ANALYSIS OF THE PERFORMANCE AND EFFICIENCY OF PRESSURE WASTEWATER COLLECTION SYSTEMS IN NEW ZEALAND

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ABSTRACT

Pressure sewer systems are being installed throughout New Zealand with the first significant networks commissioned in June 2008 in Rotorua and Rodney. This paper analyses flow, pressure and rainfall data collected from Rodney District Council's Point Wells pressure sewer network and provides a quantifiable review of pressure sewer design assumptions and operation. This system consists of approximately 7.5km of pressure sewers and will eventually service 510 dwellings. As of 28 June 2009 the network included 161 grinder pump units servicing 66% of the existing community.

The preliminary results from system performance monitoring on this pressure sewer system confirm that both the design and operational performance of the system is similar to historical experience in the USA and Australia. There is a strong correlation that the system does experience wet weather inflow, however Rodney District Council has identified the sources of inflow by tracking pump run hours. Therefore, while a wet weather peaking factor of approximately 1.2 is currently experienced, Rodney District Council have quickly identified the sources and are in the process of eliminating the inflow.

When compared to the costs related to installing an equivalent gravity sewer system, the pressure sewer system is considerably cheaper over the life of the system. Also, as wet weather flows can be identified and eliminated, the cost of treating wet weather flow volumes is considerably reduced. This study shows that the pressure sewer system has resulted in reliable and cost effective solution for the community of Point Wells

KEYWORDS

Low pressure sewer, pressure wastewater collection, wastewater collection systems, flow analysis, flow monitoring

1 INTRODUCTION

Pressure sewer systems are being installed throughout New Zealand with the first significant networks commissioned in June 2008 in Rotorua and Rodney. These systems have an established reputation, particularly in the USA and Australia, where pressure sewer systems have been used for over 40-years. This experience has shown they have the potential to reduce capital cost, eliminate wet weather flow, reduce energy consumption and maintenance costs. In New Zealand the hydraulic design of pressure wastewater collection systems has been based on the performance of systems in the USA. Principally the Albany Study (Carcich, I G., et al, 1972) which developed the probability method as the default pressure sewer design methodology.

Due to the small number of significant installations in New Zealand there has been no quantifiable data available to confirm if the probability method is applicable to the New Zealand context. This paper has therefore analysed flow and pressure data collected from the Point Wells pressure sewer network to provide quantifiable review of pressure sewer design assumptions.

2 SCOPE

The data collected from the Point Wells network has been analysed to determined the following:

- Are there wet weather flow issues and should there be an allowance for this in the design?
- How accurate is the probability method in determining the peak flows?
- Are the operational pressures consistent with the design model?
- Does the system offer tangible benefits when compared to a conventional network

3 BACKGROUND

3.1 POINT WELLS

A pressure sewer system was commissioned in June 2008 for the community of Point Wells in the Rodney District, approximately 80km North of Auckland's CBD. This system consists of approximately 7.5km of pressure sewers and will eventually service 510 dwellings (Scard, S A., 2008). As of 28 June 2009 the network included 161 grinder pump units servicing 66% of the existing community. The grinder pump units have been supplied by eOne (151 pumps), and Barnes (10 pumps). The community is consists of a mix of permanent residents and holiday homes. Based on pump run hour logging it is thought that 137 of the 161 pump unit installations servicing permanent residents.

The layout of the network is shown in Figure 1 and consists of a single trunk pressure sewer (between 180mm and 110mm outside diameter) that runs north to south along the main road into Point Wells (Point Wells Road). There are 18 branches off the trunk pressure sewer that service the surrounding streets and right of ways. The pressure sewer network discharges into a 300mm diameter rising main. This rising main services the beach community of Ohama, and it discharges to the Rodney's Jones Road Wastewater Treatment Plant.

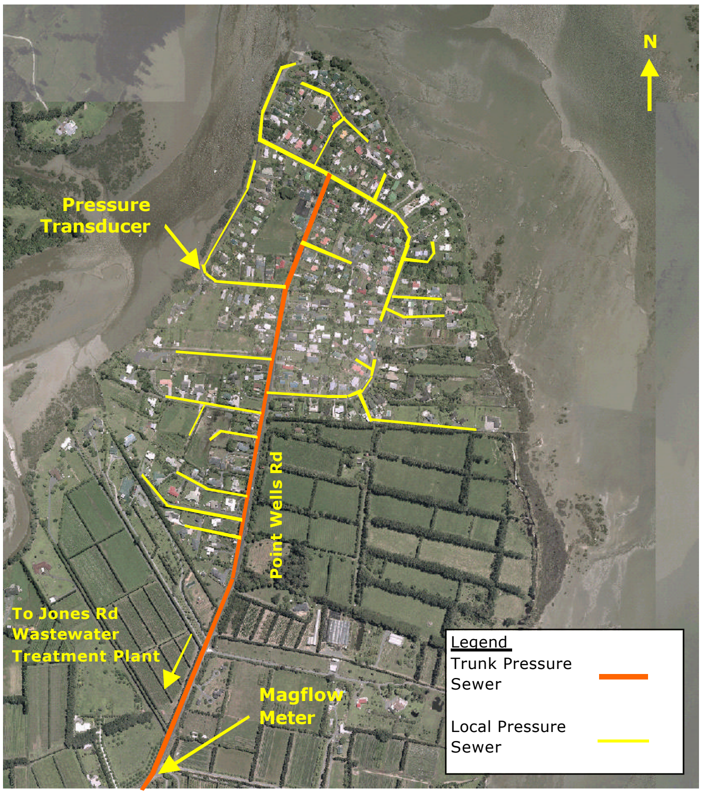

Figure 1 – Point Wells PWC system schematic layout

3.2 PRESSURE SEWER DESIGN

The design of Point Wells pressure sewer network used the probability method to determine peak flows. This methodology is based on the Albany Study which analysed 58,000 pump events in a 307 day period (Carcich, I G., et al, 1972). The study determined that the peak flow from a pressure sewer network can be based on the maximum number of pump units that would pump at the same time in a catchment (Carcich, I G., et al, 1972). The percentage of pumps pumping simultaneously diminishes as the number of pumping units increases as shown in Table 1.

Table 1: Maximum number of grinder pump units operating simultaneously

Number of upstream pump units	Maximum number of grinder pump units operating simultaneously	Maximum percentage of pump units operating
1	1	100%
2-3	2	100%
4-9	3	75%
10-18	4	40%
19-30	5	26%
31-50	6	19%
51-80	7	14%
81-113	8	10%
114-146	9	8%
147-179	10	7%
180-212	11	6%
213-245	12	6%

As pressure sewer pumping units are semi-positive displacement pumps with an almost vertical H-Q curve, the flow from each pump is approximately constant. Therefore the maximum flow for a given catchment would be the pump flow multiplied by the maximum number of pumps operating. Using this information the network can be sized using a standard headloss formula such as Hazen-Williams, Darcy-Weisbach, or Colebrooke-White. The pipe diameters need to be optimised to minimise headloss and retention time while maximising the velocity.

4 RESULTS

4.1 DATA COLLECTED

In Point Wells installation automatic monitoring has been undertaken to establish baseline data to measure performance against. The following automatic recordings were logged:

1. Total Flow: A 150mm diameter magflow meter located downstream of the Point Wells network (figure 1). Flow was recorded in one minute increments between 20 February and 28 July 2009.

2. Pressure monitoring: The bandwidth of the operating pressure of the pump units in this specific system was established (Point Wells is a flat area). With the operating pressure the number of simultaneous pumps operating was monitored (Table 1). Pressure was recorded in two minute increments between 10 July and 1 August 2009.

3. Rainfall: Normal rainfall recording in the catchment in 10 minutes increments between 16 April and 28 July 2008.

The following general system performance information is also logged by Rodney District Council:

4. On-site system performance:

- Pump performance at commissioning - The time in seconds to empty the tank (i.e. one pump cycle).

- Pump hour meter - to monitor performance versus fault reporting. Also used to establish baseline data on average daily pump run times for dry and wet weather flows over specific rainfall periods (long term and short term).

- Service call logging – to log specific faults and service.

5. Network performance: Reactive and preventative maintenance logging.

4.2 DESIGN CRITERIA

The design of Point Wells pressure sewer system was based on the following design criteria and assumptions:

- Pressure Sewer energy loss based on uniform flow with a Hazen William C coefficient of 120.
- Daily flow 220 L/ person/day (572l/dwelling/day)
- The design is based on a maximum pump flow rate of 0.58L/s (E/One, Mono and Barnes).
- Existing number of connections installed – 245
- Future number of connections (dwellings) - 510

Based on the existing number of commissioned pumping units in Point Wells as of 28 July 2009 the following design flows have been estimated

Holiday daily flow (161 pump units) - 92m³/day

Normal daily flow (137 pump units) - 78m³/day

Peak flow - 5.8l/s (holiday and permanent)

Peak flow – 5.22l/s (permanent residents only)

4.3 FLOW ANALYSIS

Figure 2 summarises the flow and rainfall during the monitoring period. The average flow during the monitoring period has been 40.9m^3/day, or approximately 300L per dwelling (permanent residents only). This flow is low and is likely to be related to the low occupancy rate and the lack of a water supply network in Point Wells. As can be seen in Figure 2 the daily flow has increased during rainfall, indicating that stormwater is entering the network. The average daily flow during the week is 1.3 m^3/day less than the weekend flow, however the weekend flow may increase during summer as holiday homes will have a higher occupancy rate. There appears to be a measured rainfall response in the flows. Analysis of the data indicates that on average wet weather flows are 1.2 times greater than the daily dry weather flows. From 9 to 12 June 2009 there was 140mm of rainfall which resulted in 144m³ of wastewater flow, most of this flow was recorded between midnight and midday indicating a strong correlation between rainfall and flow. The reasons for this rainfall response will be expanded on in Section 4.4.

Figure 3 illustrates the average day flow (l/s) for each month during the monitoring period. This shows that typically average diurnal morning peak is between 1.1 and 1.3l/s. Note the average flows presented are the average of a probability mass function, based on the probability of a number of pumps pumping at the same time. Therefore instantaneous flows at any given time can vary significantly. The diurnal flow pattern observed in the flow data was similar as experienced in Australia and USA, with the peak hour 2.8 times the daily average during the morning, and 1.4 times daily average during the evening (Enfinger, K L., Stevens, P L., 2006 and www.pssolutions.net.au).

As shown in Figures 4 to 8 which superimpose the monthly flows over a single 24 hour period, flows up to 6l/s where experienced during normal operation. This aligns very close to the design peak flow of 5.22l/s to 5.8l/s. Flows greater than 6l/s have been recorded, however these flows are influenced by rainfall. These graphs also demonstrate the probability of a given peak flow occurring by the density of the data points.

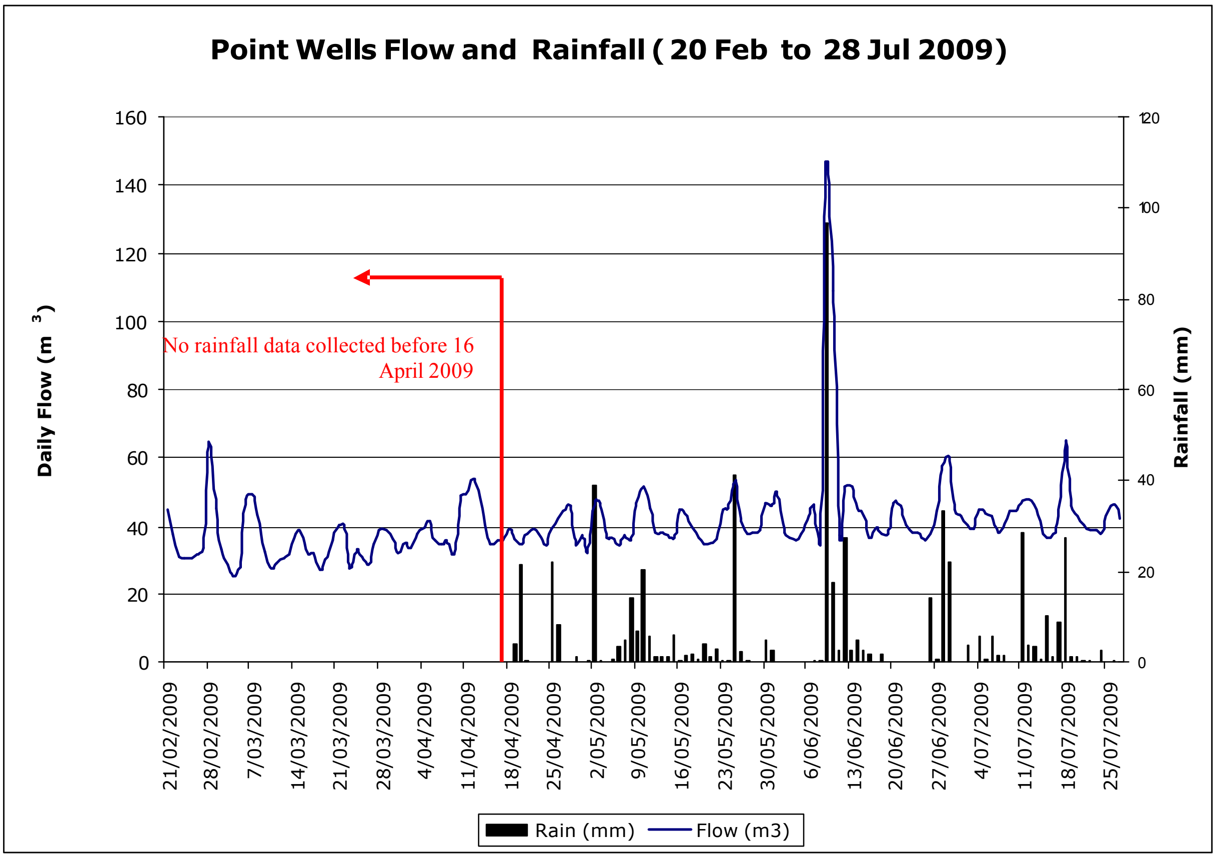

Figure 2 – Point Wells daily flow and rainfall February to July 2009

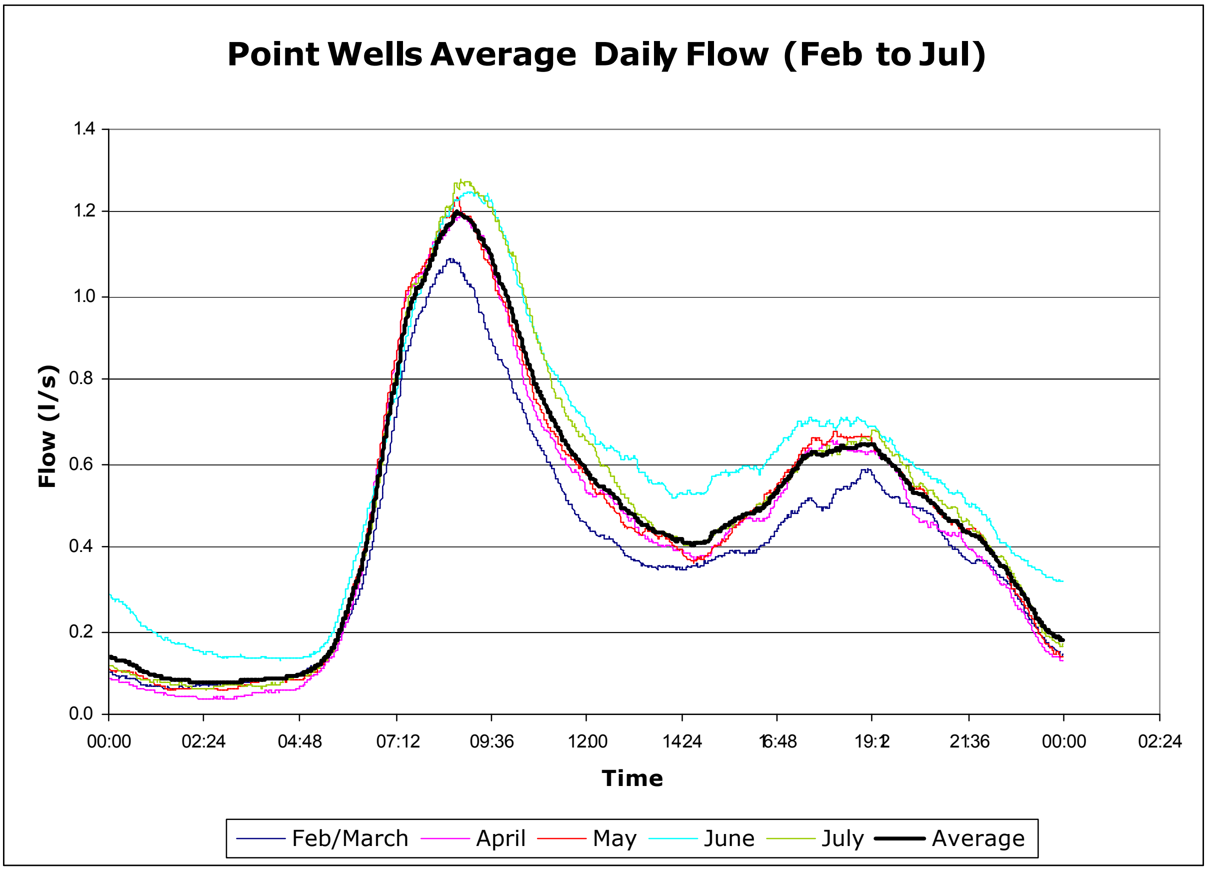

Figure 3 – Point Wells Average Flow February to July 2009

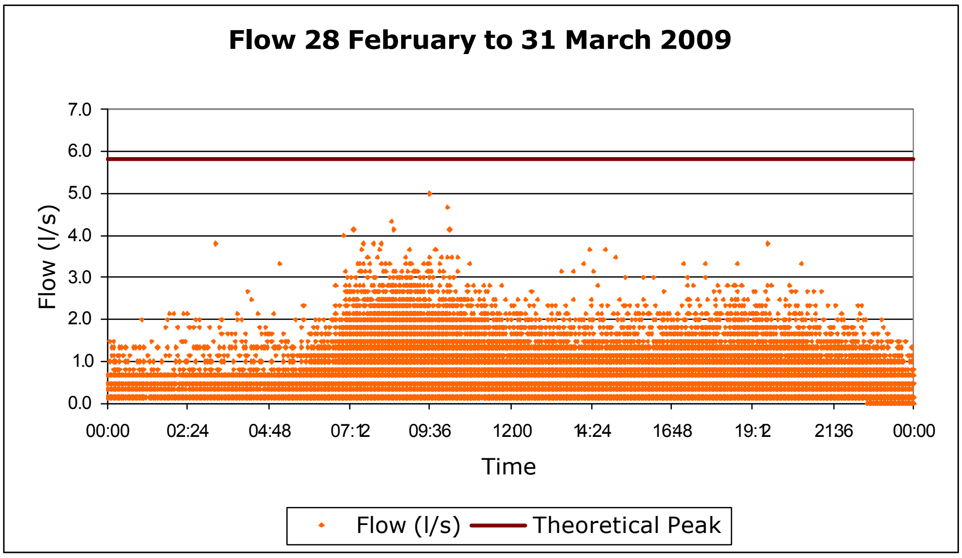

Figure 4 – Point Wells Monthly Flow (February and March)

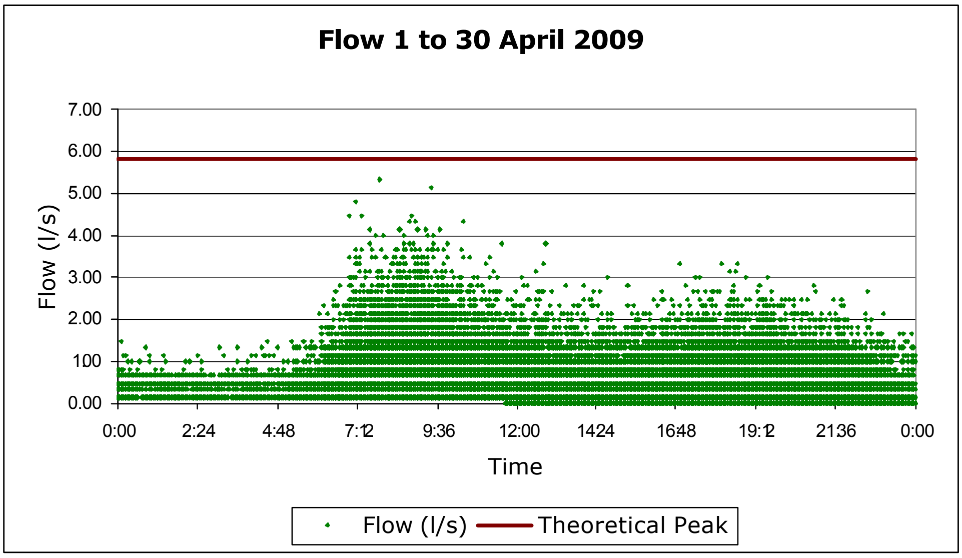

Figure 5 – Point Wells Monthly Flow (April)

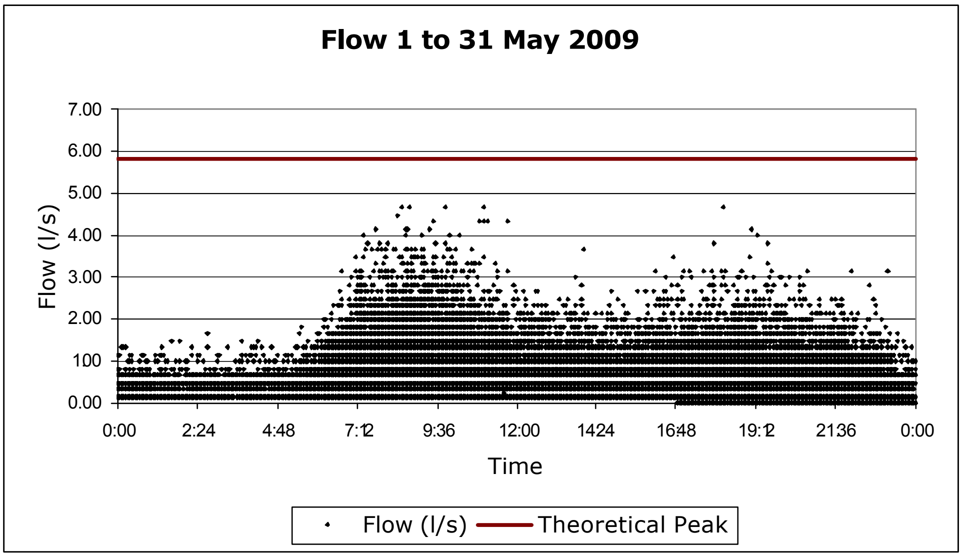

Figure 6 – Point Wells Monthly Flow (May)

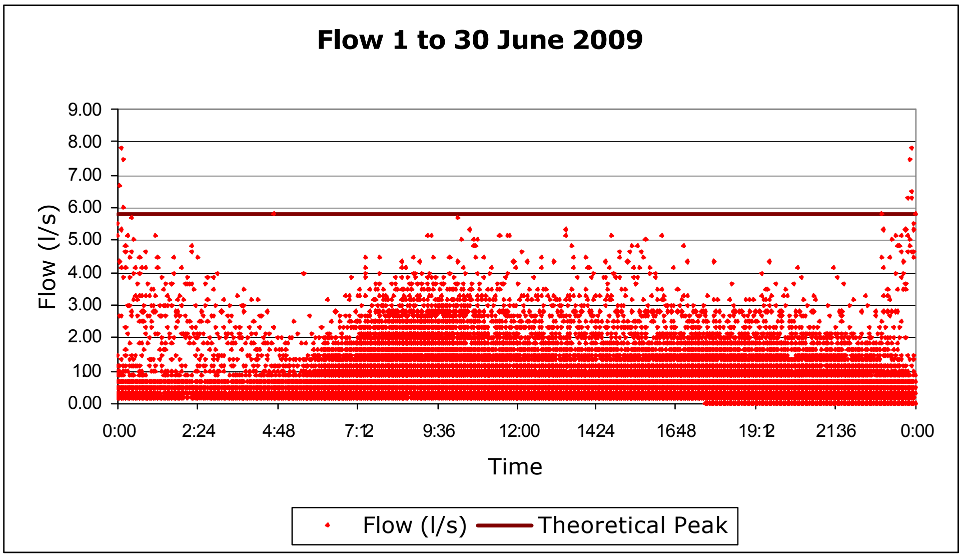

Figure 7 – Point Wells Monthly Flow (June)

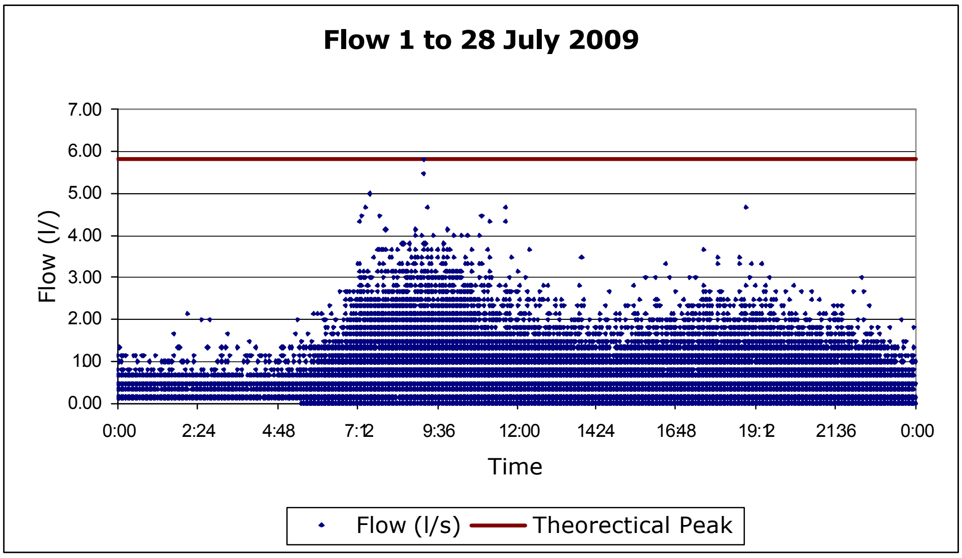

Figure 8 – Point Wells Monthly Flow (July)

4.4 RAINFALL

Although very little wet weather was experienced during the monitoring period, a significant weather event was recorded from 9 June to 12 June. A total 140mm of rainfall occurred during this period with 97mm recorded on 9 June. The Point Wells area was flooded and a flow 3.5 times daily average was recorded. From this event it was found that:

1) one pumping chamber lid was submerged,

2) one dwelling's gulley trap was approximately 100mm underwater, and

3) at one dwelling the rainwater or gutter down pipes were connected to pumping unit.

Based on the pump run hours the total inflow from these three pump units contributed approximately 60% of the total flow on 9 June 2009 (86 m³ of a total volume of 144 m³).

After this event pump hour meter readings were taken over 16 days dry weather period, and then again over four days of wet weather between 26 and 29 June (70mm of rainfall). During the four days of wet weather the following was observed:

1) The diurnal flow pattern clearly reflected inflow during raining hours.

2) The peak hour was 3.2 times daily average during morning and 2.5 times the daily average during early evening.

3) During this period 14% higher daily flow was recorded than with dry weather.

4) Comparing the average pump run times of each lot with dry weather information, 12 out of 151 (eOne installations only) pumping units were identified that have elevated pump run hours. These sites will be monitored more closely to determine the source of inflow.

4.5 PRESSURE

The operational pressure of the network varies between 0.6bar (60kPa) and 1.8bar (180kPa). Figures 9 and 10 summarise the variability in pressure and flow characteristics of the network.

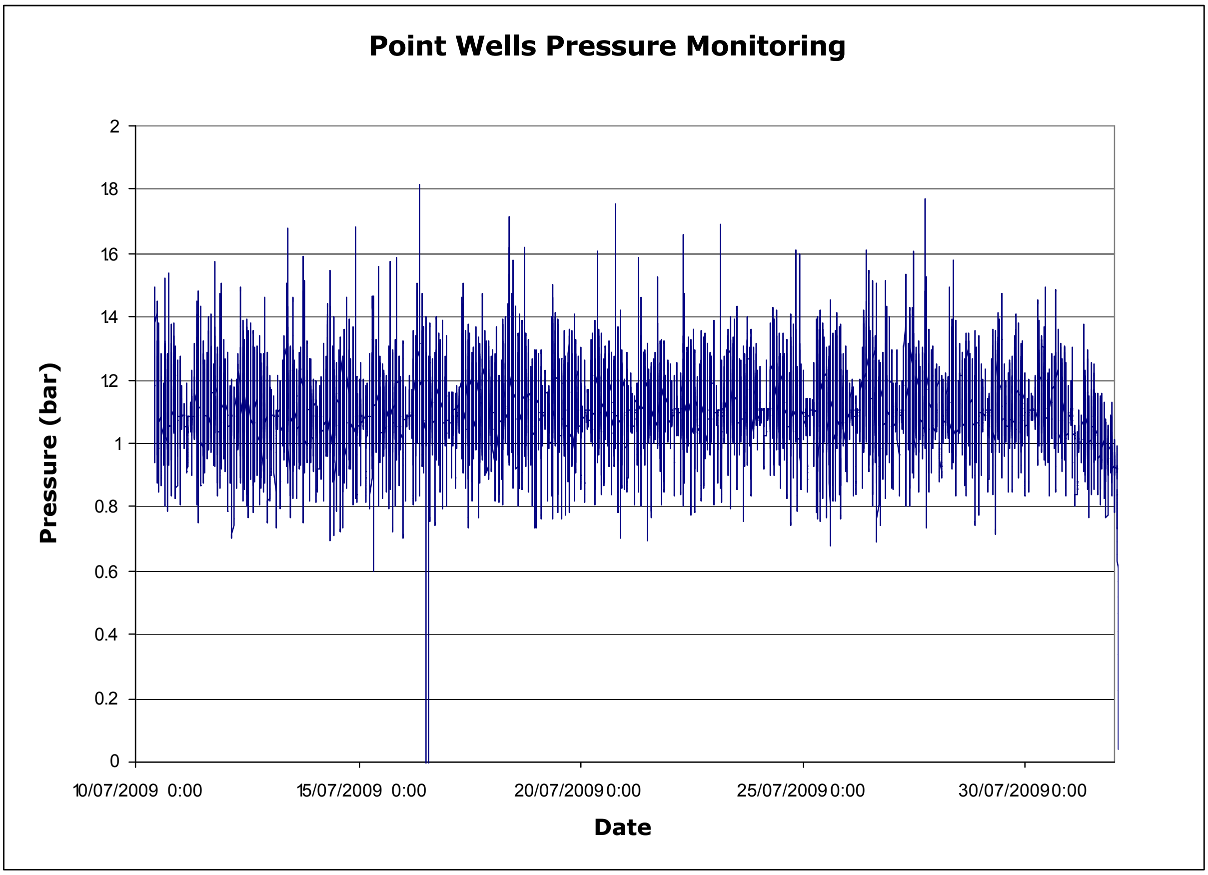

Figure 9 – Point Wells pressure 10 to 1 August 2009

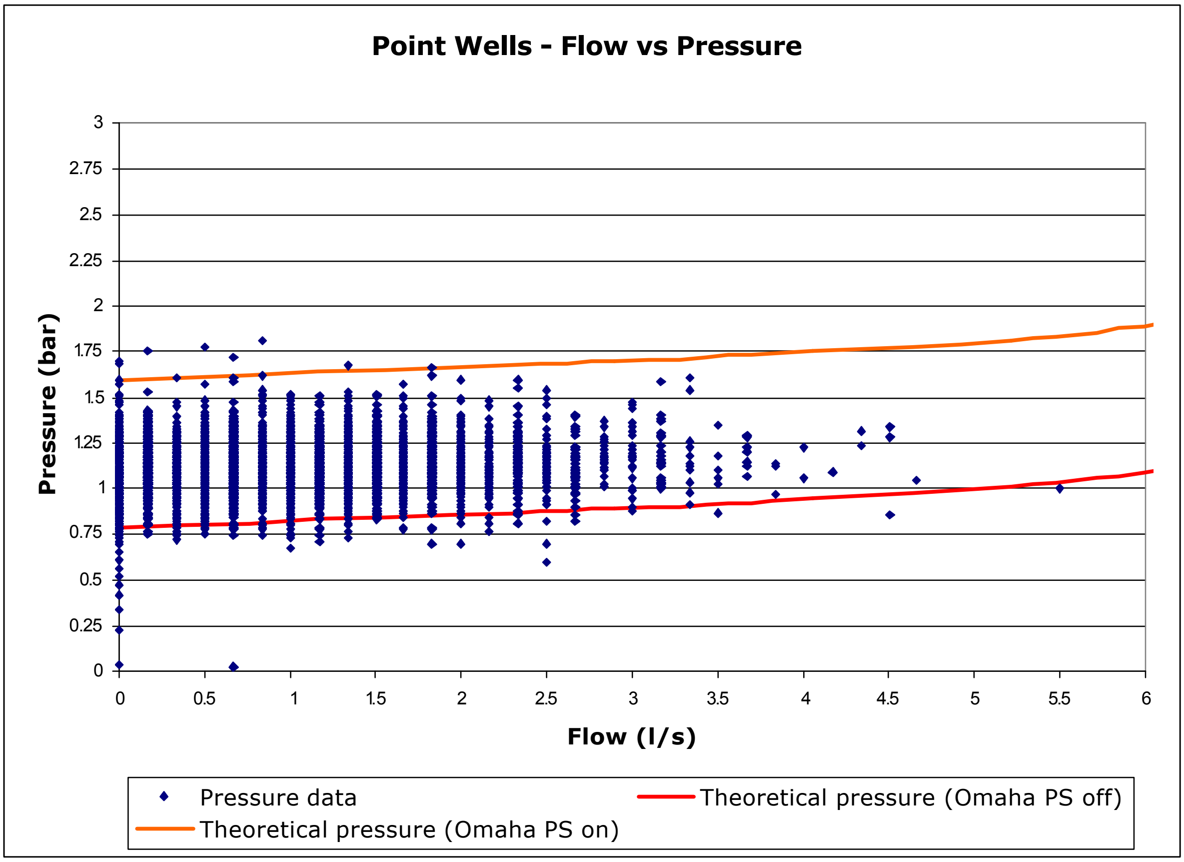

Figure 10 – Point Wells pressure data comparison to design hydraulic model pressure

The pressure measured in the network is between two theoretical extremes. These extremes occur when the pressure network pumps flow into the Omaha rising main when Ohama's main pumping station either pumping or not pumping. The data shows that the pressure is generally higher than expected when the Omaha Pump Station is off. A possible explanation is that the network has not been flushed since commissioning (it should have been flushed three or four times in this period). Therefore, solids and slime have accumulated in the pressure mains increasing the pipe fiction. As only three weeks of pressure data has been collected it is difficult to confirm any long term trends or changes.

4.6 OPERATION AND MAINTENANCE

Monitoring of pumping systems, which are privately owned, is undertaken by approved installers as part of thier support service which is regulated in Rodney District Council's Wastewater Bylaw. From commissioning of the first installation in July 2008 to July 2009, the following calls were registered by Rodney District Council's call centre.

Table 3: Pressure Sewer Pump Unit Call Outs

Approved installer	Number of units	Number of call outs
Ecoflow (eOne)	151	20
Pump and Valve (Barnes)	10	0

Table 4: Fault list as reported by Ecoflow (eOne)

Fault	Number	Reason
Low voltage supply	12	Variable voltage supplied by the power company
Start/stop sensor	2	Replaced in first month
Owner misuse	1	Burnt out stator replaced
Flooding	3	Situation rectified
Non-related	2	Call outs not related to the pressure sewer system/network

No maintenance was recorded on the network by Rodney District Council's maintenance contractor. While a regular flushing program has been prepared for the network, no flushing has been performed since the network was commissioned. No odour problems have been reported by the public during the operational period even though the initial wastewater retention time when the network was commissioned was up to eight hours. This can be attributed to the flat topography which limits the volume of air exhausted by air release valves. At the Jones Rd Wastewater Treatment Plant no operational issues have been reported.

4.7 COMPARISON TO A GRAVITY NETWORK

The cost of a theoretical gravity sewer system has been prepared to compare with the actual costs related to the pressure sewer system. A gravity system would be consist of 6.2km of sewers, and four pumping stations (Haarhoff, T B., 2007). Table 5 compares the capital, operational, and lifetime cost of a pressure and gravity system.

Table 5: Sewer System Cost Comparison for Point Wells

	Pressure Sewer	**Gravity System**
Capital Cost (Network)[1]	$ 914,033.21[2]	$ 3,873,500.00[3]
Capital Cost (Private Connections)	$ 2,278,500.00	$ 220,500.00
Total Capital Cost	**$ 3,192,533.21**	**$ 4,094,000.00**
Power and Operational Costs (year 1)	$ 37,609.00	$ 37,500.00
Lifetime Costs[4]	**$ 4,691,500.00**	**$ 5,419,700.00**

The pressure sewer system is has a lower capital and lifetime cost when compared to a gravity system. The operational costs are the same. Generally pressure sewer systems tend to be a cost effective solution for low density residential areas. When considering servicing multi-unit or commercial/industrial areas gravity systems tend to have lower costs. As the bulk of the pressure sewer network in installed in the public road reserve, the disruption to private land is minimised. This is an important consideration for retrofit projects.

5 DISCUSSION

These results from system performance monitoring on the pressure sewer system at Point Wells provide a positive indication that both the design and operational performance of these system in New Zealand is similar to historical experience in the USA and Australia. Peak flows are generally the same as the design peak flows. Furthermore, the pressure recording indicate that headlosses are as expected, although the short monitoring period (3-weeks) is not sufficient to confirm this finding.

From an operational perspective it is clear that the system does experience inflow and there is a correlation between flow and rainfall. However it has been simple process for Rodney District Council to identify sources of inflow by tracking pump run hours. Therefore, while a wet weather peak factor of approximately 1.2 is currently experience, Rodney District Council have quickly identified the sources and are in the process of reducing and possibly eliminating the inflow. Further flow monitoring will confirm the effectiveness of this approach.

The most common reason for pump alarms has been variable voltages supplied by the local power company. This is an important issue to consider particularly in rural areas. Rodney District Council is currently working with the local power company to improve the level of service to Point Wells. The other call outs have been of a minor natural. There have been no issues operating the pressure sewer network however Rodney District Council have not performed flushing which is required to prevent the build up of slime and solids in the pressure sewers. The lack of flushing, and the likely slime build up, could be causing slightly elevated

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[1] The initial capital cost is based on servicing the existing 245 residential dwelling
[2] Actual construction cost
[3] Estimated cost based on similar projects in the Auckland Region. Data collected by Harrison Grierson Consultants
[4] 50 year Net Present Value cost, 8% discount rate.

pressures in the network. These elevated pressures however would have a negligible effect on the pumping units that can pump at least 6 bar.

When compared to the costs related to installing an equivalent gravity sewer system, the pressure sewer system is considerably cheaper over the life (50 year analysis) of the system including both private and public costs. Furthermore, as wet weather flows can be monitored and reduced easily, the cost of treating wet weather flow volumes can be considerably reduced and allows for reduced buffering storage or peak flow treatment at the wastewater treatment plant.

6 CONCLUSION

Based on the investigation of the operation of the pressure sewer system at Point Wells the following is concluded:

- The probability method was an accurate tool for designing the pressure sewer systems at Point Wells.
- A wet weather peaking factor of 1.2 was measured, however the sources of wet weather inflow can easily be identified and reduced/eliminated by monitoring pump run hours.
- The pressure sewer system has resulted in reliable and cost effective solution for the community of Point Wells

ACKNOWLEDGEMENTS

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