PRESSURE SEWER SYSTEMS: NEW DESIGN INNOVATIONS CAN IMPROVE SYSTEM PERFORMANCE

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ABSTRACT

An innovative approach to dynamic modelling of pressure sewer systems is outlined. The effect of this approach on the number of simultaneous pump runs for a given system and the consequential beneficial effects on hydraulic characteristics of the pressure sewer system is discussed. The innovative dynamic modelling approach is compared to typical system outputs and the effects on retention time, post power outage recovery and other hydraulic characteristics.

KEYWORDS

Pressure Sewer, Timer Control, Septicity, Odour, Corrosion, Peak Flow Attenuation, Innovation, FluxSmart™

1 INTRODUCTION

Pressure sewer systems are growing in acceptance as an effective solution to provide a reticulated wastewater collection network to communities currently lacking service. In addition to pressure sewer systems well recognized advantages in flat, low lying areas with high water table, or steep rocky terrain, other attributes of pressure sewer systems have significant advantages in reducing capital and operating costs in the downstream infrastructure, particularly in trunk transfer, treatment plant and disposal systems. This is primarily reduced peak flows and an ability to significantly reduce Inflow & Infiltration.

While pressure sewer systems have a range of beneficial attributes, attention must be given during the detailed design process to avoid possible negative attributes. Hydraulic attributes such as residence time and pipe fluid velocities must be taken into account, and if not properly attended to in the design phase may lead to ongoing wastewater septicity and associated odour issues. Care must also be taken to ensure pumps at the extremity of networks are not significantly hydraulically disadvantaged, that flows on start up following power outages are managed and that vulnerable pumps do not spill following prolonged network outages. The design process must address the conflicting requirements of large pipe diameters to maintain pumping heads within acceptable ranges, and small pipe diameters to minimise wastewater age and associated septicity and odour.

2 DESIGN INNOVATIONS IMPACTING ON HYDRAULIC PERFORMANCE

Pressure sewer systems currently rely on wet well water level sensors to control pump start and stop. As each on-property tank fills, the pump start level is reached and the unit will pump out until the pump stop level is reached. Hydraulic design is carried out by using one of three design methods approved by WSA 07, The Probability Method, The Rational Method or Dynamic Hydraulic Modelling. In each design method the hydraulic sizing of the network is related to the number of pumps running simultaneously. The number of pumps running simultaneously runs dictate the hydraulic capacity requirements of the network. For a given number of properties each method approximates the likely number of pumps running simultaneously, indicating an acceptable envelope of pipe sizes to maintain the Total Dynamic Head (TDH) within acceptable levels while also meeting minimum hydraulic requirements such as self cleansing velocities and minimising residence times.

Given certain system or catchment constraints, there is a risk minimum hydraulic characteristics cannot be achieved whilst keeping TDH below acceptable maximum limits. This may be a particular problem for systems with very few initial properties in relation to the final design population, or systems requiring long pipe runs between properties or to the discharge point. It is a fundamental requirement that TDH within the reticulation cannot exceed any given grinder pump's maximum operating head. For typical pressure sewer progressive cavity grinder pumps this is in the order of 56m head of water.

The consequence of not achieving minimum hydraulic requirements will be a lack of self cleansing and / or high residence times leading to septic sewage, which when released into downstream infrastructure produce odour and potential corrosion. Given a typical scenario of a new development discharging into existing gravity reticulation, the consequence of discharging septic sewage may be severe, with odour issues spread widely along the gravity reticulation, along with corrosion of the existing asset contributing to reduced asset life.

Downstream infrastructure must be sized accordingly to handle the peak flows produced by the pressure sewer network. Wastewater treatment plants are rarely located conveniently close to new wastewater schemes. Often pressure sewer schemes are well suited to service populations that are some distance from existing transfer and treatment infrastructure, requiring effluent from the pressure sewer schemes to be transferred some distance. Reducing the peak flow design requirements can provide significant capital savings to the scheme, or alternatively allow further population growth for the given capacity of existing infrastructure.

Reducing peak flow rates for a given catchment or population can provide significant benefit to the community and Asset Owner.

2.1 TIMER CONTROL OF PUMP OPERATION

Timer control limits the pump run time to 30 seconds. The wet well may remain above the pump start level. The pump is switched off for a mandatory period of 10 minutes. This allows other pumps in the network to pump out. The pump may then commence another pump out cycle until the well level is reduced below the pump on level.

With level control systems, the well level will reach pump on and the pump will run until the well level reaches the pump off system. The volume pumped is often in the order of 80l but can vary depending on tank design and pump control set points.

By using a timer to control pump operation, the number of simultaneous pump runs can be reduced for a given design population.

2.1.1 TIMER CONTROL OPERATION

Timer control of pump operation reduces:

- Peak flow rates
- Emergency recovery flows
- Required pipe sizes
- Residence times in the reticulation
- The risk of septicity, odour and corrosion, and
- The risk of on-property pump units spilling during operational or emergency network outage recovery.

2.2 TANK OPERATING AND STORAGE VOLUME MANAGEMENT

Typically, pressure sewer on-property tanks are cylindrical or near cylindrical in shape, with suitable ribs and flanges for strength to assist in the prevention of buoyancy. The operating volume between pump start and stop can be significant, and can typically be measured in 10's of litres.

Pressure sewer on-property tanks are required to provide 24hrs storage. For a typical dwelling this is 660 l above the pump on level. The dimensions of the tank to provide this storage volume are typically carried down to the operating volume section of the tank, giving rise to the large pump operating volumes typically present in systems currently.

By reducing the diameter of the tank at the operating section, operating volumes can be significantly reduced. The operating volume can be reduced by a factor of 10, so that volumes are measured in litres rather than 10's of litres. This leads to more frequent pump starts which serves to reduce retention time, and contributes to a flattening of network hydrogaphs, reducing peak flows within the system.

Additionally by reducing the diameter of the tank within the operating section, the retained volume below pump off is substantially reduced. This also serves to reduce residence times and removes the risk of retained septic wastewater acting as seed for additional wastewater entering the system.

2.3 HYDRAULIC BENEFITS OF THE DESIGN INNOVATIONS

These two design innovations modeled in a dynamic hydraulic model using Infoworks CS, to represent the Wanga Park pressure sewer scheme, Yarra Valley, Victoria.

The design innovations resulted in the following:

- Reduction in peak flow from 14 l/s to under 9 l/s (35% reduction)
- Decreased all pipes by one pipe size – resulting in capital cost savings
- Reduced residence time from 10 hrs for some areas to under 3 hrs (70% reduction)
- Reduced septicity, odour and corrosion
- Peak power outage recovery flow reduced from 61 l/s to 14 l/s (77% reduction)
- Risk of spilling at private pumps stations significantly reduced

2.3.1 SYSTEM EMERGENCY RECOVERY FLOWS

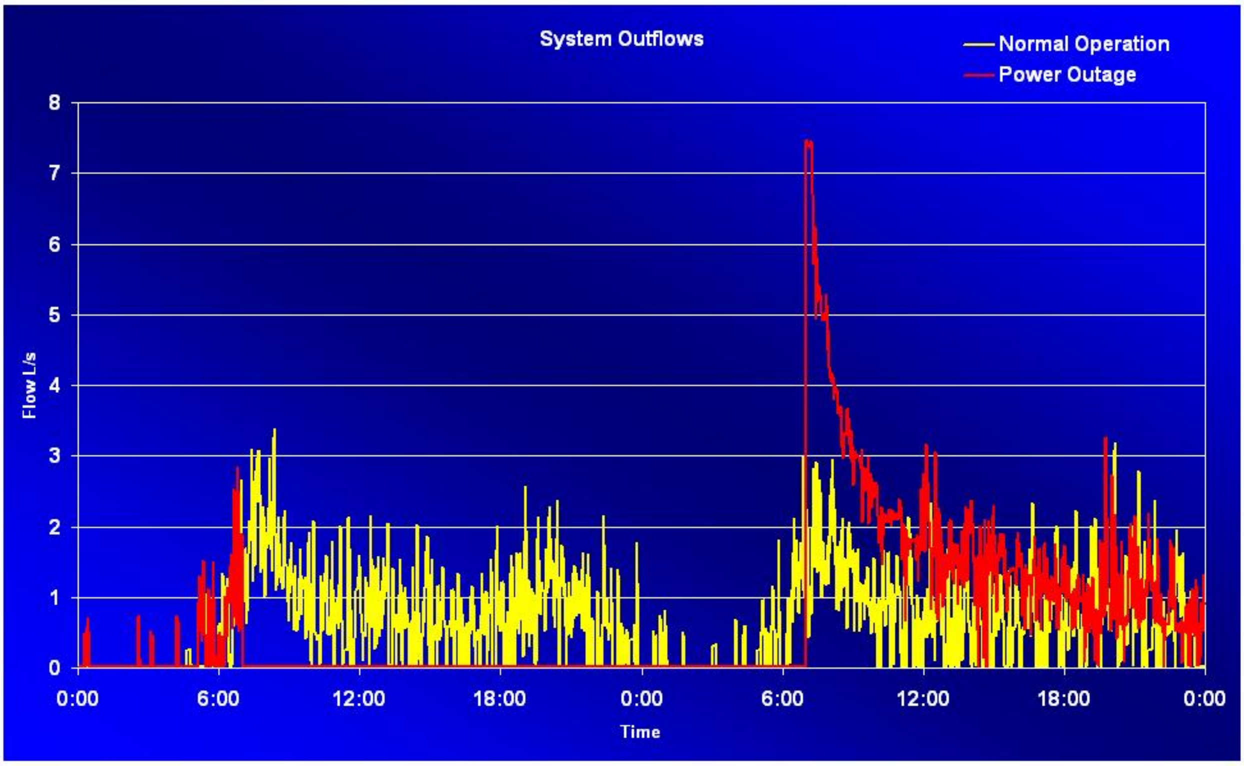
Otherwise referred to as 'power outage recovery flows', emergency recovery flows are a primary consideration for the designer. Effects of very high peak flows on downstream infrastructure can be significant, resulting in either a need to build significant additional capacity with associated cost, or introduce the risk of wastewater spillage into the surrounding environment.

In the Wanga Park example, peak recovery flows were modeled and found to be 61 l/s. This is over 4 times greater than the designed normal operation flows of 14 l/s. By introducing the timer control mechanism, the recovery flows were able to be reduced to 14 l/s, a 77% reduction, while the normal operation peak flows were reduced from 14 l/s to 9 l/s, or a 35% reduction.

Recovery flows were modeled under the scenario that power is cut to the whole catchment at 7am (just before morning peak flow) and is not restored until 24 hrs later.

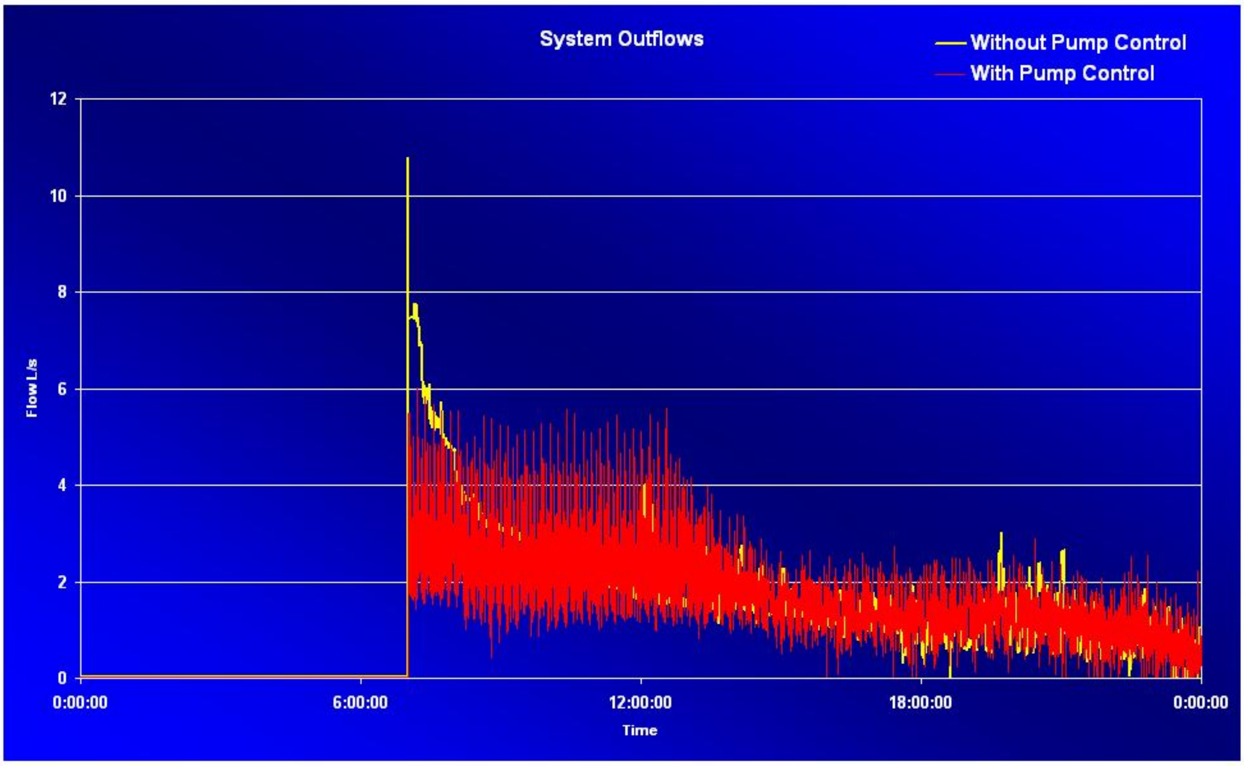
Figure 1 below presents a sub catchment showing the recovery flows modeled assuming conventional wet well level stop start set points. The sharp increase in flowrate lasting for a relatively short duration during network recovery (power supply restored in this example) can be noted.

Figure 1: Sub Catchment Recovery Flows – Conventional Level Control



For comparison, the sub catchment was also modeled using timer pump control. As depicted by figure 2 below, the timer control provides attenuation in peak flow, ensuring the peak flow does not spike and maintains peak flows within manageable levels. It is noted that the duration of peak flow is extended over a greater period which is deemed to not be a disadvantage and facilitates the more easily managed recovery flows.

Figure 2: Sub Catchment Recovery Flows – Timer Pump Control



Consideration must be given to the most hydraulically disadvantaged pumps in the network. These are typically pumps on properties at the extremities of the network, or those working against significant static head dictated by local topography. With conventional pump control using water level only, there is a risk that the hydraulically disadvantaged pumps may not be able to pump out and spill if the network does not recover in sufficient time. This is because the most disadvantaged pumps must wait for every other pump in the network to pump out, fully emptying their tanks, before the hydraulically disadvantaged pump sees network pressures low enough to enable it to pump out. This means that some properties on the network can have full to overflowing on-property tanks, while other properties in the network have completely empty tanks.

This phenomena is addressed by the timer pump control. All pumps in the network get an equal opportunity to start pumping, but the pump out time is limited to 30 seconds. This allows the pump to reduce the emergency storage level below the overflow level, but prevents that pump from dominating the network while it empties the tank completely.

Figure 3: Individual Pump Flow During Network Recovery Situation

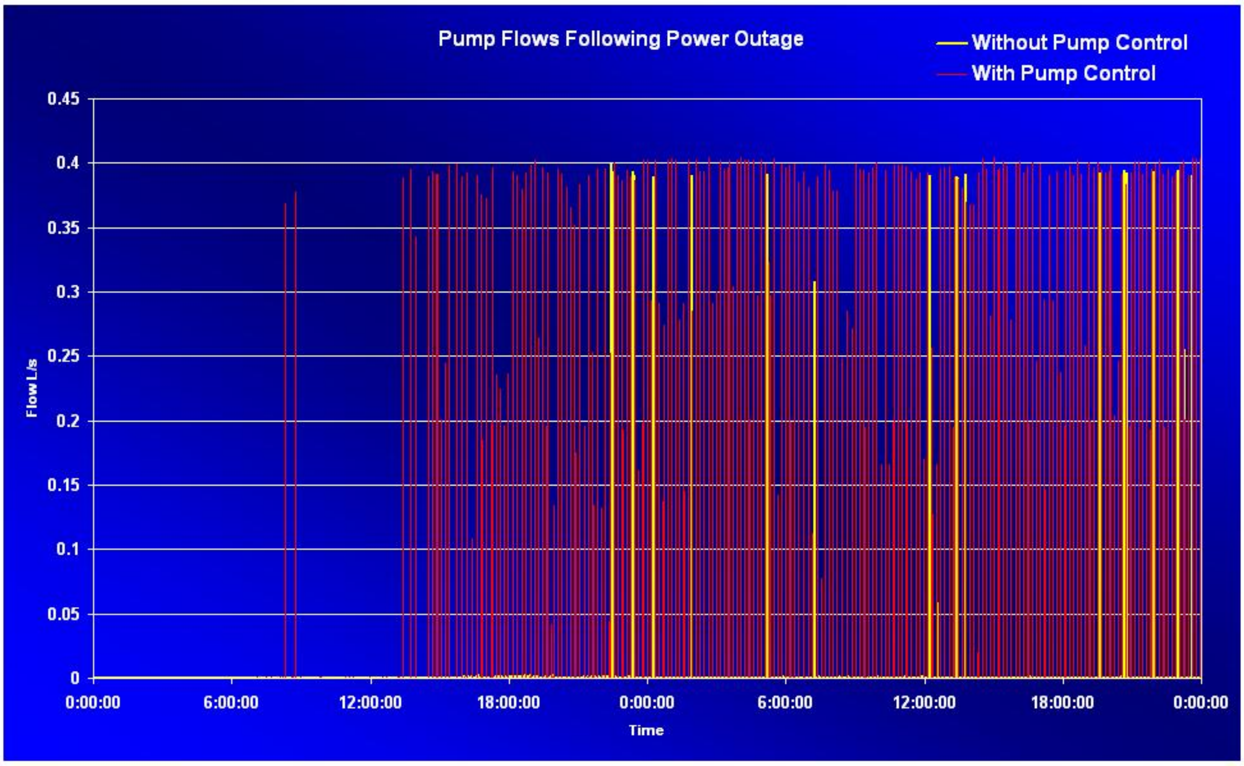


Figure 3 above shows the flows for an individual pump during a network recovery situation. Under conventional level control (yellow line) the pump must wait a considerable time to start pumping, but when it does start it pumps until empty. Under timer control the pump (red line) can start operating much sooner in the recovery process, but then must stop and wait some time before pumping again. This can be seen on the graph as the two red lines between hours 6 and 12 for initial pump runs, followed by a number of short pump runs that occur prior to a pump with conventional level control would be able to start a pump run. These two initial short pump runs reduce the well level sufficiently to significantly reduce the risk of spillage on that property while the remainder of the network recovers. In the above example, the pump in question is able to start a short pump run 14 hrs sooner than the equivalent pump on conventional level control.

3 FLUXSMART™

The design innovations outlined above are subject to patent pending applications as follows: Patent Pending AU 2010257258, NZ 589998, US 12/971,026 & CA 2725950. FluxSmart™ is the registered trade name of the design innovations.

4 CONCLUSIONS

Conventional pressure sewer networks rely on wet well levels for pump control.

Hydraulic design is based on determining an acceptable pipe size envelope to maintain total dynamic head within acceptable limits while ensuring minimum hydraulic characteristics are met, specifically self cleansing velocities and residence time.

The number of pumps running simultaneously dictate the hydraulic capacity of the pressure sewer network.

Reducing the number of simultaneous pump runs reduces the required hydraulic capacity of the network for the same population connecting to that network.

Pressure sewer pump timer control reduce the number of simultaneously running pumps for a given population connecting to the network.

Design innovations including pump timer control and reduced wet well operating volumes provide significant hydraulic benefits when applied to the design of pressure sewer networks.

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