Wastewater Treatment and Land Treatment in Highly Variable Holiday Locations – Case Studies of two Queenstown Lakes Projects

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ABSTRACT

Queenstown Lakes District Council (QLDC) recently took back management of the Glendhu Bay Lakeside Holiday Park – a very popular summer holiday spot on the shores of Lake Wanaka. Numbers increase rapidly from 2 permanent residents in winter to over 1,200 campers through the New Year, with flows climbing from under 10 m^3/day in early December to over 140 m^3/day by the end of December. These flows last for 3 to 4 weeks before decreasing rapidly at the end of January. This creates problems for wastewater treatment in a very pristine, high recreational use environment. Lowe Environmental Impact staff were engaged to consent and then prepare Design-Build-Operate documentation for procurement. This was awarded to Innoflow Technologies who designed, built and commissioned the plant in December 2011.

Queenstown Lakes District Council also recently undertook upgrades to the Lake Hawea oxidation pond system. This treats wastewater from a small lakeside township with a resident population of about 1,000 (average flow of 175 m^3/d) that rises to 2,500 (average flow of 270 m^3/day) over the Christmas holiday season. Part of the upgrade was to install a combined land treatment and land disposal system, as described by Potts (2013).

This paper provides issues for operation of these fluctuating load communities and provides effluent results and cut and carry system results prior to the conference field trip.

KEY WORDS

Variable, Holiday, Results, Wastewater, Treatment, Nitrogen

GLENDHU BAY

Background and System Details

The QLDC owned Glendhu Bay Lakeside Holiday Park is located on the shores of Lake Wanaka, 11 km west of Wanaka Township. Its patronage rapidly increases from 2 people to over 1,200 during the peak summer period and at Easter. The size of the existing grease traps and septic tanks were considered inadequate, with resulting poor effluent quality. The disposal system was into very free draining (Category 1) gravels adjacent to the high recreational use bay.

Lowe Environmental Impact staff gained consent and tendered the design build and operate (DBO) of a new wastewater treatment plant and dispersal system in 2011. The consent requirements were for a system capable of meeting the effluent requirements shown in Table 1.

Table 1: Effluent Requirements as Consented

Parameter	Mean	80%tile *
BOD (mg/L)	20	30
TSS (mg/L)	20	30
TN (mg/L)	25	40
E.coli (cfu/100 ml)	100	200

* Applies to a 12 month rolling calendar period

Peak flows were estimated at 140 m^3/d but the system was required to be designed for 150 m^3/d, with the ability to be expanded to 190 m^3/d at a maximum rate of application of 32 mm per day into the dispersal system.

The camp ground consists of 3 shower blocks, 6 toilet blocks, 2 communal kitchens and 2 houses within the holiday park. Some blocks were individually served by septic tanks, grey water tanks, or grease traps, and some shared tank facilities.

Innoflow Technologies were awarded the contract for a turnkey design, construction of the primary system, reticulation system, secondary system, tertiary system and dispersal system, as well as the operation of it for 5 years. It was commissioned in December 2013, two weeks before the peak season.

Innoflow replaced all but one of the existing septic tanks with new Septic Tank Effluent Pump (STEP) tanks and a small diameter effluent sewer reticulation network. Primary effluent, largely free of suspended solids and reduced BOD_5, was pumped to a pre-anoxic zone followed by pre-aeration before aerobic treatment through a bank of four AdvanTex–MAX™ recirculating textile packed bed filters (as seen in Figure 1). A post-anoxic zone was installed to meet the TN limits and a fifth AdvanTex–MAX™ is used for polishing prior to ultraviolet light disinfection and irrigation. The land application system comprises 24 discharge control trenches, each 93 m long. Distribution pipes are buried at the depth of 350 mm to avoid damage as the entire area contains tent and caravan camp sites.

Figure 1: Photo showing Completed System

Results

Telemetry monitoring to date shows that flow data trends mirror occupancy very well, indicating no ingress and infiltration issues. Figure 2 shows how highly seasonal flows actually are. Peaks are about 150 m^3/d and troughs are typically less than 1 m^3/d through winter. Of importance to designing and operating a wastewater treatment plant (WWTP) is the rapid increase in flows in December.

Figure 2: Flows and Effluent Test Results

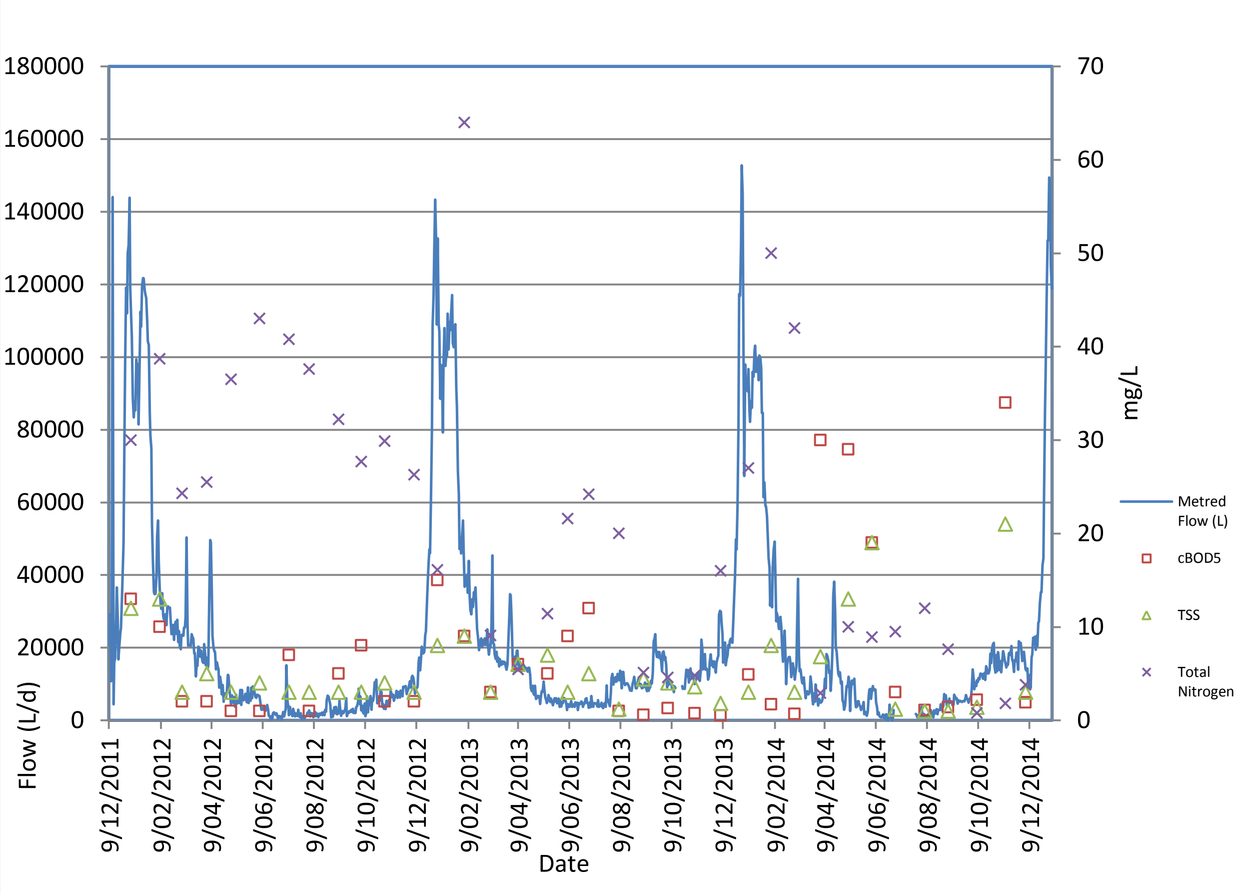

Figure 2 also shows effluent results for BOD, TSS and nitrogen. BOD and suspended solids tend to track flows whereas total nitrogen concentration is higher in winter when higher Dissolved Oxygen (DO) levels and a low Carbon to Nitrogen Ratio (C:N), and to a lesser degree low winter temperatures affect denitrification. However, the higher concentration relate to very low flows, so the mass of nitrogen discharged is very low.

Table 2: Results of Effluent Quality (January 2012 – December 2014)

Parameter	2012		2013		2014	
	Mean	80%tile	Mean	80%tile	Mean	80%tile
BOD	5	8	5	9	11	27
TSS	5	5	5	7	7	12
TN	33	39	17	21	15	24
E.coli	45	2	40	2	3	2

Note: Shading denotes it is outside of consent compliance

Discussion

As above, the nitrogen concentration is sometimes elevated in winter when low biological loads coupled with a large treatment plant designed for a short duration peak result in difficulties maintaining ideal anoxic conditions for denitrification. . However, annual means and the 80th percentile are well within the required effluent quality apart from the initial start-up period.

Recirculating packed bed reactors, such as the AdvanTex-MAX™, being a multiple pass attached growth process provide highly consistent treatment even under fluctuating flow conditions. Hydraulic retention and primary anaerobic treatment through the STEP tanks helps to buffer typical diurnal flows and lowers the organic loading to the treatment plant.

The wastewater treatment plant has performed exceptionally well through the peak summer period. Results for $cBOD_5$ during January (sampled in the first week) average 11.0 mg/L and for TSS average 7.7 mg/L. In addition to this average Total Nitrogen during January over three years is 24.4 mg/L.

Whilst the summer peak is important, where approximately 50% of the annual wastewater production occurs between Boxing Day and New Year's Day, and when influent concentrations are typically higher, the most important aspect of the design was ensuring compliance during the remaining 11 months of the year.

In order to achieve the consented limits for Total Nitrogen, it is important that the plant is largely free of toxic substances, that there is sufficient alkalinity available for nitrification and as a buffer against pH change, that a C:N ratio of between 3:1 and 4:1 is available in anoxic zones and the temperature is maintained above 10 °C.

The design by Innoflow Technologies allowed for both supplemental alkalinity and carbon dosing proportional to daily flow. Alkalinity in the form of sodium bicarbonate is added to the pre-anoxic tank at a rate of 168 kg/day at peak flows. Carbon in the form of Micro C2000™ is added to the pre-anoxic tank at a rate of 10 L/day and to the post-anoxic tank at 40 L/day at peak. The rate of dosing is proportional to incoming flow and based on estimated influent concentrations.

A general trend in performance is that the effluent quality results, especially for Total Nitrogen is improving as more data is collected on influent and the operation of the treatment plant.

The oxidation of inorganic material does not yield as much energy as the oxidation of organic carbon sources, as performed by heterotrophic bacteria, so nitrifiers have a very slow growth rate within the microbe community in wastewater plants. Bioaugmentation of the plant to increase the population of nitrifiers was considered necessary due to the rapid increase in flows over the peak season and the slow growth of these bacteria species. Therefore, in addition to supplemental chemical addition, Innoflow Technology add chemoautotrophic bacteria to the textile sheets as part of the operation leading into the peak season. Chemoautotrophic bacteria such as *Nitrosomonas*, *Nitrobacter*, and *Nitrospira* use CO_2 as their carbon source and oxidation of non-organic material to generate cellular energy.

The entire treatment plant is remotely monitored and controlled using an Orenco Systems® Incorporated TCOM control panel. The panel trends incoming flows and automatically adjusts process settings to optimise plant performance. One of the main adjustments is to the recirculation ratio. A high recirculation ratio will lead to high DO levels in the filtrate that is returned to the pre-anoxic tank and also transferred into the post-anoxic tank. Ideally, DO levels in these tanks should be as close to zero as possible, however the filtrate can be anywhere between 4 - 6 mg/L. If DO is too high, denitrifying bacteria will utilise DO rather than oxygen from nitrate and thus denitrification does not occur. The trending calculations also regulate the amount of filtrate returned to the anoxic zones, with an ideal return being 10 – 20% of daily flow.

Of all the influences on Total Nitrogen removal, controlling DO and C:N ratio during the off season has been the most difficult. During the 2012 winter period, when Total Nitrogen was highest, the trending function was not active as Innoflow were optimising the process in the first year of operation. This led to increased recirculation ratios and higher DO. Once this function was activated, there was a significant improvement in removal rates. C:N ratios are regulated by the amount of supplemental carbon added to the anoxic zones. Adding too much carbon is costly and not enough carbon results in nitrate slippage. Again, the trending function and adjustments to the dosing rate has improved denitrification rates in 2013 and 2014. In October and November 2014 rates were increased again, resulting in near zero levels of nitrate in the treated effluent and Total Nitrogen of 0.77 mg/L and 1.8 mg/L respectively, however, since carbon is effectively BOD, the effluent BOD result in November jumped to 34 mg/L. A reduction in the carbon dose in late November resulted in the December sampling being in compliance at $cBOD_5$ of 1.9 mg/L and Total Nitrogen of 3.8 mg/L.

Toxicity is an ever present concern at camping grounds, not only from the types of sanitisers used to clean the facilities but also from chemical toilets used in motorhomes and camp sites. At Glendhu Bay, 3 chemical dump stations were installed to capture and retain chemical blackwater, which is then carted off-site when storage tanks are full. Only one toxic event was observed and coincided with a change in camp management. This in-turn resulted in a change in cleaning products which had a detrimental effect on plant performance. Total Nitrogen reached 64 mg/L in February 2013. The removal of the offending product resulted in a quick turnaround in plant performance with Total Nitrogen at 9.4 mg/L in the subsequent sample in March.

Seasonal variations in temperature have not adversely affected plant performance to a significant level. Ammonia levels have remained very low (typically less than 1 mg/L) throughout the seasons. All biological processes are below ground level and the packed bed reactors are housed in an insulated fibreglass basin.

Conclusions

The DBO process has worked well for this project; because sufficient design information was provided at tendering stage to allow all bidders to design a system with confidence and with limited tags and exclusions. Tying a contractor into the ongoing operation of the plant is also very important, as it ensures the risk and associated costs are met by the designer/supplier and tenders can be evaluated on a whole of life basis rather than just initial capital cost. In addition, package treatment plants tend to be bespoke designs and their operation is often best handled by those most familiar with their design.

The packed bed reactor, with appropriate operation, was the Best Practical Option to use at a site where flows ramped up very quickly in summer.

LAKE HAWEA

Introduction and Background

The wastewater treatment plant (WWTP) 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. The volume of the pond is 10,250 m^3 and has a hydraulic retention time of 50 days. The original discharge system comprised an infiltration trench with an overflow pipe to the Hawea River.

The upgraded system utilises an upgraded disposal trench, with the overflow removed and a 2.33 ha land treatment area (LTA) using fixed sprinklers, as shown in Figure's 3a and 3b.

Figure 3a: Sprinkler System

Figure 3b: Trench System

The LTA soils are silty loam to silty clay loam in nature. The soil's infiltration potential was assessed using a plate permeameter. Soils are free draining, with mesoporosity ($k_{-50\ mm}$) in the order of 40 – 100 mm/hr.

The peak day population in the design horizon (2023) is about 3,500 people, with an average dry weather flow (ADWF) of 364 m^3/d, a peak dry weather flow (PDWF) of 775 m^3/d and a peak wet weather flow (PWWF) of 950 m^3/d.

The pond effluent quality prior to the upgrade within the pond is shown in Table 3.

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

Characteristic		Effluent Sampling			Typical
		Mean	95% ile	Std Dev.	Values*
BOD_5	mg/L	38	69	17.2	15 – 110
SS	mg/L	146	228	62.7	10 – 150
TN	mg/L	30	40	6.8	10 – 50
NH_3-N	mg/L	12	25	10.6	0.1 – 30
TP	mg/L	7.5	9.5	1.2	4 – 16
E Coli	cfu/100mL	$1.8x10^4$	$5.3x10^4$	$1.9x10^4$	$2x10^3 – 50x10^3$

- From Oxidation Pond Guidelines, NZWWA 2005

The upgrades that have been undertaken to the pond system to improve operation and effluent quality include putting in an automated system to control dissolved oxygen (DO), controlling the water level in the ponds, and installing flow meters on the discharge to the trench and to the LTA. In addition, the pond was desludged in February 2013.

Pond System – Updated Results

The effluent quality from December 2010, after the pond system modifications, are shown in Table 4 below.

Table 4: Effluent Results Post Upgrade (December 2010 to November 2014)

		Mean
BOD_5	mg/L	35
SS	mg/L	106
TN	mg/L	37
NH_3-N	mg/L	23
TP	mg/L	7.1
E. *coli*	cfu/100mL	$2.8x10^4$

Of concern to QLDC is the increase in ammonia and total nitrogen. This is possibly due to short-circuiting due to wind action or the control of the aerators based on DO to reduce power costs. It is likely that insufficient aeration is occurring to nitrify the wastewater from ammonia to nitrate and therefore less denitrification occurring in the facultative layer.

Trench System – Updated Results

The trench system was only meant to be used 4-months per year during the winter months May to August and at times of very wet weather. The trench is also used for approximately a two week period each time the land treatment area is due to be harvested. This was to occur 3 – 4 times per year.

During the first year of operation (December 2012 – November 2013), it was used 153 days, i.e. 5 months/year. This increased to 283 days (only considering discharges > 10 m^3/day; 303 days if we consider all discharges > 0 m^3/day) in the 2014 season.

As shown in Table 5 below, the hydraulic load to the trench was 29,000 m^3/yr in 2013, with no loading in January – March. This is an average trench loading of 190 m^3/d, or 0.6 m/d. This increased to 38,000 in 2014, at an average of 135 m^3/d, or 0.45 m/d.

The nitrogen applied to the trench system was 1,185 kg in 2013 and 1,617 kg in 2014.

Land Treatment Area – Updated Results

The LTA was planted in lucerne in December 2012 and first irrigated on 21.12.2012.

The LTA system was used for 134 days during the first year of operation (December 2012 – November 2013). This increased to 145 days in the 2014 season.

As shown in Table 5 below, the hydraulic load to the LTA was 19,000 m^3/yr in 2013. This equates to 812 mm/yr loading, with no loading from June to October. The maximum month was January 2013 at 262 mm (8.5 mm/day). This was reduced to 17,300 m^3 in 2014, corresponding to 743 mm/yr, with a maximum of 135 mm during the month of March 2014 (4.35 mm/day).

Table 5: Hydraulic Loading of the Trench and LTA [Perhaps delete]

Month	2012/13 Trench Discharge Flow (m^3)	2012/13 Irrigation LTA Flow (m^3)	2012/13 Irrigation (mm)	2013/14 Trench Discharge Flow (m^3)	2013/14 Irrigation LTA Flow (m^3)	2013/14 Irrigation (mm)
Dec	1,037	2,912	125	3,039	1,097	47
Jan	1	6,110	262	4,066	1,685	72
Feb	0	2,367	102	756	2,482	107
Mar	0	2,721	117	1,056	3,148	135
Apr	150	2,168	93	3,747	1,342	58
May	2,093	1,647	71	5,935	11	1
Jun	5,101	1	0	5,469	0	0
Jul	5,783	8	0	4,925	0	0
Aug	4,432	24	1	4,517	0	0
Sep	3,783	16	1	3,514	935	40
Oct	4,534	0	0	485	3,877	166
Nov	2,151	948	41	617	2,743	118
Total	**29,065**	**18,922**	**812**	**38,126**	**17,319**	**743**

The nitrogen applied to the LTA system was 734 kg in 2013 (315 kg N/ha/yr) and this was reduced to 714 kg in 2014 (307 kg N/ha/yr), as shown in Table 6 below.

Table 6: Nitrogen Loading to Trench and LTA

Month	2012/13 N Applied by Irrigation (kg Total)	2012/13 N applied by Irrigation (kg/ha)	2012/13 N discharged to trench (kg)	2013/14 N Applied by Irrigation (kg Total)	2013/14 N applied by Irrigation (kg/ha)	2013/14 N discharged to trench (kg)
Dec	49.5	21.2	17.6	63.6	27.3	176.3
Jan	232.2	99.6	0.0	84.2	36.2	203.3
Feb	118.4	50.8	0.0	94.3	40.5	28.7
Mar	117.0	50.2	0.0	113.3	48.6	38.0
Apr	93.2	40.0	6.5	57.7	24.8	161.1
May	67.5	29.0	85.8	0.4	0.2	231.5
Jun	0.04	0.0	204.0	0.0	0.0	202.4
Jul	0.3	0.1	231.3	0.0	0.0	201.9
Aug	1.2	0.5	212.7	0.0	0.0	176.2
Sep	0.6	0.2	136.2	41.1	17.7	154.6
Oct	0.0	0.0	167.8	155.1	66.6	19.4
Nov	54.0	23.2	122.6	104.3	44.7	23.5
Total	**734**	**315**	**1,185**	**714**	**307**	**1617**

Land Treatment System – Nitrogen Removed

No herbage was harvested in the initial 2012/13 season. Herbage was harvested three times in the 2013/14 season. Results are shown in Table 7. The 15,500 kg DM removed equates to 6,650 kg DM/ha/yr.

Table 7: N Removed via Baleage

Month	Mass Baleage removed per cut (kg)	Dry Matter (%)	Dry Matter Removed (kg)	Dry Matter N conc. (%)	N removed in Baleage (kg)	N removed (kg/ha)
Dec 2013	13,475	62.2	8,380	2.65	222	95
Feb 2014	3,800	80.8	3,070	2.18	67	29
Apr 2014	6,050	66.9	4,050	3.56	144	62
Total 2013/14	**23,325**		**15,500**		**433**	**186**

Nitrogen Balance

Other factors have been modelled, such as ammonia volatilisation, denitrification and soil storage. These losses vary depending on ammonia content, temperature, etc. and have averaged out at about 21%.

The overall nitrogen balance for the site is shown in Table 8. This shows that prior to the installation of the LTA, N leached from the site was 1,775 kg/yr. This reduced to 1,763 kg/yr in 2013 and 1,747 kg/yr in 2014.

Table 8: Nitrogen Balance

	N Applied (kg)	N losses (kg)	N exported (plant growth)	N Leached (kg)	N Leached (kg/ha)
Pre 2012 Trench	**1,775**	**0**	**0**	**1,775**	**N/A**
2012/13 Trench	1,185	0	0	1,185	N/A
2012/13 LTA	734	156	0	578	248
Total 2013	**1,919**	**156**	**0**	**1,763**	**N/A**
2013/14 Trench	1,617	0		1,617	N/A
2013/14 LTA	714	151	433	130	56
Total 2014	**2,331**	**151**	**433**	**1,747**	**N/A**

This compares to the predictions made for consenting (Potts, 2013) shown in Table 9.

Table 9: Comparison with Assessment of Effects

Parameter	AEE Prediction	Actual 2014
Dry Matter Production (kg/ha/yr)	18,000	6,650
Nitrogen removed – baleage (kg/ha/yr)	536	186
Nitrogen Gaseous Losses (kg/ha/yr)	74	65
Nitrogen Leached – LTA (kg/ha/yr)	95	56
Nitrogen Leached – Trench (kg/yr)	920	1,617

Discussion

The LTA has been lightly loaded compared to what it was designed for. Hydraulic loading in the summer months has been minor, in an area that is severely moisture limited. December received about 1.5 mm/day average, whereas it should have been getting the full flow, equating to 5.7 mm/day. The trench system is only meant to be used in winter and during harvest periods but has been used significantly more. The operators have been questioned about this with a view to changing their procedures to maximise irrigation and limit trench use.

The nitrogen balance shows that the dry matter production is significantly less than predicted and thus the nitrogen removed is a lot less. In addition, the herbage nitrogen concentration is very variable and usually less than that predicted, resulting in an actual herbage removal of 186 kg N/ha/yr cf 536 kg N/ha/yr predicted. The major reasoning for this is considered to be the lack of moisture and nitrogen applied in the summer months.

There has been a major improvement in soil pH and calcium levels since irrigation started, however, soil sampling has shown a slight imbalance of other major nutrients and these have been rectified with the application of 21 kg/ha of P, 40 kg/ha of K and 50 kg/ha of S. It is considered that dry matter production will improve as organic matter builds up in the soil to provide better water holding capacity and the benefits of the fertiliser addition.

Conclusions

The land owned by QLDC and available for land treatment was not optimal, i.e. it was poor soil and not of sufficient area. Although the nitrogen renovation has not yet achieved what was expected, it is still a huge improvement on what was happening prior to the LTA being installed.

Changes to the prioritisation of the use of the LTA over the trench should see improvements in future years.

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