Memorandum

To:	Alan Dyer	**At:**	InSitu Advisory Pty Ltd
From:	Sam Butler	**At:**	SLR Consulting Australia Pty Ltd
Date:	1 November 2019	**Ref:**	610.19102-Leachate Generation Assessment-v1.3.docx
Subject:	Tumblong Quarry Leachate Generation Assessment		

1 Introduction

SLR has been engaged to undertake water balance modelling in order to determine storage requirements for leachate generation at the Bangus Quarry landfill development. Bangus Quarry is located in Tumblong, NSW identified as Lot 7004 of Deposited Plan 1028797 and Lot 7300 of Deposited Plan 1149008.

The conceptual design for the landfill design has been undertaken by Insitu Advisory and the key components of this design that impact the leachate generation have been discussed and agreed with Insitu Advisory prior to commencement of the modelling (refer Tumblong Quarry HELP Model Assumptions Memorandum, SLR 2019).

SLRs scope of works has included:

- HELP modelling to determine leachate generation rates from the two most critical landfilling scenarios
- Sizing of a leachate storage pond and irrigation system (location to be determined by others); and
- Reporting (this memo).

HELP modelling involves input of:

- Climate data (including rainfall and evapotranspiration);
- Anticipated thickness/depth and type of waste;
- Information on materials likely to be used in the final capping (e.g. soil type, permeability, porosity, run-off); and
- Consideration of leachate disposal method (e.g. irrigation, leachate evaporative ponds etc.).

This memo details the assumptions adopted for the water balance modelling and provides recommendations for leachate storage.

2 Assumptions

Assumptions agreed by SLR and Insitu Advisory for the development of the water balance modelling are detailed in **Table 1**.

Table 1 Water Balance Modelling Assumptions

Item	Detail
HELP Model	Hydrologic Evaluation of Landfill Performance, version 3.95D
Climate Data Origin	SILO data from 35 09'S 148 00'E Climate data for the model will be 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 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 will be obtained for maximum and minimum temperature, pan evaporation, vapour pressure, and relative humidity at the times of maximum and minimum temperature.
Time Step	Daily (1950-2018)
Data Period	69 years
Rainfall Input Data	In accordance with the dataset, A 90th percentile wet year is estimated to be 949.5 millimetres. For the purposes of this assessment, the closest modelled rainfall year is 1970 (949.8 millimetres).
Proposed Leachate Management Infrastructure	Leachate storage pond and irrigation system

2.1 Climatic Parameters

2.1.1 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.

2.1.2 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).

2.1.3 Growing Season

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. The mean minimum and mean maximum temperature for the area is included in **Figure 1**.

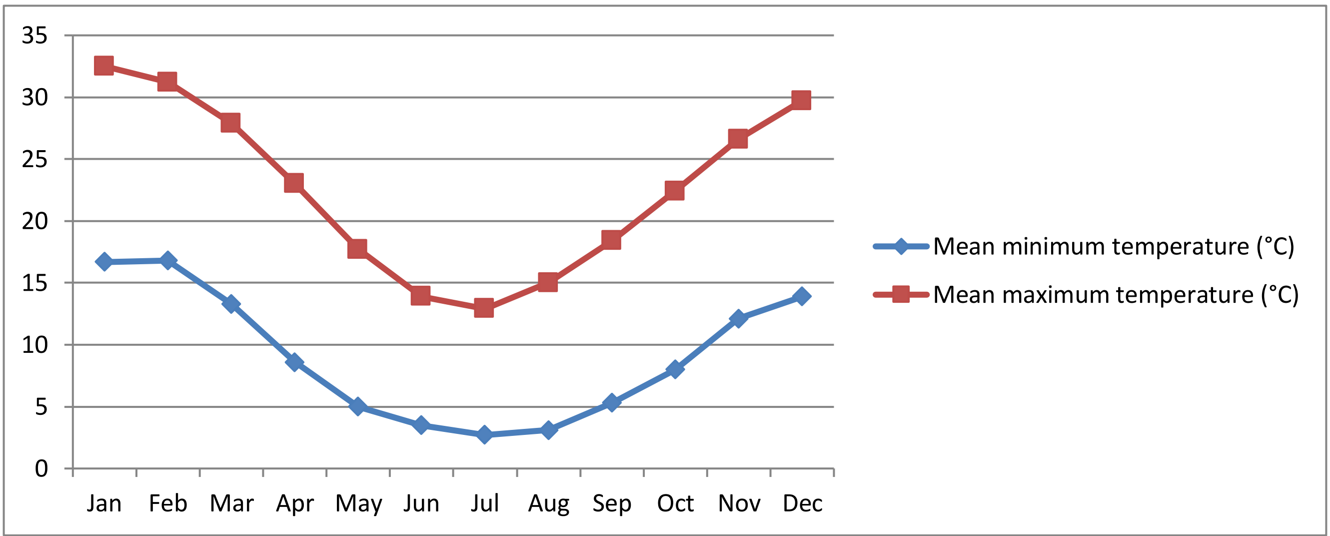

Figure 1 Growing Season

2.1.4 Other Climate Data Inputs

The average yearly average wind speed is 3.3 km/hr (at 2m above ground level) and the average relative humidity for the area (BOM, 2018) is described within **Table 2.**

Table 2 Average relative humidity

Quarter	Average Relative Humidity (%)
First Quarter	47.2
Second Quarter	68.0
Third Quarter	71.8
Fourth Quarter	50.0

2.2 Runoff curve number

Surface water runoff and infiltration will be dependent on the surface slope, slope length, soil texture of the top layer and vegetation. The HELP model computed runoff curve numbers utilized for this model are given in **Table 3**. The slope length of the final cover is assumed to be reduced due to the installation of regularly spaced batter slope drains.

Table 3 HELP Computed Runoff curve number

Scenario	Slope (%)	Slope Length (m)	US Soil Texture	Vegetation	Runoff Curve Number
Daily Cover	25	50	10 – Sandy Clay Loam	Bare Soil	94.39
Intermediate Cover	25	50	24 – Sandy Clay Loam	Bare Soil	96.97
Final cover	25	50	4 – Loamy Sand	Bare Soil	82.93

2.3 Material Properties

The HELP model requires material properties relating to hydraulic behaviour. These are summarised in **Table 4**.

Table 4 HELP Model Material Parameters

Layer	Layer Type	Soil Texture Number	Depth (m)	Pore Volume	Field Capacity	Wilting Point	Hydraulic Conductivity (m/s)
Temporary Cover Systems							
Daily Cover	Vertical percolation layer	10 – Sandy clay loam	0.15	0.39	0.244	0.136	1.2×10^{-6}
Interim Cover	Barrier Soil layer	24 – Sandy clay loam	0.30	0.365	0.305	0.202	2.7×10^{-8}
Final Cover System							
Topsoil	Vertical percolation layer	4 – Loamy Sand	0.2	0.437	0.105	0.047	1.7×10^{-5}
Soil sub-base	Vertical percolation layer	13 – Sandy Clay	0.8	0.43	0.321	0.221	1×10^{-7}
LLDPE	Geomembrane	36 – Linear Low Density Poly Ethylene	0.002	-	-	-	4.0×10^{-11}
Geosynthetic Clay Liner	Barrier layer	17 – Bentonite Mat	0.006	0.75	0.747	0.40	1.9×10^{-11}

Layer	Layer Type	Soil Texture Number	Depth (m)	Pore Volume	Field Capacity	Wilting Point	Hydraulic Conductivity (m/s)
Seal bearing layer	Vertical Percolation layer	13 – Sandy Clay	0.3	0.43	0.321	0.221	3.3 x 10^{-7}
Waste							
Waste	Vertical percolation layer	18 – Municipal Waste	11.7m (Cell1) 30.7m (Cell 2)	0.671	0.292	0.077	1.0 x 10^{-5}
Basal Lining System							
Leachate Drainage Layer	Lateral Drainage Layer	21 – Gravel	0.3	0.39	0.032	0.13	1.0 x 10^{-3}
Geosynthetic Clay Liner	Barrier layer	17 – Bentonite Mat	0.006	0.75	0.747	0.4	1.9 x 10^{-11}
HDPE Geomembrane	Barrier layer	35 – High Density Poly Ethylene	0.002	-	-	-	2.0 x 10^{-13}

3 Results

The 90th percentile annual total of the leachate generation for Cell 1 (final cover) and Cell 2 (daily and interim cover) is detailed within **Table 5**.

Table 5 HELP Modelling Results

Month	Precipitation (mm)	Runoff (mm)	Evaporation (Actual) (mm)	Leakage Through Layer 4 (mm)	Leachate Generation (m^3)
January	101.4	0	51.9	15.1	413.9
February	37.6	0	24	21.5	587.9
March	48.8	0	28.7	2.9	78.2
April	121.5	0	33.8	14.0	382.2
May	57.7	0	38.8	13.7	373.9
June	45.7	0	27.5	50.9	1,393.1
July	34.7	0	29.1	48.8	1,336.8
August	126.1	0	35.2	14.7	402.1
September	154.1	0	55.7	17.5	477.9
October	36.9	0	36.2	28.5	780.6

Month	Precipitation (mm)	Runoff (mm)	Evaporation (Actual) (mm)	Leakage Through Layer 4 (mm)	Leachate Generation (m^3)
November	134.5	0	58.4	54.6	1,496.3
December	50.8	0	31	53.7	1,471.2
Total:	**949.8**	**0.0**	**450.3**	**335.8**	**9,194.1**

4 Leachate Storage Pond and Irrigation System Sizing

4.1 General

The leachate pond will store leachate generated by landfilling activities at the site. The conceptual leachate pond is sized based upon the leachate generation (HELP) modelling, evaporation data, irrigation model sizing and assumptions detailed within the memorandum 'Tumblong Quarry HELP Model Assumptions' (SLR, 2019).

4.2 Leachate Management

For the purposes of leachate generation assessment, two worst-case leachate management scenarios have been prepared for the site, as detailed in **Table 6**.

Table 6 Leachate management scenarios

Scenario	Cell	Capping Arrangement	Estimated Landfilled Area (ha)	Leachate Management Strategy
1	1 (0.79 ha)	Cell 1 completed to final height (daily cover installed)	0.79	Leachate pond only
2	1 (0.79 ha) and 2 (2.74 ha)	Cell 1 completed to final height (final capping installed) Cell 2 two-thirds filled (combination of interim and daily cover area installed). Assumption that the entire Cell 2 area will contribute to leachate generation.	3.53	Leachate pond and irrigation system

4.3 Water Balance Input Data

The water balance model accounts for all predicted leachate inputs and outputs from the leachate management system. Leachate generation (inputs) and source reduction (outputs) considered within this assessment include the following:

Leachate Generation

- Leachate generation produced from Cell 1 and Cell 2; and
- Direct leachate pond rainfall.

Source reduction

- Pond evaporation; and

- Irrigation (Scenario 2 only).

Evaporation totals are based on pan evaporation data obtained from the Silo Data Drill. A pan co-efficient (a ratio of evaporation from a large body of water to that measured in an evaporation pan) of 0.7 (NSW EPA, 2016) is included within this assessment.

4.3.1 Conceptual Irrigation System

In accordance with *Environmental Guidelines: Solid Waste Landfills, Second Edition 2016*, irrigation should be managed in accordance with *Environmental Guidelines: Use of Effluent by Irrigation* (NSW DEC, 2004b). Preference by the NSW EPA is to irrigate over rehabilitated landfill areas.

NSW EPA requirements for the irrigation system are as follows:

- 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.
- All runoff from the irrigation area should be collected and managed as leachate. Irrigation rates should be based on water balance modelling that demonstrates that a water deficit will be maintained and percolation and/or runoff will be minimised.
- Irrigation system to be located in an area of restricted public access and low levels of human contact.
- It should not cause spray drift of leachate.
- Signs should be prominently displayed to inform the public that leachate irrigation is taking place.

An irrigation water balance has been prepared to determine the maximum volume that can be sustainably irrigated each year. The elements to be considered in an irrigation system water balance are:

- Precipitation;
- Irrigation volume applied;
- Evapotranspiration;
- Percolation; and
- Runoff.

In accordance with *Environmental Guidelines: Use of Effluent by Irrigation*, the water balance equation is determined as follows:

Precipitation + Irrigation volume applied = Evapotranspiration + Percolation + Runoff

The surface area required of the irrigation system was determined via an iterative process, by adjusting the monthly irrigation volume applied. The irrigation volume was adjusted so that it did not exceed monthly evapotranspiration and percolation totals to ensure no runoff from the irrigation area would occur.

Assumptions for the design of the irrigation system are detailed in **Table 7**.

Table 7 Irrigation design assumptions

Element	Design Assumption
Location and size of irrigation area	Constructed over an existing landfilled area with a minimum 300mm intermediate or final cover as defined on *Figure 12 – Typical Capping Construction Details (InSitu Advisory, 2019)*. Irrigation area to be located in an area of restricted public access and low levels of human contact. The irrigation area is assumed to be 4,500m^2 in size.
Rainfall scenario	90^{th} percentile wet year is assumed.
Irrigation Discharge Volume Applied	Monthly irrigation discharge volume was iteratively adjusted in the model in accordance with seasonal variations in evapotranspiration, leachate generation and rainfall. No discount for losses from spray irrigation was conservatively assumed.
Evapotranspiration	Evapotranspiration varies throughout the year depending on temperature, humidity, solar radiation, wind, crop type and crop growth. It is estimated by multiplying monthly evaporation values by an appropriate crop factor for the particular species of plant. Crop factors are expressed as the ratio of crop evapotranspiration to pan evaporation. For the purposes of this assessment, a 'pasture' crop factor is applied as defined in Table 4.1 of *Environmental Guidelines: Use of Effluent by Irrigation (NSW DEC, 2004b).*
Percolation	The fraction of percolation water passing through the capping layer after any rainfall event that exceeds the soil moisture deficit, is determined in accordance with the guidelines. For the purposes of this assessment, the percolation fraction was estimated to be 0.068.
Runoff	Runoff as a result of irrigation with effluent is conservatively set to zero in the monthly water balance. This provides a safety factor to ensure that runoff is not used as a means to dispose of the effluent to the environment and ensure runoff does not increase significantly above the natural baseline
Irrigation Method	Assumed irrigation method is via fixed spray nozzle sprinklers delivering uniform distribution of leachate to the irrigation area. Irrigation discharge method is assumed to be capable of evenly distributing up to 27m^3 per day over the irrigation area whilst minimising the risk of aerosol drift.

4.4 Water Balance

Water balance inputs and outputs for the leachate pond and irrigation system are calculated are included within **Table 8** and **Table 9**.

Table 8: Summary of water balance inputs and outputs – Scenario 1

Element	January	February	March	April	May	June	July	August	September	October	November	December	Annual
Inputs													
90th Percentile rainfall over leachate pond area (m^3)	132	49	63	158	75	59	45	164	200	48	175	66	1,235
Monthly leachate production (90th percentile) (m^3)	245	201	53	194	333	465	213	29	302	369	421	437	3,264
Outputs													
Mean leachate pond evaporation (m^3)	214	217	161	100	54	37	55	70	83	135	170	225	1,522

Table 9: Summary of water balance inputs and outputs – Scenario 2

Element	January	February	March	April	May	June	July	August	September	October	November	December	Annual
Inputs													
90th Percentile rainfall over leachate pond area (m^3)	247	92	119	296	141	111	85	307	375	90	328	124	2,314
90th Percentile rainfall over Irrigation Area (m^3)	456	169	220	547	260	206	156	567	693	166	605	229	4,274
Monthly leachate production (90th percentile) (m^3)	413	587	78.2	382	373	1393	1336	402	477	780	1496	1471	9,194
Irrigation Volume Applied (m^3)	320	320	320	0	0	0	0	0	0	800	0	800	2,560
Outputs													
Mean leachate pond evaporation (m^3)	400	406	302	188	102	69	103	131	156	254	319	422	2,852
Irrigation Area Crop Factor	0.7	0.7	0.7	0.6	0.5	0.45	0.4	0.45	0.55	0.65	0.7	0.7	-
Irrigation Area Evapotranspiration (m^3)	740	750	558	298	135	82	108	156	227	435	590	779	4,857
Irrigation Area Percolation (m^3)	217.7	217	217	0.0	0.0	0.0	0.0	0.0	0.0	544	0.0	544	1,741
Irrigation Area Runoff (m^3)	0	0	0	0	0	0	0	0	0	0	0	0	0
Application of leachate to Irrigation Area?	YES	YES	YES	NO	NO	NO	NO	NO	NO	YES	NO	YES	-

4.5 Leachate Pond Sizing

As detailed within **Figure 2** and **Figure 3**, the model is developed using monthly time intervals, and estimates the changes in the cumulative volume with each month. The size of each leachate storage dam is based on a maximum cumulative monthly volume over a period of one wet year (90th percentile). In addition, the leachate pond design allows for the direct rainfall on the dam from a 1-in-25-year average recurrence interval 24-hour rainfall event for the location without overflowing.

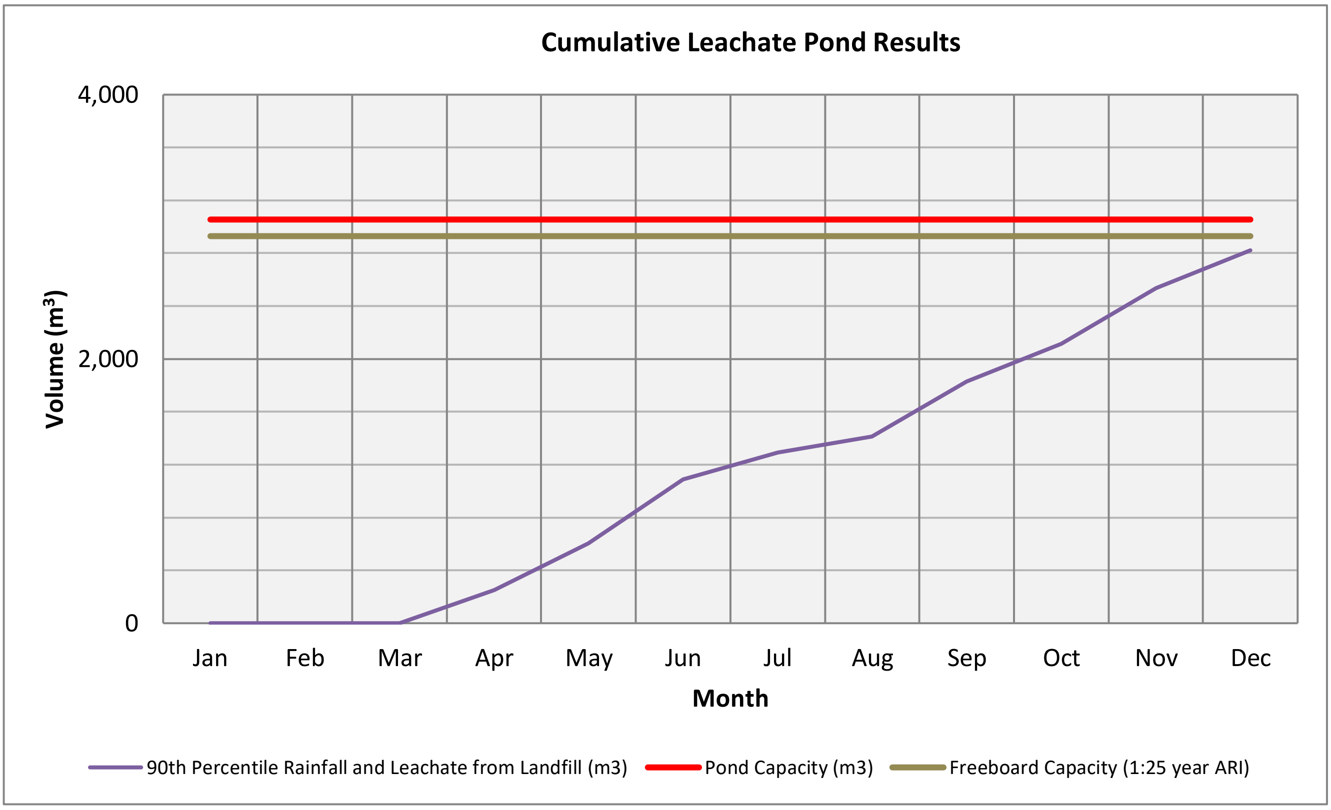

Figure 2: Leachate pond sizing assessment – Scenario 1

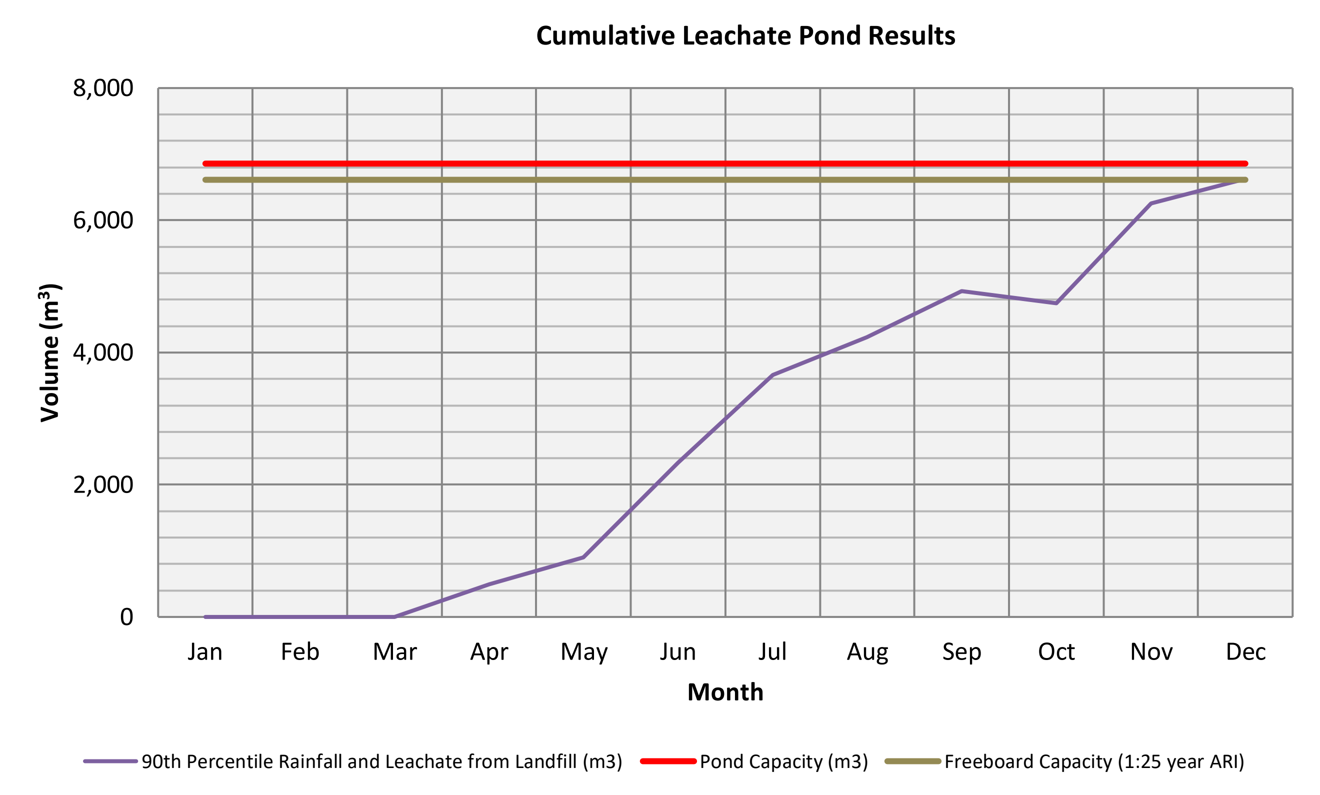

Figure 3: Leachate pond sizing assessment – Scenario 2

The proposed leachate pond sizing details are summarised within **Table 10**.

Table 10: Leachate Pond Properties

Proposed Pond Dimensions	Scenario 1	Scenario 2
Leachate Pond Base Width (m)	5	8
Leachate Pond Width at Top (m)	25	28
Leachate Pond Base Length (m)	30	67
Leachate Pond Length at Top (m)	50	87
Leachate Pond Depth (m)	5	5
Leachate Pond Surface Area (m^2)	1,250	2,436
Leachate Pond Volume (ML)	**3.06**	**6.86**

5 Conclusion

In summary, the model has been prepared in accordance with the *Environmental Guidelines: Solid Waste Landfills, Second edition* (NSW EPA, 2016) and *Environmental Guidelines: Use of Effluent by Irrigation* (NSW DEC, 2004b). The water balance models prepared account for all predicted leachate inputs and outputs from the leachate management system. The leachate pond volume allows for rainfall infiltration into the waste that becomes leachate (rainfall depth x surface area), rainfall onto the leachate dam, less evaporation from the leachate dam. The model incorporates rainfall volumes from a historically wet year (90th percentile wet year) in the locality. The model was run using monthly time intervals and estimates the changes in the cumulative volume with each month over a period of one year.

Based upon this assessment, the results indicate the minimum volume (including freeboard allowance) of the leachate storage pond for Scenario 1 should be 3.06 ML with a surface area of 1,250 m^2 and 6.86 ML with a surface area of 2,436 m^2 for Scenario 2. Should a larger or smaller pond surface area be adopted, the pond sizing may change due to increased or decreased evaporation.

Checked/ Authorised by: DOT