Ghallis Non Hazardous Landfill

Leachate Management and Disposal Options Report

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1.0 INTRODUCTION

SLR Consulting Limited (SLR) was instructed by WasteServ Malta Limited (WasteServ) to undertake an assessment of leachate management and disposal options for the Ghallis Ta Gewwa Non Hazardous Landfill (Ghallis). WasteServ has been operating landfill facilities at Ghallis since 2007 and a substantial area of the site has already been landfilled. WasteServ are now preparing for the development of the final phases of landfilling planned for the site. This work has also been carried out by SLR with options presented to progress rock excavation, landfill cell construction and waste infilling up to the completion of the site in a phased manner, filling either 3 new phases of landfill (Phases D, E and F) or 6 sub-phases (Phases D1, D2, E1, E2, F1 and F2). Different rates of waste deposit have also been considered in this work, dependent on the development of other waste management infrastructure and subsequent changes to the tonnages available for landfilling, along with the effects this may have on development of the Ghallis landfill site over time.

This report presents the findings of Lot2: Technical Consultancy (as set out in SLR's proposal ref P403/4168 dated 17 February 2015), namely: Leachate Management Plan.

This will include an assessment of the volumes of leachate already present within the landfill site above the permitted compliant level, the rate of generation of new leachate during the future filling and capping of the site and for a period of 30 years after projected closure date. In addition, existing leachate quality information will also be assessed and summarised. This information will be reviewed and presented for both the existing Ghallis landfill and the proposed new Phases of landfilling.

Information from this review will be used to assess suitable leachate disposal techniques and technologies for the site, to include:

- outline description of options / processes to deliver modelled leachate disposal needs;
- an indication of the physical plant, equipment and space required for each option;
- an indication of the capital investment required;
- an indication of on-going operational costs; and
- an indication of practicalities and management required for each option

These options will be reviewed in the context of both financial performances, ability to deliver compliant leachate levels within the landfill over the duration of the active and post-closure landfill period and the potential risks and benefits to WasteServ as a result of their operation.

This information may then be used by WasteServ to assist in the selection of appropriate on-site leachate disposal options.

1.1 Abbreviations used in this report

The following abbreviations are used in this report;

Abbreviation	**Definition**
BAT	Best Available Technology
BOD	Biochemical Oxygen Demand
Capex	Capital Expenditure
COD	Chemical Oxygen Demand
CIP	Cleaning In Process
DO	Dissolved Oxygen
de-N	De Nitrifying
EC	Electrical Conductivity
EfW	Energy from Waste
EIA	Environmental Impact Assessment
EQSD	Environmental Quality Standards Directive
GCL	Geosynthetic Clay Liner
H_2S	Hydrogen Sulphide
HDPE	High Density Poly Ethylene
HRT	Hydraulic Retention Time
LTP	Leachate Treatment Plant
MBR	Membrane Bio Reactor
MLSS	Mixed Liquor Suspended Solids
NO_2	Nitrite
NO_3	Nitrate
Opex	Operational Expenditure
pH	Scale of measurement of acidity or alkalinity of a substance
PHS	Priority Hazardous Substances
PLC	Programmable Logic Controller
PS	Priority Substances
RO	Reverse Osmosis
SCADA	Supervisory Control and Data Acquisition
S Solids	Suspended solids
SBR	Sequence Batch Reactor
TKN	Total Kjeldahl Nitrogen
ToC	Total Organic Carbon
TON	Total Oxidised Nitrogen (NO_2 + NO_3)
Totex	Total Expenditure
UF	Ultra Filtration
UV	Ultra Violet
WAS	Waste Activated Sludge

2.0 BACKGROUND

The Ghallis landfill site is located to the west of the closed Maghtab landfill approximately 8km to the northwest of Valletta. The landfill is adjacent to the coast on a headland overlooking the town of Bugibba and is situated in limestone geology.

2.1 Permit and Regulation

The landfill is regulated by the IPPC Permit number IP 0001/06/B, issued by the Malta Environment and Planning Authority, which contains the following conditions in relation to the management of landfill leachate:

- condition 1.1 and Table 1.1 (Permitted Activities) – recirculation of leachate (from leachate generation to on-site recirculation);
- condition 3.4.1.2 – tanks containing potentially polluting liquids to be bunded with a minimum capacity of 110% of the volume of the largest tank or 25% of the total volume of all the tanks with in the bund (whichever is the greatest);
- condition 5.9.5 – no on-site treatment of leachate is permitted in this permit;
- condition 5.9.6 – the leachate storage tank should have a capacity of 7 days production of leachate; and
- condition 5.9.7 – leachate should be pumped out when it reaches 30% of the bund height measured in the lowest point of the cell.

The Permit for the existing Ghallis landfill also includes the following condition in relation to the management of landfill leachate:

- condition 7.10 and Table 7.1 (Leachate monitoring programme) details the monitoring, sampling and analysis requirements with respect to leachate at the site, including a leachate Control level of 0.80m and a Trigger level of 1.0m above base of leachate well.

In addition discharges to sewage treatment works, either directly to sewer networks or via tankered input, are regulated via guideline maximum discharge concentration values as summarised in Table 2-1 below, these limits being found in Legal notice L.N 139 OF 2002. Any discharge of leachate from the Ghallis landfill site will need to be able to demonstrate compliance with these limits should discharge to sewage works be required. It is also likely that any discharge to public sewers will need to be any dissolved methane reduced so as to control the risk of the build-up of explosive atmospheres in the sewer network. Typically this is achieved by control of dissolved methane to below 0.14mg/L in any discharge (or 10% of the lower explosive limit of methane in air).

Table 2-1
Guideline Maximum Discharge Concentration Values for Discharges to Sewers

Determinand	Unit	Limit
pH	pH unit	6.0 - 10.0
Temperature	^{o}C	40
Settleable Solids	ml/L	20
Suspended Solids	mg/L	500
Total Kjeldahl Nitrogen	mg/L	100
Sulphides*	mg/L	10
Hydrocyanic acid**	mg/L	10
Total Sulphates	mg/L	1,000

Determinand	Unit	Limit
Free and emulsified grease	mg/L	200
Free Chlorine	mg/L	100
Chloride	mg/L	1,000
Total Chromium	mg/L	5
Total Silver	mg/L	5
Total Nickel	mg/L	5
Total Copper	mg/L	5
Total Lead	mg/L	1
Total Zinc	mg/L	10
Total non-ferrous metals	mg/L	30
Total soluble non-ferrous metals	mg/L	10
Total Arsenic	mg/L	0.05
Total Fluoride	mg/L	10
Total Boron	mg/L	2

Note: * and compounds releasing hydrogen sulphide on acidification
** and compounds releasing hydrocyanic acid on acidification

2.2 General Site Infrastructure and Resources

The landfill site is bounded to the south by open ground proposed to be developed as waste management infrastructure (a biological waste treatment plant) and the existing (completed) Zwejra Landfill. To the west is further open ground proposed to be developed as waste management infrastructure (including a mechanical waste treatment plant) and a hazardous waste cell. To the northwest and southeast the site is surrounded by farm land. To the northeast the site is bound the Tull Il-Kosta Road adjacent to the coast. The site is well served by access roads and its western perimeter is within 1.5km of the urbanised area of Bugibba. A general site layout drawing is presented as Drawing No 1.

It is assumed that an electrical connection exists for the site and so for the purposes of this report it is assumed that a connection and distribution point is in place so that a mains supply is possible and within less than 50m of any proposed LTP location. It is also assumed that access to the public sewer is possible within 500m of the site boundary.

It is also assumed that a suitable compound could be constructed for leachate management equipment such as small control buildings, storage tanks and ultimately leachate treatment facilities at a number of locations around the periphery of the landfill, the exact choice of location being driven largely by ease of access to suitable load bearing ‘spare’ land and economic proximity to power and sewerage and/or the coast.

2.2.1 Existing and Future Leachate Infrastructure

The existing landfills have been developed with a composite basal lining system and it is assumed that any future development will also incorporate a similar liner detail, summarised as follows:

- 300mm gravel;
- protection textile;

- geomembrane;
- GCL; and
- 500mm mineral liner.

Each hydraulically independent area of the landfills base falls to a leachate collection and monitoring well. The leachate wells are built up from the base of each landfill cell and extend to the current site surface to allow for monitoring of leachate levels, sampling of leachate quality and pumping of excess leachate for recirculation back into the waste mass. The existing landfill site has 11 leachate collection wells numbered LCP1 to LCP11. These wells are shown on Drawing No. 2.

Base and surface levels for each well along with the calculated depth of well are presented in Table 2-2 below;

Table 2-2
Existing Leachate Well Elevations

LCP ID	Base Level (mAD)	Surface Level (mAD)	Depth of LCP (m)
1	23.79	66.31	42.52
2	22.48	62.93	40.45
3	23.63	65.21	41.58
4	17.68	42.48	24.8
5	16.96	26.48	9.52
6	11.82	40.19	28.37
7	20.16	58.69	38.53
8	17.2	45.99	28.79
9	15.6	43.2	27.6
10	11.82	44.04	32.22
11	10.77	25.93	15.16

Note: Data from latest site survey, carried out in December 2015.

It is assumed that whether the extension of the Ghallis landfill takes place as 3 phases or as 6 sub-phases of development, each phase will be similarly supplied with suitable leachate collection and monitoring wells constructed from the basal drainage layer to surface.

It is understood that at present the existing Ghallis landfill has not been finally capped and restored. However, capping of the site is required (based on the sites EIA) and so it is assumed that during the development and filling of the Ghallis landfill extension area the existing Ghallis site will be progressively capped and that capping will then subsequently be carried out to the completed Ghallis phases. Capping detail is likely to comprise the following;

- 1000mm thick restoration soils;
- 300mm thick protection layer;
- geo-composite drainage layer;
- 1.5mm thick Geomembrane; and
- 300mm stabilisation layer.

This constitutes a high quality, low permeability landfill cap that will substantially reduce infiltration of rainfall to the waste mass once installed.

It is reported that leachate generated within the existing Ghallis landfill site is pumped from the leachate wells as required and re-circulated within the waste mass. It is therefore assumed that suitable leachate pumping systems will be routinely installed to all leachate wells at the site so that leachate can be removed and managed either by recirculation or disposal. Whilst leachate has been re-circulated at the existing site is it not known if this has been via engineered sub-surface systems or by simple application back to the surface of the waste. Should recirculation be employed as a leachate management option in the post capping period of the landfills life then engineered sub-cap systems will need to be employed to facilitate the managed re-introduction of leachate to the waste mass.

2.2.2 Existing and Proposed Site Areas

Drawings No. 3 and 4 depict the possible further development of the Ghallis landfill site as 6 sub-phases in the void adjacent to the existing Ghallis landfill. Using this indicative development plan site areas can be defined as follows;

Table 2-3
Ghallis Landfill Site Areas

Site	Cell / Phase	Surface Area m^2
Existing Ghallis[1]	Whole Site	95,600
Existing Ghallis [2]		49,300
Ghallis Extension	Phase D1	10,500
	Phase D2	5,000
	Phase E1	5,000
	Phase E2	10,400
	Phase F1	14,200
	Phase F2	27,800
Total at Completion		122,200

Note: [1] Current surface area
[2] Surface area at completion of Ghallis landfilling, after over-tipping of existing Ghallis western flank

2.3 Outline Leachate Disposal Options

As discussed above (see Section 2.2.1) leachate generated at the existing landfill site and present in the waste mass at levels in excess of the Permitted limits is pumped out of the affected wells and recirculated into the waste mass. This activity is allowed by the sites Permit.

However, review of leachate level monitoring data suggests that recirculation alone may not be a sustainable means of managing leachate at the site in the future as it is apparent that excess leachate levels have begun to accumulate in the waste mass. This suggests that the accessible adsorptive capacity of the waste has now been utilised. Whilst placement of ‘new’ waste within the Ghallis landfill will undoubtedly deliver additional adsorptive capacity this may not be sufficient to accommodate the non-compliant ‘excess’ volume already present within the existing Ghallis landfill along with the new leachate that will continue to be generated in both the existing and new waste bodies.

Also, if the experience of the existing Ghallis landfill is used as a model for the proposed Ghallis landfilling, it is likely that any adsorptive capacity in the Ghallis landfill will have been used up and excess leachate heads generated in this waste body in, at the most, 7 – 8 years. As such, management of leachate by recirculation is likely to need to be supplemented or fully replaced by some form of off-site leachate disposal.

Outline leachate disposal options, along with some comment on the positive and negative aspects of each, are as follows:

- on-site recirculation of leachate;
    - low cost, easy to set up leachate management option;
    - can stimulate more rapid degradation of waste and so can stimulate landfill gas production in the short term;
    - spare adsorptive capacity of waste is finite, whereas leachate production is on-going, therefore it is likely that at some point excess leachate production will take place;
    - longer term (30+ years) may affect the ability of the waste mass to stabilise as pollutant is not removed from the site, could extend post-closure aftercare period;
    - can be operated in conjunction with other options.
- tankering for disposal at suitable off-site facility
    - if a suitable disposal site exists within an economically viable transport distance, this option has low capital set up costs;
    - can be operated in conjunction with other options;
    - acceptance criteria at disposal site may mean that pre-treatment is necessary, if this is the case then additional capital costs will apply;
    - on-going operational costs can be high (haulage plus receiving site gate fees);
    - risks to the landfill operator are high as the disposal option is subject to commercial arrangements with a 3rd Party that may change at any time.
- discharge to public sewer;
    - if a sewer exists within an economic distance of the site for discharge to sewer this is often the preferred solution as required effluent quality is often less onerous than for discharges direct to controlled waters;
    - capital and operational costs are often not as high as for discharge to surface water and total lifetime expenditure (30+ years) is often favourable compared to tankering;
    - pollutant is removed from site so can assist in stabilising the waste mass and shortening aftercare periods;
    - some risk that sewer operators may change or withdraw consent to discharge.
- discharge to controlled waters;
    - in principal discharge can be to freshwater river, tidal river and sea (in some circumstances discharge to groundwater is also possible);
    - not always available nearby to site, generally water bodies with a greater flow can accommodate higher volumes and loads of effluents;
    - can often require a higher standard of treatment than for discharge to sewers;
    - capital and operational costs are often high due to need to treat to a higher standard however total lifetime expenditure (30+ years) is still often favourable compared to tankering;
    - pollutant is removed from site so can assist in stabilising the waste mass and shortening aftercare periods;
    - some minor risk that legislative changes may amend or withdraw consents to discharge.

- ‘no discharge’ treatment options;
  - typically only employed in ‘niche’ circumstances, some treatment option can result in no discharge from the landfill;
  - evaporation of the liquid element of leachate can be employed so that only solid residues remain;
  - if using ‘natural’ processes (evaporation ponds, application of leachate to biomass as irrigation water) can be relatively cheap to construct and operate;
  - considered mainly where other off-site discharges are not available or possible (i.e. arid and remote locations);
  - risks are that these techniques are generally dependent on prevailing climatic conditions and result in the need to dispose of a solid residue by one means or another.

At Ghallis landfill site a number of site specific circumstances mean that the general consideration outlined above may in this instance need to be amended. Site specific factors that need to be considered are:

1) The apparent lack of a known potential off-site disposal site capable of receiving liquid wastes such as leachate for disposal;
2) The likely Chloride limit of 1,000mg/L for any effluent entering the sewers or being treated at sewage treatment works (whether that liquid is delivered by the sewer network or in a tanker);
3) The likely TKN limit of 100mg/L for any effluent entering the sewer of being treated at a sewage treatment works (whether that liquid is delivered by the sewer network or in a tanker); and
4) The climate of Malta being possibly conducive to ‘no discharge’ treatment options.

2.3.1 Tankered off Site Disposal Sites

As the site is located adjacent to major road systems it is anticipated that tankering of leachate from the site using 30ton maximum payload articulated road tanker would not be a logistical problem.

However, it is not known that there are any suitable leachate disposal sites that would be able to accept leachate for treatment and disposal. It is likely that any such disposal site (for example, a sewage treatment works) would require leachate delivered to it to be pre-treated so that its quality conforms to that detailed in Table 2-1 above.

2.3.2 Discharge to Sewers

Due to the proximity of the site to an urban area it is anticipated that a sewage system may exist within reasonable distance of the site. Should this be the case agreement may be reached with the sewage operator that the sewer has sufficient capacity to carry inputs of leachate from the site (i.e. there is spare ‘flow’ capacity within the pipework) and that the ultimate receiving sewage works is capable of accepting the pollutant load that will be delivered by discharges of landfill leachate.

Again, it is likely that any such discharge would require leachate delivered to it to be pre-treated so that its quality conforms to that detailed in Table 2-1 above

2.3.3 Discharge to Suitable Controlled Waters

Should a discharge to sewer not be possible the next route of disposal for an on-site LTP would be to surface water. The landfill site is not located close to a suitably sized river, however its eastern boundary is within 150m of the sea.

It is likely that any such discharge would need to be treated to a better quality than would be required for discharge to sewer. An example of a discharge consent for discharge of treated leachate to a 'Transitional and Coastal' (i.e. saline) water body in the UK is presented below in Table 2-4. This indicates that discharge to controlled water is likely to require much greater removal of ammonia, BOD and COD than would be needed for discharge to sewer. Active reduction in metals concentration may also be required to a much greater extent that is likely to be the case for a discharge to sewer. However, if the receiving water body is saline (as in the example presented in Table 2-4) Chloride and other similar ions may not be limited.

Table 2-4
Example Discharge Consent Conditions to Tidal Waters

Parameter	Unit	Value
Ammonia	mg/L	15
BOD	mg/L	30
COD	mg/L	No limit
Total Sulphates	mg/L	No limit
Free Chlorine	mg/L	0.01
Chloride	mg/L	No limit
Total Chromium	mg/L	0.0006
Total Silver	mg/L	0.0005
Total Nickel	mg/L	0.02
Total Copper	mg/L	0.005
Total Lead	mg/L	0.0072
Total Zinc	mg/L	0.04
Total Arsenic	mg/L	0.025
Total Iron	mg/L	1
Total Fluoride	mg/L	5
Total Boron	mg/L	7

2.3.4 'No Discharge' Technologies

These would not require a discharge consent to be issued and may not require any specific leachate quality conditions to be met. The main constraints on these technologies are the availability of sufficient land on which they can operate, noting that in most circumstances this can be the landfill cap. In addition, the long term fate of the 'contaminants' needs to be considered:

For irrigation to biomass crop type solutions, contaminant is ultimately taken up into the crop and/or deposited to the soils in which they grow. Whilst most contaminants in landfill leachate can to some extent or another be considered as nutrients for plant growth, elements such as Chloride will build up in soils over long periods of time and may give rise to issues such as contaminated run-off or the need to dispose of soils as contaminated waste

For evaporation pond type solutions, sludge is produced that contains all of the contamination from the leachate that has passed through the system. This can be returned to the landfill site, although like recirculation this means that no contaminant ever actually leaves the waste mass. Alternatively the sludge can be disposed of to another solid waste management facility, however such facilities need to be economically available and it may be that the sludge would be classed as a hazardous waste.

2.3.5 Leachate Disposal Process Selection Constraints

SLR assumes that WasteServ wish to explore options available to introduce leachate disposal techniques to the site that achieves the following goals:

- disposal of sufficient leachate to reduce non-compliant leachate levels where they exist and then prevent further build-up of leachate in the sites;
- employ processes capable of reliably achieving the assumed required standards of treatment and complying with all relevant regulation and guidance;
- employ processes with a strong record of successful treatment of similar waste streams and that can be considered as BAT;
- wherever possible to employ low capital expenditure (CapEx) technologies but also taking into account operational expenditure (OpEx) over the potential aftercare period of the landfill site with the aim of providing minimum overall total expenditure (TotEx). Therefore technologies are preferred that minimise the need for operator intervention, resource use and production of wastes and by-products so as to reduce the following:

    - operational costs;
    - traffic movements; and
    - health and safety risks:

- to select processes that can be constructed and operated in the environmental setting of the Ghallis landfill site where availability of stable ground, provision of power and accessibility to other amenities may be restricted; and
- employ an on-site treatment technology that is broadly in keeping with the local landscape and land use;

So that suitable and appropriate leachate disposal technologies can be assessed for the site it is important to estimate the volumes of leachate that may need to be managed over the operational and post closure periods. In addition, leachate quality and likely required effluent quality also needs to be understood.

3.0 REVIEW OF LEACHATE LEVELS

Leachate level data is recorded at the existing Ghallis landfill site from the locations listed in Table 2-2 and presented on Drawing No. 2. Leachate levels are recorded on a quarterly basis and review of the data from 2012 to 2014 indicates that for the entire period LCP1, 2 and 3 were dry. These are the deepest leachate wells in the deepest part of the landfill. Leachate wells LCP4 to LCP9 all had leachate present in them for periods during each year over the period 2012 to 2014.

Leachate levels recorded from the site has been average and compared to the compliance level. Table 3-1 below summarises the average leachate levels recorded from each site area over the last year:

Table 3-1
Ghallis Landfill 2014 Leachate Level Summary

Leachate Well ID	Depth to Base (m)	Average Dip to Leachate 2014 (m)	Average Leachate Head above Base (m)	Average Head above Control Level (m)
LCP01	42.52	42.52	0.00	0.00
LCP02	40.45	40.45	0.00	0.00
LCP03	41.58	41.58	0.00	0.00
LCP04	24.80	15.7	9.10	8.30
LCP05	9.52	5.80	3.72	2.92
LCP06	28.37	21.50	6.87	6.07
LCP07	38.53	15.40	23.13	22.33
LCP08	28.79	17.00	11.79	10.99
Average Non Complaint Leachate Head				6.33

This work indicates that leachate levels are only in excess of compliance levels in the shallower and most recently tipped areas of the Ghallis landfill. However, it is likely that over time leachate levels will begin to accumulate throughout the site as on-going leachate generation continues to contribute more liquid to the waste mass.

4.0 REVIEW OF LEACHATE QUALITY

Leachate quality results have been made available for the period of 2011 to 2014 for a number of sample points at the existing Ghallis landfill. Leachate quality analysis is undertaken on a quarterly basis from individual wells (if leachate is present) and is summarised as an annual average figure per well. This data is presented in Appendix A.

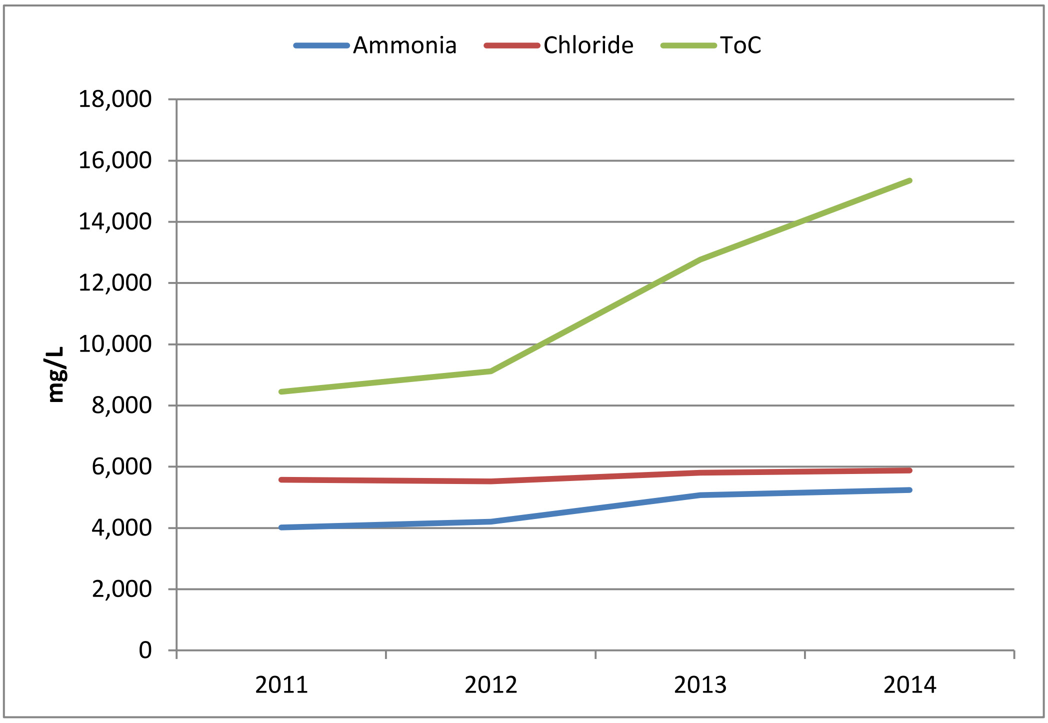
A summary of the leachate quality reported over the period is presented below as Table 4-1.

Table 4-1
Summary of Leachate Quality

Determinand	**Unit**	**Average of All Wells Data**				**Maximum**
		2011	2012	2013	2014	
Conductivity	µS/cm	36,428	40,648	44,021	34,472	52,575
Potassium	mg/L	1,762	2,599	2,920	6,988	27,845
Total Organic Carbon	mg/L	8,450	9,114	12,930	16,180	22,550
Chloride	mg/L	5,571	5,521	5,679	6,065	7,017
Ammoniacal Nitrogen	mg/L	4,022	4,204	5,380	5,296	6,913
Sodium	mg/L	2,409	3,936	3,907	3,767	5,388
Magnesium	mg/L	67.6	109.2	724.8	253.1	3,168
Sulphate	mg/L	12.1	12.8	145.3	762.0	2,395
Calcium	mg/L	16.5	25.1	82.5	436.3	2,224
Phenol index	mg/L	2.5	109.9	122.8	167.5	351
Iron	mg/L	7.15	19.64	24.48	69.31	225
pH	pH unit	8.4	8.6	8.4	8.1	8.7
Zinc	mg/L	0.68	0.75	1.21	1.90	8.18
Fluoride	mg/L	1.58	2.78	1.28	<0.10	4.60
Chromium	mg/L	0.99	0.97	1.11	1.67	3.26
Copper	mg/L	0.17	0.19	0.32	0.57	2.41
Lead	mg/L	0.11	0.08	0.39	0.26	1.76
Nickel	mg/L	0.53	0.44	0.73	0.75	1.33
Arsenic	mg/L	0.87	0.58	0.70	0.58	1.03
Barium	mg/L	0.05	0.12	0.13	0.18	0.54
Molybdenum	mg/L	0.05	0.02	0.17	0.03	0.28
Selenium	mg/L	0.01	<0.0005	0.13	0.10	0.15
Toluene	mg/L	0.03	0.02	0.03	0.02	0.08
Antimony	mg/L	0.03	0.05	0.06	0.04	0.07
Cadmium	mg/L	0.01	0.01	0.02	0.02	0.02
Naphthalene	mg/L	0.00	0.00	0.00	0.00	0.01
Mercury	mg/L	0.001	0.002	0.001	0.001	0.003

In addition to the data presented above, a brief review of how leachate quality is changing over time has been undertaken on the main pollutants of concern in landfill leachate (Ammonia, Chloride and Total Organic Carbon) for the existing Ghallis landfill site. This has been done by averaging all of the reported value for each determinand recorded at the site on any given sample date and plotting the resulting 'site average' figure. This data is presented below as Figure 1.

Figure 1
Existing Ghallis Landfill Leachate Quality Variation



This work indicates that the average figures calculated for Ammonia and Chloride leachate quality appear to be reasonably consistent over time and so represent a reasonable basis around which to assess leachate disposal infrastructure requirements. ToC concentrations appear to be rising, this likely to be due to high BOD and COD leachates having a greater influence on overall site leachate chemistry as a result of acetogenic decay of more recently deposited wastes. Detailed design of any treatment plant employing biological aeration as a process would need to take into account the potential for an increasing load of ToC over time.

It is assumed that leachate generated by the waste deposit in the proposed Ghallis landfill extension will have a similar quality to that reported above for the existing Ghallis landfill.

4.1 Comparison of Leachate Quality to Likely Discharge Quality Limits

Comparison of the leachate quality reported from the existing Ghallis landfill (see Table 4-1) and the example effluent quality limits that might be applied to discharges to sewer (see Table 2-1) or to saline waters (see Table 2-4) has been carried out along with initial estimates of the degree of removal required from the 2014 average leachate quality reported from the Ghallis landfill to achieve each quality standard. This information is presented below as Table 4-2 and indicates the following:

- for a discharge to sewer:
  - significant reductions in Chloride concentration will need to be achieved;
  - significant reductions in Ammoniacal Nitrogen concentrations will need to be achieved, any conversion of Ammoniacal Nitrogen to Nitrates will need to be followed by significant de-Nitrification as the limit is expressed as TKN;
  - the majority of metals present in the leachate would not need to be reduced in concentration; however Arsenic concentrations would need to be substantially reduced.

- for a discharge to saline water;
    - significant reductions in Chloride concentration would not need to be achieved;
    - significant reductions in Ammoniacal Nitrogen concentrations will need to be achieved with no need for de-Nitrification;
    - The majority of metals present in the leachate would need to be reduced in concentration.

Table 4-2
Summary of Likely Required Reduction Rates for Main Contaminants

Determinand	2014 Average Leachate Concentration	Unit	Sewer		Saline Water	
			Likely Limit	% Reduction Required	Likely Limit	% Reduction Required
Conductivity	34,472	µS/cm	nd	-	nd	
Potassium	6,988	mg/L	nd	-	nd	
Total Organic Carbon	16,180	mg/L	nd	-	30	99.8%
Chloride	6,065	mg/L	1,000	83.5%	No limit	-
Ammoniacal Nitrogen	5,296	mg/L	100*	98.1%	15	99.7%
Sodium	3,767	mg/L	nd	-	No limit	-
Magnesium	253.1	mg/L	nd	-	nd	-
Sulphate	762.0	mg/L	1,000	0%	nd	-
Calcium	436.3	mg/L	nd	-	nd	-
Phenol index	167.5	mg/L	nd	-	nd	-
Iron	69.31	mg/L	nd	-	1	98.6%
pH	8.1	pH unit	6.0 - 10.00	0%	6.0 - 10.00	0%
Zinc	1.90	mg/L	10.00	0%	0.04	97.9%
Fluoride	<0.10	mg/L	10	0%	5	0%
Chromium	1.67	mg/L	5.00	0%	0.0006	99.96%
Copper	0.57	mg/L	5.00	0%	0.005	99.1%
Lead	0.26	mg/L	1.00	0%	0.007	97.2%
Nickel	0.75	mg/L	5.00	0%	0.02	97.3%
Arsenic	0.58	mg/L	0.05	91.3%	0.03	95.7%
Barium	0.18	mg/L	nd	-	nd	-
Molybdenum	0.03	mg/L	nd	-	nd	-
Selenium	0.10	mg/L	nd	-	nd	-
Toluene	0.02	mg/L	nd	-	nd	-
Antimony	0.04	mg/L	nd	-	nd	-
Cadmium	0.02	mg/L	nd	-	nd	-
Naphthalene	0.0003	mg/L	nd	-	nd	-
Mercury	0.001	mg/L	nd	-	nd	-

Note: * Limit expressed as TKN
nd Not determined / no limit quotes

It is noted that leachate quality monitoring from the Ghallis landfill does not include priority hazardous substances (PHS), priority substances (PS) and 'other pollutants' covered by the Environmental Quality Standards Directive (EQSD) (2008/105/EC). Suitable analysis of these substances would need to be undertaken and reviewed for the presence of substances not currently analysed for in the raw leachates from the existing Ghallis landfill (and potentially the proposed future Ghallis landfill phases) to ensure that any decisions about detailed treatment plant design can take into account the potential presence of such substances.

5.0 ESTIMATE OF LEACHATE VOLUMES

So that an appropriate leachate disposal strategy can be developed for the site it is also necessary to estimate the volumes of leachate requiring disposal to maintain compliance with the leachate compliance limits at the existing and proposed Ghallis landfill sites.

The required leachate disposal volume is made up from two elements, the volume of leachate currently present within the site held above the compliance limits plus any leachate that is generated on an annual basis due to infiltration into the waste from rainfall.

Volumes of leachate that will require disposal have been estimated based on information relating to the surface area of each landfill along with recently reported leachate levels and assumptions on infiltration of water through landfill caps.

As the existing and proposed Ghallis landfill cells are either currently un-capped or as yet undeveloped, an assumed site development scheme needs to be developed to describe how uncapped and capped areas of the site will change over time.

Landfill site areas have been based on those reported in Drawing No. 3 and Drawing No. 4.

5.1 Excess Leachate Volume

To estimate the volume of leachate held within the landfill site the average non-compliant leachate level, as presented in Table 3-1 is applied to an assumed current site basal area that is itself based on the assumption that the sites base represents only 70% of the existing site surface area. This information has been used to calculate a volume of leachate saturated waste held above compliant levels.

To calculate the volume of freely draining leachate that is contained within the saturated waste held above compliance, the percentage porosity of the waste contained within this volume is needed. Assessments of waste porosity are notoriously difficult to make due to the heterogeneous nature of waste and differing methods of waste emplacement resulting in various degrees of compaction at time of deposit. Furthermore conditions within a site will vary at different depths and locations over time. In essence however most commentators[1] on the subject agree that porosities of somewhere between 2% and 12% exist within most domestic waste landfills below a depth from surface of around 5m. Porosities will in general decrease with depth and age of waste and with a greater proportion of waste soils and/or cover deposited in the site. The waste porosity is estimated from the depth of the leachate surface below surface and the relevant porosity applied to the saturated waste volume.

Excess leachate volume has been calculated as follows:

Site Basal Area, assuming current site surface area of 95,600m^2 (see Table 2-3):	66,920m^2
Average non-compliant leachate head (see Table 3-1):	6.33m
Average waste porosity at depth of 2014 average leachate levels:	2.83%
Excess leachate volume at 66,920 x 6.33 x 2.83%:	11,960m^3

[1] Powrie, W and Beaven, R P. 'Hydraulic Properties of Household Waste and Implications for Landfills'. Proceedings of the Institute of Civil Engineers; Geotechnical Engineering, October 1999, pp235-247.

The resultant excess leachate volume is then assumed to be removed and disposed of over a reasonable period of time when calculating required leachate disposal rates for the site.

5.2 New Leachate Generation

To calculate the new leachate generation volume it is normal to use estimates of the infiltration rates through the surface of the landfill due to rainfall. The amount of rainfall that becomes leachate by infiltration is influenced by climate (how much rainfall is lost to evaporation and transpiration) and site engineering (how much of the landfill surface is capped or uncapped at any given point in time). Estimates of future site development and capping need to be made along with infiltration rates for capped and uncapped waste.

5.2.1 Site Development Assumptions

Site development can be assessed by making assumptions over the rate of landfill capping that is likely in each year and the rate at which newly created landfill void is consumed by waste inputs to the landfill site.

Development of the Ghallis landfill in 6 sub phases has been assessed along with different scenarios for waste filling rates as per the SLR report ‘Ghallis Non Hazardous Landfill; Landfill Phasing and Construction Programming. Version No: 3, SLR Ref: 403.00585.00026, September 2015. The fastest (Scenario 1) and slowest (Scenario 4) waste filling scenarios have been considered along with reasonable assumptions on the progress of capping the existing Ghallis landfill and the capping of the new Ghallis sub-phases shortly after waste filling is projected to have been completed. Scenario 1 site development is summarised below as Table 5-1.

Table 5-1
Site Development Plan Summary, Scenario 1

Year	Uncapped Area m^2	Capped Area m^2	Total Site Area m^2
2015	95,600	0	95,600
2016	71,450	27,250	98,700
2017	38,500	65,000	103,500
2018	36,500	70,000	106,500
2019	36,000	74,700	110,700
2020	31,900	84,900	116,800
2021	27,800	94,400	122,200
2022	0	122,200	122,200

Scenario 4 site development is summarised below as Table 5-2.

Table 5-2
Site Development Plan Summary, Scenario 4

Year	Uncapped Area m^2	Capped Area m^2	Total Site Area m^2
2015	95,600	0	95,600
2016	71,450	27,250	98,700
2017	38,500	65,000	103,500
2018	36,500	70,000	106,500

Year	Uncapped Area m^2	Capped Area m^2	Total Site Area m^2
2019	36,000	74,700	110,700
2020	36,000	74,700	110,700
2021	31,900	84,900	116,800
2022	31,900	84,900	116,800
2023	27,800	94,400	122,200
2024	27,800	94,400	122,200
2025	0	122,200	122,200

In reality, it is likely that the Ghallis landfill site will be filled and capped at rates that differ from those presented above in Table 5-1 and Table 5-2. However, the assumptions presented are sufficiently robust and reasonable to be used in modelling leachate generation at the site. It is also noted that the difference between the two models is only relatively minor, the period of active filing being extended by only 3 years from 2021 in Scenario 1 to 2024 in Scenario 4.

5.2.2 Infiltration Rate Assumptions

Whilst conservative figures may be used when undertaking hydrogeological risk assessments and water balance calculations for the purposes of regulators, when sizing infrastructure it is more usual to employ figures based on observations of how similar landfills are observed to behave, so that more realistic new leachate generation figures can be obtained. In this way oversizing of infrastructure is avoided and capital and on-going running costs can be kept to a minimum. From observations at over 100 UK landfill sites infiltration rates to uncapped waste can be estimated as being equivalent to ‘effective’ rainfall (i.e. rainfall after taking account of losses to evaporation and transpiration) and for capped waste infiltration rates of around 9.5% of effective rainfall has been found to be a reasonable assumption.

So that a comparison between UK sites and conditions on Malta can be undertaken, rainfall and average maximum temperatures have been obtained for Malta and for locations in the UK that have a similar total rainfall amount. The closest match was found to be Lincoln in the east of the UK where average annual rainfall is 623mm/yr compared to 618mm/yr for Malta (Valletta). However, average temperatures on Malta are typically around 10^{o}C warmer than for Lincoln.

For Lincoln, effective rainfall has been estimated at 205mm/yr[2], so 33% of total rainfall. Of the 418mm/yr of rainfall that is lost to evapotranspiration it is assumed that 50% is due to evaporation and 50% to transpiration.

So that a similar estimate of effective rainfall can be made for Malta, and taking into account the higher average temperatures that are likely to increase the rate of evaporation, it has been assumed that percentage losses to evaporation are double those experienced in the UK. Therefore it has been assumed that the effective rainfall in Malta is only 24% of total rainfall.

Rainfall, temperature and resultant proposed infiltration rates are presented below in Table 5-3.

[2] UK Geological Society ‘Effective Rainfall Map of England and Wales’.

Table 5-3
Assumed Rainfall and Infiltration Rates

Period	Lincoln UK[1]		Valletta, Malta[2]	
	Average Maximum Temperature °C	Average Rainfall mm	Average Maximum Temperature °C	Average Rainfall mm
January	7	52.8	16	93.0
February	8	36.2	16	62.5
March	10	37.6	18	43.1
April	13	48.5	20	24.0
May	16	44.2	24	20.7
June	19	56.6	29	6.6
July	22	62.5	31	0.4
August	22	51.4	32	18.9
September	18	57.7	28	63.5
October	14	72.3	25	76.8
November	10	53.6	21	94.8
December	7	49.2	17	114.1
Annual	14	622.6	23	618.4
Uncapped Infiltration (Effective Rainfall)		205.5		153.1
Post Capping Infiltration		19.5		14.5

Notes: 1 UK MetOffice Data
2 From www.worldweatheronline.com. The data above are taken from year 2000 to 2012

Using these figures and the site areas as reported in Drawings No. 3 and No. 4 as summarised in Table 5-1 and Table 5-2, it is possible to calculate a range of new leachate generation rates for the existing and proposed Phases of the Ghallis landfill. Calculations of new leachate generation rates are presented in Appendix B and are also summarised below in Table 5-4.

Table 5-4
Estimate of Leachate Generation Rates by Filling Scenario

Year	Scenario 1 New Leachate Generation Rates			Scenario 4 New Leachate Generation Rates		
	Uncapped Waste m^3	Capped Waste m^3	Total Site m^3	Uncapped Waste m^3	Capped Waste m^3	Total Site m^3
2015	14,630	0	14,632	14,632	0	14,632
2016	10,936	396	11,332	10,936	396	11,332
2017	5,893	945	6,838	5,893	945	6,838
2018	5,586	1,018	6,604	5,586	1,018	6,604
2019	5,510	1,086	6,596	5,510	1,086	6,596
2020	4,882	1,234	6,117	5,510	1,086	6,596
2021	4,255	1,373	5,627	4,882	1,234	6,117
2022	0	1,777	1,777	4,882	1,234	6,117
2023	0	1,777	1,777	4,255	1,373	5,627
2024	0	1,777	1,777	4,255	1,373	5,627

Year	Scenario 1 New Leachate Generation Rates			Scenario 4 New Leachate Generation Rates		
2025	0	1,777	1,777	0	1,777	1,777
Total to 30yrs post closure			111,050			127,614

This work confirms that the filling scenario that completes the landfill earliest (Scenario 1) results in the least overall leachate generation for the site. However, the difference between the fastest (Scenario 1) and slowest (Scenario 4) filling rates only results in a difference of 16,564m^3 of leachate generation. It is therefore likely that any suitable leachate disposal system will be able to be sufficiently sized to accommodate leachate generation rates from either scenario without the need for excessive over-sizing.

5.3 Estimate of Required Disposal Volumes

The required rate of leachate disposal is calculated by adding the new leachate generation to the volumes of excess leachate presumed to be disposed of each year to eventually bring the landfill site into compliance with its Permit condition.

Two options have been considered for each of the filling scenarios (Scenario 1 and 4).

The first option is that all newly generated leachate is disposed of each year and that 1/5th of the excess volume is removed for the first 5 years, bringing the landfill site into compliance with its permit at the end of the 5th year of the plan. For both filling scenarios a maximum daily leachate disposal need of 40m^3/day is calculated for the first year and, once capping is completed, leachate disposal needs fall to 5m^3/day.

The second option is that only 25m^3/day of leachate is disposed of and that the remaining volumes of newly generated and excess leachates are recirculated within the landfill site. In this option additional non-compliant leachate volumes are allowed to accumulate in the waste mass and are only removed and treated as new generation rates fall to below 25m^3/day. Once new generation rates fall to below 25m^3/day excess leachate is progressively removed until ‘compliance’ is ultimately achieved. This option results, for both filling scenarios, in a maximum daily leachate disposal need of 25m^3/day that is sustained for a long period of time and that, after capping is completed and accumulated excess leachate removed, leachate disposal needs fall again to 5m^3/day.

Details of these models are presented in Appendix B and summary outputs are presented below as Table 5-5.

Table 5-5
Estimate of Leachate Disposal Rates by Filling Scenario

Scenario	Description	Unit	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	Yr 2027 onwards
Filling Scenario 1, Disposal Option 1	Excess Volume to Disposal	m^3	0	2,392	2,392	2,392	2,392	2,392	0	0	0	0	0	0	0
	Total for Disposal	m^3	14,632	13,724	9,230	8,996	8,988	8,509	5,627	1,777	1,777	1,777	1,777	1,777	1,777
	Daily Equivalent	m^3/day	40	38	25	25	25	23	15	5	5	5	5	5	5
	Annual Volume to Re-circ	m^3	0	0	0	0	0	0	0	0	0	0	0	0	0
	Re-circ Daily Equivalent	m^3/day	0	0	0	0	0	0	0	0	0	0	0	0	0
Filling Scenario 4, Disposal Option 1	Excess Volume to Disposal	m^3	0	2,392	2,392	2,392	2,392	2,392	0	0	0	0	0	0	0
	Total for Disposal	m^3	14,632	13,724	9,230	8,996	8,988	8,988	6,117	6,117	6,117	5,627	5,627	1,777	1,777
	Daily Equivalent	m^3/day	40	38	25	25	25	25	17	17	17	15	15	5	5
	Annual Volume to Re-circ	m^3	0	0	0	0	0	0	0	0	0	0	0	0	0
	Re-circ Daily Equivalent	m^3/day	0	0	0	0	0	0	0	0	0	0	0	0	0
Filling Scenario 1, Disposal Option 2	Excess Volume Held in Site	m^3	17,467	19,674	17,387	14,866	12,337	9,329	5,831	0	0	0	0	0	0
	Annual Treatment Volume (at 25m^3/day LTP)	m^3	9125	9125	9125	9125	9125	9125	9125	7,608	1,777	1,777	1,777	1,777	1,777
	Treatment Daily Equivalent	m^3/day	25	25	25	25	25	25	25	21	5	5	5	5	5
	Annual Volume to Re-circ	m^3	8,342	10,549	8,262	5,741	3,212	204	0	0	0	0	0	0	0
	Re-circ Daily Equivalent	m^3/day	23	29	23	16	9	1	0	0	0	0	0	0	0

Scenario	Description	Unit	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	Yr 2027 onwards
Filling Scenario 4, Disposal Option 2	Excess Volume Held in Site	m^3	17,467	19,674	17,387	14,866	12,337	9,808	6,800	3,792	294	0	0	0	0
	Annual Treatment Volume (at 25m^3/day LTP)	m^3/yr	9125	9125	9125	9125	9125	9125	9125	9125	9125	5,922	1,777	1,777	1,777
	Treatment Daily Equivalent	m^3/day	25	25	25	25	25	25	25	25	25	16	5	5	5
	Annual Volume to Re-circ	m^3/yr	8,342	10,549	8,262	5,741	3,212	683	0	0	0	0	0	0	0
	Re-circ Daily Equivalent	m^3/day	23	29	23	16	9	2	0	0	0	0	0	0	0

6.0 TREATMENT PROCESS SELECTION

6.1 Approach

The aim of this process is to review all potential treatment technologies, initially no process is exempt, but at the end of the review a short list of potential processes will be produced. Relevant factors considered include;

- applicability to the issues at Ghallis;
- robustness of treatment process (i.e. can it accommodate changes to flow and load);
- flexibility of the process (i.e. can it be amended to treat various contaminants);
- capital costs to construct;
- operational costs throughout the lifetime of the plant (30+ years);
- footprint occupied by a typical plant required to treat the load anticipated at the Ghallis landfill; and
- risks such as those to the environment as well as health and safety.

The technologies assessed are scored on the individual factors listed above being assigned a score of five for best (i.e. lowest capital cost) and zero for worst (i.e. highest capital cost). Scores for applicability in the specific instance at Ghallis, taking into account the information presented in the earlier Sections of this report, are made between zero (least applicable) and twenty (most applicable). In this way the specific requirement of Ghallis landfill site outweigh all other considerations.

Each of the process scores are then totalled and ranked, to give WasteServ clear, concise information with which they can make a decision regarding which treatment technology to employ on this particular site.

6.2 Results

The full review of all potential treatment technologies is contained within Appendix C. Following the review, scoring and ranking, the technologies which make up the top 10 most appropriate processes are shown in Table 6-1. The top 4 processes were separated by 2 points on the scoring system, followed by processes ranked 5 to 10 being separated by only 4 points. These technologies are discussed in greater depth in Section 7.0, but it should be noted that this selection process has highlighted two main primary treatment processes in Contaminant Separation / Volume reduction (Reverse Osmosis, Vacuum Evaporators and Evaporation Ponds) and Suspended Growth Systems (Sequence Batch Reactor, Membrane Bio Reactor, Facultative Lagoons, Activated Sludge and Aerated Lagoons) and a third group of processes, Wetlands (Horizontal and Vertical flow types), that are more likely to be applicable as final ‘polishing’ processes should Suspended Growth Systems require additional polishing stages.

It is likely that the availability and cost effectiveness of the final point of discharge will ultimately be fundamental in the decision as to which of these processes is best suited for the site. Should a discharge to sewer be the most favourable option then one of the Contamination Separation / Volume Reduction processes will be most appropriate, if discharge to sea is decided upon, one of the Suspended Growth Systems with further effluent polishing in Wetlands (otherwise known as reed beds) may be more appropriate and if no discharge from the site at all is possible, one of the ‘no-discharge’ processes may be most appropriate (Long Retention or Facultative Lagoons followed by irrigation to biomass plots or Evaporation Ponds).

Table 6-1
Summary of Applicable Technologies Review

Treatment Process	Specific Applicability	General Applicability	Robustness	Flexibility	Capital costs (Capex)	Operational costs (Opex)	Manpower requirements to run	Repair and Maintenance	Power requirement	Use of other consumables	Emissions (wastes / by-products etc.)	Environmental risks	Health & Safety Risks	Process Stability	Footprint	Ease of modular construction	Factors affecting performance	Overall Score	Rank
Sequence Batch Reactor	18	4	4	4	2	2	3	3	3	3	4	4	3	4	3	3	4	71	1
Horizontal Flow Reed beds	15	2	3	4	3	4	4	4	4	4	4	4	5	3	1	3	3	70	2
Vertical Flow Reed bed	15	2	3	4	3	4	4	4	4	4	4	4	5	3	1	3	3	70	3
Membrane Bio Reactor	18	4	3	4	2	2	2	2	2	3	4	4	4	4	4	3	4	69	4
Reverse Osmosis	18	5	4	4	2	1	3	2	1	2	1	3	4	4	4	5	3	66	5
Facultative Lagoon	16	2	3	3	2	4	4	4	4	4	5	3	3	4	0	0	4	65	6
Activated Sludge - including denitrification	15	4	4	4	2	2	3	3	3	3	3	3	3	4	3	3	3	65	7
Evaporation Ponds	10	3	2	2	4	4	5	5	5	5	2	2	4	3	2	4	2	64	8
Aerated Lagoons	16	4	3	4	3	3	3	3	3	3	3	3	3	2	2	2	3	63	9
Vacuum Evaporators	16	3	4	4	1	1	3	2	2	3	2	3	2	4	4	4	4	62	10

6.3 Selection Matrix Output

The leachate from the Ghallis landfill site is likely to be treatable using conventional leachate treatment processes[3] to a quality that is likely to achieve the possible discharge consent conditions detailed in Table 2-1 and Table 2-4. Different processes are likely to be most appropriate if discharge is to sewer than if discharge is to sea or indeed if no discharge from site at all is possible. In either case, it is not necessary to consider more ‘novel’ or untried treatment processes.

Treatment or removal of major ‘matrix’ contaminants such as ammonia, COD and BOD will be required to a very high standard and so a robust, well understood treatment system is required.

As noted in Section 2.3 the possible discharge location (to sewer, to water or no discharge) and the site specific circumstances at the Ghallis landfill site are also likely to influence the recommendation of a preferred treatment process as well as the overall costs of each potential viable solution.

In principal, discharges to sewer are preferable for a number of reasons;

- regulators tend to prefer the landfill operator to not be the principal discharger to the environment, pre-treatment with discharge to sewer means that landfill effluent has a second chance to be treated in the receiving sewage works;
- consents to discharge to sewer are generally more generous than discharges direct to water bodies (largely as a result of the addition treatment they will receive as discussed above), this usually being particularly true for metals;
- contaminants are removed from the landfill waste mass, thus ensuring that the total contaminant load contained within the landfill reduces over time and so in theory allows for progress towards the site ceasing to pose a risk to the environment to begin to occur; and
- sewer operators are generally more tolerant of occasional breaches of discharge consent conditions so any short term LTP performance issues are less likely to lead to enforcement action.

These factors usually compensate for negative or more risky aspects of this disposal route such as the ‘commercial’ nature of the arrangement (so consents to sewer can be more prone to being amended or withdrawn than discharge consents issued via environmental regulators ….although in either case this is not common).

However, at Ghallis it is likely that Chloride concentrations will need to be reduced to 1,000mg/L (a greater than 80% reduction from raw leachate quality, see Table 4-2) and as such the only technologies that can reliably achieve such a reduction are RO or Evaporators (usually Vacuum Evaporators are used). Other determinands will also need to be reduced in the raw leachate but as a consequence of reducing Chloride to 1,000mg/L is it likely that all other determinands that need reduction will also be accounted for. The limiting factor for deployment of these technologies is the route of disposal for the concentrates that are produced which either have the potential to result in longer term issues with landfill and leachate management if recirculated back into the waste or are very costly unless a suitable disposal site is nearby.

[3] It is recommended that treatability trials for the chosen treatment process are considered as part of any further work to progress with on-site treatment options

If disposal of treated effluent to sewer is not possible or the risks and/or costs associated with disposal and management of concentrate are unacceptable, disposal to controlled waters is the next most preferable solution.

In principal, discharges to controlled waters are less preferable than to sewers for a number of reasons;

- regulators tend to prefer the landfill operator to not be the principal discharger to the environment;
- consents to discharge to controlled waters are generally more onerous to achieve that discharges direct to water bodies, so a greater degree of treatment is required that generally costs more in terms of both capital and operational costs;
- environmental regulators are generally less tolerant of occasional breaches of discharge consent conditions so any short term LTP performance issues are more likely to lead to enforcement action; and
- in sensitive locations discharges to controlled waters may not be allowed, for example in areas of special scientific or cultural interest.

However, the acceptability of discharge to controlled waters can usually be assessed by a quantitative risk assessment methodology and, if a suitable local point of discharge is approved, contaminants are removed from the landfill waste mass, thus ensuring that the total contaminant load contained within the landfill reduces over time and so in theory allows for progress towards the site ceasing to pose a risk to the environment to begin to occur.

At Ghallis the most likely receiving water body is the sea as the site is very close to the coast. This gives some advantages in that Chloride concentrations are unlikely to be an issue and that compared to discharging to rivers (fresh water) dilution factors will be greater so potentially enabling relatively generous discharge limits for other parameters of concern.

However, discharge to controlled waters will inevitably mean that very clean discharge quality will need to be achieved and, for a discharge to sea, engineering complications arise over the installation of suitable discharge pipelines and headwall arrangements[4]. In addition, due to Malta's position as a prominent tourist destination, issues may arise with discharging effluent near to bathing beaches etc. which to comply with the Bathing Beach Directive may include a requirement for Ultra Violet disinfection of the treated leachate prior to discharge.

Should discharge of effluent off-site not be possible or desirable, solutions do exist that may not require formal discharge of liquid effluent from the site. Recirculation has already been discussed in Section 2.3 and its use as the sole method of leachate disposal and management at the site questioned in terms of sustainability as leachate heads are already being generated in excess of permitted levels and leachate generation set to continue, albeit at reduced rates, even after capping has been installed. However, recirculation might be a useful technique to employ alongside other forms of leachate management to enable optimal use to be made of treatment plant capacities. Because the volumes of leachate anticipated as being produced at the site are relatively small, coupled with the fact that as new waste is deposited new adsorptive capacity will exist at the site, a further scenario has been considered in each instance where an LTP is developed that treats only $25m^3$/day of leachate with any additional leachate pumped from the waste re-circulated back to the waste mass. This situation would continue for a number of years, with the volumes of excess

[4] Most assessment methodologies for the acceptability of discharges to sea allow for more generous discharge conditions the further off-shore and deeper below water the point of discharge is located. So there is usually a trade-off between the costs of providing treatment and the cost of extending sea outfalls to deeper waters further off-shore

leachate slowly increasing, until the whole site (both the existing and new Ghallis Phases) is capped. At this point new leachate generation rates would be likely to fall to well below 25m^3/day, at which point the smaller throughput LTP would continue to work at full capacity for a number of years until such time as all excess leachate had finally been removed from the landfill site. This option represents a higher risk of enforcement action from regulators and potentially higher risks to the environment (from the effects of elevated leachate levels). However, it may result in a more economically acceptable plant for WasteServ as initial capital costs will be lower (although they are not directly scalable to plant throughput) and the plant itself will be utilised at its full capacity for longer.

Other 'no discharge' options would include pre-treatment followed by irrigation to biomass plots. Such systems can be relatively cheap to construct and operate but have the negative effect of depositing contaminant such as Chloride and Sodium onto the irrigation plots. Elsewhere in Europe where this has been used as a leachate management technique there have been issues with both how this is permitted (in some jurisdictions it is considered to be deposit of waste to land) and the residual issues associated with build-up of contaminants in the biomass and soils in which they grow. Run-off waters may also become contaminated with some of the contaminants as they accumulate in soil profiles. However, these problems can be overcome as long as the longer terms risks of accumulation of salts in the soils are accepted.

Alternatively, passive evaporation systems may be used to evaporate the liquid element of landfill leachate to atmosphere whilst retaining a sludge that contains all of the contaminant from the leachate. This technique typically employs evaporation ponds or basins and uses sunlight to evaporate off liquids. Concentrated sludges are periodically removed from the bottom of the ponds or basins for disposal. Disposal of these sludges represents similar problems to those of concentrates from RO or Vacuum Evaporators. However, a brief review of reported evaporation pond performance where employed in the treatment of landfill leachate suggests that up to 0.54m^3 of leachate can be successfully evaporated per year from each m^2 of evaporation pond, this taking place in a location where average annual rainfall is 235mm/yr, significantly lower than the annual rainfall on Malta of 618.4mm/yr as reported in Table 5-3. This would suggest that the amount of incident rainfall on Malta is close to the evaporation rate from a suitably designed evaporation pond and so it would be unlikely that sufficient evaporation could take place to account for both incident rainfall and inputs of leachate. As such this potential treatment solution has not been considered any further.

6.3.1 For Discharge to Sewer

Immediate candidate processes combinations seem to be as follows:

Reverse Osmosis: Would provide a high quality effluent with little operator input, estimated at 0.5 days per week (after commissioning) to perform basic R&M, monitoring and calibration etc. (see Section 8.2).

Vacuum Evaporation: Would provide a high quality effluent with little operator input, estimated at 0.5 days per week (after commissioning) to perform basic R&M, monitoring and calibration etc. This process plant has very similar characteristics to RO in that it is a mechanical treatment system that produces a high quality effluent and a concentrate for disposal employing a containerised plant design. As such it is essentially interchangeable with RO except for the fact that it is a slightly more novel approach than RO for treatment of landfill leachates, as a result of which it's score in the selection matrix is marginally lower. It is therefore not considered further in detail in this report as considerations for RO are almost interchangeable.

For RO to be a viable option a disposal outlet for concentrate would need to be available. Typically recirculation of concentrate back to the landfill site is the default disposal outlet although the long terms effects and risks of this activity are not fully understood; therefore risks are involved with this as a solution.

Alternatively as Energy from Waste plant (Incinerators) have become more prevalent, disposal of RO concentrate to EfW has become more common. In principal as long at the EfW plant is design to accommodate the additional liquid inputs alongside the solid waste feed then this method of disposal is viable and resolves the potential ‘risks’ associated with longer term recirculation of concentrate back to landfill. However, a nearby EfW plant is required that is willing and able to accept small volumes of concentrate on a daily basis.

6.3.2 For Discharge to Surface Water

Immediate candidate processes combinations seem to be as follows:

<u>SBR + ‘polishing’:</u> Can provide the level of treatment necessary if well designed and operated. As part of the plant design it is likely that effluent ‘polishing’ to achieve the reduction in metals required will be needed.

<u>Aerated Lagoons + ‘polishing’:</u> Essentially identical to SBR + polishing with the exception that lagoons are employed rather than tanks. This means that plant footprint must be larger but capital and operational costs can be lower.

<u>MBR + ‘polishing’:</u> Similar to SBR but with the addition of a membrane process to undertake some polishing and to go further to ensuring a more compliant effluent regardless of fluctuations in influent feed volumes and quality and resultant changes to effluent flow. It is also likely that any subsequent polishing process could be smaller (less capital cost) as the membrane process will retain a proportion of contaminants that are not dissolved in the leachate.

<u>‘Polishing’ processes</u>; could be one or a mixture of;

- vertical Flow Wetlands (Reed beds) - aerobic; and / or
- horizontal Flow Wetlands (Reed beds) – anaerobic.

The standard activated sludge system is the treatment technology from which SBR and MBR systems were developed. However, the need for a larger number of process units, and a separate solids settlement tank leads to increased footprint and capital expenditure (Capex). As such this process is not considered further as specific processes (MBR, SBR) have been developed over the past twenty years in response to the issues found in using activated sludge plants in the context of leachate treatment.

Disinfection of the treatment effluent may be required should the Bathing Beach Directive apply at the location of the Ghallis landfill. It is likely that this would employ the use of UV disinfection with a larger UV unit required for SBR than for MBR as the membranes used in the MBR process may in itself be considered capable of providing sufficient disinfection to comply with the needs (if required) of the Bathing Beach Directive as membranes hold back significant percentages of bacteria, and the added clarity usually associated with MBR effluent improves the effectiveness of UV disinfection should this be required. However, it is not clear at this stage if bathing beaches are sufficient nearby for the Bathing Beach Directive to apply.

6.3.3 For 'No Discharge'

Immediate candidate process combinations seem to be as follows:

Facultative Lagoons + Irrigation to Biomass: Can provide the level of treatment necessary to enable treated effluent to be irrigated to biomass plots such that residual contaminants do not have a significant detrimental effect on soils or plants, allowing the plants (biomass) to take up micronutrients and transpire the water content of leachate. Run-off from biomass plots during heavy rainfall can be collected by the landfill sites surface water management systems and dealt with accordingly.

7.0 DESCRIPTIONS OF SELECTED PROCESSES

The following Section provides descriptions of the processes highlighted as being appropriate for the treatment of leachate at the Ghallis landfill site to the quality required by the assumed discharge consent requirement.

7.1 Reverse Osmosis

RO is a process that discharges a clean ‘permeate’ and retains a ‘concentrate’ containing >99% of the influent contaminants, including both organic and inorganic constituents of the leachate (notably including ions such as Sodium and Chloride). This is achieved by generating very high operating pressures (in excess of 60 bar) on the ‘dirty’ side of a semipermeable membrane, forcing the clean permeate (essentially water) through the membrane from where it is collected and discharged to the environment. Concentrate is then also collected and removed for disposal.

Whilst in Europe there are known to be over 100 such plants operating on landfill leachate, some of which have now been in operation for more than 15 years, in the UK there are thought to be currently only two such plants operating on landfill leachate.

The lack of uptake for such plants in the UK is largely as a result of the issues surrounding disposal of concentrate. Whilst the process itself is technically well suited to the requirements at Ghallis if disposal to sewer is possible, the fact that at present there is no known outlet on Malta that can accept concentrate from such a process it is only likely to be a viable treatment option if WasteServ are prepared to accept the risks and challenges surrounding recirculation of concentrate back to the waste mass, at least in the short to medium term. Should a local EfW process be developed adjacent to the landfill site that specifically considers the challenge of disposal of concentrate by incineration in the short to medium term then this option becomes much more attractive.

7.1.1 General Description

RO is a filtration method where contaminants are not destroyed or altered but simply concentrated into a smaller volume of liquid. The filtration is so fine that even soluble material is retained within the concentrate. RO provides filtration in the particle range of < 0.001 micrometres.

RO is used extensively in the production of ‘fresh’ water from saline sources but also now in wastewater treatment applications. In recent years, particularly in Europe, RO has been further developed as a landfill leachate treatment technology driven by improvements in membrane reliability and the use of 3 stage plants which commonly report removal efficiencies of greater than 99.98%. RO processes use artificial, semi-permeable membranes of thin film composite construction. Membrane manufacturers (in particular spiral wound types) have developed membranes for use in leachate treatment that have high salt rejection and are now able to display very high physical and chemical durability

Removal efficiencies begin to deteriorate as the influent ‘strength’ of leachate begins to increase. However, this affect can be adjusted for by altering the relative yield of concentrate and permeate from the process. Typically the yield of concentrate and permeate from an RO plant is around 20% - 30% concentrate (and so 70% - 80% permeate) per cubic metre of influent leachate. Should leachate ‘strength’ increase this yield can be adjusted so that a greater proportion of concentrate is produced whilst still maintaining >99% contaminant removal.

The main advantage of RO in leachate treatment is its ability to produce a very high quality effluent. RO is the only process that is capable of removing all contaminants of concern at Ghallis with a single treatment step whilst having the ability to also treat contaminants that are of concern when discharging to sewer (Chloride and TKN).

As a non-biological process, RO has advantages in that it is relatively insensitive to changes in leachate strength. As leachate fed to an RO plant becomes more contaminated this can be sensed in a well-designed plant, usually via the use of Electrical Conductivity probes, which will automatically adjust the concentrate: permeate yield, continuing to produce a high quality effluent. Should influent leachate strengths then fall again, this can also be sensed as a reduction in Electrical Conductivity and the yield or permeate automatically increased. RO plants can also happily operate intermittently being largely unaffected by 'stop / start' operations.

RO plants usually comprise a raw leachate store, RO process plant, chemical dosing systems, permeate storage tank and discharge system and a concentrate tank and discharge system. The RO plant itself is typically housed within a standard ISO shipping container that will house all of the main pumps and filtration systems as well as pre-filters and small storage vessels for acid dosing as well as for chemical cleaning processes. Filtration systems typically comprise a series of membrane housed in interconnected pressure tubes mounted on racks against the container walls. The container will also house feed and recirculation pumps which circulate leachate in each membrane stage in order to provide ideal conditions on the membrane surface. The feed to a membrane must be of a high velocity in order to prevent fouling that would decrease their efficiency.

Within the shipping container is usually found a separate room where the PLC and SCADA systems are located. External to the ISO container are the main plant storage tanks (influent leachate, permeate and concentrate) as well as acid and alkali stores. Acid stores are usually also supplied with vent gas scrubbing equipment.

As such RO plants are generally containerised modular plants that are fully automated and capable of been monitored and controlled remotely. Modules are available with leachate throughput capacities from 25m³/day up to 200m³/day housed in single 40" ISO containers. RO plants are typically available to purchase or to hire with most reputable suppliers tending to be of German origin.

7.1.2 Process Description

Raw leachate would be pumped from the landfill site to the LTP location. Due to the robustness of the process, raw leachate storage tanks can afford to be somewhat smaller than is typically employed in other treatment processes as issues such as the need to 'buffer' influent strengths are not so great and also 'start/stop' operation is not a problem.

Leachate is drawn into the RO plant via a series of pre-filters to remove course solids. These filters are typically sand filters or strainers or, in more modern plants, can be cartridge type filters (such as 'candle' filters). The pH of the leachate is then typically 'corrected' as the RO process works best in slightly acidic conditions.

Most RO plants, designed for the treatment of leachate, are now of three stage (multi-permeate) configuration. The first stage 'works hardest' delivering the majority of the contaminant separation while subsequent stages 'polish' the permeate produced in the first stage further.

Concentrate produced can either all be stored for disposal or, in some configurations, concentrate from Stages 2 and 3 can be returned to the raw leachate tank for further passes through the plant (thus reducing concentrate volumes). Permeate is pumped to external stores where it often requires addition of alkali (typically caustic soda) to raise the pH back to levels acceptable by the discharge consent. Depending on the influent characteristic of the raw leachate, permeates can sometimes suffer from emission of off-gases, particularly methane and hydrogen sulphide (H_2S). Where this is a problem treatment by addition of hydrogen peroxide can resolve the issue or scrubbing of any off-gases through carbon or biological air filters could be employed. Permeate is normally suitably clean to be allowed direct discharge without any further treatment.

RO plant operation can typically continue uninterrupted and with little requirement for manual intervention for several days at a time. However, as with most systems that employ membrane technologies, efficiencies (usually described by flux rates across the membrane) gradually reduce over time. To resolve this most modern RO plants incorporate automated backwash cycles and periodic chemical cleans. Chemical cleaning usually takes the form of a weekly ‘CIP’ clean that requires specific chemicals to be used, usually an acid and alkali rinse followed by a soak in a specific proprietary membrane cleaning detergent and/or anti-scalant. Such washes can usually be set up and run automatically and/or remotely but do need preparation of cleaning chemical stores. The cleaning process can be limited to around ½ a day per week. Concentrate is stored for disposal. Typically in Europe concentrate is re-circulated back into the landfill site or removed from site for incineration.

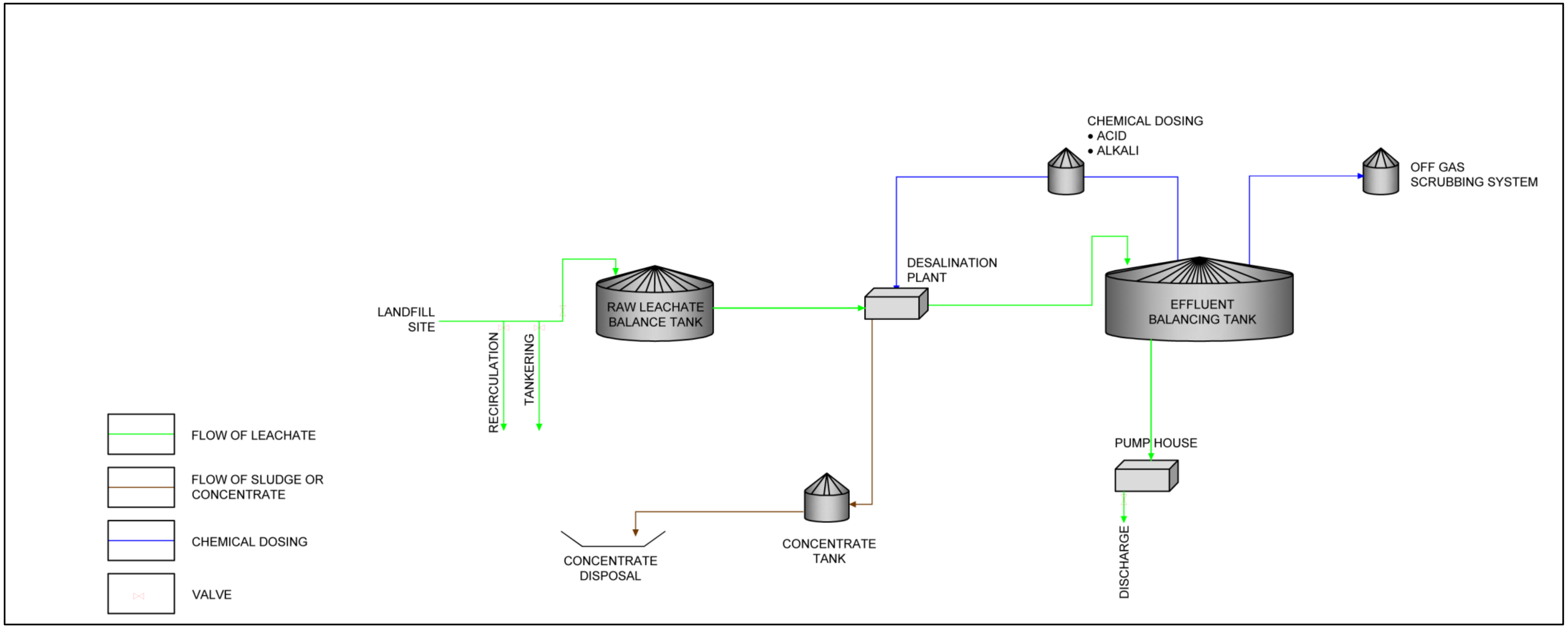
As such, the following system has been considered for an RO Plant at the Ghallis Landfill site:

1. Raw Leachate Balance Tank;
    - $50m^3$ for $40m^3$/day plant, $30m^3$ for $25m^3$/day plant, assume epoxy or glass coated steel, bunded tanks
2. Chemical Dosing Systems;
    - $5m^3$ bunded sulphuric acid tank and vent scrubber (HDPE)
    - $5m^3$ bunded caustic tank and dosing pumps (HDPE)
3. RO Process Container:
    - 12.2m x 2.4m x 2.4m Containing all main plant equipment, chemical dosing and PLC / SCADA
4. Effluent Balance Tank:
    - 1 x $40m^3$ for $40m^3$/day plant, 1 x $25m^3$ for $25m^3$/day plant, assume epoxy or glass coated steel, bunded tanks
5. Concentrate Storage Tanks:
    - 1 x $40m^3$ for $40m^3$/day plant, 1 x $25m^3$ for $25m^3$/day plant, assume epoxy or glass coated steel, bunded tanks
6. General Civils and Ancillaries;
    - Concrete hard standing with bunding provided by 1m high concrete walls
    - General pipework / electrics etc.
    - Off-Gas scrubber
    - General access and security
    - All health and safety features
7. Effluent Discharge Pipeline:
    - 500m long complete with connection into manhole on public sewer
8. Under-Cap Recirculation :
    - Engineered sub-cap recirculation drainage systems for $25m^3$/day LTP version

Overall estimate of plant footprint: $250m^2$ for $40m^3$/day plant and $200m^2$ for $25m^3$/day plant.

An outline process flow diagram is presented as Figure 2.

Figure 2
Generalised RO Plant Process Flow Diagram



7.1.3 Operational and Environmental Considerations

Operational: Use of RO at the Ghallis landfill would have many advantages, not the least being the very high quality effluent that could be produced, capable of achieving the discharge consent without the need for further treatment processes even with discharge consent restrictions on contaminants such as Chloride and TKN. This, in addition to the robustness of the RO treatment process would mean that the additional ‘ancillary’ plant required such as raw leachate reception tanks, effluent tanks, concentrate tanks etc. could be relatively simple and small.

It is estimated that chemical usage would be limited to less than 5m^3/month of sulphuric acid (or similar), 1m^3/month of caustic (or similar) and then small volumes of cleaning chemicals. As such, chemical stores need not exceed 5m^3 in volume.

RO systems are fully automated systems, but still require on-site understanding and troubleshooting capabilities. LTP operator input would also be relatively low, estimated as being as low as one day per week. An RO plant is capable of being almost fully automated and would be capable of being operated almost entirely remotely if required. Operator input would be limited to sampling for the purposes of compliance with the sites Permit and the supervision of chemical deliveries. In addition, weekly set up of chemical stores to allow CIP washes would be required although this would amount to only around 1 or 2 hours of work.

Health and Safety: Aside from those associated with any industrial activity of this nature such as slips, trips and falls, working around vehicles, working at height etc., would focus on the handling and storage of chemicals, the production and control of off-gases and vapours and the presence of high pressure vessels at more than 60 bar.

Noise can be an issue within the main process cabin, ear defenders being required to be worn if working with the plant in operation.

Environmental: The RO process will produce a very high quality effluent and, if well designed and operated, will be extremely robust and unlikely to produce non-compliant effluent unless the plant is left unattended and in a state of disrepair. Due to the nature of the RO process influent and effluent quality monitoring is possible (and in terms of influent usual) and could be used to automatically manage influent loads and plant performance as well as being capable of shutting down the plant and preventing non-compliant discharge on effluent quality. This is because changes in Electrical Conductivity in both the raw leachate and permeate effluent can be used to closely monitor the plants performance. EC monitoring equipment is robust and accurate and so can be trusted to perform this function at a plant with little need for re-calibration, manual cleaning or supervision.

Some risk of emissions to the environment exists from the storage of process chemicals but in a well-designed LTP these should be mitigated and would not present a significant issue. Similarly, the possibility of emissions of off-gases also exists but again, plant design can mitigate these.

The main environmental issue of concern from an RO plant is the disposal of concentrate produced. At a plant treating on average 40m^3/day, around 12m^3/day (or 4,380m^3 per annum) of concentrate may be produced. This concentrate will contain essentially all of the contaminants originally found in the raw leachate and so will have concentrations of these contaminants at roughly four times those of the raw leachate. Options for concentrate disposal are usually to re-circulate back to the landfill or dispose of off-site to a suitably licensed facility. Returning of concentrated liquors to the landfill seems counter intuitive and may not be supported by regulatory authorities. Concerns surround the fate of pollutants returned to the landfill site, the possibility of producing an ever strengthening leachate in the landfill and the landfills subsequent ability to conform to Landfill Directive requirements on hydrogeological risk assessment. Ultimately the ability of the landfill operator to surrender the landfill Permit could be called into question, However, RO plant vendors point to extensive reference sites in Europe that indicated that this does not cause operational issues for the sites concerned.

7.2 Aerobic Suspended Growth Treatment Plants

Aerobic suspended growth biological treatment plants employ the well-established aerobic biological treatment process. The main difference between the various processes encompassed by this descriptive name is the size of vessel required for treatment and how and where solids separation takes place. Due to the relatively high contaminant loading rate (daily volume multiplied by influent ammonia, BOD and COD) delivered by landfill leachate, process designs that are able to operate at greater activated sludge densities tend to be employed to reduce construction costs and land take. Aerobic biological treatment processes are designed to be able to perform the following main treatment objectives:

- carbonaceous oxidation of organic carbon compounds;
- nitrification of ammoniacal-N; and
- full or partial de-nitrification of nitrate-N (if required)

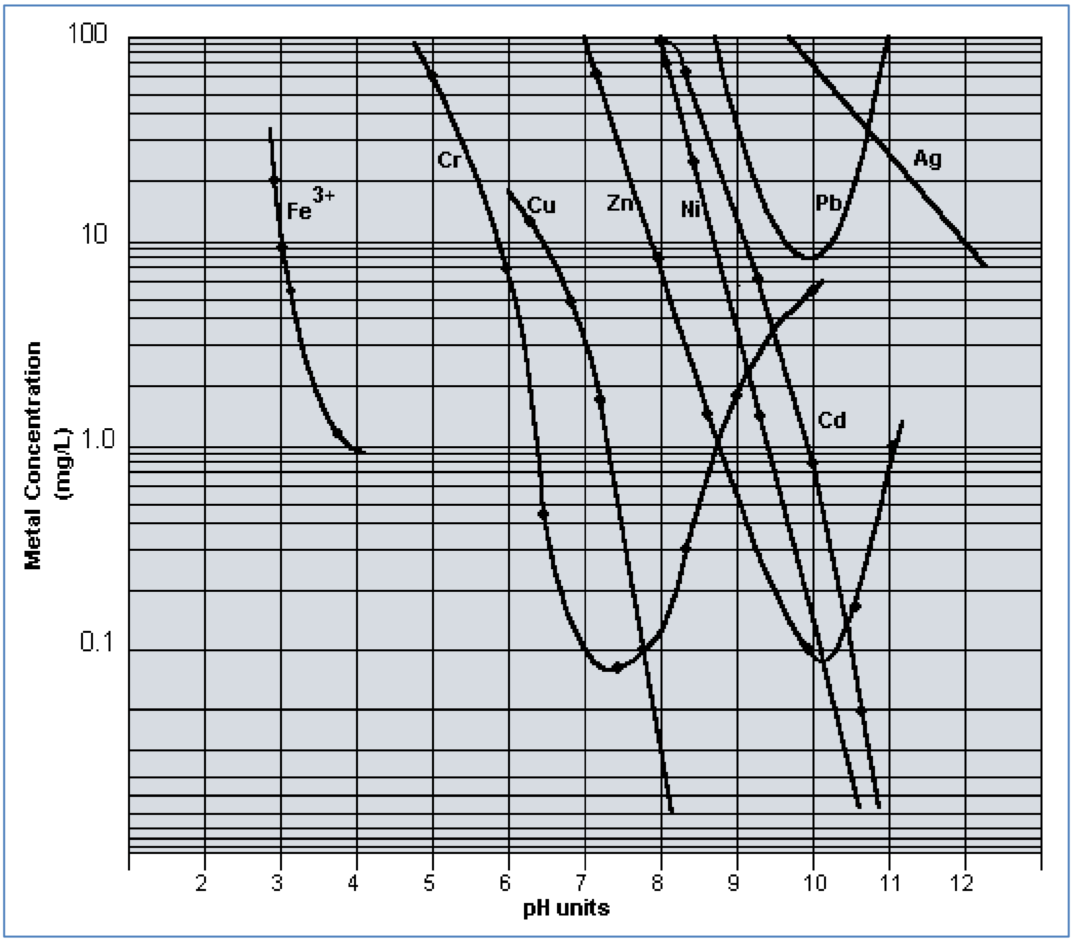
During aerobic biological treatment, organic compounds can be largely oxidised to carbon dioxide and water, and ammoniacal nitrogen (ammoniacal-N) can be removed by oxidation (nitrification) to nitrate. Nitrification is a widely adopted biological treatment process for domestic and industrial effluents, although relatively high concentrations of ammoniacal-N (often greater than 1000mg/L) in leachates can require specific process designs, if treatment efficiency is not to be inhibited by toxic effects. Treatment is provided by microorganisms that use the contaminants in leachate to derive energy.

Higher treatment rates are achieved by containing a greater mass of organisms within a given treatment vessel volume, this often being expressed as Mixed Liquor Suspended Solids (MLSS). Solids need to be retained within the treatment vessel and so need to be separated from the treated effluent before discharge.

However solids are separated (for example by settlement in an SBR or via filtration as in an MBR) the treatment principal is the same:

1. Raw leachate containing organic contaminants of concern are introduced to the Treatment vessel in a controlled fashion.
2. Within the treatment vessel conditions are created that allow activated sludge to metabolise the organic contaminants via a variety of processes typically destroying all BOD and around 60%-70% of COD and converting ammonia to nitrate (this can be further converted to nitrogen gas if required).
3. Other contaminants of concern, typically metals, also enter the treatment vessel and are either precipitated out of solution (usually as metal hydroxides) or otherwise removed from solution and associated with the biomass. Different metals are least soluble at different pH's but usually the higher the pH the lower the solubility. Figure 3 presents common metal hydroxide solubility curves.

Figure 3
Metal Hydroxide Solubility Curves



4. Solids (both biomass and mineral solids) are separated from treated effluent by processes such as settlement (in an SBR) or filtration (in an MBR) and are retained within the treatment vessel. In systems such as an SBR, varying amounts of solids can 'carry over' with the effluent if the system is incorrectly set up or if solids settlement is poor. This problem can often occur as a result of rapid changes to treatment plant loading (i.e. rapid changes in feed volume or, more usually, changes in feed quality parameters such as ammonia, BOD or COD) and it can also be the result of 'toxic' affects from the raw leachate feed, such as elemental chromium concentration increasing to above 0.8mg/L This problem should not occur with an MBR system as, regardless of the solids content of the effluent for discharge, the physical filtration process should prevent solids being carried through the system. In addition, this can be an advantage if UV disinfection is required.
5. Clarified effluent, now with little or no ammonia and BOD and reduced COD and metals, can be passed onto further treatment stages (such as reed beds) or to discharge. In an MBR system only contaminants in solution will be discharged. In an SBR system some non-dissolved contaminants can carry over if solids settlement has not been completely successful.
6. Levels of solids will, over time, build up within the treatment vessel. This is due to two main processes;
    a. Precipitation of contaminants out of solution (mineral solids): As this takes place increasing concentrations of metals will be detected in the Treatment

Tank if analysis is for ‘Total’ metals. These metals are unlikely to be present in their elemental form but will be in complexes, typically hydroxides.

b. Biomass growth: In theory, for every kilogram of ammonia that is converted to nitrate 0.22kg of biomass growth will occur. Similarly, if nitrate is converted to nitrogen in the process further biomass growth will take place (hence de-nitrifying processes have higher sludge production rates than nitrifying processes). However, at the same time individual organisms that make up biomass are also dying off and being consumed by living organisms which are looking for organic carbon to consume. Therefore there is a dynamic cell growth , death and consumption process taking place within the treatment tank that often leads to an increase in the total biomass but can under ‘perfect’ conditions reach an equilibrium where-by there is no overall increase as all cell growth is balanced by consumption of dead organism.

Removal of excess sludge (Waste Activated Sludge or WAS) is required if MLSS levels are to be kept within acceptable limits (if they get too high adequate settlement is not possible in an SBR and membrane filters block in an MBR). This is usually accomplished by removing settled sludge from the treatment vessel (in an SBR) or Mixed Liquor from the treatment tank (in an MBR) and disposal off site. This process also has the effect of removing mineral solids at the same time, so reducing to concentration of ‘Total’ metals retained within the treatment vessel. Ideally, as a rule of thumb, for an SBR MLSS should be kept at around 5,000mg/L and for an MBR at around 8,000mg/L. As with all aspects of biological treatment processes, rapid changes should be minimised and so removal of ‘a little but often’ is recommended rather than ‘campaign’ removal of solids. When WAS is removed very frequently sludge ages are ‘young’ and will typically have few species of microorganism, when WAS is removed infrequently sludge ages are ‘old’ and a greater variety of micro-organisms can be present. Either way, a ‘healthy’ biomass containing the ‘right’ kind of microorganism is essential for a successful treatment process. Incorrect conditions or operation can lead to the dominance of unhelpful bacterial populations that can then cause issues with the successful operation of the process.

The most appropriate process design for landfill leachate treatment employing aerated suspended growth systems has been highlighted within the SLR selection matrix as Sequence Batch Reactors (SBR) and Membrane Bio Reactors (MBR). These types of treatment plant are very widely used for this purpose having developed out of the basic activated sludge process designs. Recently (MBR’s) have become more common as membrane technology has improved making the potential benefits of such plants (increased security of high effluent quality) more affordable. Both process designs have continued to developed, using differing aeration and filtration systems, as experience has been gained of their operation.

The two systems differ in how they are configured to allow the treatment process to proceed. Both types employ large treatment tanks, the large volume of the main tank makes for efficient aeration, high rates of dilution of incoming leachates, and high resistance to shock loading. However in an SBR all treatment and solids separation takes place in the same tank. In MBR solids separation usually takes place in a spate process.

In addition to these main two plant configurations, two biological processes are also commonly employed in these systems. Both processes treat BOD and COD but most common aerated suspended growth plants perform nitrification of ammonia only. However, it is possible to undertake nitrification with de-nitrification. De-nitrification may be required by the conditions of the discharge consent as in some instances nitrate is also a contaminant of concern and so has to be removed. Increasingly however the combination of nitrification and de-nitrification is being viewed as a means to achieving reduced treatment costs and increased process stability even where reduction of nitrate is not required by discharge consents.

7.2.1 The Nitrification Process

The process of treating leachates of high ammonium strength depends on a variety of bacteria known as *Nitrosomonas* and *Nitrobacter*. These bacteria use the energy in the release of the nitrogen in the ammonium constituent of leachate, and turn it into nitrite, then nitrate. They use inorganic carbon as a food source. A by-product of the whole process is the production of acid. If the acid is allowed to build up then the process becomes inhibited.

$$\text{Leachate} \longrightarrow \xrightarrow[\text{Oxygen}]{\text{Nitrosomonas / Nitrobacter}} \longrightarrow \text{Nitrate + Acid}$$

More correctly, the reaction is given as:

$$55\ NH_4^+ + 76\ O_2 + 5\ CO_2 \longrightarrow 54\ NO_2^- \quad 109\ H^+ + 52\ H_2O \quad C_5H_7O_2N$$

$$115\ NO_2^- + 52.5\ O_2 + 5\ CO_2 + NH_4^+ + H_2O \longrightarrow C_5H_7O_2N + H^+ \quad 115\ NO_3^-$$

Both groups of bacteria are relatively sensitive to environmental conditions and either one or both stages can be easily inhibited by:

- Low pH-values (below about 6.5);
- Insufficient dissolved oxygen (below about 2 mg/L);
- Low temperatures (below 5°C), or high temperatures (above 35°C); and
- Toxic inhibition.

A wide range of chemicals are known to inhibit the process by toxic effects, although such inhibition is rare in most leachates. However, the range of toxic chemicals includes both ammonium itself (above about 80 mg/L of ammonium in the aeration tank will significantly inhibit the process) and the intermediate oxidation product, nitrite, both of which can potentially inhibit the second stage of the reaction, leading to a build-up of nitrite in effluent. The optimum pH-value is typically between 7.5 and 8.0, and treatment rates decrease very sharply at pH values below 5.5. Therefore, as leachate rarely contains sufficient alkalinity itself, the treatment reaction will ultimately fail unless pH is controlled. Control is usually achieved by adding alkalinity in the form of caustic soda. Failure of the process of pH control, together with failure to maintain sufficient concentrations of dissolved oxygen, are the most common causes of failure in full-scale treatment plants trying to accomplish nitrification.

7.2.2 The de-Nitrification Process

De-nitrification is the reduction of nitrate nitrogen to nitrogen gas, using a wide variety of facultative organisms that use organic carbon (rather than carbon dioxide as for *Nitrosomnas* and *Nitrobacter*) for energy and also as a carbon source. Because these organisms are facultative they can happily coexist with *Nitrobacter* and *Nitrosomnas* in a mixed nitrification / de-nitrification system. These organisms can use molecular oxygen (i.e. oxygen added from the air by aerating the contents of the tank), but under anoxic conditions (no added air) the organisms can get oxygen from nitrate (and other oxidised forms, such as sulphate). ‘Anoxic’ is a state where there is oxygen available, bound up in other chemicals, and is not the same as ‘Anaerobic’ which is a state where no oxygen exists at all.

One advantage of employing a mixed nitrification / de-nitrification system is that by creating definite oxygenated and anoxic zones or periods within the treatment process this tends to inhibit the growth of some of the more problematic microorganisms that can cause problems with process stability and issues such as sludge bulking (for example filamentous organisms such as *Microthrix parvicella* or *Sphaerotilus natans).*

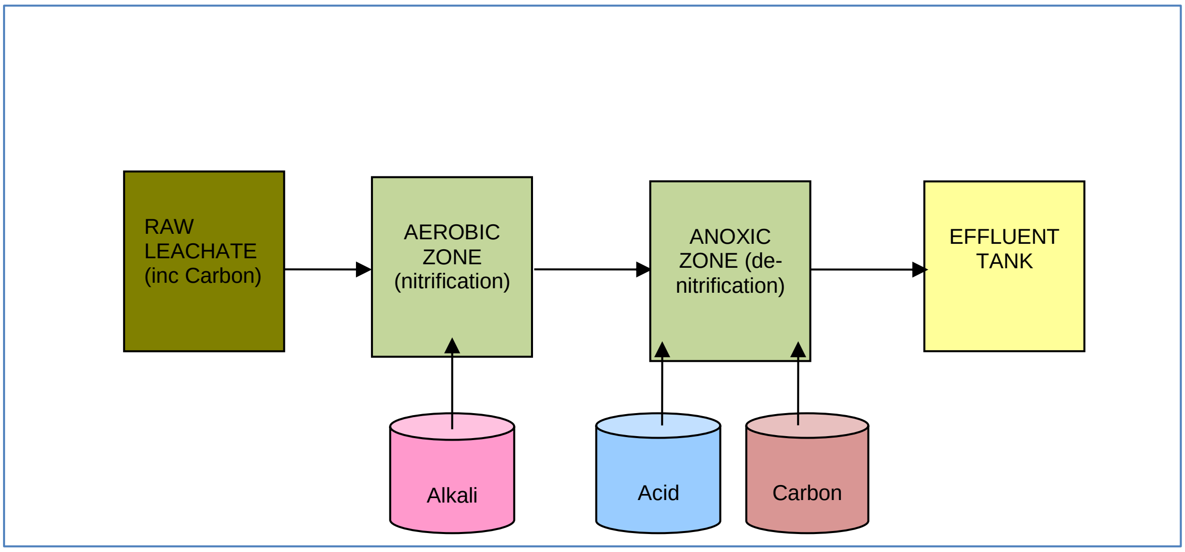
Facultative organisms in a de-nitrification plant need an organic carbon source – popular substrates to add to the process are methanol and ethanol. Because there is extra safety and administrative concerns with storing bulk amounts of these chemicals, recent plants have used glycerol as a carbon source, produced as a waste stream from Bio Diesel manufacture. In this reaction, alkalinity is produced in the form of carbonate. For this reason, acid should be available as part of the process control, to keep the pH within consent limits and within the limits of the process.

The overall reaction for de-nitrification, using the example of methanol as a carbon source substrate is as follows:

$$NO_3^- + 1.08\,CH_3OH + 0.24\,H_2CO_3 \longrightarrow 0.06\,C_5H_7O_2N + 0.47\,N_2 \longrightarrow 1.68\,H_2O + HCO_3^-$$

Combined nitrification and de-nitrification can be achieved in three ways. The first is to conduct the nitrification process first, then pass the effluent to a de-nitrification part of the process as show in Figure 4:

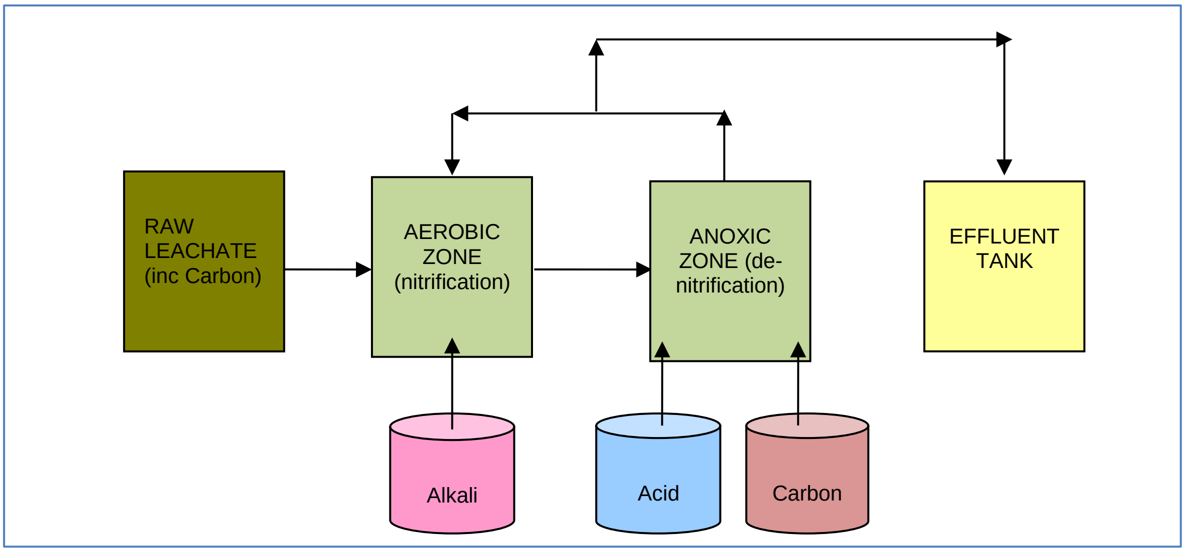
Figure 4
Post De-nitrification Process Diagram



This method is known as 'Post De-nitrification' and has been shown to be >95% effective in removing ammonia and nitrogen from the effluent and so is capable of achieving very high quality effluent, but suffers because the method of operation is expensive, due to the need to add large quantities of alkali, then large quantities of acid in sequence as well as supplying a carbon source.

The second method is known as 'Pre De-nitrification' and involves re-circulating a portion of the de-nitrification process back into the nitrification process, and from the nitrification process back to the de-nitrification process. This has advantages over the post de-nitrification process because, since the nitrification process releases acid and the de-nitrification process releases alkali, the process benefits from considerably less consumption of chemicals, and is more pH stable. However, because there is mixing between the two processes, it is not possible to completely remove all nitrogen. The process is show in Figure 5.

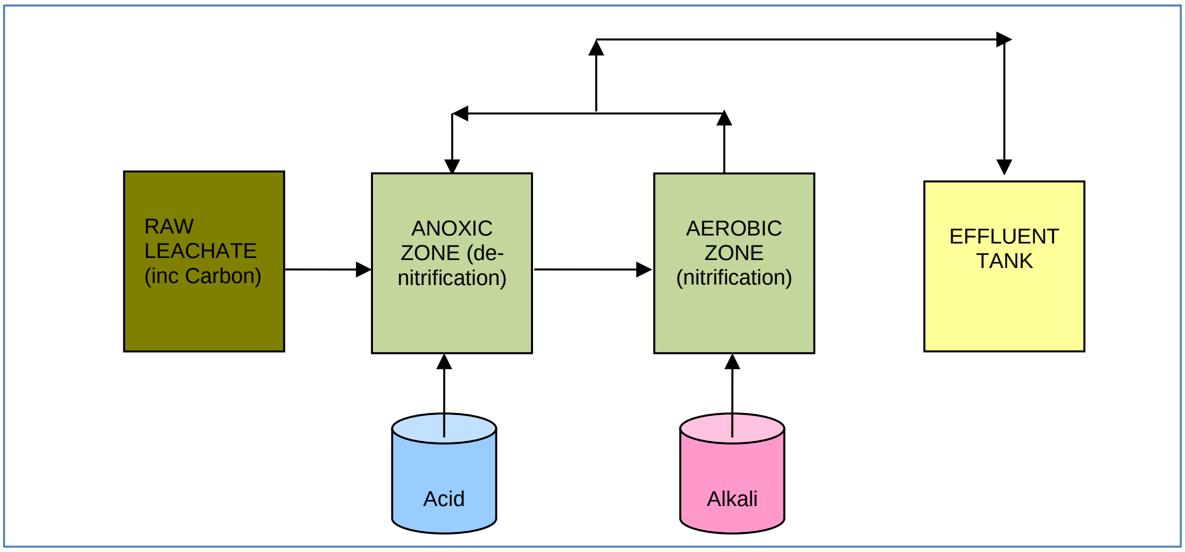
Figure 5
Pre De-nitrification Process Diagram



The third option is an amended version of option 2 but can be used where there is no need to de-nitrify from a regulatory standpoint or where the degree of de-nitrification required is relatively modest. The set-up is similar to pre de-nitrification except that the source of organic carbon employed is the raw leachate itself. In this way very low chemical treatment costs can be achieved as acid and alkali needs are balanced by the recirculation of effluent between nitrification and de-nitrification stages and an external source of organic carbon is not required. Once the nitrification and de-nitrification process is begun (during which time some chemical dosing may be needed to start up the process) raw leachate is fed in a controlled manner to the anoxic phase where organic carbon, supplied in the influent BOD and COD from the raw leachate, is consumed whilst nitrate is reduced to nitrogen gas. As effluent is then passed through a nitrification phase the ammonia content of the effluent is converted to nitrate, which in turn returns to the anoxic tank for de-nitrification.

As previously described, employing this method of treatment it is not possible to reduce nitrate to zero. Advantages of the process are the very low treatment costs and improved process stability. The improved process stability being a result of the anoxic stage of the process acting as a 'selector' tank, promoting growth of the desired *Nitrosomnas*, *Nitrobacte*r and groups of facultative bacteria whilst inhibiting growth of more problematic filamentous bacterial groups. In addition a typical problem of controlling variations in influent feed COD and BOD concentrations is largely accommodated by the use of this material as an energy source in the anoxic process. A simplified process diagram is presented as Figure 6.

Figure 6
Pre De-nitrification using Leachate as Carbon Source Process Diagram



7.3 Sequence Batch Reactor

The Sequence Batch reactor (SBR) is a variant of the aerated suspended growth treatment process described in Section 7.2. Raw leachate is pumped from the landfill and held in a storage vessel prior to pumping in controlled 'doses' to a treatment tank. Within the treatment tank raw leachate is intimately mixed with activated sludge and provided with oxygen whilst pH is maintained at a level of around pH 7.5. Ammonia is converted to nitrate whilst contaminants making up BOD and some COD are consumed by various populations of microorganisms.

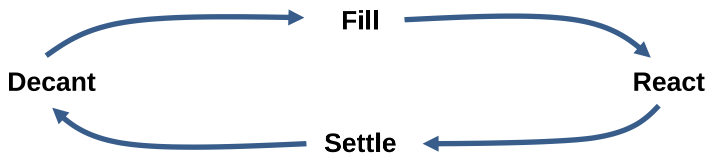
The tank contents are then left to settle to enable separation of sludge from treated effluent. During this stage all feeding of raw leachate, mixing and aerating are suspended. Clarified effluent is then decanted from the tank and passed onto discharge systems, after which the SBR 'cycle' starts up again.

This is a very well established and successful treatment process used extensively in landfill leachate treatment. It is capable of producing an effluent of high quality but, in the instance at Ghallis, would be likely to require final 'polishing' as well as a specific process for removal of metals, plus disinfection if the point of discharge would be subject to the Bathing Beach Directive.

7.3.1 General Description

The Sequencing Batch Reactor (SBR) treatment process has been developed as an automated, extended aeration system, which is suited to the higher organic strength and concentrations of ammoniacal-N in landfill leachates. The larger volume of the main SBR tank makes for efficient aeration, high rates of dilution of incoming leachates, and some resistance to shock loading. The great majority of aerobic biological leachate treatment systems successfully installed in the UK make use of SBR technology.

An SBR is a cyclically operated, suspended growth activated sludge process. The main difference between the SBR and other activated sludge system is that each SBR tank carries out functions such as aerobic biological treatment, settlement of solids, effluent clarification and decanting over a time sequence rather than in separate tanks or processes. The ability to vary the time sequence (compared to the inflexibility of specific volumes of separate tanks) enables a robust and flexible treatment system to be operated. SBR systems that have been designed for particular loading rates of ammoniacal-N or of organic contaminants will have considerable flexibility to receive this as either small volumes of strong leachate, or as larger volumes of weaker leachate, what is important is that, over a period of days, a relatedly consistent 'load' is provided to the process. This can be important as leachate character changes over time to ensure that optimum treatment performance is maintained. The operating cycle of a typical SBR system comprises four main phases, normally:



Feeding of leachate generally takes place throughout the 'react' stage, in order to manage oxygen demand and supply, to avoid shock loadings and to avoid toxic inhibition from contaminants such as ammoniacal-N.

In leachate treatment, the process is usually automated, and generally operated within a 24-hour cycle, in a single tank which is sufficiently sized to provides a typical mean hydraulic retention time (HRT) of ten days or longer when treating strong leachates, so in the instance of the Ghallis landfill where a maximum treatment rate of 40m^3/day is anticipated the SBR will need to be at least 1,545m^3 whereas for the option where a 25m^3/day LTP is proposed the SBR size could reduce to 966m^3. As the load of ammonia wishing to be treated increases the HRT also need to extend to in excess of 10 days. Installation of smaller tanks that do not provided the extended HRT required may save on installation costs but do not reduce operational costs and will almost certainly lead onto problems with poor treatment and solids carry-over along with other signs of process stress. A significant benefit of a batched treatment process is that it is possible to set a standard time at which all effluent is produced. This can therefore be monitored before allowing release from the process.

In most instances, where the relatively high flow rate from the SBR cannot be fed directly to discharge, an effluent balance tank is used to balance flows over a 24 hour period. Plants tend to incorporate PLC and SCADA system, to provide a high level of protection and safety, as well as the maintenance of detailed operating records

7.3.2 Process Description

Raw Leachate would be pumped to a raw leachate balance tank in the LTP. Due to the issues associated with 'shock' loading biological treatment systems large raw leachate buffering tank would be required. Also, the SBR process does not respond well to rapid changes in feed volumes and so significant 'up-front' storage would be required to enable any changes in production from the field to be smoothed.

From the raw leachate balance tank, leachate is pumped to the SBR. To ensure that influent loads to the biological process do not vary too quickly raw leachate quality will need to be monitored (at least daily) for constituents such as ammonia and COD and feed flow rates adjusted by the operator to compensate for changes in quality.

The SBR tank consists of a tank installed with the following key items:

- SBR feed pump(s) and pipework
- aeration equipment (for example jet ejectors or air diffusers)

- decant system (including scum protection) to allow the treated supernatant liquor to be removed
- instrumentation to monitor, DO, pH, Temperature, level, flow
- waste sludge removal pipework & valves
- chemical dosing equipment

The SBR treatment process is usually set to run in 24 hour cycles, although it is possible to run shortened cycles. A typical cycle consists of:

1. Aeration & feed: The SBR is aerated continuously for up to 20 hours/day, 7 days a week. Raw leachate is added at a constant rate during the aeration period (usually in brief ‘shots’ every half hour). During the aeration periods, the pH is monitored and is adjusted by automated dosing of an alkali, normally sodium hydroxide.
   During the aeration and feed cycle it is also normal to add Antifoam to control the foam levels which can be an issue with some leachates.
   Phosphoric acid is also occasionally dosed, this is a nutrient required by the microorganisms in the activated sludge that is sometime deficient in the raw leachate.

2. Settle: At the end of the aeration period, all mixing and aeration is turned off and a settling period takes place.

3. Decant: The decant pipework is then opened allowing a measured volume of treated effluent to discharge to a separate storage vessel.

4. The aeration and feed cycle is then begun again.

Over time, concentrations of sludge within the SBR are likely to build up to unacceptable levels. When this happens waste activated sludge must be removed from the tank for disposal. Such sludges only actually contain around a maximum of 2% dry solids and are typically removed from the SBR during settlement phases for storage in a sludge tank from where it can be tankered away for disposal off site as a liquid waste or further treatment processes can be employed to reduce the volume of the sludge for more economic disposal. Typically employed processes are sludge drying techniques such as belt processes etc. but these often have significant operational difficulties when working with activated sludges. More success has been reported from sludge drying reed beds.

Should the plant be required to act as a de-nitrifying system, either due to the inclusion of a ToC limit on the discharge consent or in an attempt to provide improved process stability, this is possible by introducing an ‘anoxic’ period into the SBR cycle. Consideration would need to be given in this case to the relative merits of achieving an anoxic cycle within the SBR tank or in a separate vessel. In addition the relative benefits of pre or post de-nitrification would need to be considered.

The SBR process is unlikely to be able, on its own, to achieve the required level of treatment for many of the metals included on the consent. Therefore a separate process will be required to achieve this. A further polishing step is almost certainly required in any case to ensure residual BOD, ammonia and any solids carry over are treated prior to discharge, this typically being provided by reed bed systems. The SBR process may be able to provide sufficient levels of de-nitrification should this be required but would not be able to further reduce chloride or COD in the effluent should restrictions be applied by the regulator. Mecoprop would however be treated by an SBR system

Choice of aeration system would also be of importance in an SBR as different systems provide different advantages and disadvantages:

- Venturi Pump Aerators; Can be submerged within the treatment tank or have externally mounted air cooled pumps. These are low cost to install but have relatively high operating costs as oxygen transfer rates are low (as coarse bubbles are produced) and if submerged require frequent removal and cleaning, which can result in health and safety issues. Have also been implicated in the production of very high process operating temperatures. Are capable of supplying both anoxic mixing and aeration;
- Oxygen Injection; Can be installed to supplement other forms of aeration and mixing or as stand-alone systems. These tend to be relatively expensive to operate as a supply of liquid oxygen is required along with storage and other ancillary equipment. There is still the need however for periodic removal and inspection of submerged elements of plant. This type of system would need to be augmented by 'mixers' should WasteServ wish the plant to be able to operate an 'anoxic' stage. Aeration would also be more 'gentle' allowing a healthier biomass with better flocc formation;
- Diffused Air; Operates by having air blowers mounted externally to the Treatment Tank connected via pipework to fine bubble diffusers submerged within the treatment tank. All moving parts are outside of the tank and so no heat is introduced and servicing and maintenance is easier. On-going power consumption is typically around 30% less than for equivalent Venturi type system due to the greater efficiency of 'blowers' and the higher oxygen transfer rates of fine bubble systems. There is still the need however for periodic removal and inspection of submerged elements of plant. This type of system would need to be augmented by 'mixers' should WasteServ whish the plant to be able to operate an 'anoxic' stage. Aeration would also me more 'gentle' allowing a healthier biomass with better flocc formation;
- Jet Aeration; These systems similarly have no moving parts within the tank, only a series of 'jet' nozzles connected through the treatment tank wall to pumps (for mixing the tank contents) and blowers (for introducing air). They are capable of providing mixing only, through to full mixing and aeration without the need for additional equipment. On-going power consumption is typically around 30% less than for equivalent Venturi type system due to the greater efficiency of 'blowers' and the higher oxygen transfer rates of fine bubble systems. There is less need however for periodic removal and inspection of submerged elements of plant. Aeration would also me more 'gentle' allowing a healthier biomass with better flocc formation.

As such, the following system has been considered for an SBR Plant at the Ghallis Landfill site:

1. Raw Leachate Balance Tank;
   - 80m^3 for 40m^3/day plant, 50m^3 for 25m^3/day plant, assume epoxy or glass coated steel, bunded tanks.

2. SBR Tank:
   - Estimated at 1,545m^3 for 40m^3/day plant, 966m^3 for 25m^3/day plant, assume poured concrete tank.

3. Chemical Dosing Systems;
   - 35m^3 bunded caustic tank and dosing pumps (HDPE);
   - 1m^3 antifoam tank and dosing pumps (HDPE);
   - Phosphoric (barrels).

4. ISO Containers:
   - 12.2m x 2.4m x 2.4m containing PLC and SCADA.

5. Sludge Management System

6. Effluent Balance Tank:
   - 50m^3 for 45m^3/day plant, 30m^3 for 25m^3/day plant, assume epoxy or glass coated steel, bunded tanks.

7. General Civils and Ancillaries:
   - Concrete hard standing with bunding provided by 1m high concrete walls;
   - General pipework / electrics etc;
   - General access and security;
   - All health and safety features.

8. Reed Beds:
   - 2 x 325m^2 reed bed systems incorporating replaceable sections for 40m^3/day plant, 2 x 175m^2 reed bed systems incorporating replaceable sections for 25m^3/day plant.

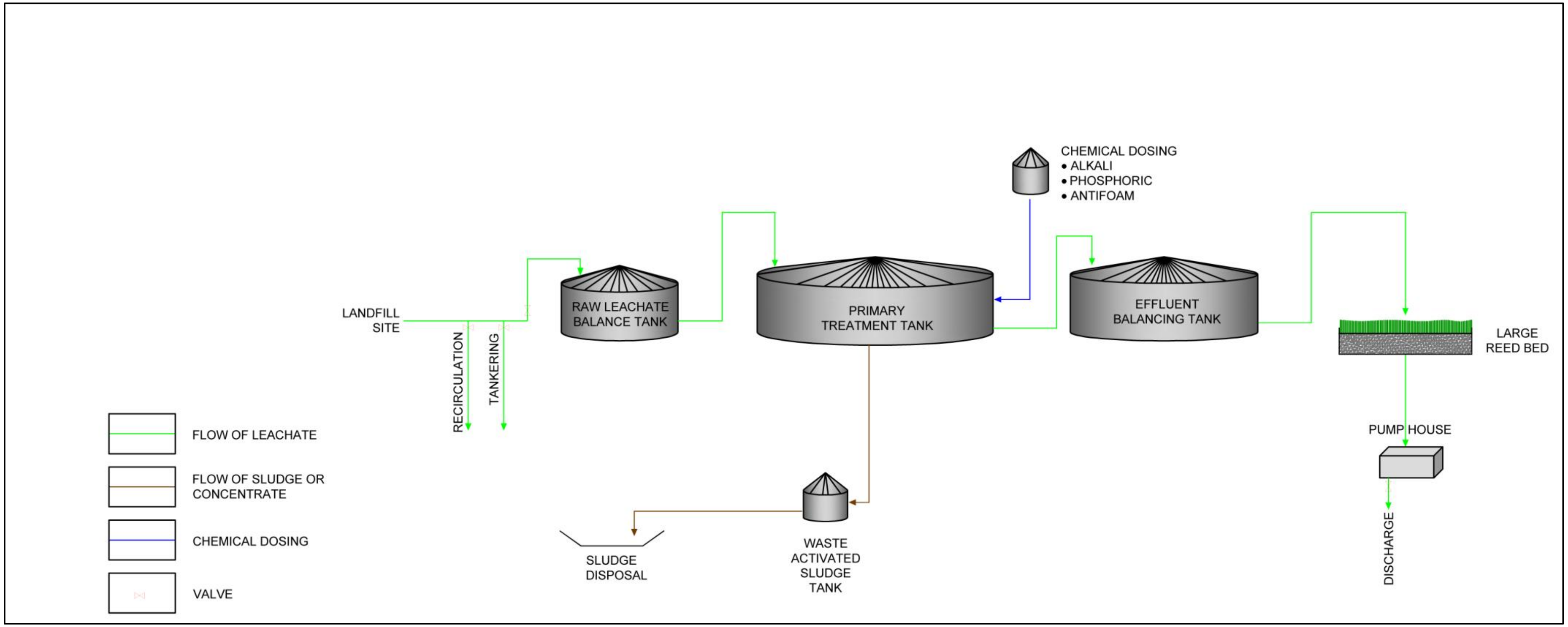
9. Effluent Discharge Pipeline:
   - 165m long complete with 25m sea outfall with headwall.

10. Under-Cap Recirculation:
    - Engineered sub-cap recirculation drainage systems for 25m^3/day LTP version

Overall estimate of plant footprint: 725m^2 for 40m^3/day plant and 450m^2 for 25m^3/day plant.

An outline process flow diagram is presented as Figure 7.

Figure 7
Generalised SBR Plant Process Flow Diagram



7.3.3 Operational and Environmental Considerations

Operational: SBR plants can typically produce a good quality effluent but are prone to periods of instability caused by issues such as toxic shock, plant overloading, high or low operating temperatures or development of incorrect operating conditions (high or low pH, low dissolved oxygen etc.). Most of these issues can be overcome with a combination of good plant design and management by a skilled and experienced operator. However, it is likely that to provide the level of control needed at such a plant, at least one full day per week of an operators time will be required to keep the LTP performing well.

Because it is relatively easy for biological processes to become unstable, frequent sampling and analysis of influent leachate and effluent quality would be required with fine adjustment of the LTP processes to accommodate any changes. Inappropriate operation of the plant can lead to issues such as foaming or solids carry-over into the effluent. This can then lead to clogging and blocking or processes downstream of the SBR and the carry-over of solids can cause breaches of the discharge consent in their own right as well as being associated with breaches of conditions relating to contaminants that become associated with the solids held within the SBR, most notably for metals, and where the Bathing Beach Directive is an issue, bacteria.

It is estimated that such an SBR, if operated as a nitrification only process, could consume up to 50L of 32% sodium hydroxide for every cubic metre of leachate treated. Therefore such a plant could require around $60m^3$/month of sodium hydroxide for a $45m^3$/day LTP or $38m^3$/month for a $25m^3$/day LTP. Therefore storage volumes of in excess of one taker load should be provided, for example $35m^3$. Requirements for antifoam and phosphoric acid storage would be much less than this at around $1m^3$ each. Should a de-nitrification process be chosen then usage of chemicals could be dramatically reduced, perhaps using little other than antifoam and phosphoric acid as a nutrient source. However, it is advised that facility to rapidly install storage and dosing for acid, alkali and a carbon source should still be included if a de-nitrification process is employed as variations in raw leachate quality over time could mean that chemical dosing may be needed from time to time.

Whilst the mechanical operation of the plant can be highly automated and provision of high specification PLC and SCADA systems result in the possibility of largely remote operation and control it is not readily possible to provide automated analysis of influent leachate strength and effluent quality to the degree of accuracy that would be required to fully automate plant operations. Raw leachate would need to be monitored for ammonia as a minimum. Similar analysis would be required on the effluent. Probes designed to monitor ammonia tend to perform poorly in high chloride effluents such as leachate

On-going maintenance issues such as probe cleaning and calibration, aeration system removal and inspection (if equipment with moving parts are submerged in the treatment tank) and supervision of de-sludging and chemical deliveries mean that such a plant is likely to require high operator input of around 1.25 days per week.

Health and Safety: Aside from those risks associated with any industrial activity of this nature such as slips, trips and falls, working around vehicles, working at height etc., would focus on the handling and storage of chemicals, the production and control of sludges and the inspection of equipment submerged in tanks. Should acids also be required to be stored to assist with de-nitrification off-gas and vapour management would need to be included in any process design.

Environmental: The SBR process is capable of producing a high quality effluent if operated correctly. At the Ghallis landfill it will need to be operated in conjunction with further polishing processes to achieve the likely consent conditions to enable discharge to sea.

The process is susceptible to instability during which time non-compliant effluent can be discharged. If monitored closely (for example daily) such issues can be detected and resolved before any contaminant is released to the environment. Conversely, if not detected, non-compliant discharges can take place. To some extent this is accommodated by the large volumes of tanks and reed beds etc. providing buffering and dilution so that any one ‘missed’ event is not likely to cause environmental harm. However a succession of such event would be of concern and could result in environmental damage.

In addition, the SBR process is likely to produce waste activated sludge which will need to be disposed from the site. If sludge drying process are not included disposal could be as high as $10m^3$/month or $120m^3$/year. Sludge drying could significantly improve the sustainability of managing such sludges as solids will represent only around 4% of this volume so could easily be reduced to around 12 tons per year of dry solid.

Odours and noise are not typically reported as problems from such plant. Foam production can however be an issue if the biological process is ‘stressed’. This can cause tanks to over-foam, overwhelming control features and escaping the tank. Such foam is usually contained within the LTP bunded area but can cause a problem if it becomes windblown.

7.4 Aerated Lagoons SBR

This is essentially an identical process to that of the SBR described above in Section 7.3, the only difference being that instead of tanks lagoons are employed. One consequence of this is that aeration systems can be less costly as floating aerators may be employed.

In all other regards other than the physical description of the plant required the process is identical to the SBR. As such, the following system has been considered for an SBR Plant at the Ghallis Landfill site:

1. Raw Leachate Balance Lagoon;
    - $80m^3$ for $40m^3$/day plant, $50m^3$ for $25m^3$/day plant, assume composite lined lagoons;

2. SBR Lagoon:
    - Estimated at $3,709m^3$ for $40m^3$/day plant, $2,318m^3$ for $25m^3$/day plant, assume composite lined lagoons;

3. Chemical Dosing Systems;
    - $35m^3$ bunded caustic tank and dosing pumps (HDPE);
    - $1m^3$ antifoam tank and dosing pumps (HDPE);
    - Phosphoric (barrels).

4. ISO Containers:
    - 12.2m x 2.4m x 2.4m containing PLC and SCADA.

5. Sludge Management System

6. Effluent Balance Lagoon:
    - $50m^3$ for $45m^3$/day plant, $30m^3$ for $25m^3$/day plant, assume composite lined lagoons;

7. General Civils and Ancillaries:
   - General pipework / electrics etc;
   - General access and security;
   - All health and safety features.

8. Reed Beds:
   - 2 x 325m^2 reed bed systems incorporating replaceable sections for 40m^3/day plant, 2 x 175m^2 reed bed systems incorporating replaceable sections for 25m^3/day plant.

9. Effluent Discharge Pipeline:
   - 165m long complete with 25m sea outfall with headwall.

10. Under-Cap Recirculation:
    - Engineered sub-cap recirculation drainage systems for 25m^3/day LTP version

Overall estimate of plant footprint: 1,725m^2 for 40m^3/day plant and 1,100m^2 for 25m^3/day plant.

The outline process flow diagram as presented in Figure 7 is also applicable for the Aerated lagoons with lagoons substituted for tanks.

7.5 Membrane Bio Reactor

The Membrane Bio Reactor processes is very similar to the SBR except that continuous effluent feeding and treatment can take place (filling, aerating and mixing at all times) but with solids separation taking place using filtration, often in a separate vessel or location. MLSS can be allowed to rise to between 8,000mg/L to 10,000mg/L and so can be accommodated in smaller tanks than are used in a similarly loaded SBR system.

7.5.1 General Description

The MBR treatment process is essentially the same as the SBR except that the separation of biomass from the treated effluent is accomplished by a separate process, usually employing ultrafiltration membranes or other filters capable of removing particles at between 0.1 micrometres to 0.005 micrometres in diameter; this retains all biomass and suspended solids including all bacteria within the treatment tank. The sludge separated out by the system is continually returned to the treatment tank as return sludge, as in a conventional activated sludge system. However, because of the efficiency of the solids separation stage much higher concentrations of biomass can be maintained within the treatment tank. This allows more intensive treatment to take place, reducing the size of plant required for a given loading of contaminants.

De-nitrification reactors can readily be added, to achieve anoxic removal of nitrate-N. The use of UF membranes rather than sedimentation or settlement for solids separation generates an effectively ‘solids free’ effluent and means that the process benefits from a physical barrier between the main treatment vessel and the environment. As such the process is more robust and less prone to issues such as solids carry-over. The higher MLSS possible in such a system also provides some protection against ‘shock’ loading’ although the reduced treatment tank volume in some way negates this advantage as the instantaneous dilution of influent leachate is somewhat reduced.

Choice of aeration systems are the same as for SBR’s however it should be noted that in part due to the higher loading rates employed in MBR’s, high temperatures are more of an issue at these plants. Therefore use of aeration systems that do not introduce heat into the treatment vessel should be considered.

Three main types of filtration systems are known to be employed in MBR systems each with specific advantages and disadvantages.

- Cross Flow Membranes: These membrane system employ tubular membrane modules housed on a skid where high membrane scouring velocities and differential pressures are maintained to effect the Ultrafiltration process. Capital costs are relatively low but operating costs are high due to very high power consumption. In addition, membranes are prone to fouling and require high operator input to maintain in good working order.
- Flat Sheet Membranes: These systems employ flat sheet membranes typically mounted in submerged frames within separate membrane tank systems. MLSS is pumped from the treatment tank to the membrane tank and air diffusers bathe the membranes in a stream of bubbles, creating a scouring effect on the membrane surface. Automatic backwash cycles are incorporated in to the systems control. A low suction is provided to the ‘clean’ side of the membranes which draws a clarified treated effluent away for disposal. Membranes are much less prone to clogging and fouling, require little management input and use much less power. Their main drawback is that much more membrane surface area is required and so are more expensive to install than similar cross flow systems. Operator input is however typically limited to weekly attendance to top up automated CIP wash chemical supplies and then six monthly to annual physical cleans depending on membrane type chosen.
- Baleen Filters: A relatively novel process that is now being used at a limited number of sites to provide the filtration step after biological treatment. Typically MLSS is allowed to run over an inclined physical ’Baleen’ screen allowing clarified effluent to pass through and building up biological solids on the filter surface. Periodically a backwash of treated effluent is used to wash off the surface of the screen, returning solids to the treatment process. The process is relatively low cost to install and operate and in theory is robust and requires little operator intervention.

7.5.2 Process Description

Raw leachate would be pumped to a raw leachate balance tank in the LTP. Due to the issues associated with ‘shock’ loading biological treatment systems a large raw leachate tank would be required to provide buffering. Also, the MBR process does not respond well to rapid changes in feed volumes and so significant ‘up-front’ storage would be required to enable any changes in production from the field to be smoothed.

From the raw leachate balance tank, leachate is pumped to the MBR treatment tank. To ensure that influent loads to the biological process do not vary too quickly raw leachate quality will need to be monitored (at least daily) for constituents such as ammonia and COD and feed flow rates adjusted by the operator to compensate for changes in quality.

The MBR treatment tank typically consists of a concrete, HDPE or glass coated steel tank and the plant will be installed with the following key items:

- MBR feed pump(s) and pipework;
- aeration equipment (for example Venturi aerators or air diffusers);
- MBR discharge pumps to allow mixed liquor to be removed;
- instrumentation to monitor, DO, pH, Temperature, level, flow;
- solids separation plant (cross flow or submerged membranes, baleen filter);

- chemical dosing equipment;
- waste sludge systems;
- effluent balance tank.

The MBR treatment process is usually set to run continuously with aeration and feed on-going 24/7 in the treatment tank. Raw leachate is added at a constant rate usually in brief ‘shots’ every half hour. pH is monitored and is adjusted by automated dosing of an alkali, normally sodium hydroxide.

It is also normal to add antifoam to control the foam levels which can be an issue with some leachates, this sometimes being a greater issue than at SBR type plants. Phosphoric acid is also occasionally dosed, this is a nutrient required by the microorganisms in the activated sludge that is sometime deficient in the raw leachate.

Mixed liquor is drawn off from the treatment tank into the solids separation process at a rate governed by the filtration method employed. For example, with cross-flow ultrafiltration plants, very high re-cycle rates are employed in order to generate high scouring velocities to keep membrane surfaces clean. Much lower recycle rates are required by flat sheet membrane systems and Baleen filters, this in part being the cause of their typically much lower electrical consumption and more gentle treatment of floccs.

Clarified liquor, almost entirely free from solids regardless of the ‘health’ of the biological process, can then be discharged to effluent storage tanks for discharge or for further treatment if required.

Over time, concentrations of sludge within the MBR are likely to build up to unacceptable levels. When this happens, waste activated sludge must be removed from the tank for disposal. Such sludges only actually contain around a maximum of 4% dry solids and are typically removed from the MBR during settlement phases for storage in a sludge tank from where it can be tankered away for disposal off site as a liquid waste or further treatment processes can be employed to reduce the volume of the sludge for more economic disposal. Typically employed processes are sludge drying techniques such as belt processes etc. but these often have significant operational difficulties when working with activated sludges. More success has been reported from sludge drying reed beds.

Should the plant be required to act as a de-nitrifying system, either due to the inclusion of a TON limit on the discharge consent or in an attempt to provide improved process stability, this is possible by introducing an ‘anoxic’ process, more usually in a separate tank in the case of MBRs rather than as a separate period of the treatment process. In addition the relative benefits of pre or post de-nitrification would need to be considered.

The MBR process is unlikely to be able, on its own, to achieve the required level of treatment for many of the metals included on the consent although it is likely to perform better than an SBR due to the fact that any metals associated with solids larger in size that fine colloidal material should be retained within the treatment tank and removed as part of any de-sludging exercise. Therefore a separate process will be required to achieve further metals reductions. A further polishing step is almost certainly required in any case to ensure residual BOD and ammonia are treated prior to discharge, this typically being provided by reed bed systems Such systems would be less prone to clogging and fouling than in a similar SBR based system.

The MBR process may be able to provide sufficient levels of de-nitrification should this be required and would also be able to reduce COD by a further 50% in comparison to the SBR process as much of the un-treatable, recalcitrant COD is made up of large molecules and particles that will not pass an ultrafiltration process. COD levels as low as 500mg/L can be produced from influent leachates with over 5,000mg/L. However, such a membrane process will have no effect on dissolved metals in their simplest, elemental forms. They will also not be able to further reduce Chloride in the effluent should restrictions be applied.

As such, the following system has been considered for an MBR Plant at the Ghallis Landfill site:

1. Raw Leachate Balance Tank;
    - 80m^3 for 40m^3/day plant, 50m^3 for 25m^3/day plant, assume epoxy or glass coated steel, bunded tanks.

2. MBR Tank:
    - Estimated at 927m^3 for 40m^3/day plant, 580m^3 for 25m^3/day plant, assume epoxy or glass coated steel, bunded tanks.

3. Chemical Dosing Systems;
    - 35m^3 bunded caustic tank and dosing pumps (HDPE);
    - 1m^3 antifoam tank and dosing pumps (HDPE);
    - Phosphoric (barrels);

4. ISO Containers:
    - 12.2m x 2.4m x 2.4m containing PLC and SCADA.

5. Ultrafiltration plant:
    - 12.2m x 2.4m x 2.4m containing cross flow UF plant: or

6. Sludge Management System

7. Effluent Balance Tank:
    - 45m^3 for 40m^3/day plant, 530m^3 for 25m^3/day plant, assume epoxy or glass coated steel, bunded tanks.

8. General Civils and Ancillaries:
    - Concrete hard standing with bunding provided by 1m high concrete walls;
    - General pipework / electrics etc;
    - Off-Gas scrubber (if required);
    - General access and security;
    - All health and safety features.

9. Reed Beds:
    - 2 x 165m^2 reed bed systems incorporating replaceable sections for 40m^3/day plant, 2 x 90m^2 reed bed systems incorporating replaceable sections for 25m^3/day plan.

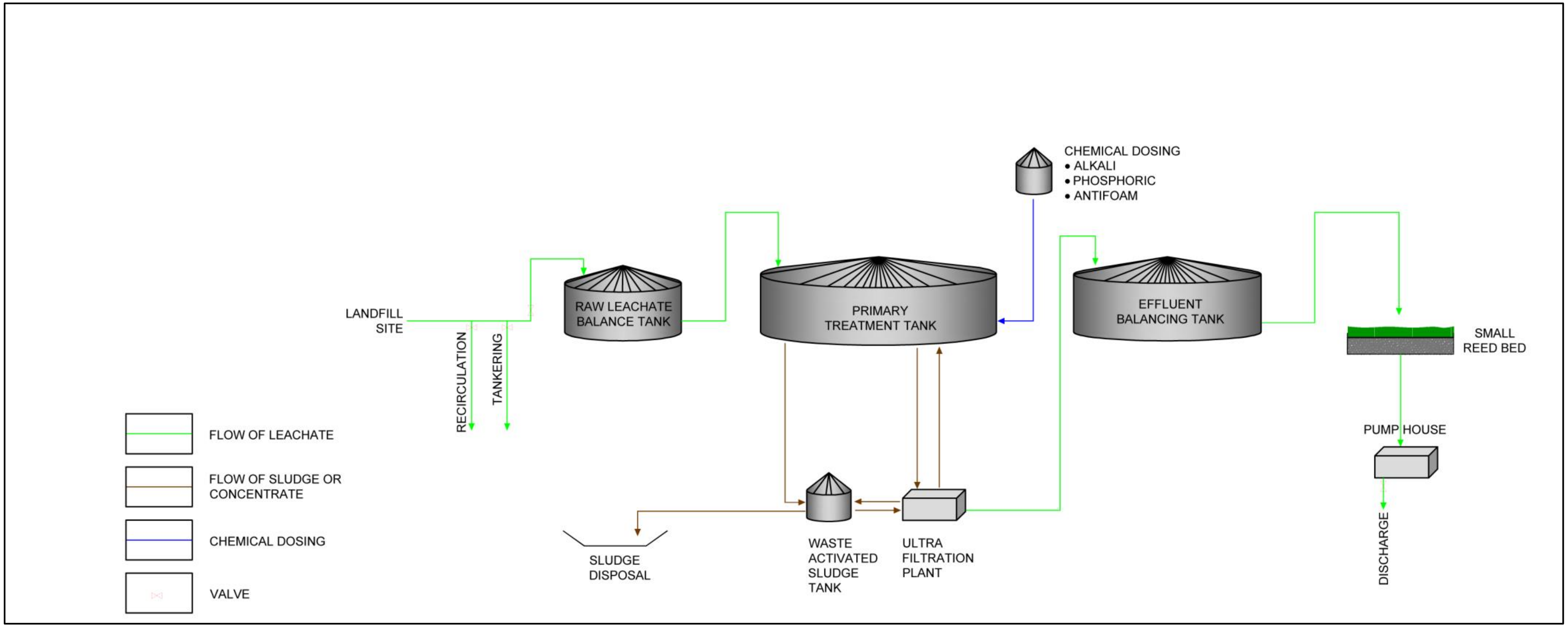
10. Effluent Discharge Pipeline:
    - 165m long complete with 25m sea outfall with headwall and if Bathing Beach Directive is an issue, UV disinfection system.

11. Under-Cap Recirculation :
    - Engineered sub-cap recirculation drainage systems for 25m^3/day LTP version.

Overall estimate of plant footprint: 480m^2 for 40m^3/day plant and 300m^2 for 25m^3/day plant.

An outline process flow diagram is presented as Figure 8 for an MBR process.

Figure 8
Generalised MBR Plant Process Flow Diagram



7.5.3 Operational and Environmental Considerations

Operational: MBR plants can typically produce a high quality effluent and are less prone to periods of instability caused by issues such as toxic shock, plant overloading, high or low operating temperatures or development of incorrect operating conditions (high or low pH, low dissolved oxygen etc.) than SBR's. Most of these issues can be overcome with a combination of good plant design and management by a skilled and experienced operator. However, it is likely that to provide the level of control needed at such a plant, at least two and a half full days per week of an operators time will be required to keep the LTP performing well.

The requirement to operate the filtration system at an MBR plant can be very time consuming particularly if cross flow membranes are used. Typically at least another 1.5 days per week can be added to the manpower requirement to accommodate operating the cross flow membrane system although it should be noted that this is not usually experienced as a regular additional 1.5 days spent on site. Instead it is normal for occasional UF blockages to take several days at a time to resolve. Employment of flat sheet membranes or Baleen filtration is likely to be less onerous adding only an additional 10 days per year to the basic 1 day per week plant operation requirement to allow for periodic maintenance.

Because it is relatively easy for biological processes to become unstable, frequent sampling and analysis of influent leachate and effluent quality would be required with fine adjustment of the LTP process to accommodate any changes.

It is estimated that such an MBR, if operated as a nitrification only process, could consume up to 50L of 32% sodium hydroxide for every cubic metre of leachate treated. Therefore such a plant could require around 60m^3/month of sodium hydroxide for a 45m^3/day LTP or 38m^3/month for a 25m^3/day LTP. Therefore storage volumes of in excess of one taker load should be provided, for example 35m^3. Requirements for antifoam and phosphoric acid storage would be much less than this at around 1m^3 each. Should a de-nitrification process be chosen then usage of chemicals could be dramatically reduced, perhaps using little other than antifoam and phosphoric acid as a nutrient source. However, it is advised that facility to rapidly install storage and dosing for acid, alkali and a carbon source should still be included if a de-nitrification process is employed, as variations in raw leachate quality over time could mean that chemical dosing may be needed from time to time.

Whilst the mechanical operation of the plant can be highly automated and provision of high specification PLC and SCADA systems result in the possibility of largely remote operation and control, it is not readily possible to provide automated analysis of influent leachate strength and effluent quality to the degree of accuracy that would be required to fully automate plant operations. Raw leachate would need to be monitored for ammonia. Similar analysis would be required on the effluent.

On-going maintenance issues such as probe cleaning and calibration, aeration system removal and inspection (if equipment with moving parts are submerged in the treatment tank) and supervision of de-sludging and chemical deliveries mean that such a plant is likely to require high operator input.

Health and Safety: Aside from those risks associated with any industrial activity of this nature such as slips, trips and falls, working around vehicles, working at height etc., would focus on the handling and storage of chemicals, the production and control of sludges and the inspection of equipment submerged in tanks. Should acids also be required to be stored to assist with de-nitrification, off-gas and vapour management would need to be included in any process design.

Environmental: The MBR process is capable of producing a high quality effluent if operated correctly. At the Ghallis landfill it will need to be operated in conjunction with polishing processes to achieve the proposed consent conditions, although these may be less onerous than with an SBR as some of the metals will be retained behind the filtration process.

The process is susceptible to instability during which time non-compliant effluent can be discharged. If monitored closely (for example daily) such issues can be detected and resolved before any contaminant is released to the environment. Conversely, if not detected, non-compliant discharges can take place. The inclusion of the membrane process tends to prevent issues associated with discharges of solids but problems associated with shock loading can still exist. This can be partially accommodated by using large tanks and reed beds etc. to provide buffering and dilution so that any one ‘missed’ event is not likely to cause environmental harm. However a succession of such events would be of concern and could result in environmental damage.

In addition, the MBR process is likely to produce waste activated sludge which will need to be disposed from the site. If sludge drying process are not included disposal could be as high as $10m^3$/month or $120m^3$/year. Sludge drying could significantly improve the sustainability of managing such sludges as solids will represent only around 4% of this volume so could easily be reduced to around 12 tons per year of dry solid.

Odours and noise are not typically reported as problems from such plant. Foam production can however be an issue if the biological process is ‘stressed’. This can cause tanks to over-foam, overwhelming control features and escaping the tank. Such foam is usually contained within the LTP bunded area but can cause a problem if it becomes windblown.

Employment of pre de-nitrification should be seriously considered, particularly if used in conjunction with submerged flat sheet membranes or Baleen filters. This treatment process is likely to result in considerably reduced used of process chemicals, also reducing their associated health and safety risks as well as operator time to manage deliveries etc. It would also have a significant effect in reducing treatment costs as well as reducing the need to maintain chemical storage and dosing equipment. The process would also be more robust and so would present less of a risk to the environment. The anoxic stage of treatment would provide a ‘selector’ process, encouraging the development of only those microorganisms that are useful in leachate treatment. Use of influent COD and BOD as a carbon source would also reduce the ability of the substances to ‘shock’ the process, again reducing operator input and improving process stability and robustness.

The main drawback of such a process is that it tends to be more costly to install, although the potential for significantly reduced treatment rates often enables such investment to pay for itself. In addition, the de-nitrification process tends to produce more sludge for disposal. This can be partially compensated for by the ability to operate such processes at higher MLSS with consequent increased auto-digestion of dead sludge but nonetheless it must be expected to need to dispose of additional waste sludge from such a process. However, if the plant were to be installed with a feature such as a sludge drying reed bed the possibility of doubling sludge production would only mean an annual dry solids disposal requirement of 24 tons as opposed to 12 tons from a nitrification only system.

7.6 Reed Beds

Reed bed (or wetland) treatment systems have been used throughout Europe and the UK for many years in the treatment of landfill leachate and other industrial and waste water effluent applications. There are many different reed bed designs, each targeted at different contaminants of concern.

Typically however a reed bed is an engineered structure, usually a shallow excavation of around 1m in depth into which is placed an impermeable liner. Media, usually washed gravel, is place within the bed along with effluent distribution and collection systems. The bed is designed to provide physical filtering as well as locations for the development of biofilms. Beds are then frequently planted with reeds who's function is to transfer oxygen from leaves and stems into the layer around their root structure, thus encouraging some aerobic activity whilst the roots also maintain hydraulic pathways though the bed structure. Various processes take place within the bed that lead to destruction and retention of pollutants within the bed system; these include sedimentation, co-precipitation, adsorption microbial degradation and chemical breakdown.

There are three main types of reed bed construction:

Surface Horizontal Flow: Usually targeted at the treatment of suspended solids and metals. The bed is designed to allow flow between reed stems which are usually planted in a soil layer. Beds allow for flow balancing and sedimentation to occur but are not designed for further BOD removal as there is little aerobic activity or contact with biofilms.

Subsurface Horizontal Flow: Usually targeted at the treatment of low BODs and suspended solids along with polishing of other organic contaminants (COD and ammonia) plus removal of some heavy metals. Beds are designed to allow flow through the gravel media and around the root systems of reeds where the effluent can come into contact with various niche ecosystems of different microorganisms that effect the further treatment processes taking place in the beds.

Vertical Flow: Usually targeted at the treatment of high BOD's, ammonia and sludges. Effluent is distributed evenly across the surface of the bed using a network of pipes, flooding the bed several times per day. Effluent then drains vertically through a graded gravel bed with reeds planted in the upper surface, drawing oxygen down through the bed as it descends.

Various other reed bed system designs exist, for example variants of the above include 'Forced Bed Aeration' where the bed is kept aerobic by the introduction of air blown in and diffused via a buried pipework system. Alternatives also exist that employ ponds with floating reed rafts rather than true beds. In addition beds can be augmented by use of different media to make up the bed structure, for example inclusion of adsorbent materials or materials with ion exchange capabilities can improve the beds ability to removal certain contaminants such as metals. Other systems employ 'sacrificial' areas, usually at the inlet to the bed that can be easily dug out and replaced or remediated on a periodic basis. Typically a number of individual beds, perhaps of slightly different designs targeted at particular contaminants of concern, are used in conjunction with one another in series or in parallel. Application of pre-treated effluents to short rotational willow coppice is also included within the grouping of reed beds. The soils in which the coppice is planted acts in a similar fashion to the media incorporated in a reed bed system providing aerobic and anoxic zones for different treatment process to take place whilst the willows themselves also take up some contaminants, utilising much of the water applied during summer months resulting in a much reduced or in dry weather no discharge requirement.

Once installed a well-designed bed should require very little maintenance and should take up almost no operator time on a routine, weekly basis. Reed bed maintenance is more usually performed on a 'campaign' basis with annual or seasonal maintained to clear weeds, improve drainage or remove excess growth. Beds should also consume minimal electricity and therefore have no running costs. Maintenance usually amounts to weeding during bed establishment followed by annual or every other year agricultural maintenance (rough cleaning of dead leaves etc.).

The primary methods for metals reduction in a wetland system such as a reed bed will be co-precipitation and adsorption into the sediments. However, some papers report that removal of metals within a wetland is inhibited by high concentration of sodium and chloride within the effluent matrix, as is the case at the Ghallis landfill.

7.7 Facultative Lagoons

Facultative, or Long Retention Time, lagoons have been traditionally used to treat liquids contaminated with organics where operators have very large areas of land available to allow construction and operation of very long retention time lagoons (typically in excess of 2 months but often much longer retention time dependant on pollutant loading). Gentle aeration and a mixing of large surface area lagoons that are at least 2m deep is used to create a stratified facultative process. Typically 3 layers are maintained and liquid moved between them. The process can be disrupted by changes to loading, disruption to the layers and other environmental factors such as changes to temperature and pH. If very large lagoons are practical then this process potentially has a wide range of applications.

In the treatment of landfill leachate this process is sometimes used in conjunction with irrigation of effluent to biomass irrigation plots (typically Short Rotational Willow Coppice, Miscanthus or other high water demand plants). Where irrigation to biomass is used as a means of disposal of effluent without the need for discharge off-site, large storage lagoons are needed in any case as irrigation can only take place during the growing season and when there is low rainfall. As leachate production and the subsequent need for treatment is continuous this seasonality of irrigation is accommodated by storage of up to 6 months of production in large lagoons prior to irrigation to large plots for 6 months.

As large lagoons are required to accomplish this storage in any-case, it is finically practical to operate the lagoons as Facultative treatment as well as storage lagoons. In this way a relatively low cost pre-treatment and on-site disposal option can be installed. As such Lagoon / SRC leachate treatment systems can be relatively low cost to construct and are very low cost to operate. They also have a significant role to play if discharge of treated off-site to a sewer or receiving water body are not possible.

Drawbacks can be that very large areas are needed for construction of suitably sized lagoons and for planting of large biomass irrigation plots (several hectares are required). At landfill sites irrigation plots are often planted on the landfill cap after installation of restoration soils, some regulatory authorities finding this problematic to regulate as irrigation of treated effluent to the plots can be interpreted as deposit of waste to ground outside of the permitted area. In addition, continuous irrigation of treated landfill leachate to the plots results in several tons per annum of substances such as sodium and chloride which whilst unlikely to be detrimental in terms of biomass growth does result in the soils becoming laden with salts. These can wash out in heavy rainfall events, potentially contaminating surrounding watercourses with brackish water and the soils may eventually need to be removed and disposed after 30 years or more of effluent application.

Lagoon / SRC plants usually comprise a Primary and Secondary facultative leachate lagoon, each holding as much as 20,000m^3 of liquid. Floating aerators / mixers are installed to each lagoon along with transfer pumps to move leachate from the Primary to the Secondary lagoon. Pre-filters and pumps are often housed in an ISO Container along with simple controls for the process. Pumps in the container distribute treated effluent during the growing season to a number of different irrigation plots where drip feed irrigation systems are installed. Plots are planted with high water uptake plants such as willow or Miscanthus. Irrigation plots are often contained or surrounded by drainage ditches to intercept and divert any potentially contaminated run-off back to the Facultative Lagoons. Biomass is regularly harvested (on a 3 to 4 year cycle) and in some instances can be sold as biomass fuel.

Lagoon / SRC plants are generally very large plants that are more akin to an agricultural rather than an industrial process.

7.7.1 Process Description

Raw leachate would be pumped from the landfill site to the location of the Facultative lagoons. Lagoons would be set up as a Primary and Secondary lagoon, each of which would be between 4,000m^2 and 6,000m^2 in area and each holding between 8,000m^3 and 15,000m^3 depending on the desired throughput (25m^3/day or 40m^3/day).

Each lagoon would be installed with level control devices to prevent them overtopping and aerators / mixers to enable gentle mixing and aeration. The Primary lagoon would be operated at a more or less constantly full level with periodic transfer of effluent into the Secondary Lagoon. The majority of leachate treatment, effectively the same nitrification and de-nitrification process described in Section 7.2 above would take place in the Primary lagoon with some further treatment taking place in the Secondary lagoon which would also act as ‘winter’ storage. However, the rate of treatment would be very low and so would not require inputs of process chemicals or significant operator intervention; however this is only achieved by lagoons being of such large capacity.

During the growing season and when rainfall amounts are below the water needs of the planted biomass crop, treated effluent would be drawn at effectively double the leachate production rate and pumped, via pre-filters, to drip feed irrigation pipework installed to Willow or Miscanthus irrigation plots. Here plant will take up the treated effluent and much of the remaining pollutant it contains and use them as water and micro-nutrients to enable rapid growth. The resultant evapotranspiration from the plants effectively ‘disposes’ of the liquid applied to them. Liquid can only be applied at a rate that makes up for the water deficit produced as a result of the rapid growth of the biomass crop and the low levels of rainfall.

Primary and Secondary lagoon sizing has been estimated using models developed for similar plants operating in the UK. Similarly, irrigation plot sizing has been estimated on the basis that to grow Willow as a short rotational coppice (SRC) requires 110mm/mth rainfall equivalent in each 'growing season' month (when temperatures are greater than 5^{o}C). On Malta this suggests irrigation could take place for most of the year and that the annual rainfall deficit for a hectare of land planted with SRC would be in the region of 7,000m^3/ha/yr.

Facultative lagoon operation can typically continue uninterrupted and with little requirement for manual intervention for months at a time. Similarly, management of irrigation systems is relatively simple requiring response to actual rainfall by adjustment of volumes of irrigation. Periodic management (possibly harvesting) of the biomass crop is also required on an annual cycle.

As such, the following system has been considered for a Facultative lagoon and SRC system at the Ghallis Landfill site:

1. Primary Lagoon;
    - 14,800m^3 (5,900m^2 surface area) for 40m^3/day plant, 9,400m^3 (3,800m^2 surface area) for 25m^3/day plant, assume HDPE and GCL composite liner.

2. Secondary Lagoon;
    - 13,300m^3 (5,300m^2 surface area) for 40m^3/day plant, 8,400m^3 (3,400m^2 surface area) for 25m^3/day plant, assume HDPE and GCL composite liner.

3. Pump and Controls Container:

- 12.2m x 2.4m x 2.4m Containing all pumps, pre-filtration and valve equipment, controls and PLC / SCADA.

4. SRC Plots:
   - 4.3ha[5] for 40m^3/day plant, 2.8ha[5] for 25m^3/day plant, including plot preparation, plating, irrigation pipework, fencing and ditching.

5. General Civils and Ancillaries;
   - General pipework / electrics etc;
   - General access and security;
   - All health and safety features.

6. Under-Cap Recirculation :
   - Engineered sub-cap recirculation drainage systems for 25m^3/day LTP version.

Overall estimate of plant footprint: 5.6ha for 40m^3/day plant and 4.6ha for 25m^3/day plant.

An outline process flow diagram is presented as Figure 9.

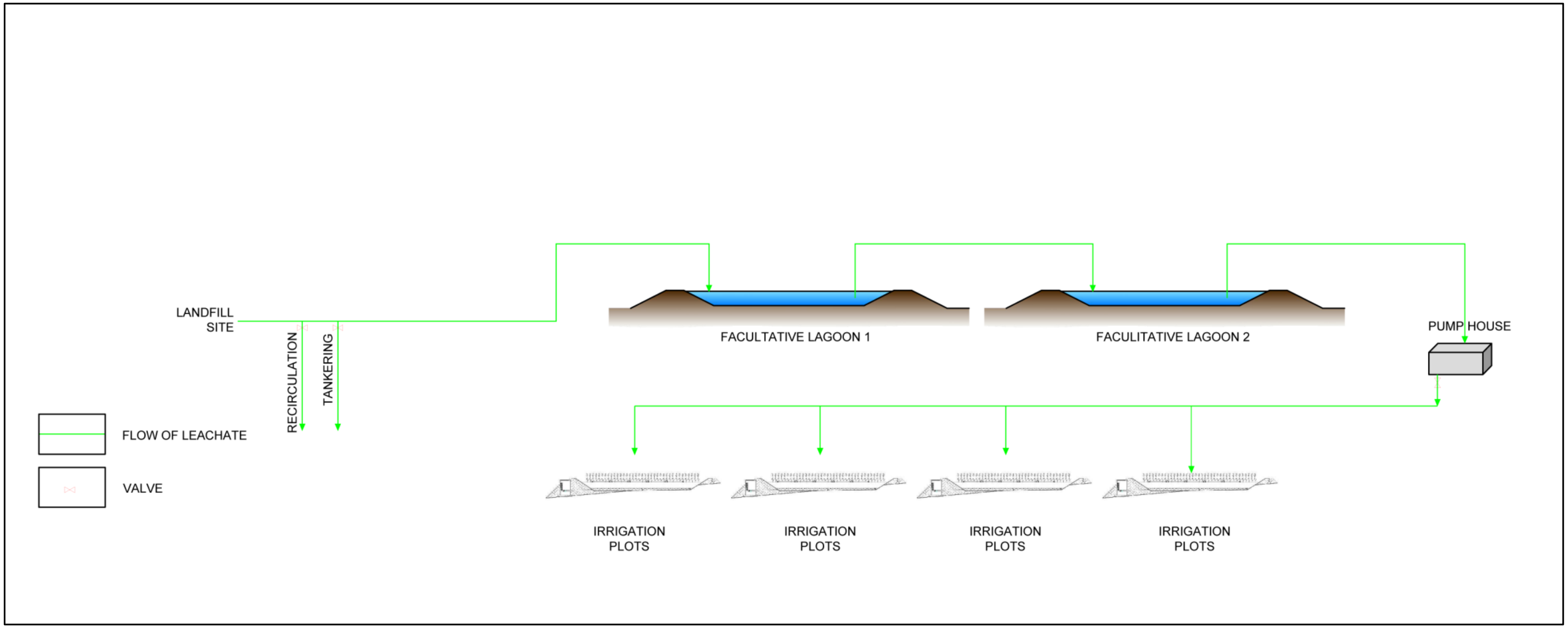
7.7.2 Operational and Environmental Considerations

Operational: Use of Facultative Lagoons and SRC at the Ghallis landfill would have one main advantage, the lack of a need to obtain a discharge consent from site for treated effluent. Other advantages are that such a system would have, once set up, very low operator requirements.

It is however highly reliant on prevailing weather conditions (should high rainfall years occur then throughputs are restricted) and the availability of large areas of land. Agricultural management of willow plots generally consist of harvesting of willow sub-plots on an annual basis such that the entire SRC is harvested once every 4 to 5 years. Biomass produced can be used as a biomass fuel and can generate a small income. Chemical usage would be limited to the occasional use of herbicides and pesticides should the biomass crop requires it. Because the treatment process is of such a low rate little intervention is required and little power is used. Maintenance requirements tend to be 6 monthly or annual servicing of aerators and pumps. Irrigation plots are usually dosed with effluent on a rotating basis between sub-plots, some areas being 'rested' when others are 'active'. This can be achieved by automated valve system or by manual intervention by an operator. During irrigation periods the operator also has to be aware of and respond to rainfall event so that over-irrigation is avoided.

[5] Note that this plot sizing is based on area required for irrigation purposes, to apply the anticipated annual loading of Chloride in compliance with loading rates recommended for agricultural purposes would require 88ha (for a 40m^3/day plant) or 55ha (for a 25m^3/day plant). As this is impractical there is a risk that Chloride accumulation in the soil may eventually inhibit plant growth, deteriorate soil structure or result in saline run-off from plots.

Figure 9
Generalised Facultative Lagoon and SRC Plant Process Flow Diagram



Health and Safety: Aside from those associated with any industrial activity of this nature such as slips, trips and falls, working around vehicles, working at height etc., would focus on the issues surrounding large open lagoons (drowning etc.) and working within coppice plots where slips, trips and falls can be a problem.

Environmental: The Facultative lagoon and SRC process can be seen as a very environmentally friendly treatment technique as it has very low resource usage (low power and chemical demand), results in large areas of grass or coppice that is a haven for wildlife and ultimately can produce a crop that may be commercially desirable. However, issues remain with the possible fate of some contaminants that will get deposited to the irrigation plot soils and may accumulate, requiring disposal at a later date, or run off, potentially polluting local water courses.

The process is a relatively novel method of leachate disposal and tends only to be considered where it is not possible to dispose of treated effluent via more conventional routes.

7.8 Common Ancillary Plant and Equipment

Certain elements of LTP plant and equipment will be required regardless of the nature of the treatment process chosen. For example, the LTP will be required to be provided with suitable bunding in accordance with current guidance, suitable access for de-sludging and maintenance, security fencing and site drainage.

Various methods of providing bunding are available, from bunding each individual tank through to bunding whole areas. Options exist to create large bunds which are then partially backfilled with drainage stone (or similar) to provide working areas. Similarly, shallow bunds can be created and lined with concrete. Many Regulators express a preference for concrete lined bunding as this will enable any incidental spills to be easily cleaned. Such large bunded areas will also need to be fitted with surface water drains and pump out facilities, usually automated, so that ‘clean’ water can be discharged to site surface water control ditches but if contaminated, water is pumped and treated as leachate.

Costs associated with providing bunding are driven by the maximum tank size to be contained. It is possible to provide the same volume of storage in a larger number of smaller tanks or in a single larger tank. Use of smaller tanks obviously means that the maximum tank size is reduced; this then enables a smaller bund size to be provided, potentially saving costs. However, any potential cost savings may be negated by increased costs to construct two tanks in comparison to one (two tanks providing the same storage volume as one typically requires around 30% more linear tank wall for example) and the increased complexity of pumping and control of two tanks in comparison to one. Similarly, it is possible to construct tanks in a concentric, ‘nested’ fashion that may also present advantages in terms of efficient use of space and control systems.

Whilst such considerations may not be critical at the Ghallis landfill it should be considered at design stage in terms of potentially offering cost savings.

Further consideration may be given to overall Plant capacity. At present it is assumed that a maximum throughput of 45m^3/day but WasteServe may wish to limit the size (and therefore to some extent the cost) of an LTP to 25m^3/day with associated recirculation of leachates.

7.8.1 Design Considerations

A number of variations on the main treatment process are worthy of consideration;

SBR versus MBR; SBR type plant designs are cheaper to install as the purchase of a relatively sophisticated membrane filtration system is not required. SBR's also tend to be cheaper to operate as, even with the lower operating costs of a submerged flat sheet membrane rather than a cross flow type system, they still require cleaning and maintenance and consume both power and operator time that is not required by an SBR. However, the provision of the physical membrane process does allow a greater surety that the effluent produced is free from solids. This has the benefit of ensuring that the effluent is compliant in terms of solids content and generally provides more surety that metals present in association with solids do not pass to discharge. In addition, the presence of a membrane ensures that 'downstream' plant such as reed beds do not become unnecessarily clogged by biological solids. In addition, there are implications for compliance with the Bathing Beach Directive (should this apply) as the membranes may provide sufficient disinfection themselves but will in any case make operation of other disinfection processes such as UV simpler and more cost effective. Also, the main treatment process can be operated more 'robustly' than in the case of an SBR where, if the biomass becomes stressed, solids carry-over is often the result, this also means that a higher solids content can be accommodated in the treatment tank, allowing the tank footprint to be much smaller for the same treatment loading. Operation of a filtration system such as a membrane allows for easier inclusion of a de-nitrification step in the treatment process if required as de-nitrifying sludges are more difficult to 'settle' than nitrification only sludges.

In short, the MBR process generally allows for a greater process flexibility (accommodates 'shock' more easily, allows easier operation of an 'anoxic' stage if required) and increased reliability of effluent quality. This comes at a cost in terms of increased capital and operational costs. Choice of membrane system can alter the balance of capital and operation costs but cannot reduce them to the same level as for SBR.

Nitrification only versus Nitrification and de-Nitrification; Unless de-nitrification is actually required by the discharge consent then addition of a de-nitrification step can seem to add unnecessary capital expense and over complication of the treatment process. However, introduction of a de-nitrification step does have several advantages as it tends to decrease the full life-time costs of the plant as process chemical costs can be significantly reduced if pre de-nitrification is employed, so over a 10+ year period a de-nitrification plant can be a better investment. In addition, the introduction of the de-nitrification process improves stability and robustness of the treatment plant, reducing the requirement for operator input and the risk of non-compliance. This is achieved via three main mechanisms; the anoxic stage acts as a 'selector' mechanism encouraging only those microorganisms beneficial to the process whilst selecting against those that cause issues such a foaming; the anoxic stage reduces the need for process chemicals and so reduces the need to supervise delivery of such materials; the anoxic stage requires organic carbon, this being present in leachate as BOD and elements of the COD means that instead of these constituents being a risk to the process they become a resource.

8.0 FINANCIAL MODELLS

Financial models have been constructed for the following potential treatment plant combinations so that initial capital costs and on-going operational costs can be considered. Consideration has been given to processes operating at 40m^3/day and at 25m^3/day with recirculation of excess leachate back to the landfill. In this way a 'whole life' cost of operating one treatment plant versus another can be estimated. LTP configurations considered are as follows:

- Reverse Osmosis;
- Sequence Batch Reactor;
- Membrane Bio Reactor;
- Aerated Lagoon SBR; and
- Facultative Lagoons and SRC

Outline costs have been estimated based on recent quotations for similar plant from a number of potential suppliers in the UK in addition to information and experience obtained by SLR on other similar projects to estimate both capital and operational costs. Quotes received often contain different cost elements and have been submitted in various forms so direct comparison of costs has not been possible. Instead SLR have used their experience to extract and compare similar cost items to build up a typical plant cost on a like-for-like basis from each quote received. In addition to the main treatment process costs a number of ancillary plant elements have also been included for each option considered.

Costs have been converted from UK Sterling to Euro using the following exchange rate: £1.00 : €1.31.

8.1 Plant Capital Costs

It should be noted that the plant concepts modelled are thought to be reasonable approximations of likely plant that would be appropriate for the situation at the Ghallis landfill, however should the project move forward it is likely that during any procurement and detailed design stages, changes to the outline design concepts may be made that could introduce additional costs or indeed cost savings.

Capital costs for the various plant configurations have assumed a designed maximum throughput of 40m^3/day and at 25m^3/day. Assumed capital costs are presented in Table 8-1.

As at this stage it is not known if the Bathing Beach Directive would apply, capital costs associated with plant capable of disinfecting the discharge from the site have not been modelled. Should such plant be required it is likely that it would be most expensive to supply for the SBR and Lagoon based SBR processes as effluents would not have already passed through a membrane process. It is likely that in such circumstances a capital cost in the region of €100,000 may be required. If a smaller plant were required after a membrane process, such as an MBR, this may reduce to around €20,000 to install.

Table 8-1
Modelled LTP Capital Costs

Plant Element	Reverse Osmosis Plant Cost €		Sequence Batch Reactor Plant Cost €		Membrane Bio Reactor Plant Cost €		Aerated Lagoon SBR Plant Cost €		Facultative Lagoon and SRC Plant Cost €	
	40m^3/d Option	25m^3/d Option	40m^3/d Option	25m^3/d Option	40m^3/d Option	25m^3/d Option	40m^3/d Option	25m^3/d Option	40m^3/d Option	25m^3/d Option
Raw Leachate Storage	52,400	39,300	65,500	52,400	65,500	52,400	13,100	10,480	-	-
Treatment Vessel	196,500	131,000	284,270	162,440	157,200	98,250	109,326	68,329	-	-
Effluent Storage Vessel	65,500	52,400	45,850	39,300	45,850	39,300	6,550	5,240	-	-
Insurances	20,960	20,960	20,960	20,960	20,960	20,960	20,960	20,960	20,960	20,960
Design / Supervision / Management	80,696	80,696	115,280	115,280	115,280	115,280	115,280	115,280	26,200	26,200
Mechanical Equipment	52,400	26,200	165,060	94,320	344,792	171,348	111,350	81,875	65,500	65,500
Electrical Systems	89,080	89,080	89,080	89,080	89,080	89,080	89,080	89,080	39,300	39,300
Instrumentation / Controls	27,248	27,248	68,120	68,120	68,120	68,120	68,120	68,120	13,100	13,100
General Items (control room, software etc.)	47,160	47,160	47,160	47,160	47,160	47,160	47,160	47,160	13,100	13,100
Civils (compound etc.)	65,500	28,820	125,760	75,456	75,456	45,274	52,400	28,820	-	-
Wetlands / Reedbed	-	-	170,300	91,700	85,150	45,850	170,300	91,700	-	-
Discharge Pipeline	52,400	52,400	68,487	68,487	68,487	68,487	68,487	68,487	-	-
Re-circ Systems	-	52,400	-	52,400	-	52,400	-	52,400	-	52,400
Facultative Lagoon Systems	-	-	-	-	-	-	-	-	356,947	236,483
SRC Plot Preparation and Planting	-	-	-	-	-	-	-	-	34,033	22,161
SRC Irrigation Systems	-	-	-	-	-	-	-	-	39,300	39,300
Total	**749,844**	**647,664**	**1,265,827**	**977,103**	**1,183,035**	**913,908**	**872,113**	**747,931**	**608,439**	**528,504**

Note * To Sea (SBR and MBR): Discharge pipeline from existing tank to 25m off-shore + headwall etc.
To Sewer(RO): Discharge pipeline (assume up to 500m) + connection manhole

8.2 Plant Operational Costs

Costs associated with operating each LTP option have also been estimated. These are based on a combination of estimates received by SLR from potential plant suppliers as well as SLR experience of operating similar processes within the UK. Operational costs are made up of fixed annual costs and also volume driven costs.

Operational costs are estimated for each process as follows in Table 8-2. As at this stage it is not known if the Bathing Beach Directive would apply, operating costs associated with plant capable of disinfecting the discharge from the site have not been modelled. Should such plant be required it is likely that it would be most expensive to operate for the SBR and Lagoon based SBR processes as effluents would not have already passed through a membrane process. It is likely that in such circumstances an annual operational cost in the region of €4,000 may be required. If a smaller plant were required after a membrane process, such as an MBR, this may reduce to around €2,000 per annum.

Table 8-2
Modelled LTP Operational Costs

Process	Power		Chemical		Disposal of Wastes		Coppice Management		Maintenance		Manpower		Consumables		Monitoring	
	Item	€/m^3	Item	€/m^3	Item	€/m^3	Item	€/yr	Item	€/yr	Item	€/yr	Item	€/yr	Item	€/yr
40m3/d RO	Assume 14.0kWh/m^3 @ €0.08/kWh	1.12	Assume €0.92/m^3 for alkali and acid	0.92	Concentrate Disposal	0	n/a	0	Assume 2.0% of Capital Cost per year	14,997	25% share of full employment cost @ €32,000/yr	8,000	H&S equipment, etc.	3,275	Sampling and analysis costs	6,550
25m3/d RO	Assume 14.0kWh/m^3 @ €0.08/kWh	1.12	Assume €0.92/m^3 for alkali and acid	0.92	Concentrate Disposal	0	n/a	0	Assume 2.0% of Capital Cost per year	12,953	25% share of full employment cost @ €32,000/yr	8,000	H&S equipment, etc.	3,275	Sampling and analysis costs	6,550
40m3/d SBR	Assume 6.0kWh/m^3 @ €0.08/kWh	0.48	Assume €8.03/m^3 for alkali and €0.26/m^3 for antifoam & phosphoric	12.3	Sludge disposal (assume maximum of 0.002m^3 per m^3 treated at €23/m^3 for disposal)	360	n/a	0	Assume 1% of Capital Cost per year	12,658	25% share of full employment cost @ €32,000/yr	8,000	H&S equipment, etc.	2,620	Sampling and analysis costs	6,550

Process	Power		Chemical		Disposal of Wastes		Coppice Management		Maintenance		Manpower		Consumables		Monitoring	
	Item	€/m^3	Item	€/m^3	Item	€/m^3	Item	€/yr	Item	€/yr	Item	€/yr	Item	€/yr	Item	€/yr
25m3/d SBR	Assume 6.0kWh/m^3 @ €0.08/kWh	0.48	Assume €8.03/m^3 for alkali and €0.26/m^3 for antifoam & phosphoric	12.3	Sludge disposal (assume maximum of 0.002m^3 per m^3 treated at €23/m^3 for disposal)	360	n/a	0	Assume 1% of Capital Cost per year	9,771	25% share of full employment cost @ €32,000/yr	8,000	H&S equipment, etc.	2,620	Sampling and analysis costs	6,550
40m3/d MBR	Assume 10.0kWh/m^3 @ €0.08/kWh	0.8	Assume €8.03/m^3 for alkali and €0.52/m^3 for antifoam & phosphoric	12.6	Sludge disposal (assume maximum of 0.003m^3 per m^3 treated at €23/m^3 for disposal)	360	n/a	0	Assume 1.5% of Capital Cost per year	17,746	50% share of full employment cost @ €32,000/yr	16,000	H&S equipment, etc.	3,275	Sampling and analysis costs	6,550
25m3/d MBR	Assume 10.0kWh/m^3 @ €0.08/kWh	0.8	Assume €8.03/m^3 for alkali and €0.52/m^3 for antifoam & phosphoric	12.6	Sludge disposal (assume maximum of 0.003m3 per m^3 treated at €23/m^3 for disposal)	360	n/a	0	Assume 1.5% of Capital Cost per year	13,709	50% share of full employment cost @ €32,000/yr	16,000	H&S equipment, etc.	3,275	Sampling and analysis costs	6,550

Process	Power		Chemical		Disposal of Wastes		Coppice Management		Maintenance		Manpower		Consumables		Monitoring	
	Item	€/m^3	Item	€/m^3	Item	€/m^3	Item	€/yr	Item	€/yr	Item	€/yr	Item	€/yr	Item	€/yr
40m3/d Aerated Lagoon SBR	Assume 5.0kWh/m^3 @ €0.08/kWh	0.4	Assume €8.03/m^3 for alkali and €0.26/m^3 for antifoam & phosphoric	12.3	Sludge disposal (assume maximum of 0.002m^3 per m^3 treated at €23/m^3 for disposal)	360	n/a	0	Assume 0.75% of Capital Cost per year	6,541	25% share of full employment cost @ €32,000/yr	8,000	H&S equipment, etc.	2,620	Sampling and analysis costs	6,550
25m3/d Aerated Lagoon SBR	Assume 5.0kWh/m^3 @ €0.08/kWh	0.4	assume €8.03/m^3 for alkali and €0.26/m^3 for antifoam & phosphoric	12.3	Sludge disposal (assume maximum of 0.002m^3 per m^3 treated at €23/m^3 for disposal)	360	n/a	0	assume 0.75% of Capital Cost per year	5,609	25% share of full employment cost @ €32,000/yr	8,000	H&S equipment, etc.	2,620	Sampling and analysis costs	6,550
40m3/d Facultative Lagoon SRC	Assume 14,000kWh/yr @ €0.08/kWh	€1,120 per year	n/a	0	n/a	0	Coppice felling etc.	2,692	Assume 1.0% of Capital Cost per year	6,084	25% share of full employment cost @ €32,000/yr	8,000	H H&S equipment, etc.	3,275	Sampling and analysis costs	6,550

Process	Power		Chemical		Disposal of Wastes		Coppice Management		Maintenance		Manpower		Consumables		Monitoring	
	Item	€/m^3	Item	€/m^3	Item	€/m^3	Item	€/yr	Item	€/yr	Item	€/yr	Item	€/yr	Item	€/yr
25m3/d Facultative lagoon SRC	Assume 8,680kWh/yr @ €0.08/kWh	€694 per year	n/a	0	n/a	0	Coppice felling etc.	2,692	Assume 1.0% of Capital Cost per year	5,285	25% share of full employment cost @ €32,000/yr	8,000	H&S equipment, etc.	3,275	Sampling and analysis costs	6,550

8.3 Financial Models Output

Detailed 30 year cost models are included in Appendix D. A summary of the modelled financial performance is presented in Table 8-3 for a maximum 40m^3/day LTP. Table 8-4 presents the same information for a maximum 25m^3/day plant.

Table 8-3
Summary of 40m^3/day LTP Cost Models

Filling Scenario	LTP Option	Capex €	Opex €	Totex €	Capex Rank	Totex Rank
1	RO	749,844	1,428,904	2,178,748	2	2
	SBR	1,265,827	2,709,255	3,975,082	5	4
	MBR	1,183,035	3,317,936	4,500,971	4	5
	Aerated Lagoons	872,113	2,479,330	3,351,442	3	3
	Lagoon SRC	608,439	997,970	1,606,409	1	1
4	RO	749,844	1,467,537	2,217,381	2	2
	SBR	1,265,827	2,992,356	4,258,183	5	4
	MBR	1,183,035	3,644,091	4,827,125	4	5
	Aerated Lagoons	872,113	2,748,870	3,620,983	3	3
	Lagoon SRC	608,439	1,053,413	1,661,852	1	1

Table 8-4
Summary of 25m^3/day LTP Cost Models

Filling Scenario	LTP Option	Capex €	Opex €	Totex €	Capex Rank	Totex Rank
1	RO	647,664	1,355,335	2,002,999	2	2
	SBR	977,103	2,605,319	3,582,421	5	4
	MBR	913,908	3,172,612	4,086,520	4	5
	Aerated Lagoons	747,931	2,445,804	3,193,735	3	3
	Lagoon SRC	528,504	953,872	1,482,376	1	1
4	RO	647,664	1,450,681	2,098,345	2	2
	SBR	977,103	2,582,570	3,559,673	5	4
	MBR	913,908	3,490,693	4,404,601	4	5
	Aerated Lagoons	747,931	2,713,482	3,461,412	3	3
	Lagoon SRC	528,504	1,006,865	1,535,369	1	1

This modelling indicates that the least cost LTP option, both in terms of initial capital costs and also total costs to 30 years post landfill closure, regardless of waste filling scenario or choice of a 40m^3/day or 25m^3/day LTP (with associated recirculation) is the Facultative lagoon + SRC process.

Next most cost effective is RO, followed by Aerated Lagoon SBR. SBR and MBR are the most costly with MBR having potentially lower capital costs but higher operational costs. Costs have been modelled without the including of disinfection as it is not known at this point if this would be required as a result of the Bathing Beach Directive. Should disinfection be needed it may be the case that MBR has a lower capital and total expenditure cost due to the likelihood of smaller UV plant and subsequent lower electrical and repair costs for this equipment.

Note that for RO the cost models presented assume zero cost associated with disposal of concentrate. This would only be the case if either recirculation of concentrate back to the landfill or disposal to an EfW constructed adjacent to the Ghallis landfill complex (that was designed so as to be able to accept and incinerate RO concentrate) was freely available. However, concentrate disposal costs would need to rise to around €30/m^3 before the Totex costs for the RO scenarios approached that of the next most costly LTP option, Aerated Lagoon based SBR.

Comparison of the 25m^3/day and 40m^3/day LTP sizing options indicates that savings of between €80k and €289k on capital costs and €17k to €410k on operational costs could be achieved should WasteServe choose to accept the additional risks associated with construction of a smaller capacity LTP and the resultant need to retain more excess leachate within the landfill waste mass for longer periods of time. Potential savings associated with construction and operation of a smaller capacity LTP are presented below as Table 8-5.

Table 8-5
Potential Cost Savings for a 25m^3/day LTP Versus a 40m^3/day LTP

Filling Scenario	LTP Option	Capex Saving €	Opex Saving €	Totex Saving €
1	RO	102,180	73,569	175,749
	SBR	288,724	103,937	392,661
	MBR	269,126	145,324	414,451
	Aerated Lagoons	124,182	33,525	157,708
	Lagoon SRC	79,935	44,098	124,033
4	RO	102,180	16,856	119,036
	SBR	288,724	409,786	698,510
	MBR	269,126	153,398	422,524
	Aerated Lagoons	124,182	35,388	159,570
	Lagoon SRC	79,935	46,548	126,483

9.0 CONCLUSIONS AND RECOMMENDATIONS

Estimations of leachate generation rates and disposal requirements for the existing and proposed Ghallis landfill phases indicate that volumes of leachate in excess of those allowed by the sites Permit have begun to accumulate in the waste and that on-going leachate generation rates are likely to be in the region of $40m^3$/day whilst the site is still largely uncapped and active landfilling progresses, falling to around $5m^3$/day in the post-closure period once the site is fully capped. Leachate generation volume rates are not significantly affected by the various different waste filling scenarios that have previously been investigated.

The presence of excess leachate volumes in the existing waste mass indicates that management of leachate by recirculation alone is unlikely to be a sustainable solution and that some disposal of leachate is likely to be required at the site for it to achieve and maintain compliance with permitted leachate heads.

Review of leachate quality analysis from the existing Ghallis landfill indicates that whilst the leachate is relatively 'strong', having high concentrations of ammonia and chloride, there is nothing in the analysis of leachate quality that has been undertaken to suggest that substances exist in the leachate that would inhibit treatment and disposal. However, it is recommended that more detailed analysis of the landfill leachate quality is undertaken to confirm this.

As it is unlikely that suitably licensed off-site disposal facilities exist that would be able to accept tankered liquid wastes such as landfill leachate on the island of Malta, leachate disposal options for on-site treatment and disposal would need to be pursued to enable leachate disposal to take place.

Three disposal options exist, disposal of treated effluent to public sewer, disposal of treated effluent to controlled waters and 'no disposal' options.

At this point in time it is not known if there are any circumstances that would prevent options to dispose of treated leachate to sewer or controlled waters should a treatment process be installed that is capable of achieving the required reductions in contaminant concentrations for each proposed effluent disposal route. However, further investigations into the practicalities and permitting of disposal to sewer or to controlled waters may result in either or both of these options being discounted.

The degree of treatment likely to be required for either option differs in that discharge to sewer would need significant reductions in inorganic nitrogen (including ammonia) and chloride and a limited suite of metals whereas a discharge to controlled waters would need significant reductions in ammonia and the majority of metals but would not require chloride to be reduced as the nearest suitable controlled waters for disposal of treated landfill leachate would be discharged to sea as the eastern boundary of the landfill site is within 150m of the coast.

The leachate produced by the site is likely to be treatable using standard leachate treatment methods, however this needs to be confirmed by detailed treatability trials to ensure that no trace inhibitory compounds or untreatable compounds that are banned from being discharged exist within the leachate that are not currently monitored for in the analysis undertaken of the Ghallis landfill leachates.

If possible, and if agreement can be reached with sewer system operators, discharge of treated effluent to sewer is usually preferred. Due to the likely need to control chloride concentrations to below 1,000mg/L on Malta only treatment processes capable of significant desalination of raw leachate would be acceptable in this instance, for example RO or evaporation.

Discharge to sea of treated effluent would be likely to require a significantly higher level of treatment than for discharges to sewer unless modelling could demonstrate to regulators that a sufficiently distant off-shore discharge at significant depth below surface could be achieved to off-set the degree of treatment needed. Choice of treatment process would not be limited to RO (and other associated desalination processes) but may need to incorporate secondary effluent ‘polishing’ and disinfection.

If no discharge route can be found that is likely to be both cost effective to engineer and agreeable to regulators it is possible to construct treatment processes that do not need to discharge liquid effluent from the landfill site footprint. Such processes do however come with significant associated risks relating to their reliance on favourable climatic conditions and the need to account for the fact that to some degree or another contaminants contained in the leachates removed are concentrated up and deposited back to the landfill in one form or another.

Review of suitable treatment processes highlighted 5 main processes that would be likely to be employed at the Ghallis landfill sites. The identified processes were RO, SBR, MBR, Aerated Lagoon based SBR and Facultative Lagoon + SRC. Financial modelling of capital and operational costs for each of these options at different plant throughput capacities was undertaken.

This work demonstrated that Facultative Lagoons + SRC was likely to be the most cost effective option. However, due to the risks associated with the ability to permit such a process, operate it reliably under a variety of weather conditions and the fate of particularly chloride and sodium, SLR would recommend that it is only considered as an option should it not be possible to find and agree a cost effective means of discharging treatment effluent from the landfill site.

The next most cost effective process was found to be RO. This process could be employed at the site to achieve the likely required discharge quality for disposal of treated effluent to sewer or to sea outfall. If discharge to sewer is required it is the only viable option (alongside allied similar process plant such as vacuum evaporators). RO would be an ideal treatment option as the process is easy to operate, can be highly modular and containerised so can be easily and relatively cheaply deployed. In addition, plants can be hired as well as purchased should this be preferable to WasteServe. However, the main drawback of RO is the need to find a disposal route for concentrates. In the short term this may be recirculation of concentrate back to the waste mass but in the medium to long term an off-site route of disposal may be required to ensure that leachate quality does not continue to rise to a point at which it cannot be treated or that the landfill site can never be considered to no longer pose a risk to the environment. An ideal scenario would be if the postulated EfW plant that is being considered for the site was to be developed and that its design incorporated the ability to accept up to 15m^3/day of RO concentrate.

Should a discharge to sea be the only viable option and the risks associated with disposal of RO concentrate not being acceptable to WasteServe, the most cost effective treatment process would be Aerated Lagoons operating as an SBR process. Such a plant would also need to be accompanied by effluent polishing processes such as wetlands or reed beds, unless a sufficiently long and deep sea outfall could be constructed, and consideration may need to be given to disinfection should the Bathing Beach Directive be an issue at the point of discharge. If compliance with the Bathing Beach Directive is applicable, it may be that

MBR becomes the preferred method of treatment as disinfection costs will be lower than for Aerated Lagoons or SBR.

In each instance, considerable costs savings could be achieved by constructing a lower capacity LTP ($25m^3$/day) and operating it alongside recirculation of leachate during active landfilling of wastes and for a short period of time after the site has been capped. This could result in additional non-compliant leachate volumes being recorded but if properly designed recirculation systems were employed sufficient distribution of leachate into waste with spare adsorptive capacity could be achieved to prevent this being a significant issue.

In summary, SLR concludes the following:

- the preferred treatment solution is a $25m^3$/day capacity RO plant, discharging to sewer, accompanied by leachate recirculation until final site capping is completed, thereafter recirculation can cease. Disposal of concentrate to recirculation in the short term, to EfW in the medium to long term;
- if construction of an EfW capable of accepting up to $15m^3$/day of RO concentrate is not likely in the medium term, the next most preferable treatment solution is a $25m^3$/day Lagoon Based SBR with reed bed effluent polishing discharging to sea outfall, accompanied by leachate recirculation until final site capping is completed, thereafter recirculation can cease; and
- if off-site discharge of treated effluent is not possible and suitable land is available, consider installation of a $25m^3$/day capacity Facultative Lagoons + SRC process, accompanied by leachate recirculation until final site capping is completed, thereafter recirculation can cease.

SLR would also recommend the following investigations are begun so that information relevant to the choice of disposal option can be obtained and reviewed:

- obtain samples of leachate (either from individual wells or, ideally, from the combined blend of leachate pumped from the site) to be analysed for priority hazardous substances (PHS), priority substances (PS) and 'other pollutants' covered by the Environmental Quality Standards Directive (EQSD) (2008/105/EC). This information could then be used to assess leachate quality in terms of its acceptability for discharge from the site, potential treatability and likely discharge limits for controlled waters. A determinand suite for this analysis is included in Appendix E for reference;
- investigate the possibility of both connection and discharge to public sewer system and outfall to sea. Investigations should include both physical engineering issues and permitting and permissions;
- consider treatability trials of leachate from the site for the two main candidate treatment processes, Reverse Osmosis and Aerated biological treatment; and
- determine whether any discharge to sea would have to meet the requirements of the Bathing Beach Directive.

10.0 CLOSURE

This report has been prepared by SLR Consulting Limited with all reasonable skill, care and diligence, and taking account of the manpower and resources devoted to it by agreement with the client. Information reported herein is based on the interpretation of data collected and has been accepted in good faith as being accurate and valid.

This report is for the exclusive use of WasteServe Malta; no warranties or guarantees are expressed or should be inferred by any third parties. This report may not be relied upon by other parties without written consent from SLR.

SLR disclaims any responsibility to the client and others in respect of any matters outside the agreed scope of the work.

Appendix A Leachate Quality Data

Determinand	Unit	2011								
		LCP1	**LCP2**	**LCP3**	**LCP4**	**LCP5**	**LCP6**	**LCP7**	**LCP8**	**LCP9**
Arsenic	mg/L	0.63			1.03	1	0.95	0.74		
Cadmium	mg/L	<0.001			0.01	0.01	0.01	0.006		
Chromium	mg/L	0.69			0.91	0.86	1.32	1.15		
Copper	mg/L	0.29			0.17	0.22	0.12	0.07		
Nickel	mg/L	0.42			0.55	0.48	0.64	0.54		
Lead	mg/L	0.09			0.1	0.17	0.11	0.06		
Ammoniacal nitrogen	mg/L	4,305			4,406	3,648	3,782	3,971		
Chloride	mg/L	6,194			5,545	4,618	6,280	5,216		
pH	pH unit	8.3			8.57	8.42	8.43	8.36		
Conductivity	µS/cm	38,800			38,500	32,475	35,367	37,000		
Naphthalene	mg/L	<0.01			0.00	0.01	<0.003	<0.005		
Toluene	mg/L	0.03			0.01	0.02	0.08	0.03		
Total organic Carbon	mg/L	3,048			4,822	4,348	7,483	22,550		
Barium	mg/L	0.08			0.06	0.03	0.07	0.02		
Mercury	mg/L	<0.001			<0.001	<0.001	<0.001	0.001		
Molybdenum	mg/L	0.05			0.05	0.04	0.05	0.05		
Antimony	mg/L	0.03			0.03	0.03	0.02	0.03		
Selenium	mg/L	<0.01			0.01	<0.01	<0.01	<0.01		
Zinc	mg/L	0.42			0.61	1.20	0.56	0.63		
Fluoride	mg/L	1.44			2.23	2.16	1.21	0.86		
Sulphate	mg/L	3.5			7.6	16.2	2.9	30.6		
Phenol index	mg/L	2.1			1.8	4.6	2.2	1.7		
Iron	mg/L	5.69			5.91	11.42	5.50	7.23		
Sodium	mg/L	3,260			32	2,738	2,915	3,102		
Potassium	mg/L	1,812			1,775	1,658	1,591	1,976		
Magnesium	mg/L	71.5			46.4	90.8	58.6	70.9		
Calcium	mg/L	16.5			17.4	18.2	13.0	17.2		

Determinand	Unit	2012								
		LCP1	LCP2	LCP3	LCP4	LCP5	LCP6	LCP7	LCP8	LCP9
Arsenic	mg/L				0.96	0.76	0.29	0.300		
Cadmium	mg/L				0.02	0.01	0.01	0.001		
Chromium	mg/L				0.65	0.77	1	1.470		
Copper	mg/L				0.04	0.6	0.02	0.090		
Nickel	mg/L				0.51	0.51	0.32	0.420		
Lead	mg/L				0.03	0.09	0.05	0.130		
Ammoniacal nitrogen	mg/L				4,234	3,991	4,553	4,037		
Chloride	mg/L				5,553	5,844	5,579	5,110		
pH	pH unit				8.65	8.63	8.65	8.600		
Conductivity	µS/cm				40,550	39,350	44,425	38,267		
Naphthalene	mg/L				0.00	0.00	0.00	<0.00001		

Determinand	Unit	2012			
Toluene	mg/L	0.01	0.02	0.02	0.02
Total organic Carbon	mg/L	7,043	5,729	14,377	9,305
Barium	mg/L	0.06	0.11	0.18	0.11
Mercury	mg/L	0.001	0.002	0.001	0.003
Molybdenum	mg/L	0.02	0.02	0.01	0.01
Antimony	mg/L	0.05	0.04	0.06	0.05
Selenium	mg/L	<0.0005	<0.0005	<0.0005	<0.0005
Zinc	mg/L	0.47	0.46	0.44	1.61
Fluoride	mg/L	4.60	3.50	1.40	1.60
Sulphate	mg/L	15.2	14.6	9.0	12.3
Phenol index	mg/L	75.8	66.6	166.0	131.0
Iron	mg/L	7.65	11.18	14.97	44.76
Sodium	mg/L	3,668	4,023	4,872	3,180
Potassium	mg/L	2,354	2,680	3,013	2,350
Magnesium	mg/L	52.8	77.1	201.0	106.0
Calcium	mg/L	24.0	7.1	27.2	42.0

Determinand	Unit	2013								
		LCP1	LCP2	LCP3	LCP4	LCP5	LCP6	LCP7	LCP8	LCP9
Arsenic	mg/L				0.85	0.75	0.69	0.65	0.662	0.6
Cadmium	mg/L				0.02	0.02	0.02	0.02	0.018	0.0142
Chromium	mg/L				1.42	0.96	0.87	1.18	1.294	0.965
Copper	mg/L				1.08	0.31	0.12	0.06	0.34	0.017
Nickel	mg/L				1.33	0.52	0.44	0.56	0.971	0.535
Lead	mg/L				0.23	0.05	0.07	0.10	1.76	0.152
Ammoniacal nitrogen	mg/L				5,026	4,841	5,435	5,395	4,672	6,913
Chloride	mg/L				5,879	6,375	5,962	5,163	5,627	5,066
pH	pH unit				8.23	8.4	8.57	8.33	8.25	8.5
Conductivity	µS/cm				41,775	52,575	43,633	40,767	41,975	43,400
Naphthalene	mg/L				0.00	0.01	0.01	0.00	0.01	0.00
Toluene	mg/L				0.02	0.03	0.02	0.03	0.06	0.02
Total organic Carbon	mg/L				11,785	9,741	15,527	16,638	10,165	13,724
Barium	mg/L				0.01	0.10	0.14	0.27	0.12	
Mercury	mg/L				0.002	0.001	0.001	0.002	0.001	
Molybdenum	mg/L				0.09	0.12	0.28	0.24	0.10	
Antimony	mg/L				0.06	0.05	0.06	0.06	0.06	
Selenium	mg/L				0.11	0.13	0.12	0.12	0.15	
Zinc	mg/L				0.79	0.52	0.48	1.06	3.21	
Fluoride	mg/L				2.00	2.10	0.92	0.93	0.44	
Sulphate	mg/L				104.0	<0.05	<0.05	166.0	166.0	
Phenol index	mg/L				53.6	53.6	201.0	212.0	93.6	
Iron	mg/L				16.30	8.78	6.92	22.00	68.40	

Determinand	Unit	2013								
Sodium	mg/L				2,850	4,320	3,644	4,320	4,400	
Potassium	mg/L				1,976	3,128	2,848	3,256	3,392	
Magnesium	mg/L				45.9	105.0	167.0	138.0	3168.0	
Calcium	mg/L				8.7	36.2	21.8	106.0	240.0	

Determinand	Unit	2014								
		LCP1	LCP2	LCP3	LCP4	LCP5	LCP6	LCP7	LCP8	LCP9
Arsenic	mg/L				0.922	0.848	0.271	0.491	0.595	0.329
Cadmium	mg/L				0.02	0.019	0.017	0.015	0.019	0.006
Chromium	mg/L				1.075	1.336	1.229	3.261	1.725	1.382
Copper	mg/L				0.105	0.212	0.096	0.023	2.409	0.6
Nickel	mg/L				0.636	0.878	0.444	0.613	0.983	0.966
Lead	mg/L				0.047	0.074	0.344	0.073	0.706	0.294
Ammoniacal nitrogen	mg/L				5,345	4,602	5,197	6,201	4,884	5,547
Chloride	mg/L				6,200	6,336	5,670	5,378	5,789	7,017
pH	pH unit				8.205	8.265	8.125	8.34	8.005	7.450
Conductivity	µS/cm				35,700	29,360	43,800	35,400	37,450	25,120
Naphthalene	mg/L				0.00	<0.00001	<0.00001	0.00	<0.0001	<0.00001
Toluene	mg/L				0.02	0.03	0.02	0.04	n.d.	0.02
Total organic Carbon	mg/L				10,716	6,792	19,840	19,063	20,345	20,322
Barium	mg/L				0.08	0.04	0.14	0.24	0.54	0.04
Mercury	mg/L				0.002	<0.00015	0.001	0.001	0.002	0.000
Molybdenum	mg/L				0.03	0.02	0.03	0.02	0.02	0.03
Antimony	mg/L				0.03	0.02	0.07	0.02	0.05	0.03
Selenium	mg/L				0.08	0.07	0.12	0.12	0.11	0.08
Zinc	mg/L				0.33	0.61	0.20	1.04	8.18	1.05
Fluoride	mg/L				<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Sulphate	mg/L				1625.0	41.0	185.0	280.0	2395.0	46.0
Phenol index	mg/L				30.0	59.9	263.0	351.0	254.0	47.3
Iron	mg/L				8.48	13.04	54.36	105.16	225.05	9.79
Sodium	mg/L				3,975	1,573	4,966	4,708	5,388	1,990
Potassium	mg/L				27,845	1,527	3,815	3,404	3,838	1,498
Magnesium	mg/L				91.0	45.5	289.0	394.0	594.0	105.0
Calcium	mg/L				32.3	14.2	98.7	242.0	2224.0	6.6

Appendix B Leachate Disposal Volume Calculations

Uncapped Waste	153.1	mm/yr
Capped Waste	14.5	mm/yr
Total Excess leachate	11,960	m^3

WASTE FILLING SCENARIO 1

Model	Parameter	Unit	Year								
			0	1	2	3	4	5	6	7	Total to 2051 (36th yr)
			2015	2016	2017	2018	2019	2020	2021	2022 onwards	
Volume Model	Uncapped	m^2	95,600	71,450	38,500	36,500	36,000	31,900	27,800	0	-
	Capped	m^2	0	27,250	65,000	70,000	74,700	84,900	94,400	122,200	-
	Total Site Area	m^2	95,600	98,700	103,500	106,500	110,700	116,800	122,200	122,200	-
	Uncapped	m^3/yr	14,632	10,936	5,893	5,586	5,510	4,882	4,255	0	-
	Capped	m^3/yr	0	396	945	1,018	1,086	1,234	1,373	1,777	-
	Total Site	m^3/yr	14,632	11,332	6,838	6,604	6,596	6,117	5,627	1,777	111,050
LTP at 40m^3/day	Excess Disposed	m^3/yr	0	2,392	2,392	2,392	2,392	2,392	0	0	-
	Total for Disposal	m^3/yr	14,632	13,724	9,230	8,996	8,988	8,509	5,627	1,777	123,010
	Daily Equivalent	m^3/d	40	38	25	25	25	23	15	5	9
	Annual Volume to Re-circ	m^3/yr	0	0	0	0	0	0	0	0	-
	Re-circ Daily Equivalent	m^3/d	0	0	0	0	0	0	0	0	-

WASTE FILLING SCENARIO 1 Continued……

Model	Parameter	Unit	Year 0 (2015)	1 (2016)	2 (2017)	3 (2018)	4 (2019)	5 (2020)	6 (2021)	7 (2022 onwards)	Total to 2051 (36th yr)
LTP at 25m^3/day	Excess Volume Held in Site	m^3	17,467	19,674	17,387	14,866	12,337	9,329	5,831	0	-
	Annual Treatment Volume (at 25m^3/day LTP)	m^3/yr	9125	9125	9125	9125	9125	9125	9125	7,608	123,010
	Treatment daily equivalent	m^3/d	25	25	25	25	25	25	25	21	9
	Annual volume to Re-circ	m^3/yr	8,342	10,549	8,262	5,741	3,212	204	0	0	-
	Re-circ daily equivalent	m^3/d	23	29	23	16	9	1	0	0	-

WASTE FILLING SCENARIO 2

Model	Parameter	Unit	Year 0 2015	1 2016	2 2017	3 2018	4 2019	5 2020	6 2021	7 2022	8 2023	9 2024	10 2025 onwards	Total to 2053 (38th yr)
Volume Model	Uncapped	m^2	95,600	71,450	38,500	36,500	36,000	36,000	31,900	31,900	27,800	27,800	0	-
	Capped	m^2	0	27,250	65,000	70,000	74,700	74,700	84,900	84,900	94,400	94,400	122,200	-
	Total Site Area	m^2	95,600	98,700	103,500	106,500	110,700	110,700	116,800	116,800	122,200	122,200	122,200	-
	Uncapped	m^3	14,632	10,936	5,893	5,586	5,510	5,510	4,882	4,882	4,255	4,255	0	-
	Capped	m^3	0	396	945	1,018	1,086	1,086	1,234	1,234	1,373	1,373	1,777	-
	Total Site	m^3	14,632	11,332	6,838	6,604	6,596	6,596	6,117	6,117	5,627	5,627	1,777	127,614
LTP at $40m^3$/day	Excess Volume	m^3	0	2,392	2,392	2,392	2,392	2,392	0	0	0	0	0	-
	Total for Disposal	m^3	14,632	13,724	9,230	8,996	8,988	8,988	6,117	6,117	5,627	5,627	1,777	139,574
	Daily equivalent	m^3/d	40	38	25	25	25	25	17	17	15	15	5	10
	Annual volume to Re-circ	m^3/yr	0	0	0	0	0	0	0	0	0	0	0	-
	Re-circ daily equivalent	m^3/d	0	0	0	0	0	0	0	0	0	0	0	-

WASTE FILLING SCENARIO 2 Continued…..

Model	Parameter	Unit	Year 0 2015	1 2016	2 2017	3 2018	4 2019	5 2020	6 2021	7 2022	8 2023	9 2024	10 2025 onwards	Total to 2053 (38th yr)
LTP at 25m^3/day	Excess Volume held in site	m^3	17,467	19,674	17,387	14,866	12,337	9,808	6,800	3,792	294	0	0	-
	Annual Treatment Volume (at 25m^3/day LTP)	m^3/yr	9125	9125	9125	9125	9125	9125	9125	9125	9125	5,922	1,777	139,574
	Daily equivalent	m^3/d	25	25	25	25	25	25	25	25	25	16	5	10
	Annual volume to Re-circ	m^3/yr	8,342	10,549	8,262	5,741	3,212	683	0	0	0	0	0	-
	Re-circ daily equivalent	m^3/d	23	29	23	16	9	2	0	0	0	0	0	-

Appendix C Treatment Plant Selection Matrix

Technique	Sub category	Processes			Specific Applicability	Score	General Applicability	Score	Robustness	Score	Flexibility	Score	Capital costs (Capex)	Score	Operational costs (Opex)	Score	Manpower requirements to run	Score	Repair and Maintenance	Score	Power requirement	Score	Use of other consumables	Score	Emissions (wastes / by-products etc.)	Score	Environmental risks	Score	Health & Safety Risks	Score	Process Stability	Score	Footprint	Score	Ease of modular construction	Score	Factors affecting performance	Score	Overall Score
	Physical Treatment										Physical Treatment																		Physical Treatment										
Air stripping	Ambient	Methane removal			Unable to achieve the likely reductions in leachate contamination concentrations required. Possible use as part of a treatment train if discharging to sewer	5	Designed to remove VOC's, in particular methane. This method would not remove other contaminants of concern such as ammonia, BOD, COD and metals. Mainly applicable to discharges to sewer.	1	Not an over-complicated system, however, the system can be prone to blockages due to precipitate. Foaming can also occur.	2	The system can only remove methane (and other VOC's). However the systems can be stop/start without affecting performance	1	Low - stripper, feed pump and blower	5	Main costs are due to running the blower, as the process requires a very large volume of air. May also need anti-foaming agent and/or chemicals to reduce/remove precipitate build-up.	4	Low - requires weekly to monthly visits depending on the rate of stripper tray fouling/precipitate build-up.	4	Stripper trays and doors and/or diffusers may need replacement over several years, as may the pumps and blower. Weekly - monthly manual cleaning of the stripper depending on rate of fouling	4	Main source is the blower	4	Anti-foam, possible anti scale	4	The process produces a vent gas containing low concentrations of methane gas, which may be subject to air emissions limits. Methane in the vent gas can be thermally destroyed (flared) or otherwise treated by various types of filter. Precipitation / scale sludges require disposal.	4	Emissions to air, odours.	3	System failure could risk explosion (if discharged to sewer). Risks of explosion / asphyxiation (if in confirmed space) within the plant if not operated correctly. Minor H&S associated with manual cleaning of the plant. Also possible storage and handling of chemicals.	3	A methane stripper will reliably remove methane provided the stripper trays / diffusers are kept free of precipitate	3	The footprint for an air stripper is relatively small, often contained within an ISO Shipping container or similar skid mounted package.	5	The plants can be installed as modules, increasing numbers for increased capacity requirements.	5	Precipitate build-up and foaming can both affect the ability of the plant to operate efficiently	3	60
	pH Adjusted	Ammonia removal	Methane removal	VOC removal	Unable to achieve the likely reductions in leachate contamination concentrations required. Possible use as part of a treatment train if discharging to sewer	5	This method would not remove typical contaminants of concern such as COD and metals. However, it could be used as a pre-treatment or polishing step to remove ammonia. Has the potential to deliver a saleable commodity from leachate (ammonium sulphate).	2	Not an over-complicated system, however, the system can be prone to blockages due to precipitate. Requires accurate pH control. Foaming can also occur.	3	The system can only remove methane and ammonia (and other VOC's). However the systems can be stop/start without affecting performance	2	Relatively low - stripper, feed pump, blower and pH dosing	4	Blower costs, plus chemical costs (acid and alkali) to maintain a high pH and pH correction. May also need anti-foaming agent.	3	Relatively low - requires weekly to monthly visits depending on the rate of stripper tray / diffusers fouling/precipitate build-up. Also attendance required to manage chemical stores.	3	Stripper trays and doors and/or diffusers may need replacement over several years, as may the pumps and blower. Weekly - monthly manual cleaning of the stripper depending on rate of fouling. pH sensors and control equipment will require regular maintenance and calibration.	3	Main source is the blower	4	Alkali to increase pH and acid to correct pH prior to discharge. Anti-foam	3	Vent gas containing high concentrations of ammonia gas, which may be subject to air emissions limits. Gas can be absorbed by sulphuric acid to produce ammonium sulphate (fertiliser), which could be sold on. Alternatively the ammonia in the vent gas can thermally destructed by using gas flare etc.	4	Emissions to air, particularly the issue of ammonia gas release, odours. Risks surrounding the safe storage of acids and alkali's.	3	System failure could risk an explosion (if discharged to sewer). Risks of explosion / asphyxiation (if in confirmed space) within the plant if not operated correctly. Minor H&S associated with manual cleaning of the plant. Significant issues with the storage and handling of chemicals.	2	A pH adjusted air stripper will reliably remove methane and ammonia provided the stripper trays / diffusers are kept free of precipitate and the pH control systems are maintained.	3	The footprint for an air stripper is relatively small	4	The plants can be installed as modules, increasing numbers for increased capacity requirements.	4	Precipitate build-up and foaming can both affect the ability of the plant to operate efficiently	3	55
	Temperature Adjusted	Methane removal	Ammonia removal	VOC removal	Unable to achieve the likely reductions in leachate contamination concentrations required. Possible use as part of a treatment train if discharging to sewer	5	This method would not remove other typical contaminants of concern such as COD and metals. However, it could be used as a pre-treatment or polishing step to remove ammonia. Has the potential to deliver a saleable commodity from leachate (ammonium sulphate).	2	Not an over-complicated system, however, the system can be prone to blockages due to precipitate. Requires heat source. Foaming can also occur.	3	The system can only remove methane and ammonia (and other VOC's). However the systems can be stop/start without affecting performance	1	Relatively low - stripper, feed pump, blower and heat source.	4	Blower costs, plus costs of heat generation. The cost of heat to maintain a increased temperature is dependent on whether a heat source is available on site e.g. landfill gas. May also need anti-foaming agent.	3	Relatively low - requires weekly to monthly visits depending on the rate of stripper tray / diffusers fouling/precipitate build-up.	4	Stripper trays and doors and/or diffusers may need replacement over several years, as may the pumps and blower. Weekly - monthly manual cleaning of the stripper depending on rate of fouling. Maintenance of the heat supply also required.	3	Main source is the blower unless and heat generation and transfer is required to increase the temperature of the stripper contents. At landfill sites a heat source may already be available (gas flare etc).	3	Anti-foam, possible antiscale	4	Vent gas containing high concentrations of ammonia gas, which may be subject to air emissions limits. Gas can be absorbed by sulphuric acid to produce ammonium sulphate (fertiliser), which could be sold on. Alternatively the ammonia in the vent gas can thermally destructed by using gas flare etc.	4	Emissions to air, particularly the issue of ammonia gas release, odours.	4	System failure could risk an explosion (if discharged to sewer). Risks of explosion / asphyxiation (if in confirmed space) within the plant if not operated correctly. Minor H&S associated with manual cleaning of the plant. Significant issues with the storage and handling of chemicals.	2	An temperature adjusted air stripper will reliably remove methane and ammonia provided the stripper trays / diffusers are kept free of precipitate and the temperature adjustment systems are maintained.	3	The footprint for an air stripper is relatively small	4	The plants can be installed as modules, increasing numbers for increased capacity requirements.	4	Precipitate build-up and foaming can both affect the ability of the plant to operate efficiently	3	56
Contaminant Seperation / Volume reduction	Reverse Osmosis	Separation of all/most contaminants	Volume reduction		Will produce an effluent of high quality capable of being dicharged to sea or to sewer, has a small footprint and can run automatically or as a "pump & treat" when needed unit. Concentrate will need a route of disposal.	18	RO will separate the majority / all of the contaminants of concern down to a particle size of <2nm into a concentrate and a permeate which will be largely free of the majority of ammonia, BOD and COD as well as metals and ions such as chloride.	5	The RO unit will reliably remove >99% of most contaminants and should operate efficiently using automated wash cycles, requiring low 'maintenance' down-time.	4	The systems can be stop/start without affecting performance and is not impacted by fluctuations in leachate composition other than the relative production rate of concentrate to permeate (higher EC results in higher concentrate production)	4	They are very expensive due to their complex nature, however, costs are reducing. Pre-treatment may also be required in the form of filtration/solids removal.	2	These costs are high due to high power consumption, chemicals required for cleaning, cyclical replacement of the membranes but mainly due to disposal/treatment of the RO concentrate remaining after treatment. Treatment costs excluding disposal of concentrate can be quite low.	1	An RO system can be full automated and monitored remotely, so manpower requirements can be low	3	The membranes will require replacement as often as every 2 years depending on the composition of the leachate being treated and the rate of fouling. Little repair / maintenance should be required on a day-to-day basis.	2	The energy requirements are high due to the pressure required to achieve the reverse osmosis effect	1	De-scalers, acid and membrane cleaner are also required to clean the RO membranes.	2	The RO will reliably produce a permeate of excellent quality, however, the permeate yield may be as low as 60%. The 'concentrate' produced from the process is highly concentrated and requires off-site disposal, additional treatment or re-circulation into the landfill which can lead to impacts of the landfill leachate.	1	The excellent quality of the permeate provides little environmental impact. However, the concentrate from the process can impact land/groundwater if not handled in the correct way. Also risks are associated with the storage and handling of chemicals required for cleaning/de-scaling.	3	The plant is automated so requires little interaction which may be a H&S risk. However, there is the need to store chemicals on site for membrane cleaning.	4	The RO plant, if designed correctly, will reliably produce very high quality permeate with little impact from stop/start of the plant and fluctuations in leachate composition.	4	The RO plant does not require a large footprint and is usually containerised.	4	The plants can be installed as modules, increasing numbers for increased capacity requirements.	5	The process will produce a high quality permeate. However, the percentage of permeate produced can vary between 60-90%. The composition of the leachate can also mean frequent washing to prevent fouling.	3	66
	Vacuum Evaporators	Separation of all/most contaminants	Volume reduction		Will produce an effluent of high quality capable of being dicharged to sea or to sewer, has a small footprint and can run automatically or as a "pump & treat" when needed unit. Concentrate will need a route of disposal.	16	Vacuum Evaporation will separate the majority / all of the contaminants of concern into a concentrate and a permeate which will be largely free of the majority of ammonia, BOD and COD as well as metals and ions such as chloride. Less well established than RO, some concerns over off-gas point source emissions to atmosphere	3	Provided the correct vacuum and/or heat are applied to the effluent the process will minimise the volume to be disposed of/treated	4	The process can be utilised regardless of the leachate composition or changes in composition. However, stop/start of the process will mean vacuum and temperatures have to be regenerated costing time and energy.	4	Relatively high	1	Relatively high as high power requirement to generate vacuum and heat requirements, some chemicals etc for cleaning. These concentrate also has to be treated and/or disposed of.	1	Operation is relatively labour-intensive, estimated at 2 hours per day for a skilled operator.	3	Whilst there are not many moving parts equipment to maintain temperature and/or vacuum can be costly to maintain.	2	Energy is required to produce the vacuum and depending on the availability of waste heat, there may be significant costs for heating.	2	Large volumes of chemicals required	3	The 'concentrate' produced from the process is highly concentrated and requires off-site disposal, additional treatment or re-circulation into the landfill which can lead to impacts of the landfill leachate.	2	There will be no discharge of treated leachate, however, the concentrate from the process is highly concentrated and can impact land/groundwater if not handled in the correct way.	3	The use and storage of chemicals are a risk. The production of the vacuum and the generation and/or transfer of heat are H&S risks.	2	The plant, if operated correctly, will reduce the volume of leachate to be disposed of significantly, however, handling of the concentrate is an issue.	4	The footprint is relatively small.	4	The plants can be installed as modules, increasing numbers for increased capacity requirements.	4	The correct vacuum and temperature inside the evaporator will impact on the efficiency of the process and in turn determine the volume of concentrate remaining.	4	62
	Evaporation Ponds	Separation of all/most contaminants	Volume reduction		Needs hot, arid climates to operate so that incident rainfall does not take up all evaporative capacity. Advantages are that no liquid discharge is required. A sludge is produced for which a disposal route is required. Can be relatively unsightly and odorous.	10	Evaporation will separate the majority / all of the contaminants of concern into a briny sludge for disposal and all liquid will be evaporated off to atmosphere. Can be unsightly and odorous and only works if land available for ponds and in a hot/arid environment Less well established than RO	3	Requires well designed ponds accounting for both leachate production and incident rainfall. Also needs the ability to clean out ponds periodically to remove accumulated solids.	2	The process can be utilised regardless of the leachate composition or changes in composition. However, highly climate / whether dependent	2	Relatively low	4	Very low, minor pumping costs and periodic drain down and removal of sludges, assuming a disposal outlet exists for the solids generated. If solids disposal costs are high then operation costs increase significantly	4	Relatively passive system apart from periodic clean out of ponds	5	Little maintenance required beyond periodic solids removal	5	Very low energy requirements	5	Little use of consumables	5	The 'concentrate' produced from the process is highly concentrated and requires off-site disposal, additional treatment or re-circulation into the landfill which can lead to impacts of the landfill leachate.	2	There will be no discharge of treated leachate, however, the concentrate from the process is highly concentrated and can impact land/groundwater if not handled in the correct way. Also visual and odour impacts are possible	2	No associated use of chemicals etc. Depth of liquid is also low so little risk of drowning etc.	4	The plant, if operated correctly, will reduce the volume of leachate to be disposed of significantly, however, handling of the concentrate is an issue. Highly dependent on climatic conditions	3	Footprint is relatively large	2	The ponds can be installed as modules, increasing numbers for increased capacity requirements.	4	Climatic issues, periods of rainfall, low temperature, low sunlight hours etc. will severely affect performance	2	64
	Ion Exchange	Removal of ions (metals and various other pollutants)			Has a small footprint and can run automatically or as "pump & treat" when needed. A route of disposal will be required for regeneration liquors and the waste stream produced during cleaning. would need to work alongside methane stripping if going to sewer. Unlikely to be able to target all paramaters of concern.	2	Ion exchange is a selective removal technology, therefore, full treatment of the leachate would not occur. It would be used as tertiary treatment.	1	The process is very effective at removing the substance(s) the ion exchange resin has been selected for, even if the leachate composition varies.	4	The flexibility is very limited as the resin is selected for its ability to remove specific substance(s). However, Stop/start would not have a big impact.	2	Relatively high - as the resin is expensive	2	Relatively high as high volumes of Chemicals are required to regenerate the resin. The waste stream from the regenerations also requires disposal	2	The filters and associated regeneration cycles can be automated, however the process is sensitive and will require regular checks.	3	There are not many moving parts so should only require occasional repair/maintenance.	4	The only power requirements would be influent and backwash pumps.	4	Various chemicals to regenerate the resin	3	The wash water from the regenerations is highly concentrated and requires off-site disposal, additional treatment or re-circulation into the landfill which can lead to impacts of the landfill leachate.	2	The excellent quality of the treated water provides little environmental impact. However, the concentrate from the process can impact land/groundwater if not handled in the correct way.	3	The filters are pressurised so are a potential danger. There are few moving parts and the filters are sealed units so there are few H&S risks. Regeneration chemicals are usually either acid or caustic.	3	The plant, if designed correctly, will reliably produce very high quality permeate (as tertiary treatment) with little impact from stop/start of the plant and fluctuations in leachate composition.	4	The footprint is relatively small.	5	The plants can be installed as modules, increasing numbers for increased capacity requirements.	4	The process will produce a good quality effluent (providing it is a polishing stage). However, as leachate often contains high concentrations of anions and/or cations it can inhibit the ability of the resin to remove the substances it has been selected for.	4	52

Technique	Sub category	Processes			Specific Applicability	Score	General Applicability	Score	Robustness	Score	Flexibility	Score	Capital costs (Capex)	Score	Operational costs (Opex)	Score	Manpower requirements to run	Score	Repair and Maintenance	Score	Power requirement	Score	Use of other consumables	Score	Emissions (wastes / by-products etc.)	Score	Environmental risks	Score	Health & Safety Risks	Score	Process Stability	Score	Footprint	Score	Ease of modular construction	Score	Factors affecting performance	Score	Overall Score
	Physical Treatment										Physical Treatment																		Physical Treatment											
Solids Removal	Sedimentation and settlement	Reduction in solids content			Unable to achieve the likely reductions in leachate contamination concentrations required. Possible use as part of a treatment train if discharging to sewer	1	Treatment consists of removal of solids, which would not provide adequate full treatment of leachate. Can be used as a pre-treatment or final treatment stage.	1	Sedimentation has been used for many years and sedimentation tanks are well designed to provide a good level of solids removal. Settlement can be assisted by the addition of flocculent/polymer.	4	The design of the tanks can be changed to optimise solids removal dependent on the composition / treatability of the leachate. However, it can only really be used to settle out solids.	2	The costs can vary dependent on the size and complexity of the tank installed but are usually significant due to the need for large tanks.	2	The operational costs a relatively low as there are only a few mechanical moving parts. Chemicals can be utilised to aid flocculation and settlement.	4	The plant is likely to require regular checks to ensure the process is operating as designed as well as to manage sludge from the process.	3	The skimmer and mechanical bridge may require repair / maintenance, there is also likely to be a sludge pump.	4	Low power requirements due to there being only a few moving parts on the plant.	4	Possible use of chemicals for flocculation.	4	The process will produce sludge as the settled out solids accumulate. This will require disposal. Odours can also be an issue.	2	If not used as an element within another overall treatment process it is likely that the leachate would not be fully treated so would be a risk to the environment. Also over-dosing can lead to an increase in COD downstream. Large tanks storing high volumes of effluent present a risk should they fail.	2	There are few moving parts, so the main H&S would be working near open and deep water. Possible storage/handling of chemicals.	3	A well designed plant would achieve a high level of solids removal regardless of fluctuations in leachate composition.	4	The tanks require a relatively large footprint to provide adequate treatment.	1	The plants can be installed as modules, increasing numbers for increased capacity requirements.	2	The tank can be incorrectly sized and not allow for sufficient residence time to settle out an optimum level of solids. The mechanical parts (e.g. skimmer) can breakdown and again reduce efficiency.	3	46
	Lamella Separator	Reduction in solids content			Unable to achieve the likely reductions in leachate contamination concentrations required. Possible use as part of a treatment train if discharging to sewer	1	Treatment consists of removal of solids, which would not provide adequate full treatment of the leachate. Can be used as a pre-treatment or final treatment stage.	1	Lamella separators can remove a high volume of solids due to the increased surface area upon which the solids can settle out. Settlement can be assisted by the addition of flocculent / polymer.	4	The lamella size and design can be selected to optimise solids settlement with lab scale trials carried out on the wastewater also undertaken to select the correct flocculent to enhance settlement.	2	Relatively low costs.	4	Chemical costs for the flocculent as well as sludge disposal costs are required.	4	The plant is likely to require regular checks to ensure the process is operating as designed as well as to manage sludge from the process.	3	The dosing and sludge pumps will require repair / maintenance.	4	Low power requirements due to only requiring a few pumps to be operating.	4	Use of chemicals to enhance solids settlement.	4	The process will produce sludge as the settled out solids accumulate. This will require disposal.	2	If not used as an element within another overall treatment process it is likely that the leachate would not be fully treated so would be a risk to the environment. Also over-dosing can lead to an increase in COD downstream.	3	There are few moving parts, so the main H&S would be working near open and deep water. Possible storage/handling of chemicals and confined spaces issues when cleaning out / repairing.	3	A well designed plant would achieve a high level of solids removal regardless of fluctuations in leachate composition.	4	The lamella separators require a relatively small footprint.	4	The plants can be installed as modules, increasing numbers for increased capacity requirements.	5	The size and design can be incorrectly selected and not allow for sufficient residence time to settle out an optimum level of solids. The flocculent can also be under or over dosed - effecting performance.	3	55
	Sand Filtration	Reduction in solids content			Unable to achieve the likely reductions in leachate contamination concentrations required. Possible use as part of a treatment train if discharging to sewer	1	Treatment consists of removal of solids, which would not provide adequate full treatment for leachate. Can be used as a pre-treatment (e.g. prior to RO) or a final polishing treatment stage. Dosing (e.g. Ferric) can also remove nutrients such as phosphorus and some COD (associated with solids).	2	Sand filters (both fixed bed and continuous flow) will achieve good levels of solids removal but require effective backwashing to prevent excessive solids build-up impacting on their ability to remove solids. Coagulants can be dosed to improve solids removal.	3	Sand filters can only remove 'solids', however, coagulants can be used to enhance solids removal as well as potentially targeting certain substances for improved removal efficiencies e.g. iron. A sand filter can also be stop / start with relatively minimal impact on the process.	3	Costs are relatively low, dependent mainly on how many filters are required.	4	Sand replacement required every 3-5 years(load dependent). Coagulant dosing is also likely to be required. Ferric dosing may also be used to remove phosphorus. Sludge produced will require disposal. CSF's can also require parts replacement due to wear caused by the movement of sand within the filter.	3	The plant can be automated, including the backwashing process, so is unlikely to require day-to-day supervision. Main requirements would be ensuring the stock tank for the coagulant is sufficiently filled. Sludge produced by the process may also need attention.	3	The CSF's may require repair / maintenance on occasion, this is unlikely to be regular or labour intensive.	4	Sand filters will require pumps and (most likely) air for the backwash process as well as pumps to transfer influent, effluent and / or chemical dosing.	3	Coagulant dosing is likely to be required. Dosing e.g. Ferric, may also be used to remove nutrients such as phosphorus.	3	The treatment process produces a sludge. In the case of the CSF's this contains a high percentage of water and additional treatment may be required to avoid large disposal costs.	3	If used as a stand alone process leachate is unlikely to be sufficiently treated to allow it to be discharged to the environment, however, as a polishing unit there would be little environmental risk.	3	There are few moving parts, so the main H&S risk is likely to be working at height, or, in the case of the CSF, risks associated with repair and maintenance work and working at height. Storage and handling of chemicals.	3	A well designed plant with the correct coagulant chosen should achieve a high level of solids removal regardless of fluctuations in leachate composition. The process should operate well provided solids loading is not excessive.	4	The CSF footprint is relatively small, with a fixed bed sand filter being larger.	4	The plants can be installed as modules, increasing numbers for increased capacity requirements.	5	Solids build-up, especially in the fixed bed filter, can hinder solids removal. Over-dosing of coagulant can also reduce the solids removal efficiency of the filter and lead to increased COD in the effluent.	3	54
	Other Filtration (e.g.: AFM activated glass media)	Reduction in solids content			Unable to achieve the likely reductions in leachate contamination concentrations required. Possible use as part of a treatment train if discharging to sewer	1	AFM - is glass which is a particular size and shape and has been treated to increase the surface area to 300 times that of sand or crushed glass. The treatment consists of removal of solids (as well as some metals such as iron and arsenic), which would not provide adequate full treatment of most leachates. Can be used as a pre-treatment (e.g. prior to RO) or a final polishing treatment stage. At present this is a relatively novel	1	AFM media filters will achieve very good levels of solids removal but require effective backwashing to prevent excessive solids build-up impacting on their ability to remove solids.	3	The AFM filter will achieve better solids removal than a sand filter and also remove some other contaminants e.g. iron and arsenic. The filter can also be stop / start with relatively minimal impact on the process.	3	Costs are relatively low, dependent mainly on how many filters are required.	4	The media (according to sales literature) will never require replacement due to the very smooth surface of the media. So regular backwashing is all that is required.	3	The plant can be automated, including the backwashing process, so is unlikely to require day-to-day supervision.	3	The filters may require repair / maintenance on occasion, this is unlikely to be regular or labour intensive.	4	The filters will require pumps for the backwash process as well as pumps to transfer influent and / or effluent.	3	There are no other consumables (i.e. sales literature suggests that flocc etc is not required).	4	The treatment process produces a sludge. However, this is likely to be returned to the previous treatment step of activated sludge to maintain bacteria populations. Otherwise it would have to be disposed of.	3	If used solely the leachate would not be fully treated, however, as a polishing unit there would be little environmental risk.	3	The filters are pressurised so are a potential danger. There are few moving parts and the filters are sealed units so there are few H&S risks.	3	Process will provide good solids removal along with theremoval of some heavy metals due to the charge on the media attracting the metals. Process should operate well provided solids loading is not excessive. It should not suffer from fluctuations in leachate composition.	4	The footprint is relatively small.	4	The plants can be installed as modules, increasing numbers for increased capacity requirements.	5	The solids load entering the filter can hinder performance if it is too high.	3	54
	Dissolved air Floatation	Reduction in solids content			Unable to achieve the likely reductions in leachate contamination concentrations required. Possible use as part of a treatment train if discharging to sewer	1	A DAF unit uses dissolved air to remove solids, particulates, colloids and floccs. It is very effective at removing F/O/G. Therefore, it will not provide full leachate treatment and is more likely to be used upstream to prevent solids overloading to subsequent treatment steps, it can also be utilised as a polishing step.	2	DAF has been proven to effectively and reliably remove solids from a waste stream, improved further by the addition of coagulant. However, the dosing of coagulant has to be precise to aid removal.	3	Provided coagulant dosing is accurate the DAF unit will remove most particulate and colloidal matter even if influent composition fluctuates and the process is start/stop.	3	Medium cost, dependent mainly on how many units are required.	3	The process requires coagulant/flocculent dosing as well as power to produce the high pressure to form the dissolved air. Sludge disposal is also required.	3	The plant will require monitoring to ensure the correct coagulant dose is maintained and the process is efficiently removing solids.	3	There are not many moving parts, however, the plant may require regular cleaning so can be labour intensive.	2	Power is required to produce the high pressure to form the dissolved air.	3	Coagulant dosing is required.	3	The plant will produce a low volume of sludge due to the solids/particulates removal process occurring, which can be returned to landfill or infrequently tankered away.	3	If used solely the leachate would not be fully treated, however, as a polishing unit there would be little environmental risk.	3	There are few moving parts, so the main H&S would be lone-working near open and deep water.	4	The process will provide a good level of solids removal provided the coagulant dose is correct It should not suffer from fluctuations in leachate composition.	4	The footprint is relatively small.	4	The plants can be installed as modules, increasing numbers for increased capacity requirements.	4	Incorrect dosing of coagulant can lead due reduced removal efficiencies and a reduction in quality of effluent, due to increases in COD.	3	51
Activated Carbon	Powdered Carbon	Adsorption of organics	Adsorption of metals.	Final Polishing	Unable to achieve the likely reductions in leachate contamination concentrations required. Possible use as part of a treatment train if discharging to sewer	1	PAC would remove COD and other organic pollutants (including hydrocarbons) but would not fully treated the leachate, and therefore, would more likely be used as a polishing stage. Would need to be followed by a process to recover the PAC (separation process).	2	The efficiency of PAC depends on the carbon, the dosing rate and the composition of the leachate. The rates of removal are very good, however, fluctuations in leachate composition could effect the process	3	The dosing rate of the PAC can be changed if the leachate becomes stronger/weaker. The process would not be affected by stop/start.	3	Relatively high, as the PAC tank/mixer has to be followed by a flocculation/coagulation tank to recover the PAC.	3	Costs of dosing the PAC, as well as dosing coagulant downstream to remove the 'used' PAC. The 'used' PAC also requires disposing of, possibly back onto the landfill.	2	The PAC dosing would have to be monitored to ensure it was effective, as well as the downstream coagulation process	4	There are not many moving parts so should only require occasional repair/maintenance.	4	Minimal power requirements, will just require power to mix and pump wastewater and dosing.	4	Depends on whether a solids separation process is included elsewhere in the treatment process. If a standalone separation process is required then added expense	5	The plant will produce a 'sludge' as the 'used' PAC will be collected and require disposal.	2	The land filling/disposal of 'used' PAC could be a potential environmental issue if contaminants were to leach into groundwater. PAC is better disposed of via incineration, however, this still leaves some waste.	3	There are few moving parts, so the main H&S would be the possibility of release of powder particularly during loading	3	The process will provide a good level of solids and organics removal provided the PAC dose is correct. It should not suffer from fluctuations in leachate composition.	4	A PAC mixing unit and a coagulant unit are required so the footprint is twice that of some of the other units, depending how separation is supplied	3	The PAC mixer and accompanying coagulation units could be modular with additional units added/removed	4	Incorrect dosing of the PAC and/or coagulant can lead due reduced removal efficiencies and a reduction in quality of effluent.	3	54
	Granular Carbon	Adsorption of organics	Adsorption of metals?	Final Polishing	Unable to achieve the likely reductions in leachate contamination concentrations required. Possible use as part of a treatment train if discharging to sewer	1	GAC would remove COD and other organic pollutants but would not fully treated the leachate, and therefore, would more likely be used as a polishing stage	2	The efficiency of GAC depends on the carbon, the dosing rate, the composition of the leachate, flow rates etc. The rates of removal are very good, however, fluctuations in leachate composition and flow rates/residence times could effect the process	3	GAC filters are usually run in series, which allows a good degree of flexibility, as the first filter takes most of the load until it is 'spent' then subsequent filters can achieve the same level of treatment whilst the GAC in the first filter is replaced. Stop/start would also not have a big impact.	3	Relatively high as 3 to 4 filters are regularly installed to allow for improved flexibility.	3	Carbon will require regeneration or replacement approximately every 2-5 years depending on the leachate composition, flow rates etc. However, this can be lower if high levels of COD are observed in the influent.	3	The filters will operate (and backwash, if required) automatically with very little which can be changed whilst on site which could not be done remotely.	4	There are not many moving parts so should only require occasional repair/maintenance.	3	The only power requirements would be influent (and possibly backwash) pumps.	4	GAC media only required	5	The GAC media once 'used' requires either disposal at landfill or regeneration off site.	3	GAC can be regenerated. The land filling/disposal of 'used' GAC could be a potential environmental issue if contaminants were to leach into groundwater.	3	There are few moving parts, and the filter units are sealed. If the top has to be accessed this would be at a considerable height.	4	The process will provide a good level of solids and organics removal. It should not suffer from fluctuations in leachate composition.	3	The footprint of a GAC filter is relatively small, however, 3-4 filters are likely to be required.	3	The plants can be installed as modules, increasing numbers for increased capacity requirements.	4	The process will produce a good quality effluent (providing it is a polishing stage), and the flexibility several filters provide, should mean there is little to impact the performance of the filter-set. However, it can not accept high solids loads so may require an additional filter (e.g. sand) upstream.	3	54

Technique	Sub category	Processes		Specific Applicability	Score	General Applicability	Score	Robustness	Score	Flexibility	Score	Capital costs (Capex)	Score	Operational costs (Opex)	Score	Manpower requirements to run	Score	Repair and Maintenance	Score	Power requirement	Score	Use of other consumables	Score	Emissions (wastes / by-products etc.)	Score	Environmental risks	Score	Health & Safety Risks	Score	Process Stability	Score	Footprint	Score	Ease of modular construction	Score	Factors affecting performance	Score	Overall Score
Chemical Treatment								Chemical Treatment																				Chemical Treatment										0
Chemical Oxidation	Ozonation	Destruction of organic compounds		Unable to achieve the likely reductions in leachate contamination concentrations required. Possible use as part of a treatment train if discharging to sewer	1	In principal Ozonation could fully treat leachate, however it is more suited to being a polishing stage, often requiring subsequent reed bed treatment	2	The efficiency of the treatment can be impacted by increased levels of degradable organic compounds, suspended solids and/or ammonia due to usage of available oxidation potential. It is a batch process so start/stop would not impact.	3	As much ozone can be added as required to oxidised all the contaminants of interest, however, this can lead to escalating costs. Therefore, easily degradable organic compound concentrations in the influent should be kept to a minimum.	4	Relatively high due to the high cost of equipment for ozone generation.	1	Relatively high due to the high electricity requirements for generation of the ozone.	1	The system can be automated so would require minimal manpower.	4	Whilst there are not many moving parts so should only require occasional repair/maintenance.	2	A lot of electricity is required to generate the ozone, especially for strong leachates.	2	The process usually uses air, however, pure oxygen is utilised in some cases.	4	The effluent should be of a very good quality. It can produce increased levels of BOD and/or other toxic by-products. However, a reed bed downstream of Ozonation would remove these potentially harmful substances prior to discharge.	3	The effluent should be of a very good quality. It can produce increased levels of BOD and/or other toxic by-products. However, a reed bed downstream of Ozonation would remove these potentially harmful substances prior to discharge.	4	Storage of handling of chemicals e.g. pure oxygen. The vessel would be a sealed unit.	2	The plant will reliably produce very high quality effluent (as tertiary treatment) provided the pre-treated leachate entering it is low in degradable organic compounds, with little impact from stop/start of the plant.	4	The footprint is relatively small.	3	The plants can be installed as modules, increasing numbers for increased capacity requirements.	3	Increased concentrations of degradable organic compounds , suspended solids and ammonia in the influent can lead to lower removal efficiencies of specific, less degradable organic and inorganic substances	3	46
	Hydrogen Peroxide	Destruction of organic compounds	Oxidation of sulphides	Unable to achieve the likely reductions in leachate contamination concentrations required. Possible use as part of a treatment train if discharging to sewer	1	Hydrogen Peroxide would not fully treat leachate, it is more commonly used to prevent/reduce leachate odours. It may be dosed to reduce other specific contaminants, such as ammonia, recalcitrant COD, phenols and cyanide.	2	The efficiency of the treatment can be impacted by pH, with a acidic conditions tending to produce more favourable results. It is a batch process so start/stop would not impact.	3	Increasing the dose of hydrogen peroxide will only improve removal efficiencies up to a point, past this point removal efficiencies plateau and other issues such as foaming may be observed.	2	relatively low if simply dosed into an existing part of the treatment process. Costs increase if a specific tank is utilised for the H2O2 dosing and reaction.	4	Relatively high due to the cost of the H2O2 dosing and pH control.	3	The system can be automated so would require minimal manpower.	4	There are not many moving parts so should only require occasional repair/maintenance.	4	Relatively low to operate the dosing pump and pH meter.	4	Requires large volumes of H2O2 and acid and alkali for pH adjustment.	3	The effluent from the process should contain low levels of the specific substance(s) (e.g. ammonia and recalcitrant COD) the H2O2 was dosed to remove. Also odours from the leachate should be at a minimum.	4	Excess H2O2 in the effluent would lead to serious environmental impacts due to the oxidation potential of H2O2. However, this would be avoided by close monitoring of the dosing.	4	Storage of handling of chemicals e.g. H2O2, acid and alkali. The vessel would be a sealed unit or dosed into an existing tank.	2	The plant will reliably remove odours and reduce concentrations of other substances such as cyanide and phenols, with little impact from stop/start of the plant. However, H2O2 dosing as well as pH control must be closely monitored	3	The footprint is relatively small.	5	Dosing can be carried out inline OR The plants can be installed as modules, increasing numbers for increased capacity requirements.	5	Accurate H2O2 dosing and pH control is vital to optimise the ability for the H2O2 to have the desired impact on the leachate.	3	56
	'Fenton's' Chemistry	Destruction of organic compounds		Unable to achieve the likely reductions in leachate contamination concentrations required. Possible use as part of a treatment train if discharging to sewer	1	Iron ions and hydrogen peroxide used to form hydroxyl radicals. Used to achieve high removal efficiencies of organics without producing toxic by-products. Increases the degradability of recalcitrant organic compounds. Can achieve metals removal. May not always effect ammonia to a great extent.	3	Removal efficiencies are effected by a number of factors, such as pH, dosing rates, chemical concentrations and reaction times. Therefore, the process has to be carefully optimised for the influent it is treating.	3	Many factors can be changed to improve removal efficiencies of contaminants, however, the conditions required may be different for different contaminants.	3	Varies - Can range from a simple dosing set-up to a fully engineered vessel for the sole purpose of the dosing and Fenton reaction.	3	Relatively high due to the cost of the H2O2 & ferrous (e.g. ferrous sulphate) dosing and pH control.	1	The system can be automated so would require minimal manpower, although significant chemical handling needs	3	There are not many moving parts so should only require occasional repair/maintenance.	4	Relatively low to operate the dosing pump, mixer and pH meter.	4	Requires large volumes of H2O2, ferrous (e.g. ferrous sulphate) and acid and alkali for pH adjustment.	2	The effluent from the process should contain low levels of the specific substance(s) (e.g. recalcitrant COD, TSS and (some) metals). Also colour from the leachate should be at a minimum. However, sludges can be produced.	3	Excess chemical dosing in the effluent would lead to serious environmental impacts due to the oxidation potential of H2O2 and hydroxyl radicals. However, this would be avoided by close monitoring of the dosing.	3	Storage of handling of chemicals e.g. H2O2, acid and alkali. The vessel would be a sealed unit or dosed into an existing tank.	2	The plant will reliably reduce concentrations of COD, TSS, metals, colour etc., with little impact from stop/start of the plant. However, H2O2, Fe^{2+} dosing as well as pH control must be closely monitored	3	The footprint is relatively small.	4	Dosing can be carried out inline OR The plants can be installed as modules, increasing numbers for increased capacity requirements.	4	Accurate chemical dosing and pH control is vital to optimise the ability for the hydroxyl radicals to have the desired impact on the leachate.	2	48
Precipitation / coagulation / flocculation	pH adjustment and Chemical Precipitation	Removal of metals	Control of pH	Unable to achieve the likely reductions in leachate contamination concentrations required. Possible use as part of a treatment train if discharging to sewer	1	Can be used to achieve good removal rates of metals, however, would require need to be used in conjunction with other technology to remove ammonia, COD, organics etc.	3	It can be difficult to maintain the optimum pH throughout a large tank to achieve good removal efficiency(s). It can also be difficult to precipitate out substances such as metals if the concentration is already low, as is often the case in leachate.	3	Each metal has a differing optimum pH at which its solubility is lowest i.e. most efficient removal by precipitation. Therefore, if several metals are required to be removed, removal efficiencies can be impacted, or several stages of precipitation may be required.	2	Relatively low - simply requires a reaction vessel(s) to dose and allow for precipitation. However, capex can escalate if subsequent clarification or similar is required.	4	Costs can be high dependent upon the volumes of chemicals required for pH adjustment /correction. Also requires chemical addition such as hydrated lime. Sludge disposal costs would also be incurred, this may require additional plant such as sludge presses etc. However, in the instance at Swanscombe it may be possible to	5	The system can be automated so in theory would require minimal manpower, however the need to maintain very accurate pH control would mean significant input to this.	3	There are not many moving parts so should only require occasional repair/maintenance. However, input required to maintain / calibrate sensors	4	Relatively low to operate the dosing pump and pH meter.	4	Potentially requires large volumes of acid and alkali for pH adjustment, as well as chemical addition to aid precipitation, such as lime.	3	The effluent should contain low concentrations of heavy metals (dependent on the selectivity of the precipitation process), however, there is a resultant sludge from the process to dispose of.	3	The storage and disposal of sludge could be a potential environmental issue if contaminants were to leach into groundwater. Overdosing or leakage of delivered or stored chemicals could also impact the environment. Potential for emission of fumes and vapours when pH adjusting waste waters.	3	Storage ~~of and~~ handling of chemicals e.g. lime, acid and alkali. Release of fumes and vapours when pH adjusting.	4	The efficiency of the process is highly dependent on an optimum pH being maintained throughout a tank, which can be difficult to achieve.	3	The footprint is relatively small. Can typically be fitted within ISO shipping container type packages / skid mounted.	4	The plants can be installed as modules, increasing numbers for increased capacity requirements.	4	Efficiency dependent on optimum pH being maintained, this is difficult to achieve and so requires accurate pH sensors, regularly calibrated. If several metals with differing pH-values for precipitation require removal, may impact overall effluent quality. Clarification or similar may be required following precipitation.	2	55
	Coagulation / flocculation	Solids removal, removal metals and some nutrient (any pollutant associated with solids)		Unable to achieve the likely reductions in leachate contamination concentrations required. Possible use as part of a treatment train if discharging to sewer	1	Coagulation / Flocculation (Coag/Flocc) produces floccs from colloidal material, which can by remove by typical physical treatments. However, it may not fully treat an effluent who's parameters of concern could be dissolved.	3	The efficiency of the process depends on the correct choice of coag / flocc, accurate dosing, good mixing and pH control.	3	The dosing rate of the coagulant and the pH can be changed dependent upon the solids to be removed, however, the process has to be correct to produce good results.	3	Relatively low as the flocculation tank/mixer requires subsequent treatment to separate the floccs/solids.	4	Costs of dosing the coagulant, as well a pH correction chemicals. The process produces a sludge which requires disposing of.	3	The sensitive dosing and mixing would have to be monitored to ensure it was effective, as well as the downstream solids separation process.	3	There are not many moving parts so should only require occasional repair/maintenance.	3	Minimal power requirements, will just require power to mix and pump wastewater and dosing. An electric mixer can also be avoided by using a static mixer	4	Coagulant and pH correction chemicals	3	The plant will produce a 'sludge' as the coagulated solids will be removed, collected and require disposal.	3	Storage and disposal of sludge could be a potential issue if contaminants were to leach into groundwater. Overdosing or leakage of delivered or stored chemicals could also impact the environment. Potential for emission of fumes and vapours when pH adjusting waste waters.	3	There are few moving parts, so the main H&S would be the storage and handling of chemicals, in particular acid and alkali.	3	The process will provide a good level of solids removal provided the conditions are correct. However, incorrect, mixing, dosing and/or pH control can impact the efficiency of the process.	3	A flocculator unit and solids separation unit are required so the footprint is twice that of some of the other units.	4	The coag/flocc mixer and accompanying coagulation units could be modular with additional units added/removed	4	Incorrect dosing of the coagulant, pH adjustment or mixing can lead to reduced removal efficiencies and a reduction in quality of effluent e.g. increased COD. This is particularly true for effluents that have a highly variable composition.	2	52

Technique	Sub category	Processes	Specific Applicability	Score	General Applicability	Score	Robustness	Score	Flexibility	Score	Capital costs (Capex)	Score	Operational costs (Opex)	Score	Manpower requirements to run	Score	Repair and Maintenance	Score	Power requirement	Score	Use of other consumables	Score	Emissions (wastes / by-products etc.)	Score	Environmental risks	Score	Health & Safety Risks	Score	Process Stability	Score	Footprint	Score	Ease of modular construction	Score	Factors affecting performance	Score	Overall Score
	Chemical Treatment								Chemical Treatment																	Chemical Treatment									0
Electro coagulation		Coagulation and removal of contaminants	Would be capable of reducing contaminant content but unlikely to affect chloride so aonly applicable to discharge to sea. Would require a disposal outlet for sludges produced and regular vehicle movements on site.	7	Process has the potentialfor high removal efficiencies for a range of pollutants both dissolved as well as those associated with solids. However, relatively poor ammonia removal is observed and would require additional treatment if this were a parameter of concern. Relatively novel process at present.	3	Requires careful selection of materials such as cathode and anode but after this can be affected by variations in influent quality.	3	Changes to pH, electrode material, temperature, conductivity, mixing and current can all be made to increase removal of certain contaminants, however, the changes may have a negative impact on the removal efficiency of other contaminants	3	Relatively high - The cost of the equipment is expensive and may require upstream solids removal. Also requires pre/post ammonia stripping	2	Relatively high - due to supply of the current, replacement of anodes and cathodes and chemical dosing	2	The system can be automated so would require minimal manpower.	4	There are not many moving parts so should only require occasional repair/maintenance.	3	Relatively high power requirements due to the volume of electricity needed for the process	2	Replacement anode/cathode and pH correction chemicals	3	The plant will produce a 'sludge' as the coagulated solids will be removed, collected and require disposal. Some off-gas can also be produced along with odours	2	The process will produce a good quality effluent. However, the handling / storage and disposal of sludge produced by the process could be a potential environmental issue if contaminants were to leach into groundwater.	4	There are few moving parts, the main H&S risk is derived from the use of electricity and water but also the storage and handling of chemicals, in particular acid and alkali.	3	The process will provide a good level of COD, solids, heavy metals etc. removal provided the conditions are correct. However, incorrect conditions in the electro coagulation cells will can impact the efficiency of the process.	4	The electro coagulation cells have a relatively small footprint. However, upstream solids removal and pre/post ammonia stripping may be required.	4	The electro coagulation less can be installed as modules.	4	The conditions in the electro coagulation cell i.e. pH, electrode material, temperature, conductivity, mixing and current all have to be optimised to optimise removal of contaminants, however, the optimised changes for one contaminant may have a negative impact on the removal efficiency of other contaminants	2	55
Adsorption	Bauxsol Media	Adsorption of contaminants	Unable to achieve the likely reductions in leachate contamination concentrations required. Possible use as part of a treatment train if discharging to sewer	1	Capable of removing metals, phosphates and colour, however, more suited as a 'polishing' stage rather than full treatment if other parameters of concern exist. Bauxite has had many trials, however, it is not commonly used at present and is relatively new to the market, still a relatively novel process.	2	The media can be used either as a 'filter' ordered as an additive powdered (for example in a vessel or reed bed etc). Data to date shows reasonable removal efficiencies for metals, phosphorous and colour.	4	The bauxite media can be deployed in a number of different applications, for example as a filter, dosed as an additive in a vessel or built into the structure of a wetland.	4	Low - if dosed as a slurry and relatively low if used as filter media in filter vessel. Costs may increase if reed bed construction is required.	4	The filter media would require replacement as the media in-situ became exhausted as it only has finite capacity for metals (and phosphate) adsorption. OR on-going dosing costs if dosed as a slurry.	4	No real man-power requirements except infrequent replacement of the Bauxite material OR ensuring the stock dosing tank it topped up.	4	There are not many moving parts so should only require occasional repair/maintenance.	4	Pumping requirements, either into filter or from a dosing pump	5	Bauxite material replacement once exhausted OR bauxite slurry dosing	4	Exhausted filter media will require disposal, however, it is possible it can be used as an odour abatement material following use as a filter media. OR there may be additional sludge produced if dosing bauxite.	4	Bauxite is essentially a waste material from the aluminium mining industry and is effectively inert. After use it will be contaminated with adsorbed pollutant and would require disposal to suitably license facilities. However, no current EA approval to use as BAT	1	Manual handling risks associated with removal and replacement of the filter media and dust handling issues if using the powdered product.	4	Assuming it is used for the correct application, it is a stable process although longevity not known.	2	Relatively small if used as a dosing media, or used as media in a filter. However, if used as media in a reed bed the footprint would be larger.	3	Very easy to use as modules	5	The media will remove metals and phosphate until it is exhausted due the high volume of adsorption sites.	3	58
	DRAM media	Adsorption of contaminants	Could meet requirements. Does have a track record of removal of oganic pollutants and metals, particularly if other methods fail (such as precipitation etc). Will need regular delivery and removal of materials from site. Disposal will be required for spent media. Still a relatively novel process.	8	DRAM is reported to be capable of removing BOD, COD, ammonia and metals. Current trials indicate that it could have a role as a main treatment process. It is not a 'tried and tested' method and is only currently used commercially at a handful of locations and predominantly for metals removal.	2	The system is a passive 'filter' so has not 'working' parts. At high flows filter structure can be lost. High or low temperatures can affect performance. After a number of months the media is prone to decay	2	The DRAM media is reported to remove a whole range of contaminants. It can easily be retro-fitted to existing plant or installed as a primary treatment process, so it is very flexible	4	Low - container costs for the DRAM material and associated pipe-work and DRAM material	4	No running costs except replacement of the DRAM material and disposal of spent material, usually to incinerators.	4	Main manpower requirement is the handling of raw and spent media. This operation could be set up so as to be relatively infrequent.	3	No mechanical aspects (unless pumping is required) so only replacement of DRAM material required	4	Vessel can be gravity fed and no moving parts - so no real power requirements	5	DRAM material only (routine replacement) No chemicals required	4	Spent DRAM material produced, could be incinerated at low cost but may also be a hazardous waste	2	The trials to date show very good removals of the contaminants of interest. May be risky to use as sole treatment but would appear to provide very good polishing stage. Material is in itself low hazard and has been used as an animal feed stuff. However, no current EA approval to use as BAT	1	Manual handling risks associated with removal and replacement of the filter media. Raw material (dry) could potentially be a fire / explosion risk.	4	Assuming it is used for the correct application, it is a stable process although longevity not known	2	Would not be excessive, especially as polishing stage.	5	Very easy to use as modules.	5	There are no known inhibitory substances. Concern is itd ability to meet required removal rates of contaminants of concern, plus high flow rates may be an issue	2	61

Technique	Sub category	Processes			Specific Applicability	Score	General Applicability	Score	Robustness	Score	Flexibility	Score	Capital costs (Capex)	Score	Operational costs (Opex)	Score	Manpower requirements to run	Score	Repair and Maintenance	Score	Power requirement	Score	Use of other consumables	Score	Emissions (wastes / by-products etc.)	Score	Environmental risks	Score	Health & Safety Risks	Score	Process Stability	Score	Footprint	Score	Ease of modular construction	Score	Factors affecting performance	Score	Overall Score
Aerobic Biological Treatment					Aerobic Biological Treatment																																		
Suspended Growth Systems	Aerated lagoons	Nitrification	Oxidation of organics		Likely to be capable of achieving the reductions in contaminants required, especially if in conjunction with additional polishing techniques, but only if reduction in chlorides are not required (so only applicable to discharge to sea). Large footprint will be required.	16	This method can be utilised to treat raw leachate, however, a secondary process is often required to further remove solids and/or other contaminants to a satisfactory concentration.	4	Lagoons do not always provide satisfactory aeration and mixing, leading to anaerobic areas. In open lagoons low temperatures (below 5°C) can inhibit the process. Lagoons tend not to be >5m deep and so can have reduced oxygen transfer rates. Algae can also form which can lead to organics in the effluent.	3	Requires either large area or very deep lagoons to be capable of providing sufficient retention times to treat high loads. Tends only to remove ammonia and organics	4	Relatively high - As a large area is required to be designed and constructed along with aeration and/or mixing plus controls on levels. Increasingly, dependent on the exact construction detail, secondary containment and or leak detection is required (if base is below ground level).	3	Relatively high - Due to the volume of air required to aerate and mix the large lagoon power supply costs can be high. Dosing of alkalinity and/or nutrients may also be required. Depending on aeration technique high R&M costs. Typically requires relatively frequent supervision / attendance.	3	Moderate - will require checks to ensure aeration and mixing is at an optimum and monitor the process. Chemical dosing system require attention and foam management may be an issue.	3	R&M is focussed on aeration systems, pumps, probes and level controls.	3	Relatively high - Due to the volume of air required to be supplied to the aerators to aerate and mix the large lagoon.	3	Dosing may be required to maintain the correct level of alkalinity and/or nutrients.	3	Lagoons can be subject to odours and sometimes foam emissions. Occasional sludge disposal will be required.	3	The lagoon and effluent will pose a risk to controlled waters and land if released. Sludge from the lagoon can also pose a risk if it were to escape. If the treatment process is inhibited (which is not unusual), contaminants of concern may not be fully treated but could continue to be discharged.	3	There is a large area of open and deep water. Storage and handling of chemicals. Occasional manual handling with installation / removal of equipment from lagoons. Potential for pathogens.	3	The treatment process is biological and so is subject to instability due to changing environmental conditions. For example changes in the requirement for supply of DO, changes in temperatures and changes in pH can all inhibit treatability. Incorrect levels of solids can also present a problem.	2	Large, especially if a second lagoon and/or reed bed is required.	2	Modular construction is difficult and impractical unless large areas of land are available.	2	treatment is provided by biological process and are therefore subject to variation by environmental factors (temperature etc), oxygen availability, pH etc. Unless these are continuously monitored and controlled treatment efficiencies are likely to be inhibited.	3	63
	Facultative Lagoon	Nitrification	de-Nitrification	Oxidation of organics	Likely to be capable of achieving the reductions in contaminants required. The space required would be an issue as would deposit of chloride to the cap (if used in conjunction with Short rotational copppice). Us of coppice would mean that no discharge off site was reqruied	16	Applicable to treatment of liquids contaminated with organics where operators have very large areas of land available to allow construction and operation of very long retention time lagoons (typically > 50 days retention time required). If this is practical then this process potentially has a wide range of applications.	2	Gentle aeration and a mixing to create a stratified facultative process. Typically 3 layers are maintained and liquid moved between them. The process can be disrupted by changes to loading, disruption to the layers and other environmental factors such as changes to temperature and pH.	3	This method can handle fluctuations in influent quality due to the extensive dilution it would receive in the long retention time lagoon, however, issues can still arise if temperatures drop too low and / or loading is not controlled over the medium to long term.	3	Relatively high - As a large area is required to be designed and constructed along with surface aerators. A second lagoon or reed bed is almost always required. Installation (operation) has to be in line with Reservoirs act which can cause issues.	2	Very low. Simple surface aerator/mixer with resultant low energy usage. Dosing of alkalinity and/or nutrients is often not required due to the facultative process balancing acid and alkali requirement. Active sludge management not required as sludges self regulate by digestion and mineralisation.	4	Relatively low - will require checks to ensure mixing is at an optimum and check on feed loading rates.	4	There are not many moving parts so should only require occasional repair/maintenance.	4	Relatively low - Due to only simple surface aerators or pumps being required.	4	No major use of consumables.	4	Lagoons can be subject to odours but this should not be an issue in a well operated system.	5	The lagoon and final effluent will still pose a risk to controlled waters and land if accidentally released. There is a lower risk of the treatment process being inhibited due to the high levels of dilution provided in the system.	3	There is a large area of open and deep water. Potential for pathogens.	3	Process is relatively stable and would normally require several weeks of inappropriate operation for the effect to be apparent.	4	Very large.	0	This is the least modular technology.	0	the main factor affecting performance one the system is correctly designed and installed is inappropriate loading.	4	65
	Activated sludge (extended aeration)	Nitrification	Carbonaceous oxidation of organics		Likely to be capable of achieving the reductions in contaminants required, especially if in conjunction with additional polishing techniques, but only if reduction in chlorides are not required (so only applicable to discharge to sea). Large footprint will be required.	15	This method can be utilised to treat most organic effluents, however, issues with solids settlement of the treated mixed liquor can lead to solids and/or other contaminants in the final effluent unless controlled	4	Aeration and mixing ensures all effluent is treated. Can be issues with solids carry-over in the effluent, inefficient or non-treatment due to incorrect process control. Process requires a healthy biomass. Flows and loads have to be controlled as a high strength effluent can be toxic to the sludge and effect treatment.	3	Operating conditions can be adjusted to accommodate fluctuations in influent composition and required discharge quality. A wide range of effluents can be targeted and there are a great many variations in plant design.	4	High - a large tank requires construction as well as aeration, mixing and control systems. A secondary process is also typically required to separate and retain solids.	2	Relatively high - due to costs for aeration and dosing of chemicals to maintain the correct conditions to enable the bacteria to flourish. Regular process control tasks should be undertaken along with on-going maintenance and inspection.	2	Relatively high - as the process will need to be monitored regularly as the process is sensitive to change.	2	The mechanical parts of the system will all need regular preventative repair/maintenance e.g. regular calibration of the sensors.	3	Relatively high - Due to the volume of air required to be supplied to the aerators to aerate and mix.	2	Chemical dosing, often of phosphate and alkali, will almost certainly be required. May require antifoam	2	Effluent of a good quality will be produced if the ASP is managed correctly. Sludge will be produced which will require disposal. There is also a potential for odours and foam to be produced.	3	If the treatment process fails, discharge of an effluent containing high solids level would be detrimental to a surface water. Over dosing of phosphate of alkali would also be detrimental. Sludge disposal is also required.	3	Working over open and deep water. Storage and usage of chemicals. Potential for pathogens.	3	The aeration and mixing in an activated sludge process ensures all the effluent is treated. However, there can be issues with solids carry-over in the final effluent, inefficient or non-treatment due to incorrect operating conditions.	3	Moderate due to the tank and settlement tank	3	Several process trains could be constructed to handle variations in flow.	3	Aeration, mixing, pH phosphate levels and temperature all have to be optimised to ensure a good quality effluent. The process requires a healthy biomass.	3	60
	Activated sludge - including denitrification	Nitrification	de-Nitrification	Carbonaceous oxidation of organics	Likely to be capable of achieving the reductions in contaminants required, especially if in conjunction with additional polishing techniques, but only if reduction in chlorides are not required (so only applicable to discharge to sea). Large footprint will be required.	15	Utilised to treat most organic effluents, issues with solids settlement of the treated mixed liquor can lead to solids and/or other contaminants in the effluent unless controlled. Dependent on the nature of the effluent being treated can required additional chemical costs but in other circumstances can reduce costs.	4	Similar to the activated sludge (nitrification only) process but can be more robust as the de-N stage can act as a selector process.	4	Operating conditions can be adjusted to accommodate fluctuations in influent composition and required discharge quality. A wide range of effluents can be targeted and there are a great many variations in plant design.	4	Slightly higher than the standard nitrification process - a large tank requires construction as well as aeration, mixing and control systems. A secondary process is also typically required to separate and retain solids.	2	Opex costs are driven by the exact system step up and quality of effluent to be treated along with the required discharge quality.	2	Relatively high - as the process will need to be monitored regularly as the process is sensitive to change.	3	The mechanical parts of the system will all need regular preventative repair/maintenance e.g. regular calibration of the sensors.	3	Relatively high - Due to the volume of air required to be supplied to the aerators to aerate and mix.	3	Chemical use is driven by the exact system step up and quality of effluent to be treated along with the required discharge quality.	3	Effluent of a good quality will be produced if the ASP is managed correctly. Sludge will be produced which will require disposal. There is also a potential for odours and foam to be produced.	3	If the treatment process fails, discharge of an effluent containing high solids level would be detrimental to a surface water. Over dosing of phosphate of alkali would also be detrimental. Sludge disposal is also required.	3	Working over open and deep water. Storage and usage of chemicals. Potential for pathogens.	3	The aeration and mixing in an activated sludge process (ASP) ensures all the leachate is treated. However, there can be issues with solids carry-over in the final effluent, inefficient or non-treatment due to incorrect operating conditions.	4	Moderate due to the tank and settlement tank	3	Several tanks could be constructed to handle larges changes in flow, however, they would not really be considered as modular	3	Aeration, mixing, pH phosphate levels and temperature all have to be optimised to ensure a good quality effluent. The process requires a healthy biomass.	3	65
	SBR	Nitrification	de-Nitrification	Carbonaceous oxidation of organics	Likely to be capable of achieving the reductions in contaminants required, especially if in conjunction with additional polishing techniques, but only if reduction in chlorides are not required (so only applicable to discharge to sea). Large footprint will be required.	18	Can be used to achieve both activated sludge processes described above. Generally used for a higher strength, lower volume waste stream to be treated. All process steps are confined to one tank but take place at different times in a set sequence.	4	The SBR can be susceptible to strong leachate as it is a batch process, causing toxic shocks. However, leachate balancing is often carried out before the SBR to balance out high loads. A healthy biomass is required.	4	Effluent introduced to the SBR slowly to the SBR to prevent 'shocking'. Denitrification stage can be incorporated within the sequence. Different methods of construction and aeration techniques can be chosen to accomplish different goals (for example retention of radiation of heat) as well as achieving different effluent qualities.	4	Relatively high - a large tank is required. Various aeration systems with different capital costs. Relatively sophisticated monitoring and control systems required (ideally including SCADA). Ancillary equipment is also often required such as leachate and effluent storage, chemical stores and pumps etc.	2	Large volume of air are required as well as mixing, chemical and occasional nutrient dosing . Sludge management is sometimes required. Often high levels of operator intervention including regular preventative maintenance and probe calibration / sampling are needed.	2	The plant can be automated but requires regular monitoring (possibly remotely) and adjustment by a skilled operator. changes to influent load need to be carefully managed to maintain a efficient treatment process.	3	Relatively regular preventative maintenance is required for the numerous elements of mechanical and electrical equipment installed at such a plant.	3	The main power requirement is for aeration systems and chemical dosing (dependent on set up). Some aeration systems potentially have lower electrical requirements than others.	3	Nutrient and pH adjustment/correctio n can be required. May require antifoam	3	Emissions mainly limited to treated effluent and sometime waste activated sludges. In a well operated plant odours should not be a n issue.	4	SCADA and plant management ensures a quality effluent. However, large volumes of potentially contaminating material are stored at any one time along with chemicals both of which could damage the environment if released. Aerosols released depending on the aeration systems.	4	Working over open and deep water. Storage and usage of chemicals. Potential for pathogens. Aerosols could be an issue.	3	Aeration and mixing should ensures all contaminant of concern are treated. Can be issues with solids carry-over in the final effluent, inefficient or non-treatment due to incorrect operating conditions. Effective process control (automation and supervision) can significantly reduce these risks.	4	Relatively large, especially if tertiary treatment is required.	3	Several tanks could be constructed to handle larges changes in flow, however, they would not really be considered as modular as they would not lend themselves to regular movement between sites.	3	A good quality effluent should be produced, provided the diffused aeration provides a good source of oxygen and good mixing. However, does require a healthy biomass.	4	71
	MBR	Nitrification	de-Nitrification	Carbonaceous oxidation of organics	Likely to be capable of achieving the reductions in contaminants required, especially if in conjunction with additional polishing techniques, but only if reduction in chlorides are not required (so only applicable to discharge to sea). Large footprint will be required.	18	Can be used to achieve both activated sludge processes described above. Generally for treatment of higher strength, lower volume wastes. Similar to SBR but with solids separation by filtration (commonly using membranes) and continuous aeration. Smaller footprint producing a high quality effluent.	4	The MBR can be susceptible to similar issues to an SBR but there is a higher risk of toxic shocks and the added issues of membrane operation. However, the presence of the membrane tends to eliminate issues of solids carry over	3	Same size plant can accept a higher of loas than an SBR. Denitrification stage(s) can be incorporated to the process. Different methods of construction and aeration can be chosen to accomplish different goals (for example retention or radiation of heat) as well as achieving different effluent qualities.	4	Relatively high - a smaller treatment is required but increased costs are incurred in supplying filtration. Sophisticated monitoring and control systems required. Ancillary equipment is also often required such as leachate and effluent storage, chemical stores and pumps etc.	2	Relatively high. Large volume of air required as well as mixing and chemical dosing . Sludge management is required. Additional costs in the operation and management of membranes. High levels of operator time including regular preventative maintenance and probe calibration / sampling.	2	The plant can be automated but requires regular monitoring (possibly remotely) and adjustment by a skilled operator. Changes to influent load need to be carefully managed to maintain an efficient treatment process.	2	Relatively regular preventative maintenance is required for the numerous elements of mechanical and electrical equipment installed at such a plant.	2	The main power requirement is for aeration systems and generation of high pressures if using cross flow membranes. Some aeration systems potentially have lower electrical requirements than others. Similarly choice of membrane systems can have a dramatic effect on power consumption.	2	Nutrient and pH adjustment / correction can be required. May require antifoam. Chemical cleaning of membranes is a likely requirement.	3	Emissions mainly limited to treated effluent and sometime waste activated sludges. In a well operated plant odours should not be an issue. If the treated effluent has to meet a regulatory bacteriological discharge limit an MBR has significant advantages over other process options.	4	Plant management should ensure a good quality effluent. However, volumes of potentially contaminating material are stored along with chemicals both of which damage the environment if released. Aerosols can be released depending on the chosen aeration systems.	4	Working over open and deep water. Storage and usage of chemicals. Potential for pathogens. Aerosols could be an issue.	4	Aeration and mixing should ensures all contaminants are treated. Can be issues with solids carry-over in the final effluent, inefficient or non-treatment due to incorrect operating conditions. Effective process control (automation and supervision) can significantly reduce these risks.	4	Usually smaller than other biological processes such as SBR or lagoons etc. Also use of a membrane means less frequent need for tertiary polishing stages such as reed beds.	4	More modular than SBR. Relatively small footprint treatment tanks mean a more modular construction is possible. Changing the number of membrane modules is also possible in a well designed plant.	3	A good quality effluent should be produced, provided aeration provides a good source of oxygen and good mixing. However, does require a healthy biomass.	4	69

Technique	Sub category	Processes		Specific Applicability	Score	General Applicability	Score	Robustness	Score	Flexibility	Score	Capital costs (Capex)	Score	Operational costs (Opex)	Score	Manpower requirements to run	Score	Repair and Maintenance	Score	Power requirement	Score	Use of other consumables	Score	Emissions (wastes / by-products etc.)	Score	Environmental risks	Score	Health & Safety Risks	Score	Process Stability	Score	Footprint	Score	Ease of modular construction	Score	Factors affecting performance	Score	Overall Score
Aerobic Biological Treatment						Aerobic Biological Treatment																				Aerobic Biological Treatment												
Attached Growth Systems	Fixed Film Systems (e.g. Percolating Filters)	Nitrification	Carbonaceous oxidation of organics	Likely to be capable of achieving the reductions in contaminants required, especially if in conjunction with additional polishing techniques, but only if reduction in chlorides are not required (so only applicable to discharge to sea). Large footprint will be required. Relatively novel technique	12	Treats biodegradable waste waters and effluents. More suited to high BOD and COD effluent with lower ammonia than suspended growth systems	3	The process is robust but requires a very large footprint to accommodate similar loads to suspended growth systems.	3	Poor - There are many factors which can impact treatment efficiency. A weak influent id required to stop inhibition of the bacteria.	2	relatively high - large tank(s) are required, and filled with media of some sort. Subsequent treatment is also likely to be necessary.	2	Relatively low - the filter is a passive system so requires little energy (only rotation of the distribution arm) and if well operated the media will not require regular replacement. Nutrient dosing may be required.	4	Very little required if operated efficiently.	4	Repairs should not be required often, maintenance of the filter bed and distribution arm should also be infrequent if operated correctly.	4	Very little power requirement, will power only possibly required for movement of the distribution arm and possibly dosing.	4	There may only be a small volume of dosing required.	4	The effluent would almost certainly require further treatment to remove solids and other possible contaminants.	4	The effluent produced will almost certainly not be of sufficient quality to pose a low environmental risk if discharged direct to surface water.	2	There are few moving parts and no open/deep water. There may be storage and handling of chemicals required.	4	Many factors can be detrimental to the treatment process and so can be unreliable even if operated correctly.	1	Relatively high - dependent on the number of tanks required and the method of subsequent treatment.	2	Numerous filters can be constructed dependent of treatment capacity required, however, they would not really be considered as modular.	2	The treatment efficiency suffers if high ammoniacal-N concentrations and/or high organic or inorganic loads are present in the influent. Cold temperatures, inability to evenly dose alkalinity and a lack of oxygen in the filter can all also impact on treatment.	1	58
	Rotating Biological Contactor (RBC)	Treatment of ammonia	Oxidation of organics	Likely to be capable of achieving the reductions in contaminants required, especially if in conjunction with additional polishing techniques, but only if reduction in chlorides are not required (so only applicable to discharge to sea). Large footprint will be required. Relatively novel technique	10	RBC can be used to treat leachate, however, influent COD and BOD concentrations have to be relatively low to prevent excessive build up of solids on the media, preventing effective treatment. Almost certainly will require subsequent solids removal treatment.	3	The process requires process water to be approximately 20 C to operate efficiently, temperatures below this will lead to poor performance. However, better mixing than observed in the percolating filters means RBC is less susceptible to changes in influent composition.	3	The filter and basal tank can be designed and changes made during operation e.g. rotation speed, level of submersion etc. pH and nutrient dosing is also more effective than in a percolating filter. However, the temperature of wastewater in the reactor must be kept at 20 degrees C	3	Relatively high - requires the RBC(s) as well as additional treatment to remove solids from the effluent and possibly metals.	3	relatively low - aeration costs are much lower than in an SBR. Chemical dosing and sludge disposal may be required. However, heating of the incoming leachate and/or wastewater in the tank is required - costs will be dependent on whether landfill gas can be used as a heat source.	3	The plant can be fully automated but requires regular monitoring (possibly remotely) by a skilled operator. Generally more labour intensive than an SBR.	4	Repairs should not be required often, maintenance of the filter discs and basal tank should also be infrequent if operated correctly.	4	Aeration is much lower than in an SBR, with small power requirements for rotation of the discs and dosing. However, heating of the incoming leachate and/or wastewater in the tank is required - costs will be dependent on whether landfill gas can be used as a heat source.	3	Landfill gas, or other gas required to heat the treatment process. Nutrient and/or pH correction may be required.	3	The effluent would almost certainly require further treatment to remove solids and other possible contaminants. There may also be sludge to be disposed of.	3	The effluent produced may not be of sufficient quality to pose a low environmental risk if discharged direct to surface water.	3	There may be working near open/deep water and storage/handling of chemicals required. Burning of gas to produce heat for the process.	3	If operated well and a temperature of 20 degrees C is maintained in the treatment process RBC should provide a good quality effluent, however, cold temperatures, influent high in BOD/COD, inefficient mixing etc. can impact the performance of the plant.	3	Relatively high - dependent on the number of tanks required and the method of subsequent treatment.	2	Numerous RBC's can be constructed dependent of treatment capacity required.	4	The treatment efficiency suffers if high BOD/COD loads are present in the influent. Cold temperatures and poor mixing in the filter can all also impact on treatment.	2	59
	Biological Aerated Filter (BAF)	Treatment of ammonia	Oxidation of organics	Likely to be capable of achieving the reductions in contaminants required, especially if in conjunction with additional polishing techniques, but only if reduction in chlorides are not required (so only applicable to discharge to sea). Large footprint will be required. Relatively novel technique	11	Used to treat leachate, able to accept higher BOD/COD concentrations than percolating filters. Upstream treatment required to reduce solids prior to entering the BAF. Also, additional treatment of COD and metals may be required.	3	Should provide good removal efficiencies of ammonia and BOD, satisfactory COD removal levels provided there is good aeration and mixing in the tank and temperatures do not drop too low (below 10°C). Continuous introduction of leachate into the filter should reduce the risk of toxic shocks.	4	Differing flow and loads of leachate can be balanced prior to introduction to the filter to ensure the bacteria on the media continue to operate efficiently and remove contaminants. However, does require a healthy biomass on the media. The process does require stopping to allow for backwashing.	3	Relatively high - requires the BAF as well as solids pre-treatment and additional treatment to remove recalcitrant COD and possibly metals.	3	relatively low - aeration costs are much lower than in an SBR. Chemical dosing and sludge disposal may be required.	4	The plant can be fully automated but requires regular monitoring (possibly remotely) by a skilled operator.	3	Repairs should not be required often, maintenance of the filter media should be carried out automatically by backwashing.	3	Aeration is much lower than in an SBR, with small power requirements for backwashing and dosing.	4	Nutrient and/or pH correction may be required.	3	The effluent would almost certainly require further treatment to remove COD and other possible contaminants. There may also be sludge to be disposed of.	2	The effluent produced may not be of sufficient quality to pose a low environmental risk if discharged direct to surface water.	2	There may be working near open/deep water and storage/handling of chemicals required.	3	If operated well the treatment process should provide a good quality effluent, however, cold temperatures, poor aeration, inefficient mixing etc. can impact the performance of the plant.	3	Relatively low - as the tank and filter are in one unit. Footprint obviously increases with the number of units required and if additional treatment is required.	3	Numerous BAF's could be installed	4	The treatment efficiency suffers if there is a high solids concentration in the influent, during cold temperatures and if poor mixing and/or poor aeration is present in the filter.	3	61
	Submerged Aerated Filter (SAF)	Treatment of ammonia	Oxidation of organics	Likely to be capable of achieving the reductions in contaminants required, especially if in conjunction with additional polishing techniques, but only if reduction in chlorides are not required (so only applicable to discharge to sea). Large footprint will be required. Relatively novel technique	10	SAF can be used to treat leachate, and is able to accept higher BOD/COD influent concentrations than the percolating filter. Upstream treatment is required to reduce solids prior to entering the SAF. Also, additional treatment of solids, COD and metals will be required.	2	Should provide good removal efficiencies of ammonia and BOD, satisfactory COD removal levels provided there is good aeration and mixing and temperatures do not drop too low (below 10°C). Continuous introduction of leachate filter reduces the risk of shocks. Subsequent solids removal is required .	3	Differing flow and loads of leachate can be balanced prior to introduction to the filter to ensure the bacteria on the media continue to operate efficiently and remove contaminants. However, does require a healthy biomass on the media. The process does require stopping to allow for backwashing.	3	Relatively high - requires the SAF as well as solids pre-treatment and additional treatment to remove solids and recalcitrant COD and possibly metals.	2	relatively low - aeration costs are much lower than in an SBR. Chemical dosing and sludge disposal may be required.	3	The plant can be fully automated but requires regular monitoring (possibly remotely) by a skilled operator.	4	Repairs should not be required often, maintenance of the filter media should be carried out automatically by backwashing.	4	Aeration is much lower than in an SBR, with small power requirements for backwashing and dosing.	4	Nutrient and/or pH correction may be required.	3	The effluent would almost certainly require further treatment to remove solids and COD and other possible contaminants. There may also be sludge to be disposed of.	2	The effluent produced may not be of sufficient quality to pose a low environmental risk if discharged direct to surface water.	3	There may be working near open/deep water and storage/handling of chemicals required.	3	If operated well the treatment process should provide a good quality effluent, however, cold temperatures, poor aeration, inefficient mixing etc. can impact the performance of the plant.	3	Relatively low - as the tank and filter are in one unit. Footprint obviously increases with the number of units required and if additional treatment is required before and/or after.	3	Numerous SAF's could be installed	4	The treatment efficiency suffers if there is a high solids concentration in the influent, during cold temperatures and if poor mixing and/or poor aeration is present in the filter.	3	59
	Moving Bed Bio film Reactor (MBBR)	Treatment of ammonia	Oxidation of organics	Likely to be capable of achieving the reductions in contaminants required, especially if in conjunction with additional polishing techniques, but only if reduction in chlorides are not required (so only applicable to discharge to sea). Large footprint will be required. Relatively novel technique	11	MBBR can be used to treat leachate, and can be set up as an anaerobic-aerobic arrangement to gain good COD and ammonia removal as well as nitrification.	3	The process should provide good removal efficiencies of ammonia and COD. This is provided there is good aeration and mixing in the tank and temperatures do not drop too low e.g. below 10 degrees C). Continuous introduction of leachate into the filter should reduce the risk of toxic shocks.	4	Flow balancing prior to the filter to ensure the bacteria on the media continue to operate efficiently and remove contaminants. Different media shape design and volumes can be used to optimise treatment. Does require a healthy biomass on the media. No backwashing is required.	3	Relatively high - requires the MBBR as well as requiring additional treatment to remove solids.	4	relatively low - aeration costs are lower than in an SBR. Chemical dosing and sludge disposal may be required.	3	The plant can be fully automated but requires regular monitoring (possibly remotely) by a skilled operator.	3	Repairs should not be required often, maintenance of the filter media should be carried out by the aeration system 'shearing off' excess bio film growth.	3	Aeration is lower than in an SBR.	3	Nutrient and/or pH correction may be required.	3	The effluent would require downstream solids separation. There may also be sludge to be disposed of.	2	The effluent produced may not be of sufficient quality to pose a low environmental risk if discharged direct to surface water.	2	There may be working near open/deep water and storage/handling of chemicals required.	3	If operated well the treatment process should provide a good quality effluent, however, cold temperatures, poor aeration, inefficient mixing etc. can impact the performance of the plant.	3	Relatively low - as the MBBR unit is not large. Footprint obviously increases with the number of units required.	4	Numerous MBBR units could be installed	4	The treatment efficiency suffers during cold temperatures and if poor mixing and/or poor aeration is present in the filter.	3	61

Technique	Sub category	Processes				Specific Applicability	Score	General Applicability	Score	Robustness	Score	Flexibility	Score	Capital costs (Capex)	Score	Operational costs (Opex)	Score	Manpower requirements to run	Score	Repair and Maintenance	Score	Power requirement	Score	Use of other consumables	Score	Emissions (wastes / by-products etc.)	Score	Environmental risks	Score	Health & Safety Risks	Score	Process Stability	Score	Footprint	Score	Ease of modular construction	Score	Factors affecting performance	Score	Overall Score
Anaerobic Biological Treatment										Anaerobic Biological Treatment																		Anaerobic Biological Treatment												
	Wet' AD	Digestion of ammonia & organics				Unable to achieve the likely reductions in leachate contamination concentrations required.	2	The process is effective at treating COD and produces a biogas which can be used to heat the reactor. However, effluent often has to undergo aerobic treatment to remove ammonia, sulphides etc. Metals can be precipitated out by the process, however, they can also often inhibit the process.	1	The process should provide good COD removal rates for influents containing up to 2000 mg/l COD. Metals can be inhibitory to the anaerobic bacteria.	2	The process ideally requires a consistent influent composition as too low COD or high metals concentrations would have negative impacts on the process. Also the process would suffer from stop/start as the bacteria require the influent as a food source.	2	Relatively expensive - the anaerobic digesters are generally large and require numerous pumps, dosing system, and regularly require downstream aerobic treatment to remove ammonia.	1	Relatively high - chemical dosing and sludge disposal costs, and is likely to require gas to supplement the gas generated by the digester (and possibly the landfill) to maintain a constant temperature above 30 degrees C in the reactor. Also costs associated with additional treatment.	1	The plant can be fully automated but requires regular monitoring (possibly remotely) by a skilled operator.	3	Repairs should not be required often however, maintenance (e.g. calibration, cleaning) of sensors, meters etc. will be required	3	Is very likely to require energy to maintain a temperature above 30 degrees C in the digester. Would also require power for pumps.	1	pH adjustment and correction chemicals required.	3	An effluent low in COD would be produced, with metals removal also likely to have occurred. However, would require ammonia removal	2	Effluent from the digester would almost certainly require further treatment to remove ammonia as well as dissolved methane and sulphides. Methane and hydrogen sulphide produced by the process could not simply be emitted to air.	1	The reactor is a pressurised vessel and produces explosive and toxic gases. Storage and handling of chemicals.	2	Fluctuations in influent could reduce the efficiency of the process, as could stop/starting of the treatment. However, should always produce an effluent low in COD.	2	Relatively large - The AD reactor would not be small but would also require additional downstream treatment	2	Not really an option as several reactors would all require energy to remain at a constant temperature	2	Low temperature, Low COD and/or high metals concentrations can reduce the efficiency of the treatment process. Start/stop of the reactor could also kill bacteria and result in inefficiency.	3	33
Anaerobic Digestion	Upflow Anaerobic Sludge Blanket (UASB)	Digestion of ammonia & organics				Unable to achieve the likely reductions in leachate contamination concentrations required.	2	The process is effective at treating high strength COD influents and produces a biogas which can be used to heat the reactor. However, effluent often has to undergo aerobic treatment to remove ammonia, sulphides etc. Metals can be precipitated out by the process however, they can also often inhibit the process.	2	The process ideally requires influent to contain >10,000 mg/L COD to be self-sufficient in energy. (Landfill leachate has often already experienced the acetogenic phase in the landfill itself, so naturally reduces COD). Metals can also be inhibitory to the anaerobic bacteria.	2	The process ideally requires a consistent influent composition as low COD or high metals concentrations would have negative impacts on the process. Also the process would suffer from stop/start as the bacteria require the influent as a food source.	2	Relatively expensive - the anaerobic digesters are general large and require numerous pumps, dosing system, and regularly require downstream aerobic treatment to remove ammonia.	1	Relatively high - chemical dosing and sludge disposal costs, and may require gas to supplement the gas generated by the digester (and possibly the landfill) to maintain a constant temperature above 30 degrees C in the reactor. Also costs associated with additional treatment.	1	The plant can be fully automated but requires regular monitoring (possibly remotely) by a skilled operator.	3	Repairs should not be required often however, maintenance (e.g. calibration, cleaning) of sensors, meters etc. will be required	3	This is dependent on whether the reactor is self-sufficient in energy. Would also require power for pumps.	3	pH adjustment and correction chemicals required.	3	An effluent low in COD would be produced, with metals removal also likely to have occurred. However, would require ammonia removal	2	Effluent from the digester would almost certainly require further treatment to remove ammonia as well as dissolved methane and sulphides. Methane and hydrogen sulphide produced by the process could not simply be emitted to air.	1	The reactor is a pressurised vessel and produces explosive and toxic gases. Storage and handling of chemicals.	2	Fluctuations in influent could reduce the efficiency of the process, as could stop/starting of the treatment. However, should always produce an effluent low in COD.	2	Relatively large - UASB reactor would not be small but would also require additional downstream treatment	2	Not really an option as several reactors would all require energy to remain at a constant temperature	2	Low temperature, Low COD and/or high metals concentrations can reduce the efficiency of the treatment process. Start/stop of the reactor could also kill bacteria and result in inefficiency.	3	36
	Anaerobic MBR	Digestion of ammonia & organics				Unable to achieve the likely reductions in leachate contamination concentrations required.	2	Effective at treating high strength COD. Membrane also removes majority of solids, along with any contaminants which are not dissolved. However, effluent often has to undergo aerobic treatment to remove ammonia, sulphides etc. Metals can be precipitated out, or removed by the membrane, they can also inhibit the process.	3	The process ideally requires influent to contain >10,000 mg/L COD to be self-sufficient in energy. (Landfill leachate has often already experienced the acetogenic phase in the landfill itself, so naturally reduces COD). Metals can also be inhibitory to the anaerobic bacteria.	2	The process ideally requires a consistent influent composition as low COD or high metals concentrations would have negative impacts on the process. Also the process would suffer from stop/start as the bacteria require the influent as a food source.	2	Relatively expensive - although smaller than a UASB it still requires numerous pumps, dosing system, and regularly require downstream aerobic treatment to remove ammonia.	2	Relatively high, chemicals (dosing and membrane cleaning) and sludge disposal costs. Higher percentage of biogas produced which means the digester provides enough biogas to maintain a constant temperature above $30^{\circ}C$. Costs with membrane replacement and additional aerobic treatment.	2	The plant can be fully automated but requires regular monitoring (possibly remotely) by a skilled operator.	3	Repairs should not be required often however, maintenance (e.g. calibration, cleaning) of membrane, sensors, meters etc. will be required	3	The additional biogas produced due to the membrane maintaining the biomass in the reactor, heating should be self-sufficient, so only usual power requirements such as pumps required.	4	membrane cleaning and pH adjustment and correction chemicals required.	2	An effluent low in COD, solids and many other contaminants (due to the membrane) would be produced. However, would require ammonia removal	3	Effluent from the digester would almost certainly require further treatment to remove ammonia as well as dissolved methane and sulphides. Methane and hydrogen sulphide produced by the process could not simply be emitted to air.	1	The reactor is a pressurised vessel and produces explosive and toxic gases. Storage and handling of chemicals.	2	Fluctuations in influent could reduce the efficiency of the process, as could stop/starting of the treatment. However, should always produce a very good quality effluent, with the exception of ammonia.	4	Relatively large - Smaller than a UASB reactor but would also require additional downstream treatment	2	Not really an option as several reactors would all require energy to remain at a constant temperature	2	Low temperature, Low COD and/or high metals concentrations can reduce the efficiency of the treatment process. Start/stop of the reactor could also kill bacteria and result in inefficiency.	3	42
	Wetlands									Wetlands																		Wetlands												
	Horizontal Flow	Treatment of ammonia	Oxidation of organics	Solids removal	Precipitation of metals	Likely to be capable of achieving the reductions in contaminants required if very large area used. More likely to be used if in conjunction with other processes as a polishing techniques, but only if reduction in chlorides are not required (so only applicable to discharge to sea). Large footprint will be required.	15	Can degrade organic matter (BOD and COD), oxidise ammonia (depending on oxygen transfer rates), remove suspended solids, and reduce concentrations of nitrate and phosphorus. Often used as a final treatment stage.	2	Provided the reed bed is well designed and has been given time to become 'established' the reed bed will be effective in removing many contaminants of concern. However, high solids loading can cause the reed beds to clog and greatly reduce effectiveness.	3	Reed beds are designed specifically for each application. This can mean use of certain 'reeds' or alternative bed media (e.g. bauxsol) to enhance removal of certain contaminants of concern.	4	Relatively low - require a lined bed, gravel (and/or other media), sand and reeds	3	Relatively low - It is a passive system which requires minimal operation and maintenance	4	Requires minimal maintenance/repair to maintain performance	4	Requires minimal maintenance to clean inlet and outlet structures, maintenance of the structures, checks to the water depth and removal of solids as required.	4	A passive system so requires very little power, possibly a small amount of pumping.	4	No consumables required - unless media such as bauxsol is utilised, then this would require replacement when exhausted	4	Should produce an effluent relatively low in BOD, COD, ammonia, TSS and some metals. However, this is only the case following treatment of weak wastewater or if used as a polishing stage.	4	The effluent produced in most cases will be of sufficient quality to pose a low environmental risk if discharged direct to surface water.	4	No chemicals, deep water or moving parts	5	If well maintained the reed bed should consistently provide a good level of removal of contaminants	3	Relatively large - a reed bed requires a large surface area to ensure residence times are large enough to achieve sufficient treatment.	1	Either a very large reed bed can be installed or several smaller reed beds installed.	3	High solids loading can impact on the performance of the process. Alternatively a reed bed is unlikely to produce a good quality effluent if high influent concentrations of contaminants are present.	3	70
Reed beds	Vertical Flow	Treatment of ammonia	Oxidation of organics	Solids removal	Precipitation of metals	Likely to be capable of achieving the reductions in contaminants required if very large area used. More likely to be used if in conjunction with other processes as a polishing techniques, but only if reduction in chlorides are not required (so only applicable to discharge to sea). Large footprint will be required.	15	Can degrade organic matter (BOD and COD), oxidise ammonia (better oxygen transfer rates than horizontal flow), remove suspended solids, and reduce concentrations of nitrate and phosphorus. Often used as a final treatment stage.	2	If well designed and 'established' will be effective in removing many contaminants . Improved oxygen transfer rates in a vertical flow should provide greater reliability with regard to ammonia removal rates. However, high solids loading can cause the reed beds to clog and greatly reduce effectiveness.	3	Reed beds are designed specifically for each application. This can mean use of certain 'reeds' or alternative bed media (e.g. bauxsol) to enhance removal of certain contaminants of concern.	4	Relatively low - require a lined bed, gravel (and/or other media), sand and reeds. Is likely to require subsequent solids removal e.g. a horizontal flow reed bed.	3	Relatively low - It is a passive system which requires minimal operation and maintenance	4	Requires minimal maintenance/repair to maintain performance	4	Requires minimal maintenance to clean inlet and outlet structures, maintenance of the structures, checks to the water depth and removal of solids as required.	4	A passive system so requires very little power, possibly a small amount of pumping.	4	No consumables required - unless media such as bauxsol is utilised, then this would require replacement when exhausted	4	Should produce an effluent relatively low in BOD, COD, ammonia, TSS and some metals. However, this is only the case following treatment of weaker wastewater or if used as a polishing stage.	4	The effluent produced in most cases will be of sufficient quality to pose a low environmental risk if discharged direct to surface water.	4	No chemicals, deep water or moving parts	5	If well maintained the reed bed should consistently provide a good level of removal of contaminants	3	Relatively large - a reed bed requires a large surface area to ensure residence times are large enough to achieve sufficient treatment.	1	Either a very large reed bed can be installed or several smaller reed beds installed.	3	High solids loading can impact on the performance of the process. Alternatively a reed bed is unlikely to produce a good quality effluent if high influent concentrations of contaminants are present.	3	70
	'Other' - WET systems (Biologic Design)	Treatment of ammonia	Oxidation of organics	Solids removal	Precipitation of metals	Likely to be capable of achieving the reductions in contaminants required if very large area used. More likely to be used if in conjunction with other processes as a polishing techniques, but only if reduction in chlorides are not required (so only applicable to discharge to sea). Large footprint will be required. Would need anoxic zones to provide level of metal stripping required.	15	WET systems are designed to treat incoming wastewater to produce a 'clean' effluent or even a zero discharge due to short-rotation coppicing (SRC). This method is not widely used and require significant footprints if the wastewater is not very weak.	1	Dependent on the ability of the system design to ensure the water flows along the whole system and does not short-circuit, thereby not receiving full treatment. Relies on the correct selection of plants to adsorb all contaminants of concern from the wastewater flow.	2	The design should allow for fluctuations in flow and load, due to the significant size of the WET system. However, large fluctuations could lead to additional area being required and a lack of 'water' supply for the plants during summer.	2	Relatively high - No gravel, liner etc. are required, however, a large area of land has to be landscaped and large volumes of plants and trees have to be planted.	1	Relatively low - It is a passive system which requires very minimal operation and maintenance	4	Requires minimal maintenance/repair to maintain performance	5	Requires minimal maintenance as is a 'natural wetland system' and should be self-sufficient.	5	A passive system so requires very little power, possibly a small amount of pumping.	4	No consumables required	5	Either zero discharge OR should produce an effluent which would of sufficient quality to be discharge direct to surface water	4	Lack of treatment or short-circuiting could allow harmful substances to be leached into the groundwater as there are no liners in the system.	2	Deep/open water	3	If correctly designed and sized the WET system should provide reliable treatment, however, any failings would rapidly result in contamination of the surrounding land and surface/ground water as there is only natural containment.	2	Relatively large - the WET system requires a very large land area to provide to sufficient treatment to the wastewater	1	Not a modular design	1	High solids loading can impact on the performance of the process. Also high concentrations of toxic substances could kill the plants and biology in the WET system.	2	59

Appendix D Financial Models

WASTE FILLING SCENARIO 1 LTP COST MODELS

40m³/day LTP	Capacity 40		2015 Y0	2016 Y1	2017 Y2	2018 Y3	2019 Y4	2020 Y5	2021 Y6	2022 Y7	2023 Y8	2024 Y9	2025 Y10	2026 Y11	2027 Y12	2028 Y13	2029 Y14	2030 Y15	2031 Y16	2032 Y17	2033 Y18	2034 Y19	2035 Y20	2036 Y21	2037 Y22	2038 Y23	2039 Y24	2040 Y25	2041 Y26	2042 Y27	2043 Y28	2044 Y29	2045 Y30	2046 Y31	2047 Y32	2048 Y33	2049 Y34	2050 Y35	2051 Y36	Total Yr 1 - 36
RO to Sewer																																								
Volume to Recirc				0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Volume to LTP				14,632	13,724	9,230	8,996	8,988	8,509	5,627	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	121,233
Power (assume 14.0kWh/m³ @ €0.08/kWh)	€/m³	€1.12		16,388	15,371	10,337	10,076	10,067	9,530	6,303	1,990	1,990	1,990	1,990	1,990	1,990	1,990	1,990	1,990	1,990	1,990	1,990	1,990	1,990	1,990	1,990	1,990	1,990	1,990	1,990	1,990	1,990	1,990	1,990	1,990	1,990	1,990	1,990	1,990	
Chemicals Main Process (assume €0.92/m3 for alkali and acid)	€/m³	€0.92		13,461	12,626	8,491	8,277	8,269	7,828	5,177	1,635	1,635	1,635	1,635	1,635	1,635	1,635	1,635	1,635	1,635	1,635	1,635	1,635	1,635	1,635	1,635	1,635	1,635	1,635	1,635	1,635	1,635	1,635	1,635	1,635	1,635	1,635	1,635	1,635	
Concentrate disposal	€/m³	€0.00		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
General Maintenance (assume 2.0% of Capital Cost per year)	€	€14,996.88		14,997	14,997	14,997	14,997	14,997	14,997	14,997	14,997	14,997	14,997	14,997	14,997	14,997	14,997	14,997	14,997	14,997	14,997	14,997	14,997	14,997	14,997	14,997	14,997	14,997	14,997	14,997	14,997	14,997	14,997	14,997	14,997	14,997	14,997	14,997	14,997	
Manpower (25% share of full employment cost @ €32,000/yr)	€	€8,000.00		8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	
Consumables	€	€3,275.00		3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	
Monitoring/Analysis Costs	€	€6,550.00		6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	
Total LTP Costs (ex depreciation)	€			62,671	60,819	51,650	51,174	51,157	50,180	44,302	36,447	36,447	36,447	36,447	36,447	36,447	36,447	36,447	36,447	36,447	36,447	36,447	36,447	36,447	36,447	36,447	36,447	36,447	36,447	36,447	36,447	36,447	36,447	36,447	36,447	36,447	36,447	36,447	36,447	1,428,904
LTP Cost per m³ leachate treated	€/m³			4.28	4.43	5.60	5.69	5.69	5.90	7.87	20.51	20.51	20.51	20.51	20.51	20.51	20.51	20.51	20.51	20.51	20.51	20.51	20.51	20.51	20.51	20.51	20.51	20.51	20.51	20.51	20.51	20.51	20.51	20.51	20.51	20.51	20.51	20.51	20.51	11.79
SBR + RB to Sea																																								
Volume to Recirc				0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Volume to LTP				14,632	13,724	9,230	8,996	8,988	8,509	5,627	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	121,233
Power (assume 6.0kWh/m³ @ €0.08/kWh)	€/m³	€0.48		7,023	6,587	4,430	4,318	4,314	4,084	2,701	853	853	853	853	853	853	853	853	853	853	853	853	853	853	853	853	853	853	853	853	853	853	853	853	853	853	853	853	853	
Chemicals Main Process (assume €8.03/m³ for alkali and €0.26/m³ for antifoam & phosphoric)	€/m³	€12.29		179,827	168,666	113,432	110,564	110,463	104,573	69,162	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	
Sludge disposal (assume maximum of 0.002m³ per m³ treated at €23/m³ for disposal)	€/m³	€360.00		10,535	9,881	6,645	6,477	6,471	6,126	4,052	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	
General Maintenance (assume 1% of Capital Cost per year)	€	€12,658.27		12,658	12,658	12,658	12,658	12,658	12,658	12,658	12,658	12,658	12,658	12,658	12,658	12,658	12,658	12,658	12,658	12,658	12,658	12,658	12,658	12,658	12,658	12,658	12,658	12,658	12,658	12,658	12,658	12,658	12,658	12,658	12,658	12,658	12,658	12,658	12,658	
Manpower (25% share of full employment cost @ €32,000/yr)	€	€8,000.00		8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	
Consumables	€	€2,620.00		2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	
Monitoring/Analysis Costs	€	€6,550.00		6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	
Total LTP Costs (ex depreciation)	€			227,213	214,963	154,336	151,187	151,077	144,612	105,743	53,797	53,797	53,797	53,797	53,797	53,797	53,797	53,797	53,797	53,797	53,797	53,797	53,797	53,797	53,797	53,797	53,797	53,797	53,797	53,797	53,797	53,797	53,797	53,797	53,797	53,797	53,797	53,797	53,797	2,709,255
LTP Cost per m³ leachate treated	€/m³			15.53	15.66	16.72	16.81	16.81	17.00	18.79	30.28	30.28	30.28	30.28	30.28	30.28	30.28	30.28	30.28	30.28	30.28	30.28	30.28	30.28	30.28	30.28	30.28	30.28	30.28	30.28	30.28	30.28	30.28	30.28	30.28	30.28	30.28	30.28	30.28	22.35
MBR + RB to Sea																																								
Volume to Recirc				0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Volume to LTP				14,632	13,724	9,230	8,996	8,988	8,509	5,627	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	121,233
Power (assume 10.0kWh/m³ @ €0.08/kWh)	€/m³	€0.80		11,706	10,979	7,384	7,197	7,190	6,807	4,502	1,421	1,421	1,421	1,421	1,421	1,421	1,421	1,421	1,421	1,421	1,421	1,421	1,421	1,421	1,421	1,421	1,421	1,421	1,421	1,421	1,421	1,421	1,421	1,421	1,421	1,421	1,421	1,421	1,421	
Chemicals Main Process (assume €8.03/m³ for alkali and €0.52/m³ for antifoam & phosphoric)	€/m³	€12.55		183,631	172,235	115,832	112,903	112,800	106,786	70,625	22,299	22,299	22,299	22,299	22,299	22,299	22,299	22,299	22,299	22,299	22,299	22,299	22,299	22,299	22,299	22,299	22,299	22,299	22,299	22,299	22,299	22,299	22,299	22,299	22,299	22,299	22,299	22,299	22,299	
Sludge disposal (assume maximum of 0.003m³ per m³ treated at €23/m³ for disposal)	€/m³	€360.00		15,803	14,822	9,968	9,716	9,707	9,190	6,078	1,919	1,919	1,919	1,919	1,919	1,919	1,919	1,919	1,919	1,919	1,919	1,919	1,919	1,919	1,919	1,919	1,919	1,919	1,919	1,919	1,919	1,919	1,919	1,919	1,919	1,919	1,919	1,919	1,919	
General Maintenance (assume 1.5% of Capital Cost per year)	€	€17,745.52		17,746	17,746	17,746	17,746	17,746	17,746	17,746	17,746	17,746	17,746	17,746	17,746	17,746	17,746	17,746	17,746	17,746	17,746	17,746	17,746	17,746	17,746	17,746	17,746	17,746	17,746	17,746	17,746	17,746	17,746	17,746	17,746	17,746	17,746	17,746	17,746	
Manpower (50% share of full employment cost @ €32,000/yr)	€	€16,000.00		16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	
Consumables	€	€3,275.00		3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	
Monitoring/Analysis Costs	€	€6,550.00		6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	
Total LTP Costs (ex depreciation)	€			254,710	241,606	176,754	173,386	173,268	166,353	124,775	69,210	69,210	69,210	69,210	69,210	69,210	69,210	69,210	69,210	69,210	69,210	69,210	69,210	69,210	69,210	69,210	69,210	69,210	69,210	69,210	69,210	69,210	69,210	69,210	69,210	69,210	69,210	69,210	69,210	3,317,936
LTP Cost per m³ leachate treated	€/m³			17.41	17.60	19.15	19.27	19.28	19.55	22.17	38.95	38.95	38.95	38.95	38.95	38.95	38.95	38.95	38.95	38.95	38.95	38.95	38.95	38.95	38.95	38.95	38.95	38.95	38.95	38.95	38.95	38.95	38.95	38.95	38.95	38.95	38.95	38.95	38.95	27.37
Aerated Lagoon SBR + RB to Sea																																								
Volume to Recirc				0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Volume to LTP				14,632	13,724	9,230	8,996	8,988	8,509	5,627	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	121,233
Power (assume 5.0kWh/m³ @ €0.08/kWh)	€/m³	€0.40		5,853	5,490	3,692	3,598	3,595	3,404	2,251	711	711	711	711	711	711	711	711	711	711	711	711	711	711	711	711	711	711	711	711	711	711	711	711	711	711	711	711	711	
Chemicals Main Process (assume €8.03/m³ for alkali and €0.26/m³ for antifoam & phosphoric)	€/m³	€12.29		179,827	168,666	113,432	110,564	110,463	104,573	69,162	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	
Sludge disposal (assume maximum of 0.002m³ per m³ treated at €23/m³ for disposal)	€/m³	€360.00		10,535	9,881	6,645	6,477	6,471	6,126	4,052	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	
General Maintenance (assume 0.75% of Capital Cost per year)	€	€6,540.85		6,541	6,541	6,541	6,541	6,541	6,541	6,541	6,541	6,541	6,541	6,541	6,541	6,541	6,541	6,541	6,541	6,541	6,541	6,541	6,541	6,541	6,541	6,541	6,541	6,541	6,541	6,541	6,541	6,541	6,541	6,541	6,541	6,541	6,541	6,541	6,541	
Manpower (25% share of full employment cost @ €32,000/yr)	€	€8,000.00		8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	
Consumables	€	€2,620.00		2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	
Monitoring/Analysis Costs	€	€6,550.00		6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	
Total LTP Costs (ex depreciation)	€			219,925	207,748	147,480	144,350	144,240	137,814	99,175	47,538	47,538	47,538	47,538	47,538	47,538	47,538	47,538	47,538	47,538	47,538	47,538	47,538	47,538	47,538	47,538	47,538	47,538	47,538	47,538	47,538	47,538	47,538	47,538	47,538	47,538	47,538	47,538	47,538	2,479,330
LTP Cost per m³ leachate treated	€/m³			15.03	15.14	15.98	16.05	16.05	16.20	17.62	26.75	26.75	26.75	26.75	26.75	26.75	26.75	26.75	26.75	26.75	26.75	26.75	26.75	26.75	26.75	26.75	26.75	26.75	26.75	26.75	26.75	26.75	26.75	26.75	26.75	26.75	26.75	26.75	26.75	20.45
Facultative Lagoon SRC																																								
Volume to Recirc				0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Volume to LTP				14,632	13,724	9,230	8,996	8,988	8,509	5,627	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	121,233
Power (assume 14,000kWh/yr @ €0.08/kWh)	€/kWh	€0.08		1,120	1,120	1,120	1,120	1,120	1,120	1,120	1,120	1,120	1,120	1,120	1,120	1,120	1,120	1,120	1,120	1,120	1,120	1,120	1,120	1,120	1,120	1,120	1,120	1,120	1,120	1,120	1,120	1,120	1,120	1,120	1,120	1,120	1,120	1,120	1,120	
Coppice Management costs	€	€2,692.00		2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	
General Maintenance (assume 1.0% of Capital Cost per year)	€	€6,084.39		6,084	6,084	6,084	6,084	6,084	6,084	6,084	6,084	6,084	6,084	6,084	6,084	6,084	6,084	6,084	6,084	6,084	6,084	6,084	6,084	6,084	6,084	6,084	6,084	6,084	6,084	6,084	6,084	6,084	6,084	6,084	6,084	6,084	6,084	6,084	6,084	
Manpower (25% share of full employment cost @ €32,000/yr)	€	€8,000.00		8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	
Consumables	€	€3,275.00		3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	
Monitoring/Analysis Costs	€	€6,550.00		6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	
Total LTP Costs (ex depreciation)	€			27,721	27,721	27,721	27,721	27,721	27,721	27,721	27,721	27,721	27,721	27,721	27,721	27,721	27,721	27,721	27,721	27,721	27,721	27,721	27,721	27,721	27,721	27,721	27,721	27,721	27,721	27,721	27,721	27,721	27,721	27,721	27,721	27,721	27,721	27,721	27,721	997,970
LTP Cost per m³ leachate treated	€/m³			1.89	2.02	3.00	3.08	3.08	3.26	4.93	15.60	15.60	15.60	15.60	15.60	15.60	15.60	15.60	15.60	15.60	15.60	15.60	15.60	15.60	15.60	15.60	15.60	15.60	15.60	15.60	15.60	15.60	15.60	15.60	15.60	15.60	15.60	15.60	15.60	8.23

25m^3/day LTP	Capacity		2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050	2051	Total
	25		Y0	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Y10	Y11	Y12	Y13	Y14	Y15	Y16	Y17	Y18	Y19	Y20	Y21	Y22	Y23	Y24	Y25	Y26	Y27	Y28	Y29	Y30	Y31	Y32	Y33	Y34	Y35	Y36	Yr 1 -36
RO to Sewer																																								
Volume to Recirc				8,342	10,549	8,262	5,741	3,212	204	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Volume to LTP				9,125	9,125	9,125	9,125	9,125	9,125	9,125	7,608	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	121,234
Power (assume 14.0kWh/m^3 @ €0.08/kWh)	€/m^3	€1.12		10,220	10,220	10,220	10,220	10,220	10,220	10,220	8,521	1,990	1,990	1,990	1,990	1,990	1,990	1,990	1,990	1,990	1,990	1,990	1,990	1,990	1,990	1,990	1,990	1,990	1,990	1,990	1,990	1,990	1,990	1,990	1,990	1,990	1,990	1,990	1,990	
Chemicals Main Process (assume €0.92/m3 for alkali and acid)	€/m^3	€0.92		8,395	8,395	8,395	8,395	8,395	8,395	8,395	6,999	1,635	1,635	1,635	1,635	1,635	1,635	1,635	1,635	1,635	1,635	1,635	1,635	1,635	1,635	1,635	1,635	1,635	1,635	1,635	1,635	1,635	1,635	1,635	1,635	1,635	1,635	1,635	1,635	
Concentrate disposal	€/m^3	€0.00		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
General Maintenance (assume 2.0% of Capital Cost per year)	€	€12,953.28		12,953	12,953	12,953	12,953	12,953	12,953	12,953	12,953	12,953	12,953	12,953	12,953	12,953	12,953	12,953	12,953	12,953	12,953	12,953	12,953	12,953	12,953	12,953	12,953	12,953	12,953	12,953	12,953	12,953	12,953	12,953	12,953	12,953	12,953	12,953	12,953	
Manpower (25% share of full employment cost @ €32,000/yr)	€	€8,000.00		8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	
Consumables	€	€3,275.00		3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	
Monitoring/Analysis Costs	€	€6,550.00		6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	
Total LTP Costs (ex depreciation)	€			49,393	49,393	49,393	49,393	49,393	49,393	49,393	46,299	34,403	34,403	34,403	34,403	34,403	34,403	34,403	34,403	34,403	34,403	34,403	34,403	34,403	34,403	34,403	34,403	34,403	34,403	34,403	34,403	34,403	34,403	34,403	34,403	34,403	34,403	34,403	34,403	1,355,335
LTP Cost per m^3 leachate treated	€/m^3			5.41	5.41	5.41	5.41	5.41	5.41	5.41	6.09	19.36	19.36	19.36	19.36	19.36	19.36	19.36	19.36	19.36	19.36	19.36	19.36	19.36	19.36	19.36	19.36	19.36	19.36	19.36	19.36	19.36	19.36	19.36	19.36	19.36	19.36	19.36	19.36	11.18
SBR + RB to Sea																																								
Volume to Recirc				8,342	10,549	8,262	5,741	3,212	204	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Volume to LTP				9,125	9,125	9,125	9,125	9,125	9,125	9,125	7,608	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	121,234
Power (assume 6.0kWh/m^3 @ €0.08/kWh)	€/m^3	€0.48		4,380	4,380	4,380	4,380	4,380	4,380	4,380	3,652	853	853	853	853	853	853	853	853	853	853	853	853	853	853	853	853	853	853	853	853	853	853	853	853	853	853	853	853	
Chemicals Main Process (assume €8.03/m^3 for alkali and €0.26/m^3 for antifoam & phosphoric)	€/m^3	€12.29		112,146	112,146	112,146	112,146	112,146	112,146	112,146	93,504	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	
Sludge disposal (assume maximum of 0.002m^3 per m^3 treated at €23/m^3 for disposal)	€/m^3	€360.00		6,570	6,570	6,570	6,570	6,570	6,570	6,570	5,478	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	
General Maintenance (assume 1% of Capital Cost per year)	€	€9,771.03		9,771	9,771	9,771	9,771	9,771	9,771	9,771	9,771	9,771	9,771	9,771	9,771	9,771	9,771	9,771	9,771	9,771	9,771	9,771	9,771	9,771	9,771	9,771	9,771	9,771	9,771	9,771	9,771	9,771	9,771	9,771	9,771	9,771	9,771	9,771	9,771	
Manpower (25% share of full employment cost @ €32,000/yr)	€	€8,000.00		8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	
Consumables	€	€2,620.00		2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	
Monitoring/Analysis Costs	€	€6,550.00		6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	
Total LTP Costs (ex depreciation)	€			150,037	150,037	150,037	150,037	150,037	150,037	150,037	129,575	50,910	50,910	50,910	50,910	50,910	50,910	50,910	50,910	50,910	50,910	50,910	50,910	50,910	50,910	50,910	50,910	50,910	50,910	50,910	50,910	50,910	50,910	50,910	50,910	50,910	50,910	50,910	50,910	2,605,319
LTP Cost per m^3 leachate treated	€/m^3			16.44	16.44	16.44	16.44	16.44	16.44	16.44	17.03	28.65	28.65	28.65	28.65	28.65	28.65	28.65	28.65	28.65	28.65	28.65	28.65	28.65	28.65	28.65	28.65	28.65	28.65	28.65	28.65	28.65	28.65	28.65	28.65	28.65	28.65	28.65	28.65	21.49
MBR + RB to Sea																																								
Volume to Recirc				8,342	10,549	8,262	5,741	3,212	204	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Volume to LTP				9,125	9,125	9,125	9,125	9,125	9,125	9,125	7,608	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	121,234
Power (assume 10.0kWh/m^3 @ €0.08/kWh)	€/m^3	€0.80		7,300	7,300	7,300	7,300	7,300	7,300	7,300	6,086	1,421	1,421	1,421	1,421	1,421	1,421	1,421	1,421	1,421	1,421	1,421	1,421	1,421	1,421	1,421	1,421	1,421	1,421	1,421	1,421	1,421	1,421	1,421	1,421	1,421	1,421	1,421	1,421	
Chemicals Main Process (assume €8.03/m^3 for alkali and €0.52/m^3 for antifoam & phosphoric)	€/m^3	€12.55		114,519	114,519	114,519	114,519	114,519	114,519	114,519	95,482	22,299	22,299	22,299	22,299	22,299	22,299	22,299	22,299	22,299	22,299	22,299	22,299	22,299	22,299	22,299	22,299	22,299	22,299	22,299	22,299	22,299	22,299	22,299	22,299	22,299	22,299	22,299	22,299	
Sludge disposal (assume maximum of 0.003m^3 per m^3 treated at €23/m^3 for disposal)	€/m^3	€360.00		9,855	9,855	9,855	9,855	9,855	9,855	9,855	8,217	1,919	1,919	1,919	1,919	1,919	1,919	1,919	1,919	1,919	1,919	1,919	1,919	1,919	1,919	1,919	1,919	1,919	1,919	1,919	1,919	1,919	1,919	1,919	1,919	1,919	1,919	1,919	1,919	
General Maintenance (assume 1.5% of Capital Cost per year)	€	€13,708.63		13,709	13,709	13,709	13,709	13,709	13,709	13,709	13,709	13,709	13,709	13,709	13,709	13,709	13,709	13,709	13,709	13,709	13,709	13,709	13,709	13,709	13,709	13,709	13,709	13,709	13,709	13,709	13,709	13,709	13,709	13,709	13,709	13,709	13,709	13,709	13,709	
Manpower (50% share of full employment cost @ €32,000/yr)	€	€16,000.00		16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	
Consumables	€	€3,275.00		3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	
Monitoring/Analysis Costs	€	€6,550.00		6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	
Total LTP Costs (ex depreciation)	€			171,207	171,207	171,207	171,207	171,207	171,207	171,207	149,319	65,173	65,173	65,173	65,173	65,173	65,173	65,173	65,173	65,173	65,173	65,173	65,173	65,173	65,173	65,173	65,173	65,173	65,173	65,173	65,173	65,173	65,173	65,173	65,173	65,173	65,173	65,173	65,173	3,172,612
LTP Cost per m^3 leachate treated	€/m^3			18.76	18.76	18.76	18.76	18.76	18.76	18.76	19.63	36.68	36.68	36.68	36.68	36.68	36.68	36.68	36.68	36.68	36.68	36.68	36.68	36.68	36.68	36.68	36.68	36.68	36.68	36.68	36.68	36.68	36.68	36.68	36.68	36.68	36.68	36.68	36.68	26.17
Aerated Lagoon SBR + RB to Sea																																								
Volume to Recirc				8,342	10,549	8,262	5,741	3,212	204	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Volume to LTP				9,125	9,125	9,125	9,125	9,125	9,125	9,125	7,608	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	121,234
Power (assume 5.0kWh/m^3 @ €0.08/kWh)	€/m^3	€0.40		3,650	3,650	3,650	3,650	3,650	3,650	3,650	3,043	711	711	711	711	711	711	711	711	711	711	711	711	711	711	711	711	711	711	711	711	711	711	711	711	711	711	711	711	
Chemicals Main Process (assume €8.03/m^3 for alkali and €0.26/m^3 for antifoam & phosphoric)	€/m^3	€12.29		112,146	112,146	112,146	112,146	112,146	112,146	112,146	93,504	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	
Sludge disposal (assume maximum of 0.002m^3 per m^3 treated at €23/m^3 for disposal)	€/m^3	€360.00		6,570	6,570	6,570	6,570	6,570	6,570	6,570	5,478	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	
General Maintenance (assume 0.75% of Capital Cost per year)	€	€5,609.48		5,609	5,609	5,609	5,609	5,609	5,609	5,609	5,609	5,609	5,609	5,609	5,609	5,609	5,609	5,609	5,609	5,609	5,609	5,609	5,609	5,609	5,609	5,609	5,609	5,609	5,609	5,609	5,609	5,609	5,609	5,609	5,609	5,609	5,609	5,609	5,609	
Manpower (25% share of full employment cost @ €32,000/yr)	€	€8,000.00		8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	
Consumables	€	€2,620.00		2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	
Monitoring/Analysis Costs	€	€6,550.00		6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	
Total LTP Costs (ex depreciation)	€			145,146	145,146	145,146	145,146	145,146	145,146	145,146	124,804	46,606	46,606	46,606	46,606	46,606	46,606	46,606	46,606	46,606	46,606	46,606	46,606	46,606	46,606	46,606	46,606	46,606	46,606	46,606	46,606	46,606	46,606	46,606	46,606	46,606	46,606	46,606	46,606	2,445,804
LTP Cost per m^3 leachate treated	€/m^3			15.91	15.91	15.91	15.91	15.91	15.91	15.91	16.40	26.23	26.23	26.23	26.23	26.23	26.23	26.23	26.23	26.23	26.23	26.23	26.23	26.23	26.23	26.23	26.23	26.23	26.23	26.23	26.23	26.23	26.23	26.23	26.23	26.23	26.23	26.23	26.23	20.17
Facultative Lagoon SRC																																								
Volume to Recirc				8,342	10,549	8,262	5,741	3,212	204	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Volume to LTP				9,125	9,125	9,125	9,125	9,125	9,125	9,125	7,608	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	121,234
Power (assume 8,680kWh/yr @ €0.08/kWh)	€/kWh	€0.08		694	694	694	694	694	694	694	694	694	694	694	694	694	694	694	694	694	694	694	694	694	694	694	694	694	694	694	694	694	694	694	694	694	694	694	694	
Coppice Management costs	€	€2,692.00		2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	
General Maintenance (assume 1.0% of Capital Cost per year)	€	€5,285.04		5,285	5,285	5,285	5,285	5,285	5,285	5,285	5,285	5,285	5,285	5,285	5,285	5,285	5,285	5,285	5,285	5,285	5,285	5,285	5,285	5,285	5,285	5,285	5,285	5,285	5,285	5,285	5,285	5,285	5,285	5,285	5,285	5,285	5,285	5,285	5,285	
Manpower (25% share of full employment cost @ €32,000/yr)	€	€8,000.00		8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	
Consumables	€	€3,275.00		3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	
Monitoring/Analysis Costs	€	€6,550.00		6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	
Total LTP Costs (ex depreciation)	€			26,496	26,496	26,496	26,496	26,496	26,496	26,496	26,496	26,496	26,496	26,496	26,496	26,496	26,496	26,496	26,496	26,496	26,496	26,496	26,496	26,496	26,496	26,496	26,496	26,496	26,496	26,496	26,496	26,496	26,496	26,496	26,496	26,496	26,496	26,496	26,496	953,872
LTP Cost per m^3 leachate treated	€/m^3			2.90	2.90	2.90	2.90	2.90	2.90	2.90	3.48	14.91	14.91	14.91	14.91	14.91	14.91	14.91	14.91	14.91	14.91	14.91	14.91	14.91	14.91	14.91	14.91	14.91	14.91	14.91	14.91	14.91	14.91	14.91	14.91	14.91	14.91	14.91	14.91	7.87

WASTE FILLING SCENARIO 4 LTP COST MODELS

40m³/day LTP	Capacity		2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050	2051	2052	2053	Total
	40		Y0	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Y10	Y11	Y12	Y13	Y14	Y15	Y16	Y17	Y18	Y19	Y20	Y21	Y22	Y23	Y24	Y25	Y26	Y27	Y28	Y29	Y30	Y31	Y32	Y33	Y34	Y35	Y36	Y37	Y38	Yr 1 - 38
RO to Sewer																																										
Volume to Recirc				0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Volume to LTP				14,632	13,724	9,230	8,996	8,988	8,988	6,117	6,117	5,627	5,627	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	137,797
Power (assume 14.0kWh/m³ @ €0.08/kWh)	€/m³	€1.12		16,388	15,371	10,337	10,076	10,067	10,067	6,851	6,851	6,303	6,303	1,990	1,990	1,990	1,990	1,990	1,990	1,990	1,990	1,990	1,990	1,990	1,990	1,990	1,990	1,990	1,990	1,990	1,990	1,990	1,990	1,990	1,990	1,990	1,990	1,990	1,990	1,990	1,990	
Chemicals Main Process (assume €0.92/m3 for alkali and acid)	€/m³	€0.92		13,461	12,626	8,491	8,277	8,269	8,269	5,628	5,628	5,177	5,177	1,635	1,635	1,635	1,635	1,635	1,635	1,635	1,635	1,635	1,635	1,635	1,635	1,635	1,635	1,635	1,635	1,635	1,635	1,635	1,635	1,635	1,635	1,635	1,635	1,635	1,635	1,635	1,635	
Concentrate disposal	€/m³	€0.00		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
General Maintenance (assume 2.0% of Capital Cost per year)	€	€14,996.88		14,997	14,997	14,997	14,997	14,997	14,997	14,997	14,997	14,997	14,997	14,997	14,997	14,997	14,997	14,997	14,997	14,997	14,997	14,997	14,997	14,997	14,997	14,997	14,997	14,997	14,997	14,997	14,997	14,997	14,997	14,997	14,997	14,997	14,997	14,997	14,997	14,997	14,997	
Manpower (20% share of full employment cost @ €32,000/yr)	€	€6,400.00		6,400	6,400	6,400	6,400	6,400	6,400	6,400	6,400	6,400	6,400	6,400	6,400	6,400	6,400	6,400	6,400	6,400	6,400	6,400	6,400	6,400	6,400	6,400	6,400	6,400	6,400	6,400	6,400	6,400	6,400	6,400	6,400	6,400	6,400	6,400	6,400	6,400	6,400	
Consumables	€	€3,275.00		3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	
Monitoring/Analysis Costs	€	€6,550.00		6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	
Total LTP Costs (ex depreciation)	€			61,071	59,219	50,050	49,574	49,557	49,557	43,700	43,700	42,702	42,702	34,847	34,847	34,847	34,847	34,847	34,847	34,847	34,847	34,847	34,847	34,847	34,847	34,847	34,847	34,847	34,847	34,847	34,847	34,847	34,847	34,847	34,847	34,847	34,847	34,847	34,847	34,847	34,847	1,467,537
LTP Cost per m³ leachate treated	€/m³			4.17	4.32	5.42	5.51	5.51	5.51	7.14	7.14	7.59	7.59	19.61	19.61	19.61	19.61	19.61	19.61	19.61	19.61	19.61	19.61	19.61	19.61	19.61	19.61	19.61	19.61	19.61	19.61	19.61	19.61	19.61	19.61	19.61	19.61	19.61	19.61	19.61	19.61	10.65
SBR + RB to Sea																																										
Volume to Recirc				0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Volume to LTP				14,632	13,724	9,230	8,996	8,988	8,988	6,117	6,117	5,627	5,627	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	137,797
Power (assume 6.0kWh/m³ @ €0.08/kWh)	€/m³	€0.48		7,023	6,587	4,430	4,318	4,314	4,314	2,936	2,936	2,701	2,701	853	853	853	853	853	853	853	853	853	853	853	853	853	853	853	853	853	853	853	853	853	853	853	853	853	853	853	853	
Chemicals Main Process (assume €8.03/m³ for alkali and €0.26/m³ for antifoam & phosphoric)	€/m³	€12.29		179,827	168,666	113,432	110,564	110,463	110,463	75,176	75,176	69,162	69,162	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	
Sludge disposal (assume maximum of 0.002m³ per m³ treated at €23/m³ for disposal)	€/m³	€360.00		10,535	9,881	6,645	6,477	6,471	6,471	4,404	4,404	4,052	4,052	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	
General Maintenance (assume 1% of Capital Cost per year)	€	€12,658.27		12,658	12,658	12,658	12,658	12,658	12,658	12,658	12,658	12,658	12,658	12,658	12,658	12,658	12,658	12,658	12,658	12,658	12,658	12,658	12,658	12,658	12,658	12,658	12,658	12,658	12,658	12,658	12,658	12,658	12,658	12,658	12,658	12,658	12,658	12,658	12,658	12,658	12,658	
Manpower (25% share of full employment cost @ €32,000/yr)	€	€8,000.00		8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	
Consumables	€	€2,620.00		2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	
Monitoring/Analysis Costs	€	€6,550.00		6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	
Total LTP Costs (ex depreciation)	€			227,213	214,963	154,336	151,187	151,077	151,077	112,345	112,345	105,743	105,743	53,797	53,797	53,797	53,797	53,797	53,797	53,797	53,797	53,797	53,797	53,797	53,797	53,797	53,797	53,797	53,797	53,797	53,797	53,797	53,797	53,797	53,797	53,797	53,797	53,797	53,797	53,797	53,797	2,992,356
LTP Cost per m³ leachate treated	€/m³			15.53	15.66	16.72	16.81	16.81	16.81	18.37	18.37	18.79	18.79	30.28	30.28	30.28	30.28	30.28	30.28	30.28	30.28	30.28	30.28	30.28	30.28	30.28	30.28	30.28	30.28	30.28	30.28	30.28	30.28	30.28	30.28	30.28	30.28	30.28	30.28	30.28	30.28	21.72
MBR + RB to Sea																																										
Volume to Recirc				0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Volume to LTP				14,632	13,724	9,230	8,996	8,988	8,988	6,117	6,117	5,627	5,627	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	137,797
Power (assume 10.0kWh/m³ @ €0.08/kWh)	€/m³	€0.80		11,706	10,979	7,384	7,197	7,190	7,190	4,894	4,894	4,502	4,502	1,421	1,421	1,421	1,421	1,421	1,421	1,421	1,421	1,421	1,421	1,421	1,421	1,421	1,421	1,421	1,421	1,421	1,421	1,421	1,421	1,421	1,421	1,421	1,421	1,421	1,421	1,421	1,421	
Chemicals Main Process (assume €8.03/m³ for alkali and €0.52/m³ for antifoam & phosphoric)	€/m³	€12.55		183,631	172,235	115,832	112,903	112,800	112,800	76,767	76,767	70,625	70,625	22,299	22,299	22,299	22,299	22,299	22,299	22,299	22,299	22,299	22,299	22,299	22,299	22,299	22,299	22,299	22,299	22,299	22,299	22,299	22,299	22,299	22,299	22,299	22,299	22,299	22,299	22,299	22,299	
Sludge disposal (assume maximum of 0.003m³ per m³ treated at €23/m³ for disposal)	€/m³	€360.00		15,803	14,822	9,968	9,716	9,707	9,707	6,606	6,606	6,078	6,078	1,919	1,919	1,919	1,919	1,919	1,919	1,919	1,919	1,919	1,919	1,919	1,919	1,919	1,919	1,919	1,919	1,919	1,919	1,919	1,919	1,919	1,919	1,919	1,919	1,919	1,919	1,919	1,919	
General Maintenance (assume 1.5% of Capital Cost per year)	€	€17,745.52		17,746	17,746	17,746	17,746	17,746	17,746	17,746	17,746	17,746	17,746	17,746	17,746	17,746	17,746	17,746	17,746	17,746	17,746	17,746	17,746	17,746	17,746	17,746	17,746	17,746	17,746	17,746	17,746	17,746	17,746	17,746	17,746	17,746	17,746	17,746	17,746	17,746	17,746	
Manpower (50% share of full employment cost @ €32,000/yr)	€	€16,000.00		16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	
Consumables	€	€3,275.00		3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	
Monitoring/Analysis Costs	€	€6,550.00		6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	
Total LTP Costs (ex depreciation)	€			254,710	241,606	176,754	173,386	173,268	173,268	131,837	131,837	124,775	124,775	69,210	69,210	69,210	69,210	69,210	69,210	69,210	69,210	69,210	69,210	69,210	69,210	69,210	69,210	69,210	69,210	69,210	69,210	69,210	69,210	69,210	69,210	69,210	69,210	69,210	69,210	69,210	69,210	3,644,091
LTP Cost per m³ leachate treated	€/m³			17.41	17.60	19.15	19.27	19.28	19.28	21.55	21.55	22.17	22.17	38.95	38.95	38.95	38.95	38.95	38.95	38.95	38.95	38.95	38.95	38.95	38.95	38.95	38.95	38.95	38.95	38.95	38.95	38.95	38.95	38.95	38.95	38.95	38.95	38.95	38.95	38.95	38.95	26.45
Aerated Lagoons + RB to Sea																																										
Volume to Recirc				0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Volume to LTP				14,632	13,724	9,230	8,996	8,988	8,988	6,117	6,117	5,627	5,627	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	137,797
Power (assume 5.0kWh/m³ @ €0.08/kWh)	€/m³	€0.40		5,853	5,490	3,692	3,598	3,595	3,595	2,447	2,447	2,251	2,251	711	711	711	711	711	711	711	711	711	711	711	711	711	711	711	711	711	711	711	711	711	711	711	711	711	711	711	711	
Chemicals Main Process (assume €8.03/m³ for alkali and €0.26/m³ for antifoam & phosphoric)	€/m³	€12.29		179,827	168,666	113,432	110,564	110,463	110,463	75,176	75,176	69,162	69,162	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	
Sludge disposal (assume maximum of 0.002m³ per m³ treated at €23/m³ for disposal)	€/m³	€360.00		10,535	9,881	6,645	6,477	6,471	6,471	4,404	4,404	4,052	4,052	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	
General Maintenance (assume 0.75% of Capital Cost per year)	€	€6,540.85		6,541	6,541	6,541	6,541	6,541	6,541	6,541	6,541	6,541	6,541	6,541	6,541	6,541	6,541	6,541	6,541	6,541	6,541	6,541	6,541	6,541	6,541	6,541	6,541	6,541	6,541	6,541	6,541	6,541	6,541	6,541	6,541	6,541	6,541	6,541	6,541	6,541	6,541	
Manpower (25% share of full employment cost @ €32,000/yr)	€	€8,000.00		8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	
Consumables	€	€2,620.00		2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	
Monitoring/Analysis Costs	€	€6,550.00		6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	
Total LTP Costs (ex depreciation)	€			219,925	207,748	147,480	144,350	144,240	144,240	105,738	105,738	99,175	99,175	47,538	47,538	47,538	47,538	47,538	47,538	47,538	47,538	47,538	47,538	47,538	47,538	47,538	47,538	47,538	47,538	47,538	47,538	47,538	47,538	47,538	47,538	47,538	47,538	47,538	47,538	47,538	47,538	2,748,870
LTP Cost per m³ leachate treated	€/m³			15.03	15.14	15.98	16.05	16.05	16.05	17.29	17.29	17.62	17.62	26.75	26.75	26.75	26.75	26.75	26.75	26.75	26.75	26.75	26.75	26.75	26.75	26.75	26.75	26.75	26.75	26.75	26.75	26.75	26.75	26.75	26.75	26.75	26.75	26.75	26.75	26.75	26.75	19.95
Lagoon SRC																																										
Volume to Recirc				0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Volume to LTP				14,632	13,724	9,230	8,996	8,988	8,988	6,117	6,117	5,627	5,627	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	137,797
Power (assume 14,000kWh/yr @ €0.08/kWh)	€/kWh	€0.08		1,120	1,120	1,120	1,120	1,120	1,120	1,120	1,120	1,120	1,120	1,120	1,120	1,120	1,120	1,120	1,120	1,120	1,120	1,120	1,120	1,120	1,120	1,120	1,120	1,120	1,120	1,120	1,120	1,120	1,120	1,120	1,120	1,120	1,120	1,120	1,120	1,120	1,120	
Coppice Management costs	€	€2,692.00		2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	
General Maintenance (assume 1.0% of Capital Cost per year)	€	€6,084.39		6,084	6,084	6,084	6,084	6,084	6,084	6,084	6,084	6,084	6,084	6,084	6,084	6,084	6,084	6,084	6,084	6,084	6,084	6,084	6,084	6,084	6,084	6,084	6,084	6,084	6,084	6,084	6,084	6,084	6,084	6,084	6,084	6,084	6,084	6,084	6,084	6,084	6,084	
Manpower (25% share of full employment cost @ €32,000/yr)	€	€8,000.00		8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	
Consumables	€	€3,275.00		3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	
Monitoring/Analysis Costs	€	€6,550.00		6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	
Total LTP Costs (ex depreciation)	€			27,721	27,721	27,721	27,721	27,721	27,721	27,721	27,721	27,721	27,721	27,721	27,721	27,721	27,721	27,721	27,721	27,721	27,721	27,721	27,721	27,721	27,721	27,721	27,721	27,721	27,721	27,721	27,721	27,721	27,721	27,721	27,721	27,721	27,721	27,721	27,721	27,721	27,721	1,053,413
LTP Cost per m³ leachate treated	€/m³			1.89	2.02	3.00	3.08	3.08	3.08	4.53	4.53	4.93	4.93	15.60	15.60	15.60	15.60	15.60	15.60	15.60	15.60	15.60	15.60	15.60	15.60	15.60	15.60	15.60	15.60	15.60	15.60	15.60	15.60	15.60	15.60	15.60	15.60	15.60	15.60	15.60	15.60	7.64

25m^3/day LTP	Capacity		2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050	2051	2052	2053	Total
	25		Y0	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Y10	Y11	Y12	Y13	Y14	Y15	Y16	Y17	Y18	Y19	Y20	Y21	Y22	Y23	Y24	Y25	Y26	Y27	Y28	Y29	Y30	Y31	Y32	Y33	Y34	Y35	Y36	Y37	Y38	Yr 1 - 38
RO to Sewer																																										
Volume to Recirc				8,342	10,549	8,262	5,741	3,212	683	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Volume to LTP				9,125	9,125	9,125	9,125	9,125	9,125	9,125	9,125	9,125	5,922	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	137,797
Power (assume 14.0kWh/m^3 @ €0.08/kWh)	€/m^3	€1.12		10,220	10,220	10,220	10,220	10,220	10,220	10,220	10,220	10,220	6,632	1,990	1,990	1,990	1,990	1,990	1,990	1,990	1,990	1,990	1,990	1,990	1,990	1,990	1,990	1,990	1,990	1,990	1,990	1,990	1,990	1,990	1,990	1,990	1,990	1,990	1,990	1,990	1,990	
Chemicals Main Process (assume €0.92/m3 for alkali and acid)	€/m^3	€0.92		8,395	8,395	8,395	8,395	8,395	8,395	8,395	8,395	8,395	5,448	1,635	1,635	1,635	1,635	1,635	1,635	1,635	1,635	1,635	1,635	1,635	1,635	1,635	1,635	1,635	1,635	1,635	1,635	1,635	1,635	1,635	1,635	1,635	1,635	1,635	1,635	1,635	1,635	
Concentrate disposal	€/m^3	€0.00		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
General Maintenance (assume 2.0% of Capital Cost per year)	€	€12,953.28		12,953	12,953	12,953	12,953	12,953	12,953	12,953	12,953	12,953	12,953	12,953	12,953	12,953	12,953	12,953	12,953	12,953	12,953	12,953	12,953	12,953	12,953	12,953	12,953	12,953	12,953	12,953	12,953	12,953	12,953	12,953	12,953	12,953	12,953	12,953	12,953	12,953	12,953	
Manpower (25% share of full employment cost @ €32,000/yr)	€	€8,000.00		8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	
Consumables	€	€3,275.00		3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	
Monitoring/Analysis Costs	€	€6,550.00		6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	
Total LTP Costs (ex depreciation)	€			49,393	49,393	49,393	49,393	49,393	49,393	49,393	49,393	49,393	42,859	34,403	34,403	34,403	34,403	34,403	34,403	34,403	34,403	34,403	34,403	34,403	34,403	34,403	34,403	34,403	34,403	34,403	34,403	34,403	34,403	34,403	34,403	34,403	34,403	34,403	34,403	34,403	34,403	1,450,681
LTP Cost per m^3 leachate treated	€/m^3			5.41	5.41	5.41	5.41	5.41	5.41	5.41	5.41	5.41	7.24	19.36	19.36	19.36	19.36	19.36	19.36	19.36	19.36	19.36	19.36	19.36	19.36	19.36	19.36	19.36	19.36	19.36	19.36	19.36	19.36	19.36	19.36	19.36	19.36	19.36	19.36	19.36	19.36	10.53
SBR + RB to Sea																																										
Volume to Recirc				8,342	10,549	8,262	5,741	3,212	683	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Volume to LTP				9,125	9,125	9,125	9,125	9,125	9,125	9,125	9,125	9,125	5,922	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	137,797
Power (assume 6.0kWh/m^3 @ €0.08/kWh)	€/m^3	€0.48		4,380	4,380	4,380	4,380	4,380	4,380	4,380	4,380	4,380	2,842	853	853	853	853	853	853	853	853	853	853	853	853	853	853	853	853	853	853	853	853	853	853	853	853	853	853	853	853	
Chemicals Main Process (assume €8.03/m^3 for alkali and €0.26/m^3 for antifoam & phosphoric)	€/m^3	€12.29		112,146	112,146	112,146	112,146	112,146	112,146	112,146	112,146	112,146	72,779	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	
Sludge disposal (assume maximum of 0.002m^3 per m^3 treated at €23/m^3 for disposal)	€/m^3	€360.00		6,570	6,570	6,570	6,570	6,570	6,570	6,570	6,570	6,570	4,264	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	
General Maintenance (assume 1% of Capital Cost per year)	€	€9,771.03		9,771	9,771	9,771	9,771	9,771	9,771	9,771	9,771	9,771	9,771	9,771	9,771	9,771	9,771	9,771	9,771	9,771	9,771	9,771	9,771	9,771	9,771	9,771	9,771	9,771	9,771	9,771	9,771	9,771	9,771	9,771	9,771	9,771	9,771	9,771	9,771	9,771	9,771	
Manpower (25% share of full employment cost @ €32,000/yr)	€	€8,000.00		8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	
Consumables	€	€2,620.00		2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	
Monitoring/Analysis Costs	€	€6,550.00		6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	
Total LTP Costs (ex depreciation)	€			150,037	150,037	150,037	150,037	150,037	150,037	150,037	150,037	150,037	106,826	50,910	50,910	50,910	50,910	50,910	50,910	50,910	50,910	50,910	50,910	50,910	50,910	50,910	50,910	50,910	50,910	50,910	50,910	50,910	50,910	50,910	50,910	50,910	50,910	50,910	50,910	50,910	50,910	2,582,570
LTP Cost per m^3 leachate treated	€/m^3			16.44	16.44	16.44	16.44	16.44	16.44	16.44	16.44	16.44	18.04	28.65	28.65	28.65	28.65	28.65	28.65	28.65	28.65	28.65	28.65	28.65	28.65	28.65	28.65	28.65	28.65	28.65	28.65	28.65	28.65	28.65	28.65	28.65	28.65	28.65	28.65	28.65	28.65	18.74
MBR + RB to Sea																																										
Volume to Recirc				8,342	10,549	8,262	5,741	3,212	683	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Volume to LTP				9,125	9,125	9,125	9,125	9,125	9,125	9,125	9,125	9,125	5,922	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	137,797
Power (assume 10.0kWh/m^3 @ €0.08/kWh)	€/m^3	€0.80		7,300	7,300	7,300	7,300	7,300	7,300	7,300	7,300	7,300	4,737	1,421	1,421	1,421	1,421	1,421	1,421	1,421	1,421	1,421	1,421	1,421	1,421	1,421	1,421	1,421	1,421	1,421	1,421	1,421	1,421	1,421	1,421	1,421	1,421	1,421	1,421	1,421	1,421	
Chemicals Main Process (assume €8.03/m^3 for alkali and €0.52/m^3 for antifoam & phosphoric)	€/m^3	€12.55		114,519	114,519	114,519	114,519	114,519	114,519	114,519	114,519	114,519	74,318	22,299	22,299	22,299	22,299	22,299	22,299	22,299	22,299	22,299	22,299	22,299	22,299	22,299	22,299	22,299	22,299	22,299	22,299	22,299	22,299	22,299	22,299	22,299	22,299	22,299	22,299	22,299	22,299	
Sludge disposal (assume maximum of 0.003m^3 per m^3 treated at €23/m^3 for disposal)	€/m^3	€360.00		9,855	9,855	9,855	9,855	9,855	9,855	9,855	9,855	9,855	6,396	1,919	1,919	1,919	1,919	1,919	1,919	1,919	1,919	1,919	1,919	1,919	1,919	1,919	1,919	1,919	1,919	1,919	1,919	1,919	1,919	1,919	1,919	1,919	1,919	1,919	1,919	1,919	1,919	
General Maintenance (assume 1.5% of Capital Cost per year)	€	€13,708.63		13,709	13,709	13,709	13,709	13,709	13,709	13,709	13,709	13,709	13,709	13,709	13,709	13,709	13,709	13,709	13,709	13,709	13,709	13,709	13,709	13,709	13,709	13,709	13,709	13,709	13,709	13,709	13,709	13,709	13,709	13,709	13,709	13,709	13,709	13,709	13,709	13,709	13,709	
Manpower (50% share of full employment cost @ €32,000/yr)	€	€16,000.00		16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	
Consumables	€	€3,275.00		3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	
Monitoring/Analysis Costs	€	€6,550.00		6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	
Total LTP Costs (ex depreciation)	€			171,207	171,207	171,207	171,207	171,207	171,207	171,207	171,207	171,207	124,985	65,173	65,173	65,173	65,173	65,173	65,173	65,173	65,173	65,173	65,173	65,173	65,173	65,173	65,173	65,173	65,173	65,173	65,173	65,173	65,173	65,173	65,173	65,173	65,173	65,173	65,173	65,173	65,173	3,490,693
LTP Cost per m^3 leachate treated	€/m^3			18.76	18.76	18.76	18.76	18.76	18.76	18.76	18.76	18.76	21.11	36.68	36.68	36.68	36.68	36.68	36.68	36.68	36.68	36.68	36.68	36.68	36.68	36.68	36.68	36.68	36.68	36.68	36.68	36.68	36.68	36.68	36.68	36.68	36.68	36.68	36.68	36.68	36.68	25.33
Aerated Lagoons + RB to Sea																																										
Volume to Recirc				8,342	10,549	8,262	5,741	3,212	683	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Volume to LTP				9,125	9,125	9,125	9,125	9,125	9,125	9,125	9,125	9,125	5,922	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	137,797
Power (assume 5.0kWh/m^3 @ €0.08/kWh)	€/m^3	€0.40		3,650	3,650	3,650	3,650	3,650	3,650	3,650	3,650	3,650	2,369	711	711	711	711	711	711	711	711	711	711	711	711	711	711	711	711	711	711	711	711	711	711	711	711	711	711	711	711	
Chemicals Main Process (assume €8.03/m^3 for alkali and €0.26/m^3 for antifoam & phosphoric)	€/m^3	€12.29		112,146	112,146	112,146	112,146	112,146	112,146	112,146	112,146	112,146	72,779	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	21,837	
Sludge disposal (assume maximum of 0.002m^3 per m^3 treated at €23/m^3 for disposal)	€/m^3	€360.00		6,570	6,570	6,570	6,570	6,570	6,570	6,570	6,570	6,570	4,264	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279	
General Maintenance (assume 0.75% of Capital Cost per year)	€	€5,609.48		5,609	5,609	5,609	5,609	5,609	5,609	5,609	5,609	5,609	5,609	5,609	5,609	5,609	5,609	5,609	5,609	5,609	5,609	5,609	5,609	5,609	5,609	5,609	5,609	5,609	5,609	5,609	5,609	5,609	5,609	5,609	5,609	5,609	5,609	5,609	5,609	5,609	5,609	
Manpower (25% share of full employment cost @ €32,000/yr)	€	€8,000.00		8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	
Consumables	€	€2,620.00		2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	2,620	
Monitoring/Analysis Costs	€	€6,550.00		6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	
Total LTP Costs (ex depreciation)	€			145,146	145,146	145,146	145,146	145,146	145,146	145,146	145,146	145,146	102,191	46,606	46,606	46,606	46,606	46,606	46,606	46,606	46,606	46,606	46,606	46,606	46,606	46,606	46,606	46,606	46,606	46,606	46,606	46,606	46,606	46,606	46,606	46,606	46,606	46,606	46,606	46,606	46,606	2,713,482
LTP Cost per m^3 leachate treated	€/m^3			15.91	15.91	15.91	15.91	15.91	15.91	15.91	15.91	15.91	17.26	26.23	26.23	26.23	26.23	26.23	26.23	26.23	26.23	26.23	26.23	26.23	26.23	26.23	26.23	26.23	26.23	26.23	26.23	26.23	26.23	26.23	26.23	26.23	26.23	26.23	26.23	26.23	26.23	19.69
Lagoon SRC																																										
Volume to Recirc				8,342	10,549	8,262	5,741	3,212	683	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Volume to LTP				9,125	9,125	9,125	9,125	9,125	9,125	9,125	9,125	9,125	5,922	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	137,797
Power (assume 8,680kWh/yr @ €0.08/kWh)	€/kWh	€0.08		694	694	694	694	694	694	694	694	694	694	694	694	694	694	694	694	694	694	694	694	694	694	694	694	694	694	694	694	694	694	694	694	694	694	694	694	694	694	
Coppice Management costs	€	€2,692.00		2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	2,692	
General Maintenance (assume 1.0% of Capital Cost per year)	€	€5,285.04		5,285	5,285	5,285	5,285	5,285	5,285	5,285	5,285	5,285	5,285	5,285	5,285	5,285	5,285	5,285	5,285	5,285	5,285	5,285	5,285	5,285	5,285	5,285	5,285	5,285	5,285	5,285	5,285	5,285	5,285	5,285	5,285	5,285	5,285	5,285	5,285	5,285	5,285	
Manpower (25% share of full employment cost @ €32,000/yr)	€	€8,000.00		8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	
Consumables	€	€3,275.00		3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	3,275	
Monitoring/Analysis Costs	€	€6,550.00		6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	
Total LTP Costs (ex depreciation)	€			26,496	26,496	26,496	26,496	26,496	26,496	26,496	26,496	26,496	26,496	26,496	26,496	26,496	26,496	26,496	26,496	26,496	26,496	26,496	26,496	26,496	26,496	26,496	26,496	26,496	26,496	26,496	26,496	26,496	26,496	26,496	26,496	26,496	26,496	26,496	26,496	26,496	26,496	1,006,865
LTP Cost per m^3 leachate treated	€/m^3			2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90	4.47	14.91	14.91	14.91	14.91	14.91	14.91	14.91	14.91	14.91	14.91	14.91	14.91	14.91	14.91	14.91	14.91	14.91	14.91	14.91	14.91	14.91	14.91	14.91	14.91	14.91	14.91	14.91	14.91	7.31

Appendix D Priority and ‘Other’ Substances List

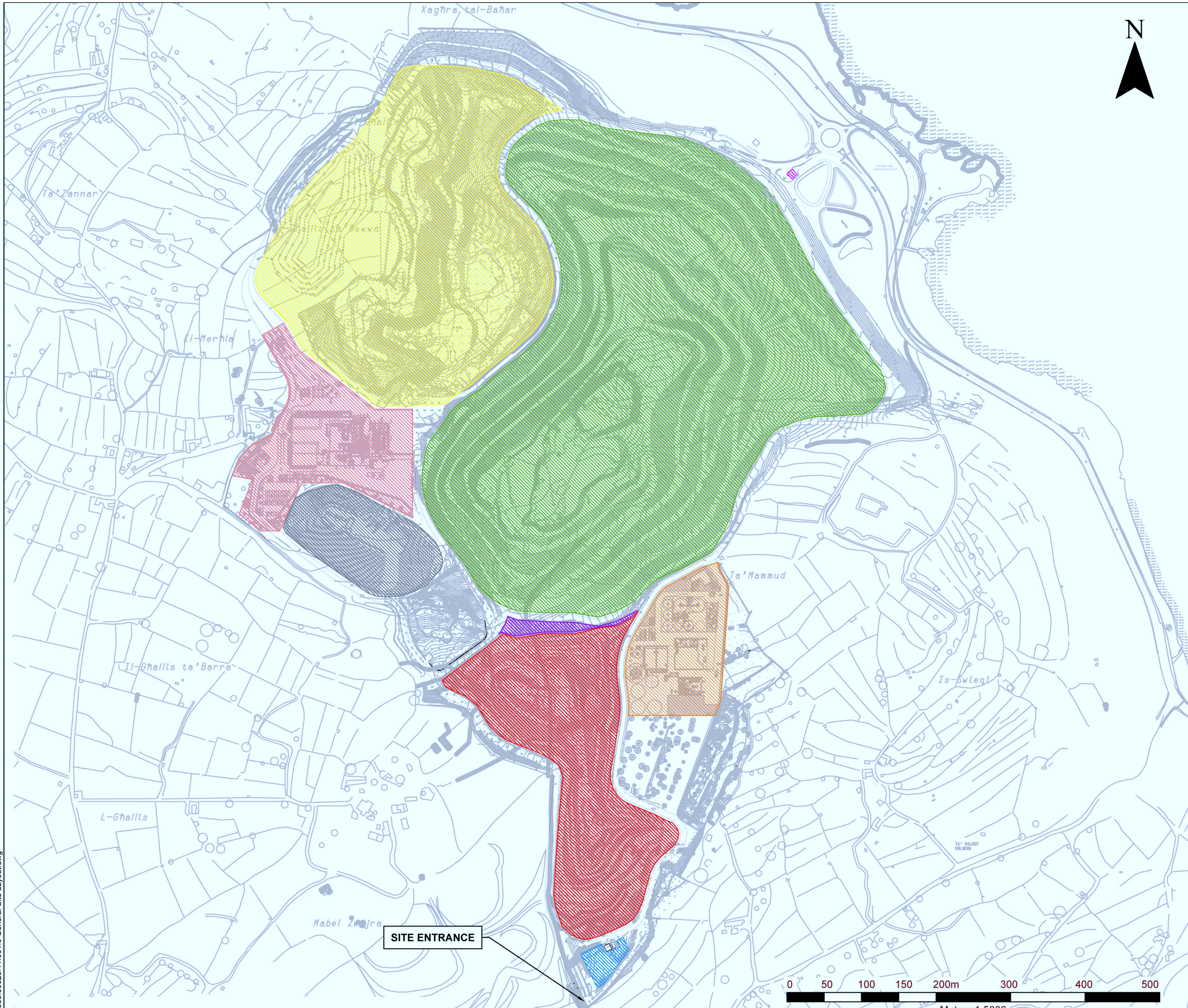
Priority hazardous substances (PHS), priority substances (PS) and 'other pollutants' list:

- Abamectin
- Alachlor
- Ammonia (un-ionised)
- Ammoniacal Nitrogen
- Anthracene
- Arsenic
- Atrazine
- Azinphos-methyl - dissolved
- Bentazone
- Benzene
- Benzo(a)-pyrene (BaP)
- Benzo(b)-fluor-anthene
- Benzo(g,h,i)-perylene
- Benzo(k)-fluor-anthene
- Benzyl butyl phthalate
- Biphenyl
- BOD
- Boron
- Brominated diphenylether - total PBDE (or congener) numbers 28, 47, 99, 100, 153 and 154
- Bromine - total residual oxidant
- Bromoxynil
- C10-13 chloroalkanes
- Cadmium and its compounds - dissolved
- Carbendazim
- Carbon tetrachloride
- 2-chlorophenol
- 3-chlorophenol - total or individual monochlorophenols
- 4-chloro-3-methylphenol
- 4-chlorophenol - total or individual monochlorophenols
- Chlorfenvinphos
- Chloride
- Chlorine - total residual oxidant
- Chloronitro toluenes
- Chlorothalonil
- Chlorotoluron
- Chlorpropham
- Chlorpyrifos (chlorpyrifos-ethyl)
- Chromium (III) - dissolved
- Chromium (VI) - dissolved
- Cobalt - dissolved
- Copper - dissolved
- Coumaphos
- Cyanide
- Cyclodiene pesticides - total aldrin, dieldrin, endrin and isodrin
- Cyfluthrin
- Cypermethrin
- DDT total
- Demetons

- Di(2-ethylhexyl)-phthalate (DEHP)
- Diazinon (sheep dip)
- Dibutyl phthalate
- 3,4-dichloroaniline
- Dichlorobenzene - total dichlorobenzene isomers
- 1,2-dichloro-ethane
- 2,4-dichlorophenol
- 2,4-dichlorophenoxyacetic acid (2,4-D)
- Dichloro-methane
- Dichlorvos
- Diethyl phthalate
- Diflubenzuron
- Dimethoate
- Dimethyl phthalate
- Dioctyl phthalate
- Dissolved Oxygen
- Diuron
- Doramectin
- EDTA
- Endosulphan
- Fenchlorphos
- Fenitrothion
- Flucofuron
- Fluoranthene
- Fluoride - dissolved
- Formaldehyde
- Glyphosate
- Hexachloro-benzene
- Hexachloro-butadiene
- Hexachloro-cyclohexane
- Hydrogen sulphide
- Indeno(1,2,3-cd)-pyrene
- Inorganic Nitrogen
- Ioxynil
- Iron - dissolved
- Isoproturon
- Ivermectin
- Lead and its compounds - dissolved
- Linuron
- Malachite green
- Malathion
- Mancozeb
- Maneb
- Manganese
- MCPA
- Mecoprop
- Mercury and its compounds - dissolved
- Methiocarb
- Mevinphos
- Naphthalene
- Nickel and its compounds - dissolved
- Nitrilotriacetic acid (NTA)

- Nonylphenol (4-nonylphenol)
- Octylphenol (4-(1,1',3,3'-tetramethyl-butyl)-phenol)
- Omethoate
- Ortho Phosphate
- Para-para-DDT
- PCSDs
- Pendimethalin
- Pentachloro-benzene
- Pentachloro-phenol
- Permethrin
- pH
- pH
- Phenol
- Pirimicarb
- Pirimiphos-methyl
- Polyaromatic hydrocarbons (PAH)
- Prochloraz
- Propetamphos
- Propyzamide
- Silver - dissolved
- Simazine
- Styrene
- Sulcofuron
- Sulphate
- Suspended Solids
- Tecnazene - total
- Temperature
- Tetrachloroethane
- Tetrachloro-ethylene
- Thiabendazole
- Tin (inorganic) - total
- Toluene
- Total anions
- Triallate
- Triazaphos
- Tributyl phosphate
- Tributyltin compounds (tributyltin-cation)
- Trichloro-benzenes
- 1,1,1-trichloroethane
- 1,1,2-trichloroethane
- Trichloro-ethylene
- Tricholoro-methane (chloroform)
- Triclosan
- Trifluralin
- Triphenyltin and derivatives
- Vanadium
- Xylene
- Zinc

Drawings



403.00585.00026.11.001.0 General Site Layout.dwg

NOTES

1. SURVEY OBTAINED FROM WASTESERV MALTA LIMITED REF: BLOCK PLAN.DWG.

LEGEND

- LEACHATE TANK
- GHALLIS LANDFILL
- MAGHTAB LANDFILL
- MECHANICAL WASTE TREATMENT PLANT
- HAZARDOUS WASTE CELL
- BIOLOGICAL TREATMENT PLANT
- ZWEJRA LANDFILL
- GAS MANAGEMENT PLANT

Revision	By	Chk'd By	Date	Comments
0	DB	IR	01/16	

WasteServ Malta Ltd

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Site
GHALLIS LANDFILL SITE

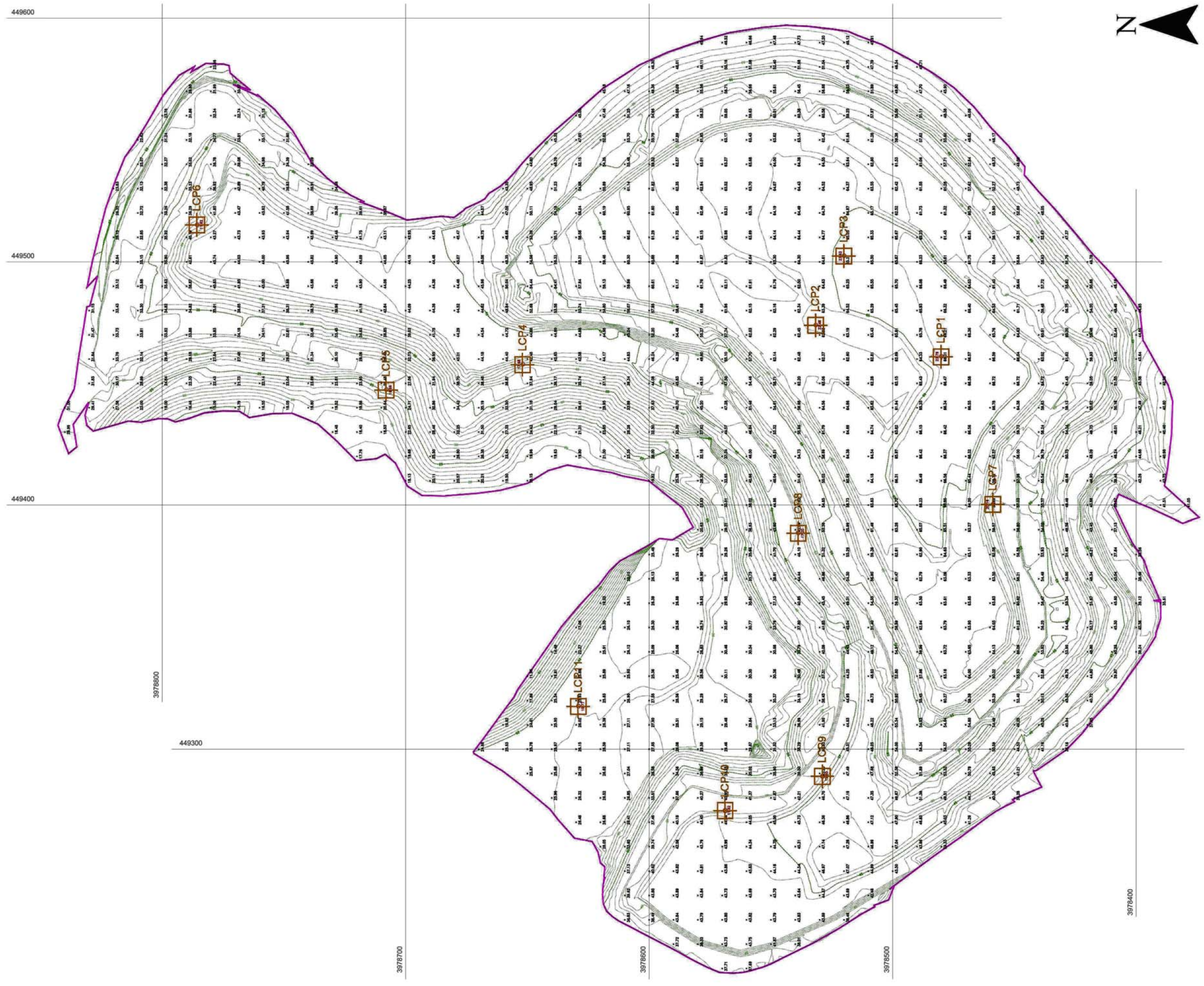
Project
LEACHATE MANAGEMENT PLAN

Drawing Title
GENERAL SITE LAYOUT

Scale	Date
1:5000 @ A3	01/16

Drawing Number	Revision
001	0

FOR INFORMATION



NOTES

1. SURVEY SUPPLIED BY ALAN MICALLEF SURVEYING SERVICES. DRAWING NUMBER 165 GH02, REV 00.

LEGEND

00.00	SPOT LEVEL ON WASTE
00.00	SPOT LEVEL ON LINER OR DRAINAGE LAYER
LCP	LEACHATE COLLECTION POINT
	CONTOUR AT 01m INTERVALS
05	CONTOUR AT 05m INTERVALS
10	CONTOUR AT 10m INTERVALS
	EDGE OF WASTE

Revision	By	Chk'd By	Date	Comments
0	DB	DJ	01/16	

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Site
GHALLIS LANDFILL SITE

Project
LEACHATE MANAGEMENT PLAN

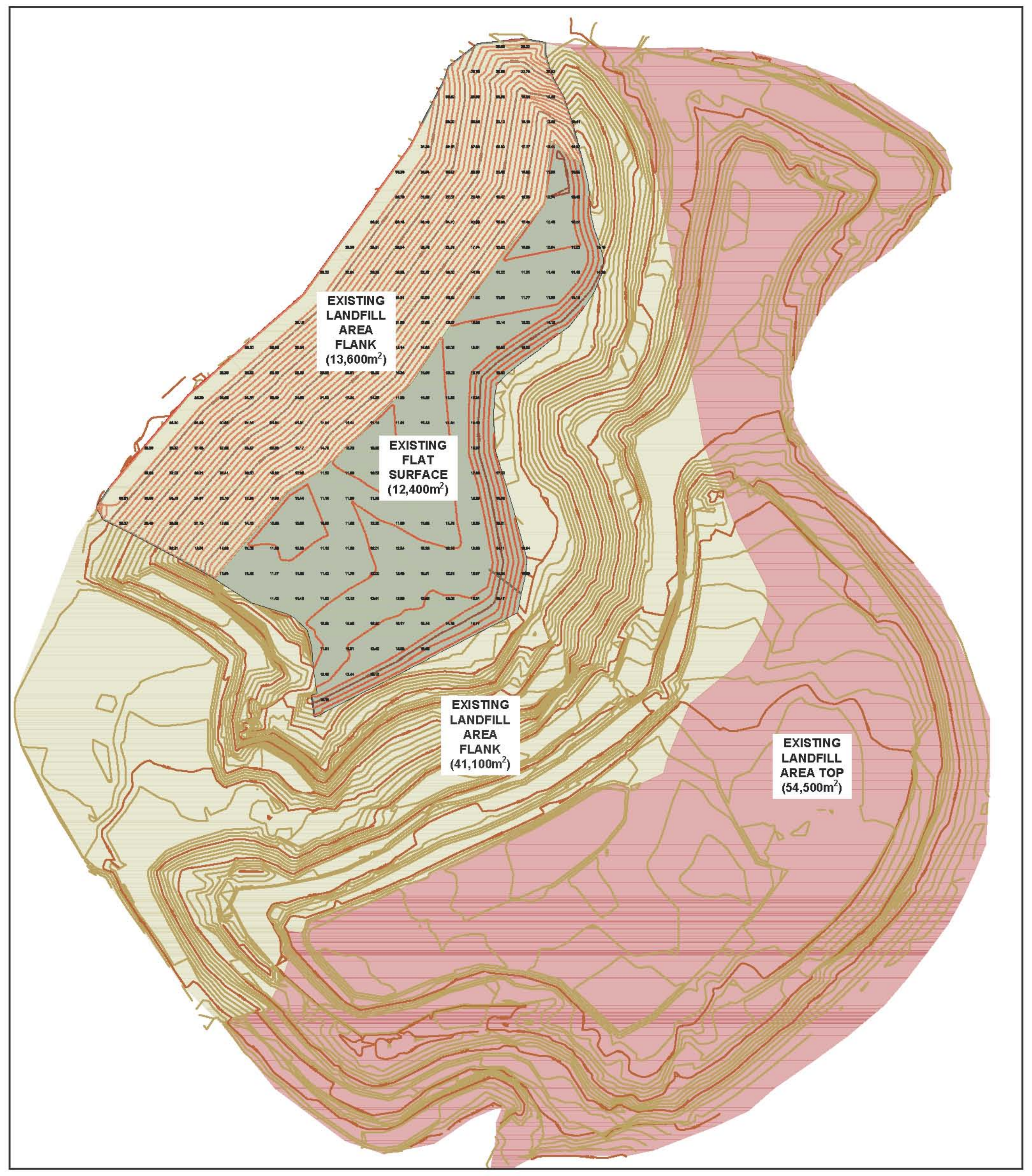
Drawing Title
LEACHATE COLLECTION LOCATION PLAN

Scale	Date
1:1500 @ A3	01/16

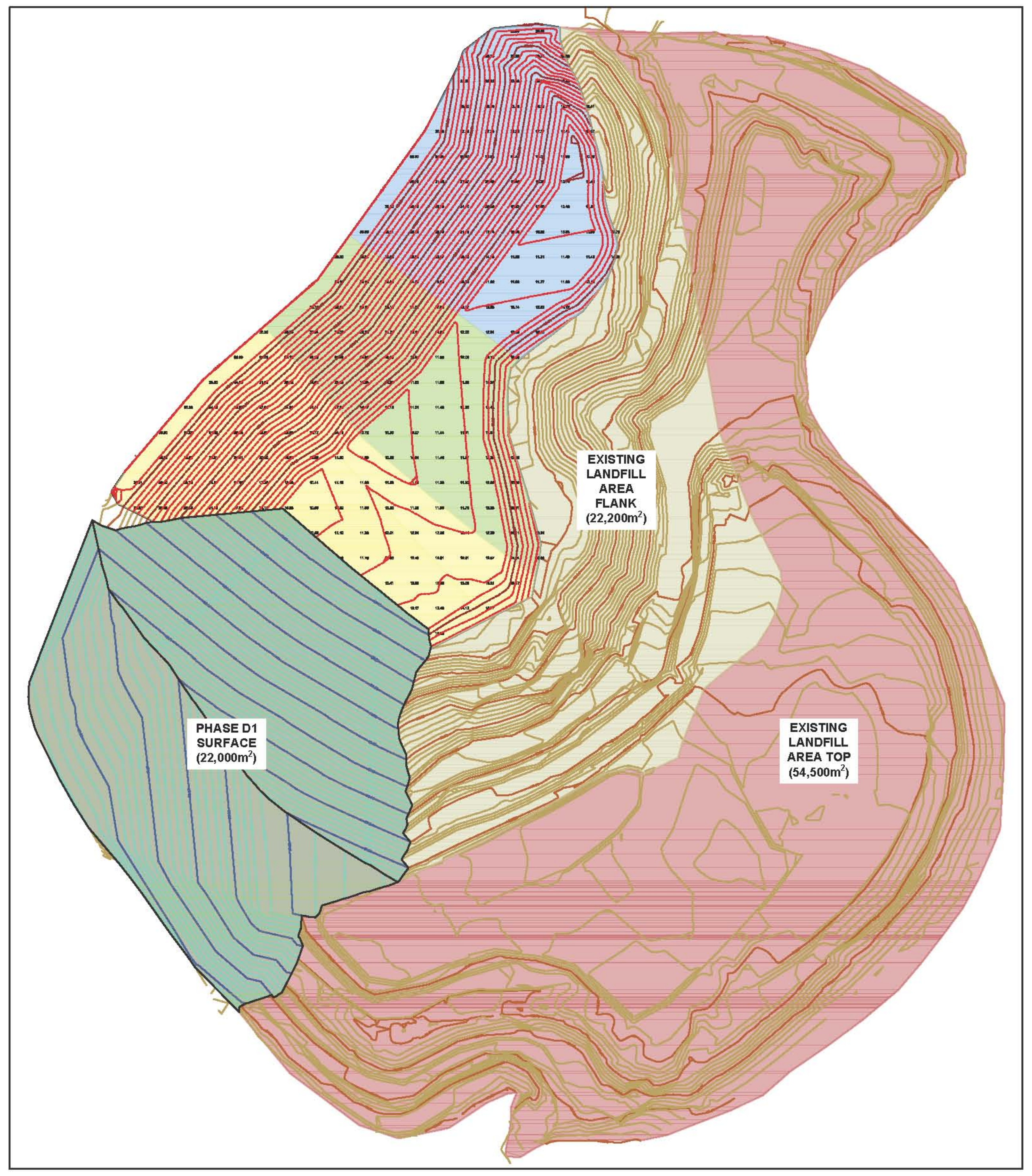
Drawing Number	Revision
002	0

FOR INFORMATION

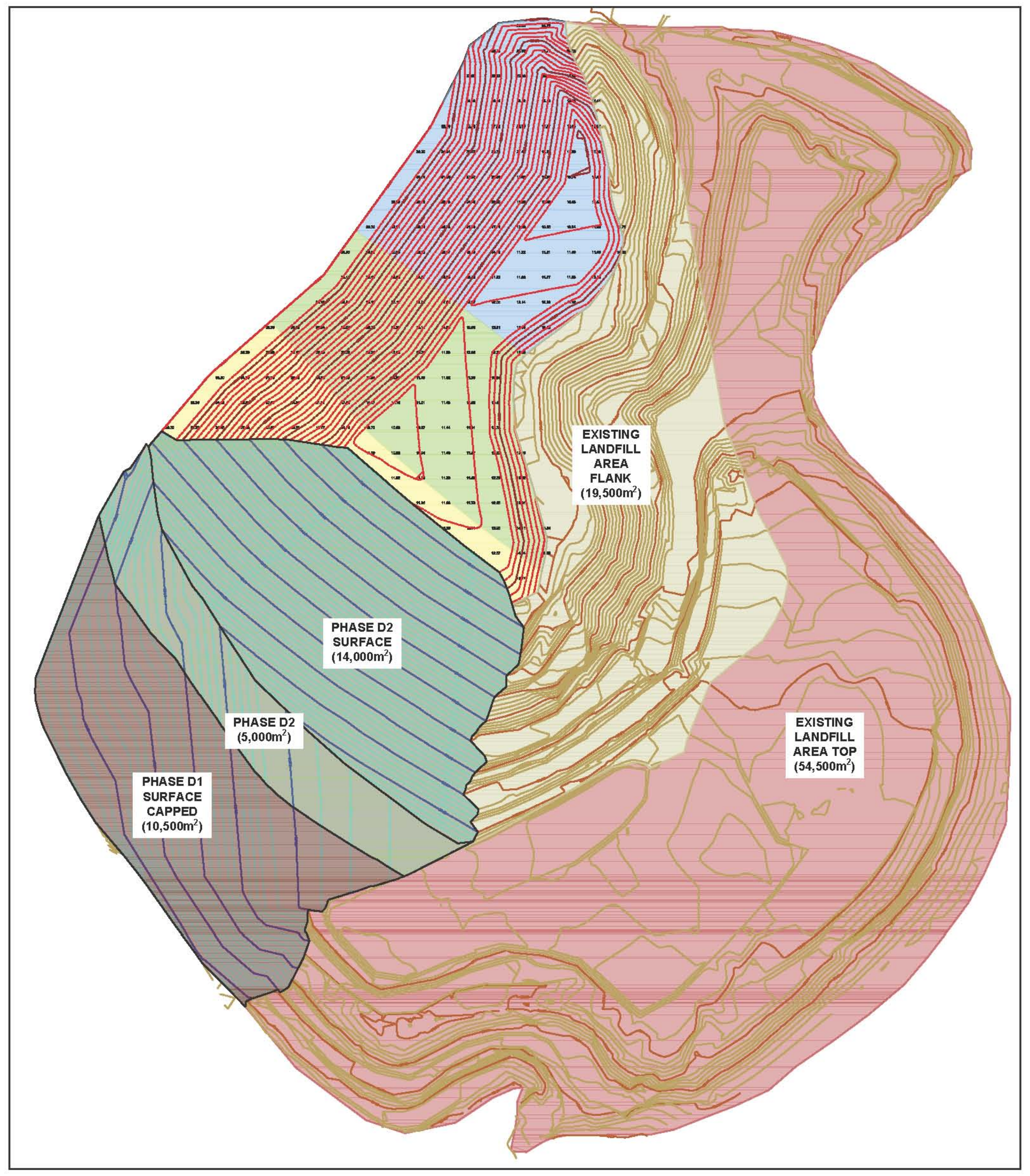
403.00585.00026.11.002.0 Leachate Monitoring Location Plan.dwg



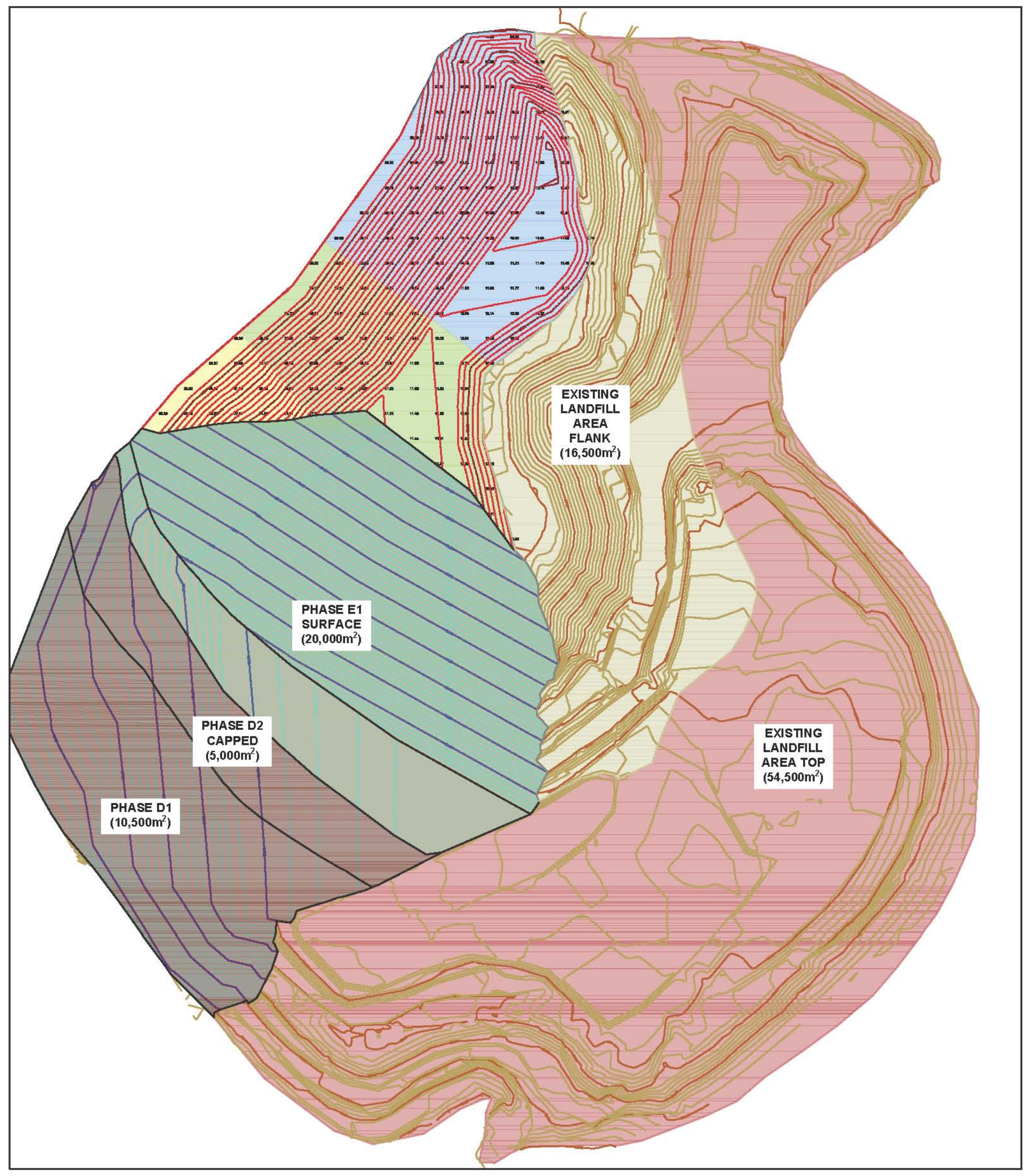
EXISTING SITE



PHASE D1 SURFACE



PHASE D1 CAPPED, PHASE D2 SURFACE



PHASES D1 & D2 CAPPED, PHASE E1 SURFACE

N

NOTES

1. TOPOGRAPHIC SURVEY INFORMATION SUPPLIED BY WASTESERVE MALTA LTD, REF: DTM WASTE UP TO END MARCH 2015.DWG & REF: DTM LEFT TO EXC END MARCH 2015.DWG, DATE RECEIVED: 12.05.2015.

2. ADDITIONAL INFORMATION SUPPLIED BY WASTESERVE MALTA LTD, REF: DTM EXC EXIST & PROP MERGED.DWG, DATE RECEIVED: 12.05.2015.

LEGEND

- 30.00 — TOPOGRAPHIC SURVEY LEVEL CONTOURS (mAOD)
- 30.00 — EXCAVATION / PROPOSED FORMATION LEVEL CONTOURS (mAOD)
- 50.00 — PROPOSED PRE-SETTLEMENT TOP OF RESTORATION LEVEL CONTOURS (mAOD)
- PHASE D
- PHASE E
- PHASE F
- SURFACE
- CAPPED
- EXISTING LANDFILL AREA FLANK
- EXISTING LANDFILL AREA TOP

0 20 40 60 80m 120 160 200

Metres 1:2000

Revision	By	Chk'd By	Date	Comments
	DB	DJ	12/15	

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Site
GHALLIS LANDFILL SITE

Project
LEACHATE MANAGEMENT PLAN

Drawing Title
PHASING D TO F - SHEET 1 OF 2

Scale
1:2000 @ A1

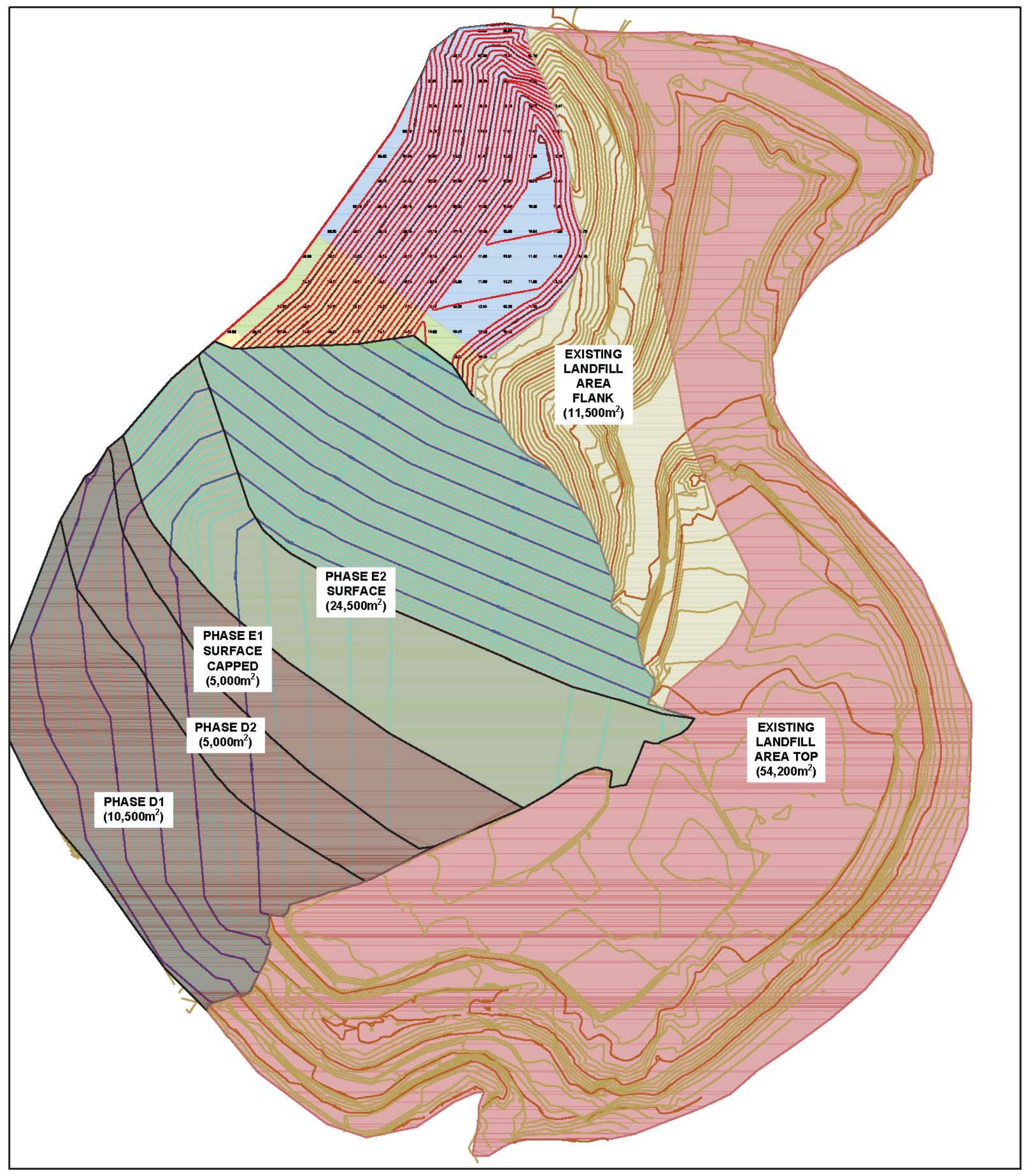
Date
12/15

Drawing Number
003

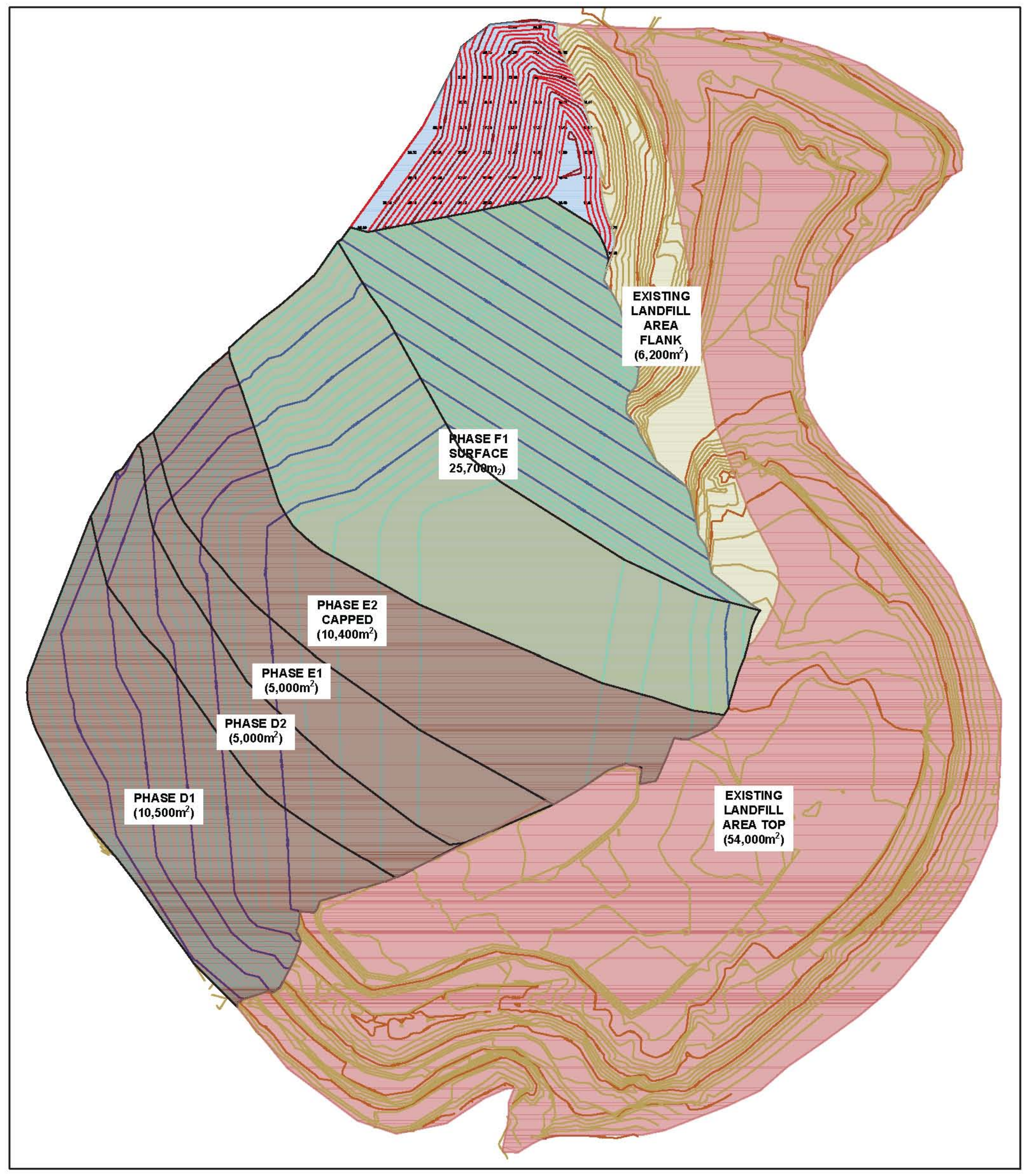
Revision
0

FOR INFORMATION

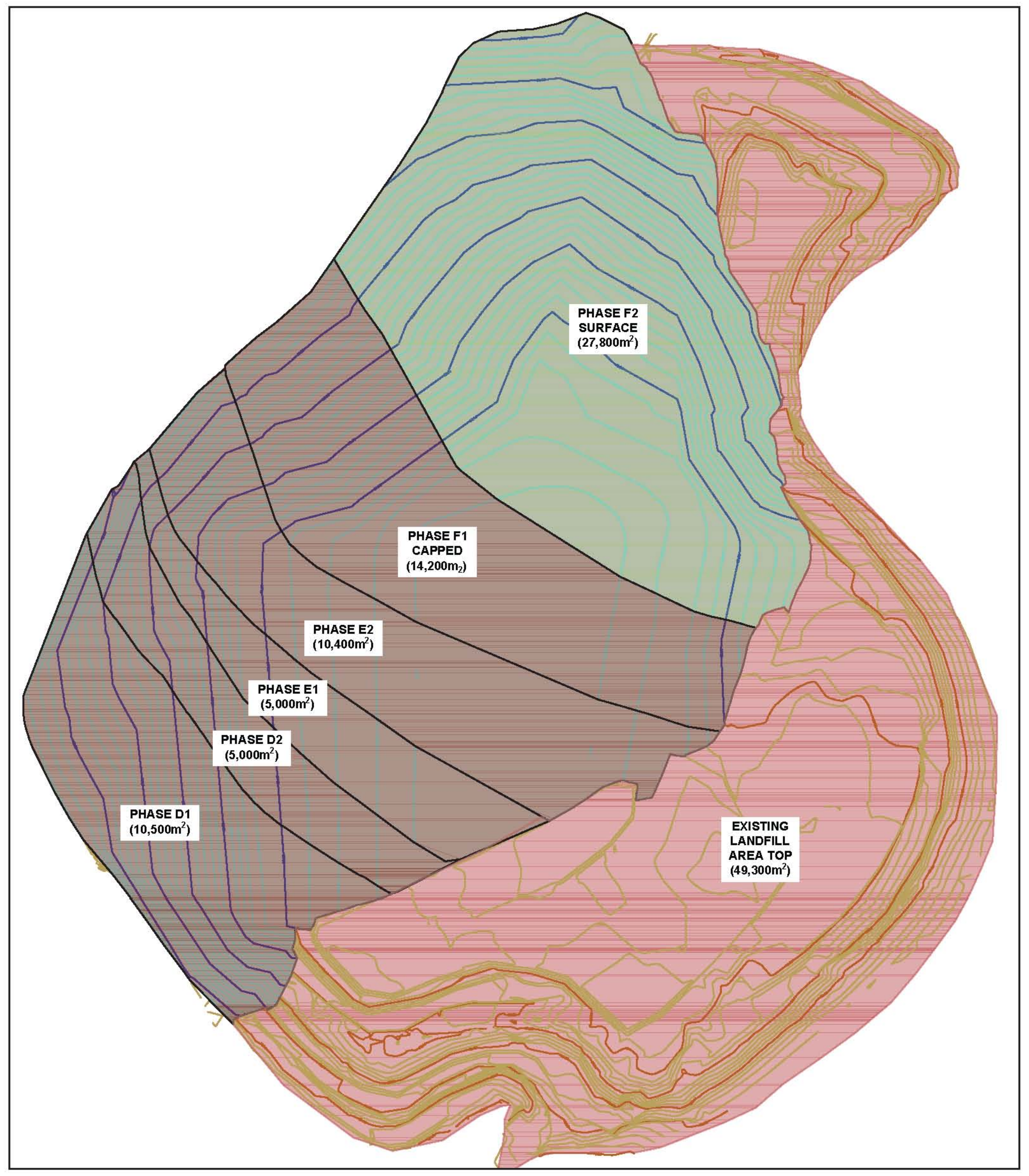
00585.00026.11.0038&4.0 Existing Landfill & Phases.dwg



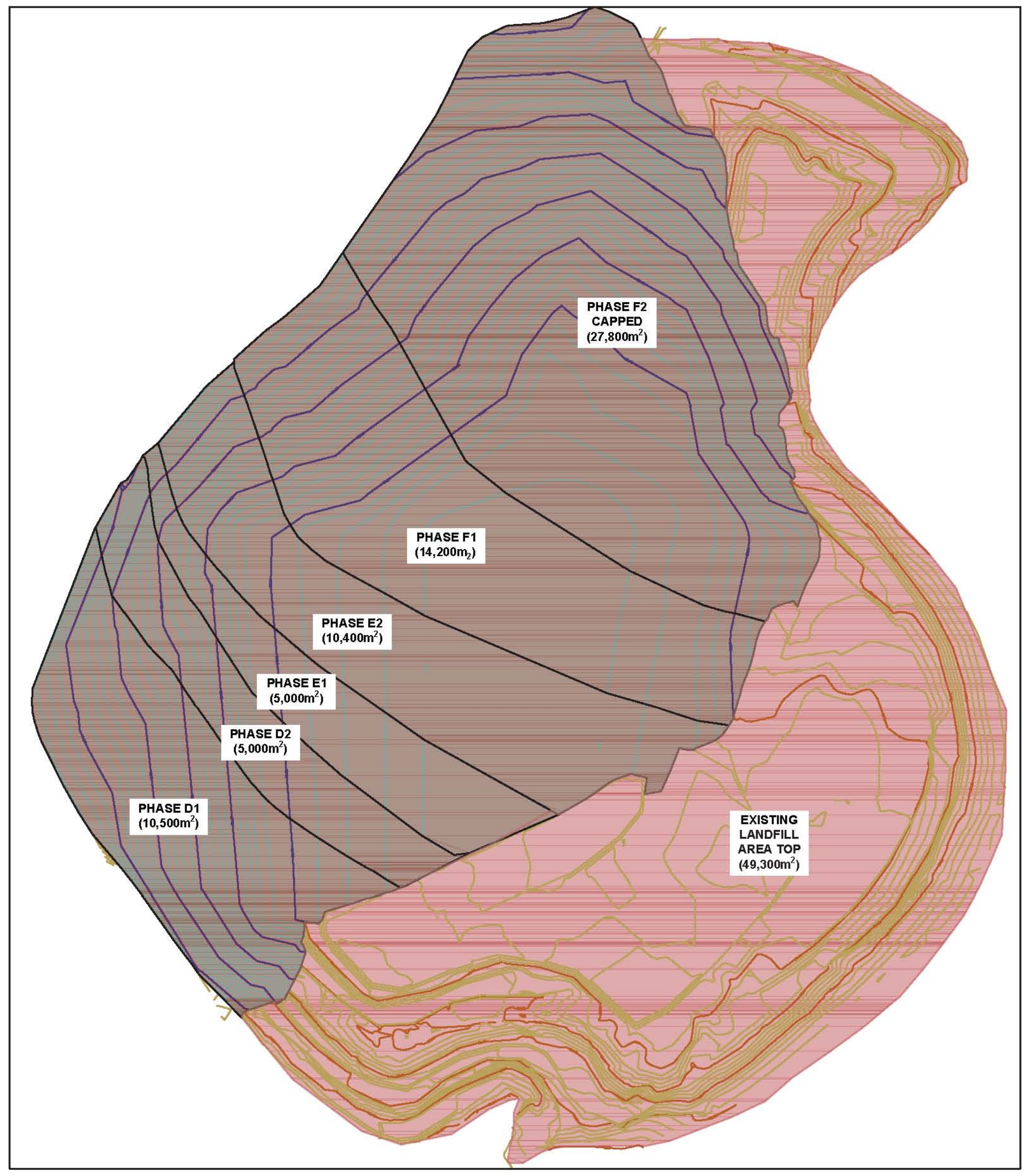
PHASES D1, D2 & E1 CAPPED, PHASE E2 SURFACE



PHASES D1, D2, E1 & E2 CAPPED, PHASE F1 SURFACE



PHASES D1, D2, E1, E2 & F1 CAPPED, PHASE F2 SURFACE



PHASES D1, D2, E1, E2 & F1 & F2 CAPPED

N

NOTES

1. TOPOGRAPHIC SURVEY INFORMATION SUPPLIED BY WASTESERVE MALTA LTD, REF: DTM WASTE UP TO END MARCH 2015.DWG & REF: DTM LEFT TO EXC END MARCH 2015.DWG, DATE RECEIVED: 12.05.2015.

2. ADDITIONAL INFORMATION SUPPLIED BY WASTESERVE MALTA LTD, REF: DTM EXC EXIST & PROP MERGED.DWG, DATE RECEIVED: 12.05.2015.

LEGEND

- 30.00 — TOPOGRAPHIC SURVEY LEVEL CONTOURS (mAOD)
- 30.00 — EXCAVATION / PROPOSED FORMATION LEVEL CONTOURS (mAOD)
- 50.00 — PROPOSED PRE-SETTLEMENT TOP OF RESTORATION LEVEL CONTOURS (mAOD)
- PHASE D
- PHASE E
- PHASE F
- SURFACE
- CAPPED
- EXISTING LANDFILL AREA FLANK
- EXISTING LANDFILL AREA TOP

0 20 40 60 80m 120 160 200
Metres 1:2000

Revision	By	Chk'd By	Date	Comments
	DB	DJ	12/15	

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www.slrconsulting.com

Site
GHALLIS LANDFILL SITE

Project
LEACHATE MANAGEMENT PLAN

Drawing Title
PHASING D TO F - SHEET 2 OF 2

Scale	Date
1:2000 @ A1	12/15

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