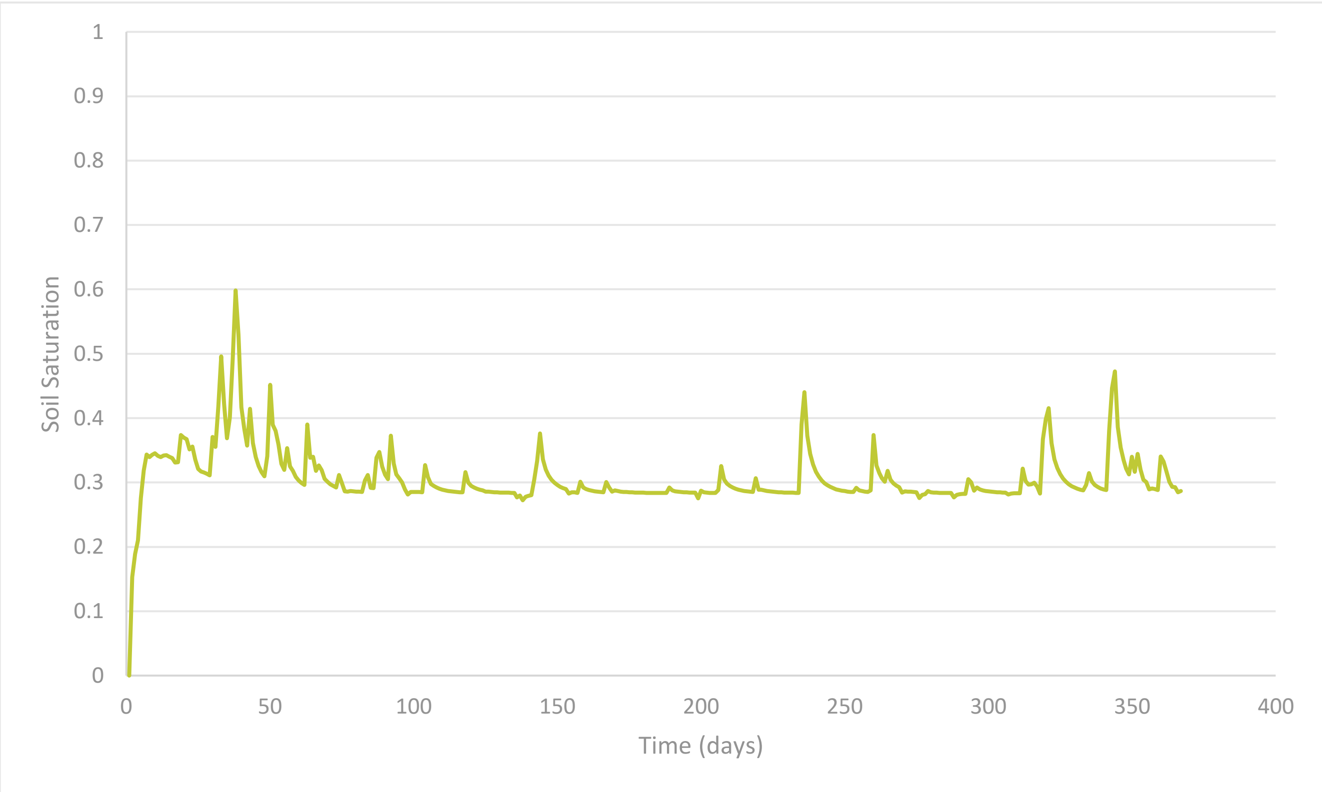

Figure 9 Degree of Soil Saturation with clay removed and 2mm of leachate applied daily (except on days with rainfall)

Recommendations

Based on the modelling that was performed in Geostudio SEEP/W an accumulative application of 730mm of leachate over the selected irrigation area per year would be acceptable with the clay cap removed. It should be noted that leachate irrigation should be avoided on days that rainfall has occurred to reduce the potential for run-off. The irrigation area should be monitored to ensure the establishment of healthy flora and that the oversaturation of the ground is not an issue.

If the clay cap remains in place the area is unlikely to be able have leachate application without risk of leachate run off generation. Additionally, creating saturated soil conditions would result in difficult flora establishment.

Furthermore, it would be advisable that a buffer zone of 5m between the crest of the embankment and the irrigation zone be established and 0.5m bunding be placed on the downslope portions of the irrigation area. The bunding would prevent run-off leaving the area in the event that rainfall occurred on the same day that leachate irrigation had taken place.