

# SOMETHING NEW WITH TOWNIE POO

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## Abstract

Clutha District Council is trying something new as it looks to improve the effluent from its oxidation ponds. The Council has already added additional treatment to five of its ten oxidation pond systems to meet new resource consent conditions and now, with numbers six and seven, is adding *Bio-Shell™ bioreactors*, new to New Zealand, and membrane filtration. This paper describes the systems being installed and how the decision was made to adopt the solution, in which the *Bio-Shell™ bioreactors* aim at nutrients and the membranes at solids and biota. Some early data is given on performance. The combination of biological and mechanical treatment is expected to ensure consent conditions are met, with an increased resilience over purely biological systems.

## Key Words

Sewage treatment membranes Bio-Shell™ bioreactors compliance nutrients nitrogen oxidation ponds

## Introduction

Clutha District Council has eleven sewage treatment facilities, ten of which incorporate oxidation ponds. The ponds were built between 1974 and 1994 and were typical of the time, providing the only treatment of the effluent. Discharge consents for the ponds began to expire in the mid-2000s, with the last to expire in 2018. As new consents have been obtained more stringent contaminant limits have been imposed. The Council has therefore added treatment downstream of the ponds in order to achieve compliance, and anticipates doing so for all ten ponds as the consents are renewed.

To date, five ponds have had *Biofiltro* plants (a type of packed bed reactor) and UV disinfection added, with the installations completed by 2012. Consents for the next two ponds, Heriot and Kaitangata, were granted in 2014 with new consent limits to apply from early 2018. Council adopted a design build procurement process, eventually negotiating a contract for an additional treatment design based on *Bio-Shell™ bioreactors* and membrane filtration. *Bio-Shell™ bioreactors* are a technology new to New Zealand which originated in the United States. They are placed in the pond and promise to reduce nitrogen concentrations in the pond effluent.

Commissioning of the new Heriot plant was completed in February 2018 and is expected at Kaitangata at the end of March. At the time of writing, little in the way of meaningful measures of effluent improvement is available. However, the paper sets out the reasons for the choice of treatment and outlines expected results.

## The Context

Ten of Council's sewage treatment facilities are based on oxidation ponds discharging to water. Two of them are twin pond systems, with the remainder single ponds. One of the twin ponds and one of the single ponds have surface flow wetlands following the pond, which were added in the early 2000s in order to meet new consent conditions. The ponds are generally small, ranging between 2,500m<sup>2</sup> to 12,100m<sup>2</sup>, with only Balclutha at 62,000m<sup>2</sup> outside that scale.

Consents for the ponds expired, or will expire, between 2005 and 2018. To date, new consents have been obtained and new facilities built for five ponds; new consents obtained for a further two ponds, Heriot and Kaitangata, where new facilities are being constructed and are the subject here; and consent applications are in process for three ponds. In each case, new, more stringent

contaminant consent limits have been imposed, or are expected.

Data for the Heriot and Kaitangata is summarised in Table 1 below. Heriot is the smallest sewage treatment and disposal system Council operates, discharging to the Heriot Burn. Daily flows are greatly influenced by a truck wash which is connected to the system, which contributes an average of 13m<sup>3</sup>/d, but a peak flow measured of 97m<sup>3</sup>.

**Table 1 Heriot and Kaitangata Data**

	Heriot	Kaitangata
Population (2013 census)	110	759
Properties connected	67	350
Mean daily Flow m <sup>3</sup>	58	527
Peak Daily Flow m <sup>3</sup>	213	1,426
Pond Area m <sup>2</sup>	2,500	9,600

Kaitangata is towards the larger end of the spectrum for Council, discharging to the Matau branch of the Clutha river. While there is also a truck wash connected to the Kaitangata system, it has little impact due to the size of the residential area served.

On the basis of the accepted design criteria of 70g BOD<sub>5</sub>/head/d and 84kg BOD<sub>5</sub>/Ha/d, both ponds are lightly loaded, Heriot at 30kg BOD<sub>5</sub>/Ha/d and Kaitangata 55kg. However, this ignores the impact of the truck washes, particularly at Heriot.

Pond performance is typical for Clutha District for Kaitangata, and was also at Heriot until 2014. Since then, at Heriot it has departed from that. This is set out in Table 2 below.

**Table 2: Pond parameter geomeans compared to presumptive consent geomeans, g/m<sup>3</sup> or cfu/100ml (E. coli)**

	Katangata	Heriot		Cons.
		Pre 2014	Post 2014	
BOD <sub>5</sub>	37	33	35	9
pH	7.5	8.0	7.9	6.5-9.0
Total P	5.2	7.7	10.5	7
Amm N	14	14	29	14
Total N	20	NA	43	26
TSS	68	42	65	16
FC / E.coli	30,000	22,000	252,000	40

In Table 2, bacteriological monitoring results are for faecal coliforms, whereas the consent limit is for E.coli. New consent limits are stated as “9 out of any 10 consecutive results not to exceed”, something akin to a 90<sup>th</sup> percentile. The presumptive consent geomeans are calculated from this limit, using ratios measured between geomeans and 90<sup>th</sup> percentiles at other Council ponds. There is a noticeable increase in nutrients and TSS concentrations at Heriot since 2014, which is highlighted in the table.

## Procurement

Historically, Council has followed a traditional procurement process when faced with having to provide additional treatment for water and wastewater. A consultant was engaged to design suitable treatment, then tendering followed for its construction. In the early days of pond upgrades, Council intended the same and some preliminary work was done by a variety of consultants.

However, in the midst of this, Council was approached by Biofiltro Ltd, offering its *Biofiltro* process on a design build basis – in effect, they offered to sell compliance to Council. They did so at a cost which, at that time (2009), promised to provide the required treatment at a cost roughly half that of any other option identified by consultant studies. The ultimate result of this approach was that five *Biofiltro* plants were constructed.

Since then, Council has become aware of other companies offering the same design build process, with pricing has moved so that there are several companies able to give proposals at a similar price point. It considered it inevitable that, if the traditional approach was adopted for procurement, a number of design build alternatives would be offered. Accordingly, a design build procurement process was adopted for these two plants. Initially, the upgrade of the Waihola pond was also included, but this dropped by the wayside as extensive delays occurred in obtaining a new consent for that plant.

The process started with a public invitation to submit draft upgrade proposals in late 2014. Proposers were invited to outline the treatment process they offered and give estimated capital and operating costs. A total of eight proposals were received and subjected to technical and financial evaluations. In the latter, Council's aim is to calculate an annual cost for each proposal, including amortised capital, depreciation, operation and maintenance costs. This is to recognise the fact that ratepayers pay an annual rate for the service, and Council's duty is to optimise that charge.

Of the eight proposals, four were adjudged to be capable of meeting the new consent limits. From these, a shortlist of three proposers was invited to submit fixed price tenders in the middle of 2015. Tenders closed towards the end of 2015, only two being received. In one sense, Council could now determine which was the most economic and proceed with that one, on the basis that each was offering a proposal to provide compliance with new consent conditions. However, each was also a proposal to provide a specific treatment plant, so Council determined to satisfy itself that the proposals would, indeed, provide compliance before committing itself to one or the other.

The outcome of this was that Council was left with some reservations, so towards the end of 2016 a fourth initial proposer was invited to submit a proposal. The evaluation of this proposal showed it offered similar economics to the other two, and gave Council fewer reservations about achieving compliance.

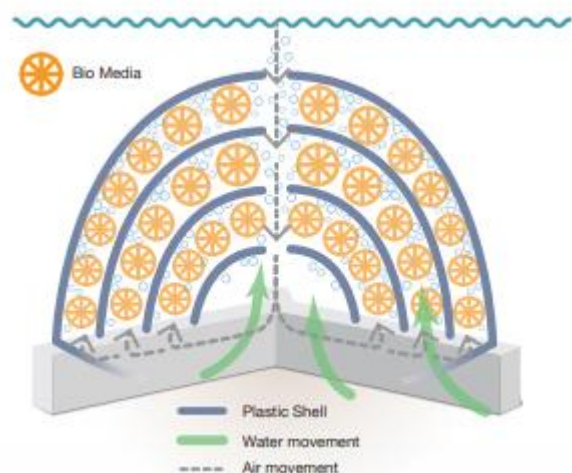
Consequently, after some refinement of the proposal through negotiation, it was accepted in early 2017.

## The Proposal

The proposal accepted was from Pall Marshall Water Consortium, a joint venture between Marshall Projects Ltd, of Invercargill, and Pall Corporation out of their Brisbane office. The proposal offered *Bio-Shell*<sup>TM</sup> *bioreactors* in the oxidation ponds, with baffles to convert the fully mixed flow to plugged flow, followed by membrane filtration of the pond effluent. The *Bio-Shell*<sup>TM</sup> *bioreactors* are intended to remove ammoniacal nitrogen, and total nitrogen, as well as BOD<sub>5</sub>. The membranes remove further BOD<sub>5</sub>, total suspended solids and E. coli.

*Bio-Shell*<sup>TM</sup> *bioreactors* are a technology new to New Zealand, a half-pipe version of *Bio-Domes*<sup>TM</sup> *bioreactors* which were developed initially at the University of Utah more than six years ago.

**Figure 1: *Bio-Dome*<sup>TM</sup> *bioreactors* Schematic Cross-section ([http://wastewater-compliance-systems.com/Documents/wcs\\_bio\\_domes .pdf](http://wastewater-compliance-systems.com/Documents/wcs_bio_domes.pdf) accessed 19 March 2018)**



A *Bio-Dome*<sup>TM</sup> *bioreactors* consists of multiple concentric plastic domes or shells, sitting on a concrete base, with the interstices between shells filled with a plastic media. The media provides a very large surface area within the shells, and the addition of air into the interstices enhances the biological activity in the pond through biofilms which form on the media. "The enhanced biology is capable of accelerating the nitrification of ammonium

and the subsequent denitrification of nitrates and nitrites.” Hence, reduction of ammoniacal and total nitrogen is claimed, together with BOD<sub>5</sub> and suspended solids (<http://wastewater-compliance-systems.com/Documents/WCS%20bio-dome%20Product%20Specification%20Sheet.pdf> and [http://wastewater-compliance-systems.com/Documents/wcs\\_bio\\_domes.pdf](http://wastewater-compliance-systems.com/Documents/wcs_bio_domes.pdf), accessed 19 March 2018).

The manufacturer’s data, based on case studies, shows a reduction of ammonia of between 0.1 and 0.33 lb/d/*Bio-Dome*<sup>™</sup> *bioreactors* as temperature increases from 0.5 to over 8°C (*Cold Weather Ammonia Removal*, [www.wastewater-compliance-systems.com](http://www.wastewater-compliance-systems.com), accessed 19 March 2018). At the temperatures experienced in South Otago, a single *Bio-Dome*<sup>™</sup> *bioreactors* could be expected to reduce ammonia by about 0.25lb/day/unit. This is a reduction in concentration of approximately 2g/m<sup>3</sup> at the average daily flow for a single *Bio-Dome*<sup>™</sup> *bioreactors* at Heriot. At the coldest temperatures experienced, the reduction would be 1 g/m<sup>3</sup> at average flow. As the *Bio-Shell*<sup>™</sup> *bioreactors* is a larger version of the *Bio-Dome*<sup>™</sup> *bioreactors*, it is expected to have a significantly better performance than a *Bio-Dome*<sup>™</sup> *bioreactors*.

The data available from installations in the United States, particularly showing performance in cold weather, gave Council confidence that the technology would provide satisfactory nutrient removal at both Heriot and Kaitangata.

The second treatment process in the offering was membrane microfiltration, offering a standard Pall Aria unit manufactured by Pall Corporation. The unit has a 0.1µm rating and is validated for greater than 4 log removal of giardia and cryptosporidium. Typical filtrate quality is claimed to be undetectable suspended solids and turbidity < 0.1 NTU.

To cater for the flows expected at Heriot and Kaitangata, the membrane plants are rated at 200m<sup>3</sup>/d and 1,100m<sup>3</sup>/d respectively. This provides a very good margin over average flows at each location. While reliance is placed on buffering in the pond for excess flows above these limits, flow records suggest that the buffering is adequate. At Kaitangata, for example, the total excess inflow to the pond over a typical 12 months would have

been 685m<sup>3</sup>, equivalent to 71mm deep over the pond. Rainfall has to be added to this, but ample storage remains.

Also included in the contract are provisions for Pall Marshall to demonstrate performance of the installation once it is commissioned. There is an initial three month period where Pall Marshall operates the plant to show compliance, and a further 21 month period where Council operates the plant under Pall Marshall’s oversight. Together these form a two year period where Pall Marshall are involved in demonstrating good plant performance.

The project also required the desludging of both ponds, common for all proposals received; the provision of a water supply; and upgrading of power supplies. Adding these brought the total capital costs of the project to \$1.14m for Heriot and \$1.71m for Kaitangata. To take account of the impact of operational and maintenance costs, a net present value for these latter costs was calculated - \$4.6m over a 25 year life. This NPV included routine attendance and maintenance, *Bio-Shell*<sup>™</sup> *bioreactors* maintenance, compressor replacement and membrane replacement on a seven year cycle. This NPV was of a similar order to the other proposals received, illustrating the improved cost effectiveness achieved for membrane plants over recent years.

## **The First Obstacle – Oil and Grease**

The warranted performance of the membranes was subject to oil and grease concentrations in the effluent not exceeding 5g/m<sup>3</sup>. When negotiating, Council’s awareness of membrane plants operating successfully at other municipal oxidation ponds in New Zealand meant that this was not identified a problematic. However, the fact that a truck wash at Heriot contributed about 25% of the average flow suggested that oil and grease levels in the Heriot effluent should be checked, so four grab samples were obtained of both Heriot and Kaitangata pond effluent.

These showed total oil and grease concentrations between 11 and 26g/m<sup>3</sup> for Heriot and 5 to 7g/m<sup>3</sup> for Kaitangata. Awareness of these results immediately followed signing of the contract for the

upgrade, and caused some disquiet. The initial assessment was that the levels at Heriot were of concern, but that Kaitangata was less troublesome, and that the Heriot levels were caused by the truck wash. While Council has no trade waste bylaw, the approval for the connection of the truck wash to the Heriot sewer, given in 2011, was conditional upon the wash discharge being of the same character as domestic sewage. Hence, on the assumption that the oil and grease concentrations in the truck wash discharge were higher than expected for domestic sewage, the truck wash operator could be expected to remove the oil and grease before discharge into Council's sewer.

Some limited research was done to identify typical levels of oil and grease in domestic sewage and the effect of oxidation pond treatment on the concentration. Very little information was found, so some local sampling was done. This revealed, for oil and grease:

- Four grab samples from the surface of the Heriot truck wash discharge showed total concentrations between 25 and 41g/m<sup>3</sup>;
- Two grab samples of purely domestic sewage showed concentrations of 35 and 61g/m<sup>3</sup>;
- Samples from 300mm below the surface had concentrations slightly higher than surface samples;
- From two grab samples from the Heriot truck wash, petroleum derived oils and greases were only 3.7% of the total; and
- Eight samples across four ponds, 32 in total, showed a range in the influent of 6 – 86g/m<sup>3</sup>, with only 3 below 10, and 5 – 33g/m<sup>3</sup>, with 9 below 10, in the effluent.

The conclusion from this sampling was that raw sewage typically has much higher than 5g/m<sup>3</sup> oils and greases and, while this is reduced through an oxidation pond, typical concentrations are still above 10g/m<sup>3</sup>. Accordingly, it is Council's responsibility to deal with oils and greases, so the treatment process must either deal with them or not be compromised by them.

However, the petroleum based oils and greases component of this is likely to be significantly less than 5g/m<sup>3</sup>. Consequently, Council is currently testing the hypothesis that oils and greases other than petroleum based product will not foul membranes. To express it differently, the membrane plant at Heriot is being operated at current oil and grease levels to see whether they compromise its performance.

It is too early to determine the results, as, at the date of writing this paper, the plant has only been operating for four weeks. However, what can be said is that, over that four weeks of low flows, fouling of the membranes by oil and grease has not been observed.

## **The Second Obstacle – Nutrients at Heriot**

The tender document included a monitoring record for pond effluent contaminants, sampled at six-monthly intervals. The record ended in 2014. This was not updated in late 2016 when Pall Marshall was invited to submit a proposal.

The truck wash at Heriot was approved in 2011, but the actual date of its connection to the sewer is not known to Council. However, there is a noticeable difference in contaminant concentrations in the oxidation pond effluent from the August 2014 sample onwards. Table 2 above shows the ammoniacal nitrogen concentration doubling and total phosphorus increasing by 36% from that date. This is likely due to the truck wash.

Results are available for four grab samples from the truck wash, three from 2014 and one from 2018, summarised in Table 3. To grasp the possible impact of these concentrations, the geomean for ammoniacal nitrogen concentrations for raw sewage in Clutha District is 26g/m<sup>3</sup>. If the truck wash comprises 25% of the total Heriot effluent flow, then it could be expected to increase this concentration in Heriot raw sewage to 46g/m<sup>3</sup>.

**Table 3: Mean Nutrient Concentrations for Heriot Truck Wash, g/m<sup>3</sup>**

Total Phosphorus	38
Ammoniacal nitrogen	107
Total nitrogen	163

The geomean of ammoniacal nitrogen concentration in oxidation pond effluent in Clutha district is 15g/m<sup>3</sup>, consistent with the Heriot result of 14g/m<sup>3</sup> prior to August 2014. This suggests a 42% removal of ammoniacal nitrogen by the ponds. Applying this to the expected truck wash-influenced concentration, the Heriot pond effluent could be expected to have a mean concentration of 27g/m<sup>3</sup>, again consistent with the post-August 2014 concentration of 29g/m<sup>3</sup>.

The new plant is being asked to deal with an influent with significantly higher nutrient concentrations than indicated by data at the time of tendering. That this is challenging to the plant as offered and constructed is evident from very early results which show ammoniacal concentrations in the post-membrane effluent in the 30s. There is clearly a problem which must be addressed.

As removal of nutrients is addressed by the *Bio-Shells™ bioreactors* and each module is designed to remove a specific quantity, this is likely to be able to be addressed by increasing the number of *Bio-Shells™ bioreactors*. More monitoring is

### Author Biography

Peter Ross has 40 years' experience in local government engineering since graduation, including technical and executive managerial roles. These have included positions in city and district councils with responsibilities which have covered all disciplines in local government engineering. He is currently a part-time Senior Projects Engineer at the Clutha District Council and spends the rest of his time in ministry at the local Anglican church, having completed a PhD in theology in 2016.

required to definitively identify the reason for the substantial increase in nutrients in the pond effluent. At the time of writing, this is beginning.

### Conclusion

The new treatment facilities at Heriot and Kaitangata oxidation ponds, consisting of *Bio-Shells™ bioreactors* in the ponds and membrane filtration following, have recently been commissioned (Heriot) or are just completing commissioning (Kaitangata). Very little data on their performance is yet available, but early results for BOD<sub>5</sub>, suspended solids and E. coli are very good at Heriot. However, nutrients are problematic at Heriot in early testing, indicating that further work is needed. This will first need to identify the reason for higher nutrient loads in the pond effluent in recent years which are outside the design parameters provided by Council for the plant. There is good reason to expect that this work, and potential subsequent plant expansion, will result in a very successful application of new technology to New Zealand.

### Acknowledgements

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### References

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accessed 19 March 2018.