SEWAGE RETICULATION – WHAT OPTION IS BEST FOR YOU?

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ABSTRACT

Recently, Pattle Delamore Partners Ltd (PDP) was engaged by several District Councils to investigate sewage reticulation options for communities of various sizes with different cultural / environmental interests. The different reticulation options considered include conventional gravity reticulation, pressure sewer reticulation (including grinder pump systems and septic tank effluent pressure (STEP) systems) and vacuum sewer reticulation.

This paper discusses a number of projects and the site-specific challenges associated with each project when investigating and developing a reticulation scheme, from conceptual to the detailed design phase. In some cases, a preliminary design of a reticulation scheme had already been completed however various issues and challenges were encountered during further detailed site investigations that made the scheme no longer feasible / practical. In general, some key issues that needed to be addressed included:

- Cultural issues – E.g. public concerns on the transfer of raw sewage from one catchment to another.
- Physical constraints – E.g. high groundwater levels which would lead to increased construction costs, as well as increased operating costs associated with ongoing infiltration / inflow for gravity sewerage.
- Costs and affordability – E.g. comparing capital, operating and life-cycle costs between options on a "like-for-like" basis.

In addition, careful consideration was required as to the effects on the downstream wastewater treatment plant. In some situations, an advantage of a STEP system over a grinder pump system was that onsite pre-treatment could potentially reduce the capital and operating costs associated with providing further treatment at the downstream treatment plant. However, in other situations, a grinder pump system had the benefit of retaining the biologically available carbon in the raw wastewater, potentially avoiding the need for additional chemical dosing at the treatment plant in order to provide supplementary carbon for nitrogen removal.

Each project assessed the options available and resulted in a different reticulation outcome. This paper discusses the site-specific factors that influenced each preferred option. It also presents a multi-criteria decision matrix that was developed to allow for an evaluation of the reticulation options on a holistic basis and to enable the right selection of a reticulation option at an early stage in the project timeline.

KEYWORDS

Wastewater, Reticulation, Pressure Sewer

PRESENTER PROFILE

Diana is an environmental engineer at Pattle Delamore Partners Ltd and has 3 years of experience in the wastewater engineering discipline. Diana has been involved in a variety of projects including detailed design of wastewater reticulation, process design of wastewater treatment plants and the assessment of environmental effects of land treatment of wastewater.

1 INTRODUCTION

Recently, Pattle Delamore Partners Ltd (PDP) was engaged by several District Councils to investigate sewage reticulation options for communities of various sizes. This paper discusses a number of projects undertaken by PDP and the site-specific challenges that were encountered with each project when investigating and developing a reticulation scheme, from conceptual to the detailed design phase. To summarise the overall learnings from each project, a multi-criteria analysis has been developed to allow for an evaluation of the reticulation options on a holistic basis.

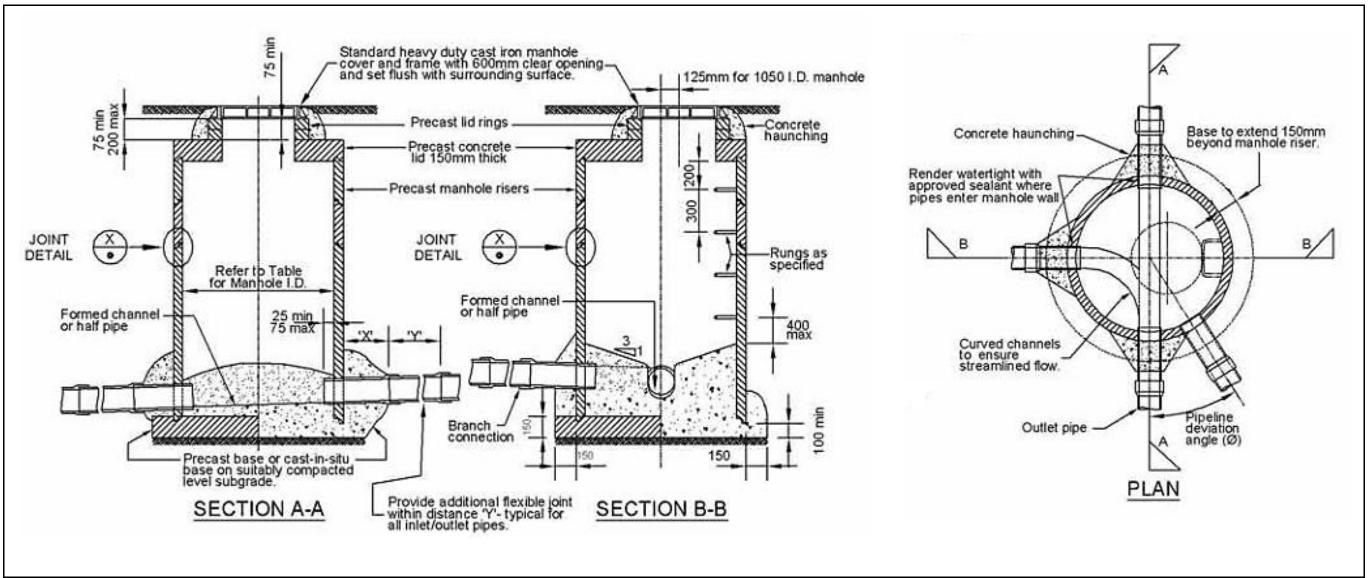
2 DESCRIPTION OF RETICULATION SYSTEMS

2.1 CONVENTIONAL GRAVITY SYSTEMS

Conventional gravity reticulation is by far the most common method of sewage reticulation in New Zealand. Conventional gravity systems typically consist of PVC pipes and concrete manholes to change alignment, gradient or pipe size.

Conventional gravity systems are simple and often reliable, and the design standards are usually well documented in the Engineering Code of Practice of District Councils (as shown in Figure 1 below). Gravity systems are also well understood by Council operating staff and have low operations and maintenance costs.

Figure 1: Standard Sewer Manhole Drawing (Issue 7.0, September 2007) from the Engineering Code of Practice, Whakatane District Council



However, conventional gravity systems are prone to stormwater inflow and groundwater infiltration problems which can lead to wastewater overflows, and in severe situations can create environmental / public health risks. As pipes often have to be laid at great depth to achieve adequate fall, conventional gravity systems are also difficult / expensive to construct in ground with high groundwater levels.

2.2 ENHANCED GRAVITY SYSTEMS

Enhanced gravity systems are similar to conventional gravity systems, except that the pipes are laid at a steeper grade and at a shallower depth. Enhanced gravity reticulation typically consists of gravity pipes at depths no greater than 3 metres and lateral connections from properties at depths no greater than 2.5 metres. This result in a greater number of pump stations required to service an area compared to conventional gravity reticulation.

2.3 PRESSURE SEWER SYSTEMS

Pressure sewer reticulation involves installing a pump chamber within the private property. A short length of gravity lateral is laid from the building to the pump chamber. The wastewater collected in the chamber is pumped into a reticulation network consisting of small diameter, shallow, polyethylene pressure pipes.

As the pipes are under pressure, the reticulation network can be laid to ground contours, not to grade and at shallower depths. Therefore, pressure sewer systems are well suited to areas of high groundwater table, and areas that are flat, steep, or rocky. However, pressure sewer systems require significantly more landowner consultation than the gravity options as pump chambers are required to be installed in each private property. Pressure sewer systems typically have higher annualised operating and maintenance costs than gravity systems due to the requirement for periodic replacement of mechanical components.

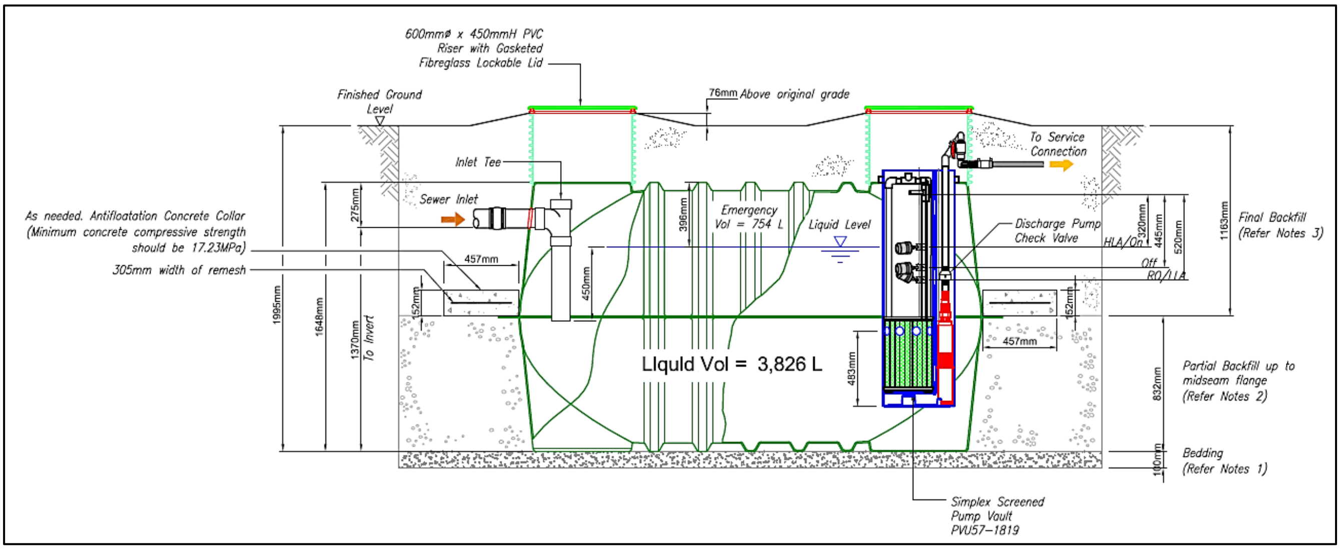
The two main types of on-property systems that are typically used for pressure sewer reticulation are grinder pump systems and septic tank effluent pump (STEP) systems. These systems are discussed in more detail in the sections below.

2.3.1 SEPTIC TANK EFFLUENT PUMP (STEP) SYSTEMS

As the name implies, a STEP system consists of a septic tank (polyethylene or fibreglass) fitted with a small pump assembly to pump only effluent through the sewer system. Solids are retained in the septic tank, decompose over time and removed periodically by a vacuum loader truck. The effluent pumps are typically multistage centrifugal pumps (similar to a bore water supply pump).

Large septic tanks (typically between 4 m^3 and 6 m^3) are required to be installed on each property, and therefore sufficient space, access and suitable ground conditions need to be available. A typical STEP system detail is shown in Figure 2 below.

Figure 2: Typical STEP Tank Detail from Innoflow Technologies Ltd

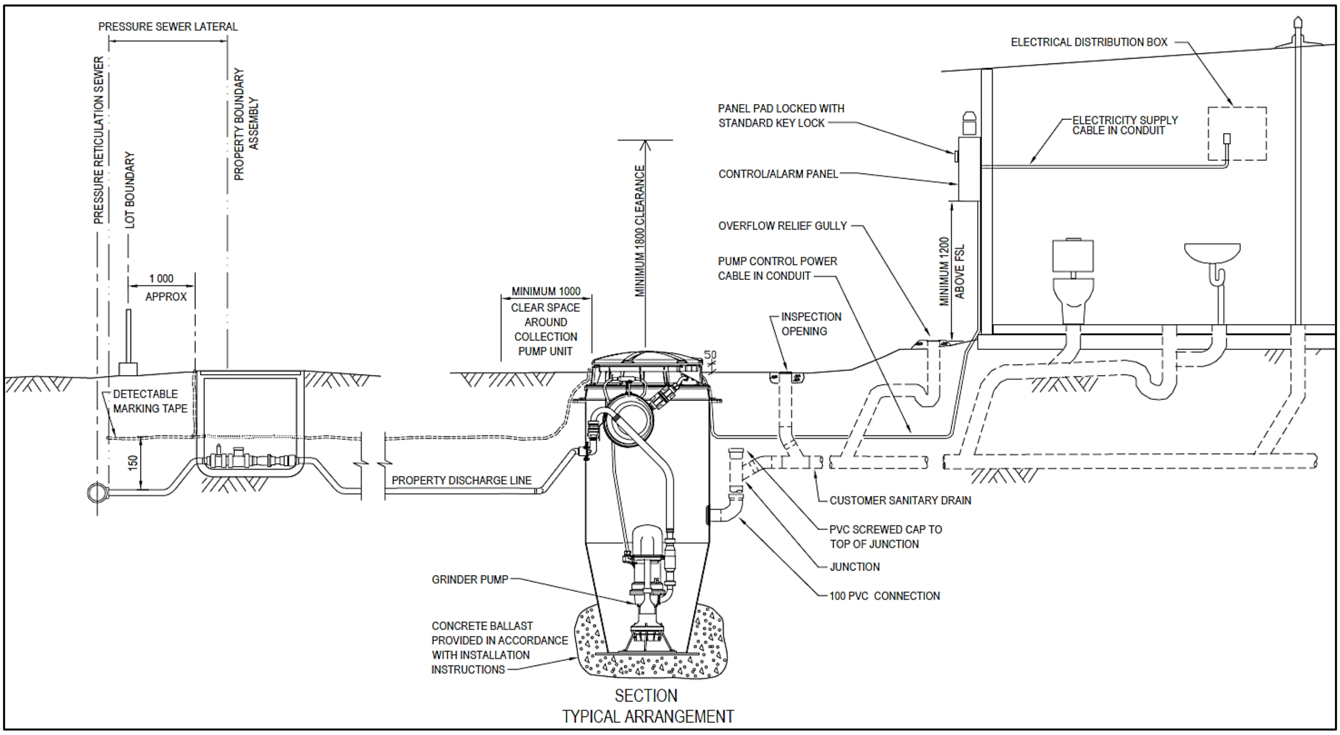


Audible and visual alarms are provided to alert the property owners of system faults so that they can contact the relevant operations and maintenance personnel. The power required to operate the effluent discharge pump is sourced from the power supply of each property.

2.3.2 GRINDER PUMP SYSTEMS

A grinder pump system typically consists of a polyethylene or fibreglass chamber into which a single electric grinder pump is installed. The grinder pump is a semi-positive displacement pump capable of pumping ~0.5 litres per second at 40 metres head. The grinder pump grinds the household waste into liquid slurry and therefore only requires a small outlet pipe (typically 40 mm OD) from the chamber to the reticulation sewer main. The typical on-property layout is shown in Figure 3 below.

Figure 3: On-property Layout Typical Arrangement and Sanitary Drainage Details from the Pressure Sewerage Code of Australia, Water Services Association of Australia



The pump chamber is usually sized to provide storage of one day's flow for a typical household. This prevents the risk of wastewater overflow in the event of a power failure. Grinder pump systems also require a power supply connection to the property. Audible and visual alarms are also provided to property owners to detect system faults.

The dimensions of the pump chamber will depend on the property size and occupancy. For example, an E/One Simplex chamber houses one grinder pump and is 800 mm in diameter and 2,000 mm in height, with a total capacity of 650 litres. An E/One Duplex chamber houses two grinder pumps and is 1,100 mm in diameter and 2,000 mm in height, with a total capacity of 1,300 litres.

3 PROJECT 1: PARTIALLY DEVELOPED INDUSTRIAL ZONE

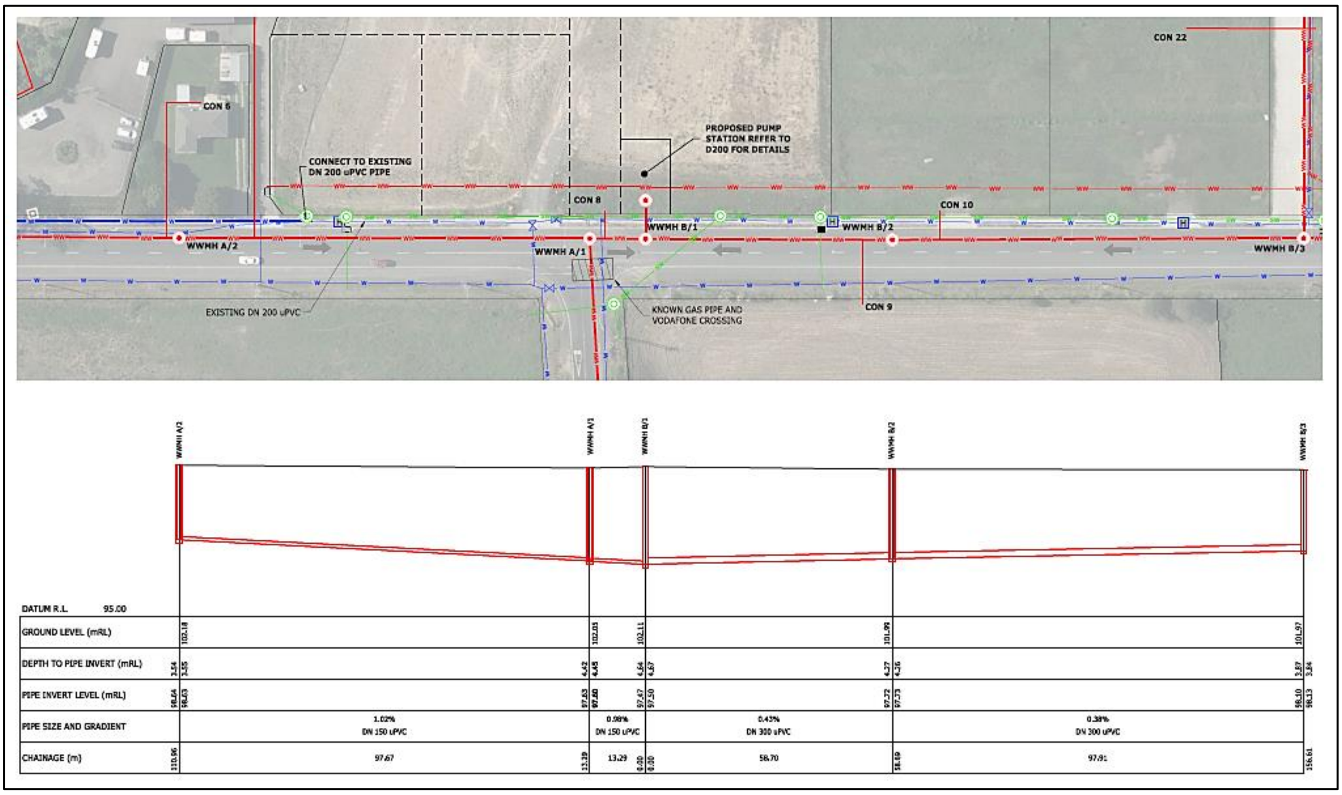
3.1 BACKGROUND

PDP was engaged by a District Council in 2016 to carry out the detailed design of a new reticulation system for a partially developed industrial zone in the Bay of Plenty. Prior to PDP's engagement, the preliminary design of a conventional gravity reticulation system for the site had been undertaken by another consultant.

PDP carried out field investigations and progressed some of the detailed design of the conventional gravity system. During detailed design, gravity reticulation was deemed unfeasible for the site as PDP discovered the following:

- Gas main crossings were required in at least 3 locations. This required the gravity reticulation pipes to be laid at considerable depth along most of the alignment (greater than 3 m) to achieve adequate clearance.
- Geotechnical investigations identified groundwater levels at approximately 2 metres below ground level across the majority of the site. The gravity reticulation pipes would have to be laid below groundwater along most of its length, which could lead to ongoing stormwater inflow and groundwater infiltration problems.
- Geotechnical investigations also identified sandy soils along the preliminary pipeline route. It was likely that well-point dewatering would be required during construction which would add significant costs.

Figure 4: A section of the preliminary reticulation layout, with the greatest depth to pipe invert at 4.67 metres to achieve adequate clearance to an existing gas main



3.2 RETICULATION OPTIONS CONSIDERED

To reduce some of the risks and associated costs of the conventional gravity reticulation system, PDP considered the use of an enhanced gravity system and a pressure sewer system (with grinder pump chambers) at the site.

1) <u>Enhanced Gravity</u>

PDP briefly considered an enhanced gravity system for the site. This would consist of shallower gravity reticulation (less than 3 metres deep) which would reduce some of the risks associated with dewatering. However the overall capital cost for the enhanced gravity system was estimated to be higher than the conventional gravity system due to the requirement of additional pump stations and therefore this option was not taken further.

2) Pressure Sewer System

A pressure sewer system for the site was considered after identifying the following advantages over a conventional gravity system:

- The potential for lower upfront capital costs, given the low level of present development. Grinder pump chambers would only be installed on vacant properties once they are occupied.

- Reticulation pipes will be shallower and pressurised, so they can be laid more easily around existing services, without the need to maintain a minimum grade. This was a big advantage for this site given the number of existing services, which included gas transmission and reticulation, stormwater, water supply, power supply, Chorus and Vodafone cables.

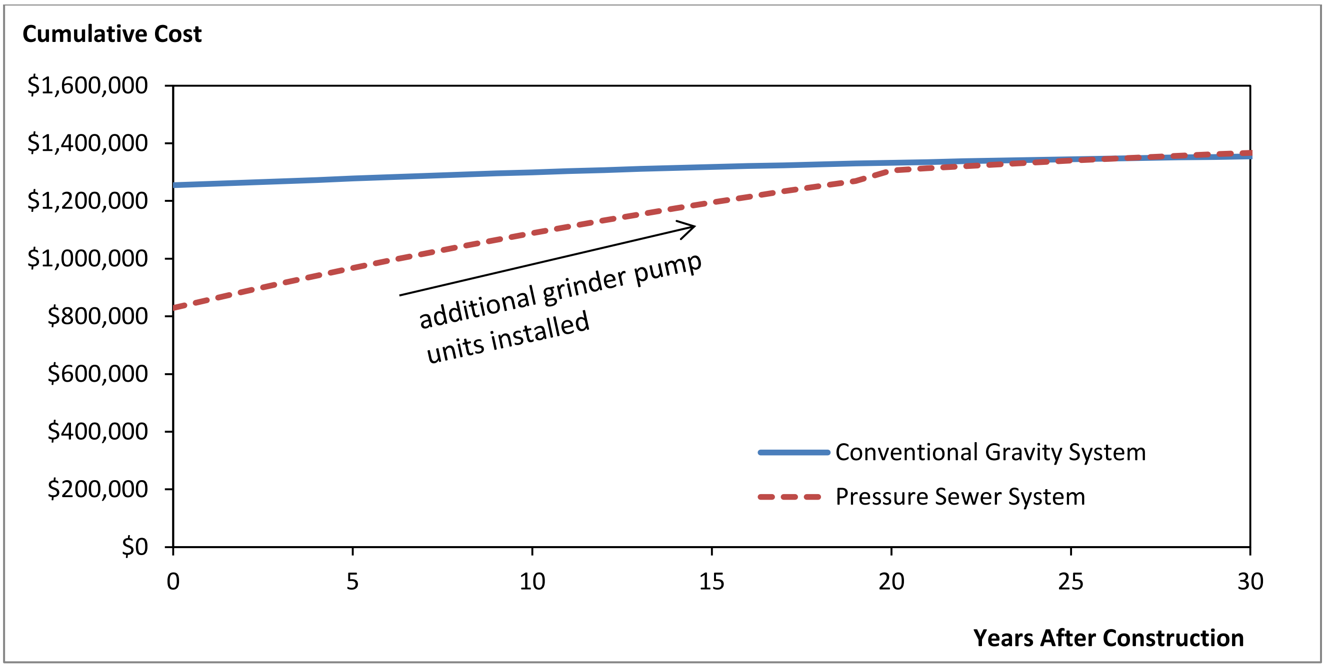
- Less opportunity for stormwater inflow and groundwater infiltration as the reticulation pipes would generally be above the groundwater table.

3.2.1 COST ESTIMATES

As part of the options assessment and for preliminary costing purposes, PDP carried out a conceptual design of a pressure sewer scheme for the site. The costing assumed that the existing 20 lots will have grinder pump stations installed at the outset of commissioning, with a total of 50 lots to be ultimately serviced by the scheme. Head losses and pipe velocities were checked for both present and ultimate development scenarios.

Comparison of cumulative costs for the gravity option and the pressure sewer option for the site is shown in Figure 5 below.

Figure 5: Comparison of ongoing costs for each option



Although the gravity reticulation option was assessed to have lower operational costs, the pressure sewer scheme remained considerably cheaper over the life of the scheme due to the ability to service only the occupied lots at the outset of commissioning. Eventually, a pressure sewer system was carried forward to detailed design due to cost implications and to minimise construction risks.

4 PROJECT 2: 60-LOT RESIDENTIAL COMMUNITY

4.1 BACKGROUND

A small coastal community in the Bay of Plenty comprises of around 60 residential properties. Presently, wastewater from these properties is treated and disposed via on-site septic tanks and soakage disposal fields. Water quality monitoring undertaken in the receiving environment has detected *Escherichia coli* (*E. coli*) at levels exceeding national guidelines. The *E. coli* contamination has been linked to failure of septic tanks and disposal systems as a result of increase in household water use and wastewater production.

As a consequence, the local District Council is proposing a new wastewater reticulation system and a proprietary wastewater treatment plant for the community. Half of the properties are located on low-lying, flat land on the harbour waterfront and therefore the option of gravity reticulation was deemed to be unfeasible.

4.2 STEP VS GRINDER PUMP

PDP was engaged by the local District Council in 2017 to provide professional services to assist in the development and construction of the new wastewater scheme for the 60-lot community. During the initial stage of the engagement, PDP carried out preliminary costing of the STEP system and grinder pump system for the community. Both systems would convey wastewater to a proprietary WWTP with discharge to a land treatment system. The findings were as follows:

1) <u>On-property Works</u>

- The STEP system was assessed as having higher costs associated with on-property civil works. The on-property units are bigger for the STEP system (4 m^3 STEP tank unit compared to 1 m^3 grinder pump chamber) therefore greater excavation and reinstatement is required at each property. The 4 m^3 STEP unit also has a higher unit price than a 1 m^3 grinder pump chamber.

2) <u>Wastewater Treatment Plant</u>

- Cost of the WWTP for both STEP and grinder pump systems were assessed based on a proprietary WWTP system and a sub-surface drip irrigation system. At the time of the assessment, costs associated with chemical dosing for nitrogen removal was not included as land treatment would provide further nitrogen removal.

- The WWTP capital cost for the grinder pump system was assessed to be higher than for the STEP system due to the extra infrastructure required at the WWTP for primary treatment of the grinder pump effluent.

- The STEP system would require periodic desludging of the on-property tanks. However for the grinder pump system, there would be a requirement for additional sludge management associated with the primary treatment required at the WWTP. Overall, both systems were assessed to have similar annual operating costs.

Overall, both STEP and grinder pump systems were assessed to require similar upfront capital costs and similar annual operating costs.

5 PROJECT 3: 250-LOT RESIDENTIAL COMMUNITY

5.1 BACKGROUND

A lakeside community in the Bay of Plenty comprises of around 250 residential properties. Failures of on-site wastewater treatment and disposal systems as a result of seasonal overload and high groundwater tables posed environmental and public health risks to the receiving environment.

The implementation of a reticulated sewage scheme in these communities is one of the measures being put in place to minimise impacts on the receiving environment. The community is characterised by difficult topography and high groundwater levels. A conventional gravity reticulation system would likely result in high construction costs due to the extensive utilisation of dewatering equipment.

A pressure sewer reticulation system to an activated sludge based, biological nutrient removal (BNR) WWTP has been proposed for the community. The proposed disposal system is a rapid infiltration system and therefore the treated effluent is required to meet stringent nutrient limits as no further treatment would be provided by land.

5.2 STEP VS GRINDER PUMP

PDP was engaged by the local District Council in 2017 to carry out a high level assessment on the rough order cost comparison between a grinder pump system and a STEP system for the 250-lot community.

The findings were as follows:

1) <u>On-property Works</u>

- Similar to Project 2 discussed previously, the STEP system was assessed as having a higher capital cost associated with on-property works.

2) <u>Wastewater Treatment Plant</u>

- As discussed previously, a BNR based WWTP is proposed for the community, with treated effluent discharge to a rapid infiltration system and therefore the effluent quality is required to meet stringent nutrient limits as no further treatment would be provided by land.

- For a grinder pump system, the WWTP will receive raw wastewater with the biological carbon retained. For a STEP system, the WWTP will receive wastewater that has undergone partial primary treatment within the STEP tanks. Therefore for a STEP system, additional chemical dosing will be required at the WWTP to provide supplementary carbon for sufficient nitrogen removal, resulting in additional operational costs compared to a grinder pump system.

6 MULTI CRITERIA ANALYSIS (MCA)

A multi-criteria analysis (MCA) could be used to evaluate reticulation options on a holistic basis. The MCA method uses a set of criteria and then each option is scored against the criteria. This assessment is subjective as the criteria that are used to score against as well as the scores which are assigned are open to personal interpretation (and therefore could be open to debate). Nonetheless, a MCA provides a means of obtaining a ranking for each option which gives an indication of its viability.

For each criterion, each option is scored against the other using a scoring system whereby the lowest score ('0') is the least favourable and 5 is the most favourable.

Note that the set of criteria considered, and the associated weighting for each criteria, should be specific to each project. Criteria should be added, deleted, or amended as necessary. The assessment criteria could include but not be limited to:

- **Constructability** – Have the groundwater levels, structural nature of soils, and the topography of the site been considered?
- **Operational complexity** – Is the reticulation system well understood by Council operating staff?
- **Operational resilience** – Would the reticulation system suffer significant damage in an earthquake and require costly repairs?
- **Capital, operational and life cycle cost** – Can the installation be staged? What would be the ownership model proposed? Who would be responsible for the on-going operation and maintenance costs associated with the on-property units? What are the operational cost implications on the downstream WWTP receiving the wastewater, e.g. is there a requirement for additional chemical dosing?
- **Cultural impact** – Is the reticulation system supported by the community (ratepayers)? Is the reticulation system supported by local Iwi? The transport of raw sewage across another catchment is considered to be offensive by some cultural groups.
- **Overall risk** – Risks associated with each option should be assessed. All types of risks should be considered, i.e. from the design phase to construction and operations phase. If significant dewatering is required during construction, this can result in delays and additional costs. If the reticulation system is prone to inflow and infiltration, this may result in an ongoing operational risk.

To report the results of the MCA, the assessment criteria and analysis for each option could be summarised into a table, as shown in Table 1 below. Note that the overall cost estimated for the project is often given a high weighting (which could potentially lead to skewed results). A recommended approach is to repeat the MCA after excluding the overall cost from the assessment criteria and to carefully consider / compare the results.

Table 1: Multi Criteria Analysis

Assessment Criteria	**Weighting**	**Reticulation Option 1**	**Reticulation Option 2**
Overall risk	*1 to 100%*	*1 to 5*	*1 to 5*
Constructability	*1 to 100%*	*1 to 5*	*1 to 5*
Operational complexity	*1 to 100%*	*1 to 5*	*1 to 5*
Operational resilience	*1 to 100%*	*1 to 5*	*1 to 5*
Overall cost	*1 to 100%*	*1 to 5*	*1 to 5*
Cultural impact	*1 to 100%*	*1 to 5*	*1 to 5*
Total Score *(highest score is the most favourable option)*		**1 to 5**	**1 to 5**

7 CONCLUSIONS

Presently, there are numerous wastewater reticulation technologies available with varying costs and benefits. When selecting a reticulation scheme for a site, consideration should be taken on the cultural issues, physical constraints, costs and affordability. A multi-criteria analysis can be used to assess different reticulation options against a site-specific set of criteria.

Capital, operational and life cycle costs should be carefully considered. PDP's experience has shown that for a partially developed zone, gravity reticulation option may have lower operational costs than a pressure sewer system, however a pressure sewer system could remain cheaper over the life of the scheme due to the ability to service only the occupied lots at the outset of commissioning.

Careful consideration is required as to the effects on the downstream wastewater treatment plant. In some situations, a STEP system may provide an advantage over a grinder pump system as it can potentially reduce the capital and operational costs associated with providing further treatment at the downstream treatment plant. However, in other situations, a grinder pump system may have the benefit of retaining the biologically available carbon in the raw wastewater so that the need for additional chemical dosing (for further nutrient removal) at the treatment plant is avoided.

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