QUANTITATIVE MICROBIAL RISK ASSESSMENT TO GAIN COMMUNITY ACCEPTANCE FOR WASTEWATER OUTFALLS - A CASE STUDY

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ABSTRACT

Marine wastewater outfalls are often contentious projects that can be difficult to permit.

Traditional methods of risk assessment have relied on faecal indicator bacteria as determinants of public health risks associated with wastewater discharges. However, there are shortcomings to this approach due to variable performance of wastewater treatment processes, particularly in respect of viruses.

A proposal by Marlborough District Council to relocate a discharge within Picton Harbour was supported by a Quantitative Microbial Risk Assessment. The actual health risks were discussed with stakeholders and Council was able to deliver a low cost, sustainable wastewater discharge solution.

INTRODUCTION

The township of Picton, including the nearby settlement of Waikawa Bay, is located in the Marlborough District at the head of Queen Charlotte Sound, at the northern tip of the South Island of New Zealand. The township is subject to seasonal population fluctuations with numbers peaking at approximately 6,000 over the summer months due to its attraction as a tourist destination, its proximity to the picturesque Marlborough Sounds and the presence of the interisland ferry terminal. This ferry service provides a key link with the North Island. In the early 1900s, raw sewage generated in Picton was collected in a septic tank. By 1948, population growth had resulted in increased flows such that, during wet weather, the sewage bypassed the tank directly to the nearby tidal flats. The tank was abandoned and raw sewage was discharged into the harbour via a short outfall until 1968 when, as a result of community concerns about public health effects, a new outfall at the outer edge of the harbour was commissioned (see Figure 1). The discharge of comminuted (“chopped up”) raw sewage continued until the Picton Sewage Treatment Plant was commissioned in 1999.

Today, raw sewage from mainly domestic and commercial premises is collected from within Picton and Waikawa Bay, and then transported via the sewer network to the treatment plant.
PICTON SEWAGE TREATMENT PLANT

The Picton Sewage Treatment Plant consists of inlet screening, an extended aeration activated sludge treatment process, clarification and UV disinfection. The plant currently treats a dry weather flow of 22l/s and a peak wet weather flow of 110l/s. Sludge is stabilised in two lagoons and dewatered on-site in drying beds before being stockpiled on the nearby closed landfill.

The treatment plant has performed well since commissioning with removal efficiencies for Total Suspended Solids (TSS) consistently in the 95 to 98 per cent range. As a result, the plant produces a clear, high quality wastewater which is conducive to effective UV disinfection. The transmittance of UV light through the wastewater has been measured at greater than 75%. The minimum dose of the UV disinfection system is 100mJ/cm², which was set to cope with wet weather events and is significantly greater than that required to achieve a 3 log reduction in most viruses at average flows.

Wastewater faecal indicator bacteria concentrations (Faecal Coliforms and Enterococci) are reduced through treatment and disinfection processes by 5 log (99.999%). Potentially pathogenic (disease-causing) viruses, which can be more resistant than bacteria to UV disinfection, are reduced by at least 3 log (99.9%).

Table 1 summarises the results of wastewater monitoring for TSS and faecal indicator bacteria in 2012/13.
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Reported as</th>
<th>Statistical basis</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>TSS</td>
<td>g/m³</td>
<td>Annual median</td>
<td>8</td>
</tr>
<tr>
<td>Faecal coliforms</td>
<td>Number/100mls</td>
<td>Annual geometric mean</td>
<td>72</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Annual 90th percentile</td>
<td>1010</td>
</tr>
<tr>
<td>Enterococci</td>
<td>Number/100mls</td>
<td>Annual geometric mean</td>
<td>26</td>
</tr>
</tbody>
</table>

RATIONALE FOR REPLACING THE OUTER HARBOUR OUTFALL

The final portion of the 300 mm diameter pipeline from the treatment plant was laid above ground on a narrow rocky platform on concrete pedestal supports. Pipe material was mainly Asbestos Cement (AC), which was failing due to corrosion and damage from falling rocks. As a result, Council had replaced a number of sections of the AC pipeline with PVC pipe.

The above-ground portion of the pipeline was generally considered to be an “eyesore” and incompatible with the role of Picton as the “tourist gateway to the south”. The harbour area is popular for water recreation, and is on the inter-island ferry route.

As a consequence, there was a need to upgrade the outfall as a matter of priority. In addition, an upgraded outfall was required to cater for increased flows from the upgrading of the Picton/Waikawa sewerage system. This upgrading (which is programmed for completion in 2019) is necessary to reduce wet weather overflows and cater for future population growth.

The outer harbour outfall was constructed prior the commissioning of the treatment plant in 1999 to maximise the distance between harbour recreational users and the discharge (thereby minimising public health risk). The high quality wastewater produced by the treatment plant provided Council with the opportunity to offer the community potential cost savings by replacing the long above-ground, visually obtrusive pipeline with a shorter, non-visible outfall while still protecting public health and the harbour environment.

Limited opportunities for summer reuse of some of the treated wastewater for irrigation of parks and playing fields were also recognised.

COMMUNITY CONSULTATION STRATEGY

The Resource Management Act, 1991 is the primary legislation concerned with maintaining and enhancing environment quality and (amongst other things) provides the basis for obtaining consents and permits to discharge contaminants to receiving waters. While consultation with the community is not a statutory requirement, the implementation of a robust and meaningful consultation process during the consenting phases of a project have been shown to significantly improve the outcomes for the applicant.

Marlborough District Council favours the Consultative Working Group (CWG) approach to obtaining key stakeholder views on proposed infrastructure projects within the district. Membership of the CWG was broad and included representation from Maori, Department of Conservation, District Health Board, environmental groups, a residents’ association and local business groups. The CWG met on a number of occasions through the project to consider wastewater disposal options, technical studies and ultimately make recommendations to Council.

In addition, Council also met independently with other key stakeholders throughout the project. Newspaper articles, together with community information updates were provided to local ratepayers. Further details on the proposal were made available from Council’s Picton Service Centre, and also placed on the Council website.

These communications proved invaluable during the decision-making and consenting processes.
OUTFALL DISCHARGE SITE OPTIONS

Three outfall site options were identified (see Figure 2) including:

- **Option A** - New 1,100 metre submarine pipeline to the existing outer harbour outfall site
- **Option B** - New 500 metre submarine pipeline to a new outfall midway between the outer and the mid-harbour sites
- **Option C** - New 150 metre submarine pipeline to a new outfall in mid-Picton Harbour

The installation of a new above-ground plastic or concrete pipeline to the existing outfall site was not supported by the community because of adverse visual effects. The difficulty in constructing a new pipeline on the beach platform, while the existing pipeline remained operational, was also recognised by Council.

![Figure 2: Harbour outfall options and identified contact recreation/shellfish gathering sites](image)

PUBLIC HEALTH EFFECTS

Basis for Health Risk Assessment

A key issue for Council was to assure the local community and other users of the Picton Harbour waters, that discharging treated wastewater at any of the short-listed outfall sites would not result in significant public health risks. In New Zealand, the Ministries for Environment and Health (2003) provide guidance on the suitability of receiving waters for contact recreation and consumption of raw shellfish in marine and freshwaters. These guidelines utilise “alert” and “action” concentrations of faecal indicator bacteria. However, the guidelines are based on epidemiological studies in waters more remote from point source discharges. For cases where discharges are near to recreational activities, the guidelines encourage a direct assessment of health risks.

The 2003 document notes that these “guidelines should not be directly applied to assess the microbiological quality of water that is impacted by a nearby point source discharge of treated effluent without first confirming they are appropriate... While it is correct to infer that water exceeding the guideline values poses an unacceptable health risk, the converse is not necessarily true. This is because effluent may be treated to a level where the indicator bacteria concentrations are very low,
but pathogens such as viruses and protozoa may still be present at substantial concentrations”. In other words, even though the receiving water quality as assessed by bacterial indicators meets the guidelines, the water may still not be safe for contact recreation or raw shellfish consumption due to the presence of viral pathogens in the wastewater that are not accounted for by the guidelines.

Furthermore, the 2003 guidelines would not apply if there was a major outbreak of an infectious disease caused by rotovirus or norovirus because in such situations, the usual relationships between indicator bacteria and health risk do not apply.

For these reasons, Quantitative Microbial Risk Assessment (QMRA) is being increasingly adopted in New Zealand as a means of quantifying and comparing human health risks arising from the discharge of treated wastewater to waters that are used for recreational or shellfish gathering purposes (eg McBride, 2007, Palliser and McBride, 2009, McBride, 2014). The QMRA assessment considers the increased risks of infection from accidental ingestion or inhalation of viruses during swimming, or from eating raw shellfish at identified sites in the vicinity of the discharge. “Background” contamination from other sources, such as stormwater flows or onsite domestic sewage discharges, are not taken into account in the QMRA process.

QMRA assesses the risk of human exposure to a representative pathogen or model “virus”. Well-developed dose-response data is available for pathogens such as rotavirus and norovirus. The procedure uses a “Monte Carlo” quantitative statistical modelling technique to calculate risk profiles for each exposure scenario identified within the receiving water. The approach uses variable inputs including viral concentrations in the discharge, wastewater dilution, dispersion and die-off data, swim contact time and shellfish meal size. Exposure sites are identified, preferably in close consultation with the community. A random sample is “taken” from each of 100 people on 1000 separate “visits”. For each of these 100,000 simulated “events” a random sample is taken (as for the roll of a dice-hence the term “Monte Carlo”) and the risk of virus exposure profile calculated. This risk profile represents a percentage of the time that a given number of infections may occur at an exposure site. This profile is presented as the Individual Infection Risk (IIR) which is calculated by the number of cases divided by the number of exposures.

The World Health Organisation has made recommendations (WHO, 2003) which set a cut-off for beaches maintaining a “very good” grading as an IIR of less than 1% for gastrointestinal illness and less than 0.3% for Acute Febrile Respiratory Disease (generic term for respiratory diseases such as pneumonia. Adopting these guidelines would mean that for contact recreation, an IIR of less than 0.3% would need to be met and for consumption of raw shellfish, the threshold would be less than 1%.

Figure 3 shows the QMRA process.
Results of QMRA Assessment for Harbour Outfall Options

A QMRA was carried out for the three harbour outfall options by the National Institute of Water and Atmosphere (or NIWA), (Palliser and McBride, 2009) – NIWA being a recognised specialist in the field in New Zealand. Rotavirus, which can cause gastroenteritis in humans, was used as the "model" for all pathogenic organisms that may be present at times in Picton’s wastewater. This represents a conservative approach as rotavirus is relatively resistant to UV treatment and survives well in the marine receiving environment.

The potential impacts of the three outfall discharge sites were assessed for the eight contact recreation and shellfish gathering sites identified in consultation with the regional public health authority as well as the local community.

The summary of results (see Table 2) showed a risk profile (IIR) for recognised bathing and shellfish gathering sites in the harbour compared to WHO (2003) guidelines. From the results in Table 2, it can be seen that under “normal” virus concentrations in the raw wastewater (i.e. non epidemic) the risk from any of the three outfall sites was negligible at all harbour contact recreational sites (“exposure” sites). For example, the mid-harbour preferred site only exceeded the IIR for contact recreation in 1 in 1887 exposure “events” on the western shoreline which is not easily accessible and where little recreation occurs. There were only two threshold exceedances for shellfish gathering at the mid-

<table>
<thead>
<tr>
<th>Outfall site</th>
<th>Number of times WHO thresholds exceeded</th>
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<tbody>
<tr>
<td></td>
<td>Contact recreation (IRR &lt; 0.3%)</td>
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<tr>
<td>Option A - outer harbour</td>
<td>0</td>
</tr>
<tr>
<td>Option B - midway outer and mid-harbour</td>
<td>1</td>
</tr>
<tr>
<td>Option C – mid-harbour</td>
<td>0</td>
</tr>
</tbody>
</table>

ECOLOGICAL STUDIES

Another key issue for stakeholders was the potential ecological impacts of the proposed discharge. The Cawthron Institute (2008) carried out baseline studies and concluded that the mid-

Table 2 - Exceedances of WHO contact recreation and shellfish gathering thresholds for harbour outfall options under normal virus concentrations

harbour site had the lowest ecological values of the three outfall sites. Modelling predicted dilutions at average discharge flows of greater than 230:1. Cawthron (2010) was able to conclude that a high quality mid-harbour...
discharge would have a less than minor effect on benthic ecology, fish and marine mammals.

**PREFERRED OUTFALL LOCATION**

After completion of technical work and consultation, the Council agreed that the preferred disposal option would be via a new mid-harbour submerged outfall.

The rationale for selection of this site (CH2MBeca, 2009) is summarised as:

- A high quality clear wastewater would be discharged through a well-designed deep water outfall
- The discharge would not cause water to be unsafe for usual harbour activities
- Neither swimming nor shellfish gathering are usual activities in this part of the harbour
- The discharge would have no significant effects on marine organisms
- A short (150 metre long) submarine outfall would have significant cost savings for the community over other alternatives

Because the wastewater is well-treated, the significant separation distance to the Picton Foreshore that was required when untreated sewage was discharged, is now no longer necessary.

A key part of the upgrade would also be the removal of the highly visual above-water pipeline to the outer harbour site.

While the discharge of human wastewater to natural waters is culturally unacceptable to Maori, the mid-harbour option was not opposed because of the high wastewater quality and the low risks of the proposal that could be demonstrated.

**SUCCESSFUL OUTCOMES**

The robust technical studies and consenting strategy resulted in a smooth consenting process. The New Zealand consenting process provides for the public notification (28 working days) of consent applications and public hearings with the right of appeal to the Environment Court, if desired.

There were only two submitters who wished to be heard on the Picton outfall project (local Maori interests and one member of the public). There were no institutional submitters and no appeals were lodged. A 35 year consent term (i.e. the longest term available under New Zealand statute) was subsequently granted to Council with monitoring conditions appropriate to the scale and effects of the outfall discharge. Because of the high quality of the treated wastewater, there is a strong emphasis on maintaining treatment plant performance and monitoring of the discharge. Environmental monitoring is kept to an appropriate minimum, yearly outfall inspections and a one-off confirmation of the performance of the diffuser.

The outfall pipeline and diffuser work was completed in December 2012 without significant disruption to harbour users at a cost of $3.7M. This represents a “win-win” for Council and the community with substantial cost savings without compromising the public health or environmental values of the harbour. Indeed, the removal of the above-ground pipeline and the outer harbour outfall and diffuser provides an additional environmental and recreational benefit to harbour users.

No effects from the discharge have been observed within or outside the mixing zone specified by the consent. A dye release study by Cawthron has subsequently confirmed that the outfall diffuser is operating according to design requirements.

**CONCLUSIONS**

The successful outcome of the Picton treated wastewater outfall project reinforces the following conclusions:

- While initial public perception may be adverse when dealing with potentially contentious projects such as outfalls, this can be altered with good technical information and appropriate and meaningful consultation.
- Robust, technically defensible information that addresses the key issues and is delivered to stakeholders, as far as possible, in simple terms is an essential part of the consenting process.
- The QMRA process provides a better assessment of the likely public health risks, associated with the presence of viral pathogens in a wastewater discharge, than guidelines that rely on the presence of bacterial indicator organisms.
- A willingness to consult in a meaningful way throughout the project with representative community and institutional groups, as well as
the wider public, is the key to good decision-making for outfall projects.

- A successful QMRA process requires stakeholder inputs at key stages, particularly when confirming the uses and likely exposure sites within the receiving water.

REFERENCES

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