Combined Land Treatment and Land Dispersal – The Way Forward

Rob Potts[A,B]

[A] Lowe Environmental Impact Ltd., PO Box 29288, Christchurch
[B] Corresponding author. Email: rob@lei.co.nz

ABSTRACT

The Queenstown Lakes District Council's Lake Hawea sewage treatment system originally consisted of a 0.94 ha oxidation pond with mechanical aerators, an infiltration trench and an overflow to the adjacent Hawea River. In recent upgrades, the trench system has been extended to 150 m length and the overflow pipe removed. Recent consenting through Otago Regional Council has resulted in a combined land treatment and dispersal (CLATAD) system being assessed, designed and installed. This was considered by the community as the best practicable option (BPO) and the definite way forward as it removed the river discharge, used land treatment whenever possible, and still used land disposal when land treatment was not possible.

The new 2.33 ha land treatment area (LTA) comprises sprinklers on 1 m high risers with medium pressure lateral pipes at 20 m centres. The harvesting equipment drives around the risers during harvesting. It is proposed to use the LTA for at least 8 months/year, with the pond levels buffering wet weather flows and the trench used when the soils are saturated or frozen. The LTA is only used at night due to the presence of an adjacent cycle/walking track. The LTA is also connected to a weather station that shuts it down in winds over 29.9 km/hr.
The nitrogen loading on the LTA in 2023 will be 1,230 kg/ha.year. The predicted nitrogen removed with the crop is in the order of 536 kg N/ha.year and gaseous losses of 171 kg N/ha.year, meaning in theory that there will still be moderate leaching loss of 516 kg/ha.yr. Adding in the leaching loss from the trench system, the total nitrogen lost to groundwater in 2023 is 2,750 kg/yr but this is significantly less than if the trench system alone was used of 4,650 kg/yr leached.

INTRODUCTION

The Queenstown Lakes District Council (QLDC) held discharge permits from the Otago Regional Council (ORC) to discharge treated wastewater from the Lake Hawea wastewater treatment system (WWTS) to land and directly to the Hawea River. The system currently receives raw municipal sewage from Lake Hawea township and consists of a 1.2 m deep and 0.94 ha oxidation pond with three mechanical aerators and an infiltration trench adjacent to the Hawea River. The volume of the pond is 10,250 m^3 and has a hydraulic retention time of 50 days. The infiltration trench previously included an overflow pipe which enabled the discharge of any overflow directly to the Hawea River; however this pipe has been decommissioned and no longer forms part of the system. The site location of the facilities is shown in Figure 1.

The current consent was granted for a short term to enable QLDC to investigate more environmentally sustainable dispersal options and to specifically investigate land treatment options.

At the time the consent was granted, population and flow projections were such that the existing system would not be appropriate going forward, hence there was a need to proceed with a significant full plant upgrade with some urgency. As a result of the recent economic downturn, a reduction in Infiltration and Ingress (I&I) and better flow prediction modelling, the population and flow projections were revised and accordingly the lifespan of the pond has been revised. Consequently QLDC now propose to continue the existing method of wastewater treatment (with some upgrades) for an interim period and to establish a land treatment system that will operate in tandem with the pond and current trench disposal system. The combined system represents an appropriate medium term wastewater treatment solution for the Lake Hawea community and will have sufficient capacity to provide for the community through to 2023 based on the new population and flow projections.

Consents were therefore applied for:

- The continuation of the existing discharge of treated wastewater from the Lake Hawea wastewater treatment system to land via a disposal trench;
- The discharge of treated wastewater to land via a land treatment irrigation system; and
- The discharge to air from the operation of the wastewater treatment plant and land dispersal systems.

Fig. 1. Location Plan

BACKGROUND AND EXISTING ENVIRONMENT

The rainfall at the site averages 520 mm per irrigation season (September to April) and evapotranspiration is 620 mm for the same period, *i.e.* a deficit of about 100 mm. Total rainfall for an average year is 810 mm.

A soil analysis of the LTA was conducted and the soils were found to be silty loam to silty clay loam in nature, and a number of large boulders near the surface were spread over the site.

The soil's infiltration potential was assessed using a plate permeameter, with flows at matrix potentials of 100 mm, 70 mm and 50 mm used to describe unsaturated flow in the micro and meso pores. Results for the various matrix potentials are provided in Table 1 below. These show a free draining soil, with rates ranging from 15 – 38 mm/h for the 100 mm matrix potentials and 38 – 105 mm/h for the 50 mm matrix potential.

Table 1. Hydraulic Conductivity Test Results.

Site 1		**Site 2**		**Site 3**	
Test	**K (m/day)**	**Test**	**K (m/day)**	**Test**	**K (m/day)**
1-A100[a]	0.36	2-A100	0.36	3-A100	0.36
1-A70	0.72	2-A70	1.26	3-A70	0.72
1-A50	1.30			3-A50	0.90
1-B100	0.36	2-B100	0.72	3-B100	0.90
1-B70	0.72	2-B70	1.26	3-B70	1.26
1-B50	1.08	2-B50	2.52		
1-C100	0.54			3-C100	0.36
1-C70	0.08			3-C70	0.72
1-C50	1.62			3-C50	2.34

[a]100 refers to 100 mm matrix potential, etc

A thermocouple temperature probe system was installed at the site with probes located at the soil surface (<50 mm), 150 mm and 300 mm below the surface. It was concluded that the soil at depth had not shown any signs of freezing but the soil surface had endured several hard frosts. The extent of temperature variation throughout the day indicated that the soil temperature increased above 0°C within several hours. The growOTAGO climate database shows the median winter (July to September) 100 mm soil temperature for the period 1970-2001 to be 3.6 – 4 °C with an annual mean soil temperature of 8.6 – 9°C.

Vegetation in the vicinity of the wastewater pond consisted largely of low-grade grassed pasture, intermingled with bracken and wild rose although there is a stand of pine trees directly west of the pond that screens it from the nearby walking/cycling track.

Groundwater level is at around 21 - 22 m below ground level (bgl). This water level appears to be contemporaneous with the stage height, observed in the Hawea River. Aquifer transmissivity is approximately 500 – 1,000 m^2 per day and this suggests that the basin comprises mostly fairly permeable gravels. Groundwater levels in the general area of the site suggest that groundwater flow is discharging into the Hawea River.

An existing irrigation race to the east of the pond runs in a North – South direction. This is approximately 35 m from the pond fence and would be approximately 30 m at the closest point from the proposed fence around the land treatment area.

The Hawea River is about 30 m from the proposed land treatment area, is deep and swift and comprises a single thread channel approximately 30 m wide. The water depth exceeds 1 m in the centre channel, even at times of very low flow. River bed substrate is dominated by large cobbles and boulders.

The discharge from Lake Hawea has been regulated for hydro-power generation on the Clutha River since 1959, which often results in it being held artificially low for long periods during summer. The natural mean annual low flow is 7.3 m^3/s, however Contact Energy is required to maintain a minimum flow of at least 10 m^3/s in the river.

The Hawea River is used for a number of recreational activities including kayaking, fishing, jet boating, swimming, and tubing. The river is used by large numbers of holiday makers especially during the summer months. A walking/cycle track runs along the banks of the Hawea River adjacent to the pond. This track is used for walking, trail running, and mountain biking.

CONCEPT DESIGN AND UPGRADE DETAILS

The peak day population in the design horizon (2023) is about 3,500 people, with an average dry weather flow (ADWF) of 364 m3/d, a peak dry weather flow (PDWF) of 775 m3/d and a peak wet weather flow (PWWF) of 950 m3/d. Projected flows into the pond are shown in Table 2.

Table 2. Current and projected wastewater flows.

Year	ADWF[a]		PDWF[b]		PWWF[c] - 12hr Storm		PWWF[c] - 24hr Storm	
	m^3/day	L/s	m^3/day	L/s	m^3/day	L/s	m^3/day	L/s
2008	197	9	442	12	518	16	542	16
2010	220	-	487	-	-	-	-	-
2018	308	11	664	17	774	22	812	22
2023	364	12	775	19	903	25	946	25
2029	430	13	908	23	1,056	29	1,108	28
2033	480	15	995	25	1,140	31	1,189	30

[a] Average Dry Weather Flow, [b] Peak Dry Weather Flow, [c] Peak Wet Weather Flow

Facultative Oxidation Pond

The pond operating system was recently upgraded to be automated, with dissolved oxygen (DO) measurement and SCADA feedback of pond levels, DO, aerator activity, etc.
The pond effluent quality prior to upgrade is shown in Table 3.

Table 3. Effluent Characteristics Prior to Upgrade (July 2008 to January 2010).

Characteristic		Effluent Sampling			Typical Values*
		Mean	95% ile	Std Dev.	
BOD_5	mg/L	37.8	68.5	17.2	15 – 110
SS	mg/L	146.4	228.4	62.7	10 – 150
TN	mg/L	30.4	40.1	6.8	10 – 50
NH_3-N	mg/L	11.7	24.8	10.6	0.1 – 30
TP	mg/L	7.5	9.5	1.2	4 – 16
E Coli	cfu/100mL	$1.8x10^4$	$5.3x10^4$	$1.9x10^4$	$2x10^3$ – $50x10^3$
pH		7.3	8.1	0.6	–

- From Oxidation Pond Guidelines, NZWWA 2005

The WWTS has been performing reasonably well for most parameters, however, as shown by the high standard deviation values there is a reasonably high degree of variability in the performance of the pond (e.g. for BOD_5 the first standard deviation is 50% of the mean).
It should also be noted that the concentration of suspended solids (SS) from the WWTP is high. Until very recently, the effluent was taken from the surface of the pond via an overflow weir. This is likely to be the source of the high SS as algae are typically found in the top 600 mm of the pond. The QLDC has recently modified the outlet structure to a submerged actuated gate outfall, approximately 600 mm below the pond surface thus reducing the capture of algae. In addition to this, a coarse screen has also been installed on the outlet to reduce the amount of larger solids in the effluent. The BOD_5 associated with algae can be as much as 30% of the total BOD_5; therefore, by reducing the capture of algae the effluent BOD_5 should be reduced.

The sampling rounds from June 2010 are after the pond system modifications but before desludging. The results are shown in Table 4 below.

Table 4. Latter Sampling from Pond Outlet (mg/L).

Date	**SS**	**BOD_5**	**TP**	**TN**
27/04/2010	180	21	6.60	31
26/05/2010	143	53	6.71	32
22/06/2010	75	20	6.24	31
21/07/2010	64	23	7.36	36
Mean 2010	146	33	7.24	34
Mean 2011	138	39	7.15	33
Mean 2012	130	33	6.75	38

The upgrades that have been undertaken to the pond system to improve operation and effluent quality include:

- Installation of DO meter linked to SCADA;
- Installation of level recorder linked to SCADA;
- Existing aerators to be able to be monitored and controlled by SCADA based on DO levels;
- Installation of a flow meter on the outlet of the pond to soakage trench linked to SCADA;
- Recently installed flow meter on inlet linked to SCADA;
- Electronically actuated flow control valve on outlet from pond to soakage trench. The rate of flow is now controlled by the levels in the pond and be able to be overridden by the operator prior to rain events and holiday periods;

- The redesign of the outlet allows for a pump station to be installed to pressurise the land treatment system;
- The outlet from the disposal trench to the river has been removed;
- Various alarms have been set up to ensure that appropriate warning of critical flows and levels is given;
- The SCADA, Aspex and O&M Manuals are being updated; and
- An estimation of the sludge content of the pond has been undertaken and the pond is currently being desludged.

Infiltration Trench

The 150 m long and 2 m wide trench system has been upgraded from a 4 point gravity fed system to an intermittently dosed system along the entire length of the trench. This is via a perforated PVC pipeline with 7 mm holes at 1 m centres (i.e. a low pressure effluent dosing (LPED) system) underlain by 600 mm of graded sand to assist in pathogen removal. Since the trench upgrade in 2008 the system has operated without overflow to the river; and accordingly in December 2009 the overflow discharge pipe was removed.

The trench system will generally only be used during the winter months May to August and at times of very wet weather, as extreme wet weather results in both high inflows to the pond and also saturated ground conditions for land treatment. The rainfall required to implement this switch over in discharge modes will be determined by the operators from observations of the operation of the land treatment system but is likely to be in the order of 20 - 30 mm rainfall in the last 24 hours. It is also anticipated that the trench will be used for approximately a two week period each time the land treatment area is due to be harvested. This could occur 3 – 4 times per year. The trench system can only be used for a maximum of four months per year – a consent condition restricts this, thus there is a strong encouragement to use land treatment.

In the design year 2023, the average trench loading will be 364 m^3/d, or 1.21 m/d. Year 2023 peak day loading of 775 m^3/d equates to 2.58 m/d hydraulic load. This is anticipated to be at the upper end of the loading as flows are buffered through the pond. The future trench operation will be monitored during higher loading periods and the trench length expanded as necessary.

Land Treatment Area

The land treatment area (LTA) will occupy the area immediately to the south east of the existing pond which is also designated for oxidation pond purposes. The total land area within the designation is 6.68 ha, however some of this is occupied by the existing pond and/or is unsuitable for land treatment. The suitable area for land treatment to the south east of the pond, after removing buffer areas, is 2.33 ha.

The proposed LTA has four wheel drive tracks and spoil heaps within it, so some minor recontouring was carried out. The soil mantle is thin and of low nutrient status. Therefore, a layer of biosolids was applied to the soil for incorporation at the time of sowing. A separate consent application for the incorporation of biosolids into the soil was obtained (see paper by Sarah Smith of Lowe Environmental Impact Ltd).

The LTA was planted in lucerne and it is intended to be cut for hay or baleage. The crop will be harvested 3 - 4 times per year by a local contractor or neighbouring farmer. The area will not be grazed.

The irrigation system comprises of PVC pipes at 20 m centres with medium pressure sprinklers on 1 m high waratah risers. The lateral pipes and submains are buried with only the risers above ground. This requires the harvesting equipment to drive around the risers during harvesting.

The sprinkler system has an application rate in the order of 10 – 15 mm/hour. The impact drive sprinklers have a relatively small wetted area and are relatively close to the ground, thus spray drift is negligible and aerosol production and migration minimal. The outer sprinklers are half circle sectioning sprinklers, thus buffer distances are only 5 m. Figure 2 shows the sprinkler layout concept.

At current average flows the hydraulic loading to the LTA is 9 mm/day; this will increase to 15 mm/day by 2023. As with the trench system, peaks will be buffered through the pond system and in extreme weather the trench system will be used rather than the LTA. These are high loadings for a land treatment system and are due to limited land area being available.

Fig. 2. Sprinkler Layout

Consenting and Effects

The LTA discharge is a discretionary activity in accordance with rule 12.6.2.1 of ORC's Regional Plan:Water. The 8.8 – 14.5 mm/day wastewater loading rate on the LTA is at a rate within the infiltrative rate of the soil and is at a rate that should not cause water logged soils. The current loading of nitrogen to the trench is in the order of 2,800 kg N/year. Following the introduction of the land treatment system, the loading of nitrogen to the trench will be reduced to 920 kg/year. By 2023, nitrogen loading to the trench will be in the order of 1,530 kg/year. Little to no reduction in nitrogen is expected long-term in the trench system.

Current nitrogen loading to the land treatment system is 735 kg N/ha.year. It is predicted that dry matter production would be in the order of 18,000 kg/year. With an average nitrogen content of 3.5%, the nitrogen removed with the crop should be in the order of 536 kg /ha.year, assuming that 85% of the crop is removed with each cut. Ammonia volatilisation from spraying is estimated at 30 kg/ha/year based on 40% of the nitrogen in the effluent being ammonia and 10% of this being volatilised. Denitrification is estimated at 10%, or 74 kg /ha.year.

Once the nitrogen removal methods above have been considered, the average losses of nitrogen from the LTA through leaching is estimated at 95 kg /ha.year (220 kg/year over 2.33 ha). If the trench leaching is added to this, then the total N being lost to groundwater is 1,140 kg N/year. This compares to the current trench only system which leaches 2,800 kg N/year, *i.e.* 60% reduction by using a combined system.

By 2023, the annual output of nitrogen from the WWTS will be in the order of 4,650 kg/year. Nitrogen to the land treatment area will be 1,230 kg /ha.year. Assuming that crop production will not change, the crop will continue to remove in the order of 536 kg /ha.year. Ammonia volatilisation from spraying is estimated to increase to 49 kg /ha.year and denitrification is estimated to increase to 122 kg /ha.year.

Once the nitrogen removal methods above have been considered the average losses of nitrogen from the LTA through leaching is estimated at 516 kg /ha.year (1,200 kg/year over 2.33 ha). If the trench leaching is added to this, then the total N being lost to groundwater is 2,750 kg N/year, compared to the current trench alone system of 4,650 kg N/year, *i.e.* 40% reduction by using a combined system.

The nearest rural-residential dwellings would most likely be cross wind of the LTA under normal wind directions. Investigations were carried out at the Rolleston WWTP and reported in literature (Noonan et al, 2002), where two application methods were examined. The method of direct relevance was via low pressure hammerhead-type sprinklers (similar system to the Lake Hawea method). The reported results for the low pressure sprinklers indicated that at a distance of 22 m no viable bacteria were detected. The samplers used in this investigation were Andersen sampler units, which are designed to mimic the filtering effect of the human lung.

Other investigations (Donnison, 2004) indicated that organisms were recovered from Andersen samplers at a distance of 100 m downwind of low pressure sprinklers (similar to the applicants proposed dispersal method). However, the bacterial concentration of the effluent used in the trials reported in the Donnison paper was $1x10^5$ organisms/mL, or $1x10^7$ organisms/100 mL. This concentration is three orders of magnitude greater than the concentration of organisms in the effluent proposed for dispersal by the applicant; being $5x10^4$ organisms/100 mL (95th%tile value).

Literature (Noonan et al, 2002) concluded that with a low bacterial concentration in effluent, bacteria cannot be detected in Andersen samplers. The literature cited another reference (Katzenelson et al, 1977) which reported that bacterial concentrations need to be at least 10^6 organisms/100 mL in the liquid to be sprayed to ensure that they are recoverable in Andersen samplers.

Application of effluent to the LTA will only occur during night time (application to occur from 11 pm), which will reduce the possibility of potential receptors being present in the receiving environment around the dispersal area (such as the cycleway which is some 10 m at its closest point to the LTA).

A community meeting was held in July 2010 after the option of using a combined trench and land treatment system was considered. In summary this meeting highlighted:

- Positive support for a land treatment system;
- There was concern by one neighbour with the use of above ground sprinkler irrigation and they would prefer to see either subsurface or surface drip; and
- Other members of the community preferred the spray system due to the lower cost.

Following the public meeting a series of resource consent conditions were developed and discussed with the community. This resulted in the following conditions being agreed:

- A 5 m buffer around the wetted area to the boundary fence;
- The area on which treated wastewater is applied by spray irrigation shall be fenced with a 2 m high deer fence with appropriate signage warning the general public of the hazard;
- Wind cloth shall be installed, and maintained until screen foliage is established, on the western, southern and eastern-most boundaries of the area on which treated wastewater is to be applied by spray irrigation;
- Suitable screening foliage, that shall be at least 3 m high but not exceed 6 m in height, shall be planted on the western, southern and eastern-most boundaries of the area on which treated wastewater is applied by spray irrigation;
- A weather station shall be installed in an appropriate location to record, as a minimum, rainfall and wind conditions at the site where treated wastewater is to be applied by spray irrigation;
- Wastewater shall not be applied to land by spray irrigation system during the hours outside of 11 pm and 5 am;
- The spray irrigation system shall not be operated in conditions where wind speed, as measured at the on-site station exceeds 29.9 km/hour; and
- Nozzle pressure must not exceed 400 kilopascals (kPa).

Consultation was undertaken with local iwi representatives (KTKO), Fish and Game, Public Health South and with the Lake Hawea Community. In summary:

- They were very happy that the river discharge had been removed as this was their major concern;
- They considered it a reasonable solution for the size of the community; and
- They were pleased to see land treatment in spring and summer when there is a soil moisture deficit and to use the land disposal in winter when the area didn’t need the water.

SUMMARY AND CONCLUSIONS

Key stakeholders and the general community did not want any discharge directly to the Hawea River due to both recreational use and cultural reasons.

A slowdown in growth in the community meant that earlier options identified no longer could be afforded by the community and less costly alternatives were needed that incorporated continued use of the pond system which was working well.

Land owned by QLDC and available for land treatment was not optimal but sufficient to provide some land treatment and an immediate 60% reduction in N loading to the groundwater/river system.

Soils are free draining and can accept loading at higher hydraulic loading than required for agronomic growth, meaning that the land treatment system can be used when irrigation is not required.

Community concerns with aerosols in close proximity to neighbouring properties and a cycle trail could easily be mitigated through design parameters, such as nozzle pressure and shelterbelts, and operational parameters, such as operating hours and wind speeds.

Combining land treatment with land disposal means that there is no need for high cost storage or high cost land purchase, so the community has ended up with a relatively low cost system that meets their needs for the next 15 years at least. And although nutrient loadings are higher than usually accepted, this is much better than full land disposal or river discharge where no reduction occurs.

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