LIMITATIONS OF INFLOW COMPUTATION FROM PUMP STATION DATA – A MONITORING/MODELING APPROACH

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ABSTRACT

Wastewater pump stations dot the landscape of almost every wastewater reticulation network across New Zealand. Typically their design, location at key nodes within the reticulation and the presence of the data logging capabilities of modern onsite SCADA systems make them tempting locations for flow measurement via the method of inflow computation.

The flow measurement information can be a critical input into network modeling, consent compliance, operational control and event trouble-shooting.

However, logged data on SCADA, even if it is verified, and applying one of several different methods for inflow calculation does not always result in a data set that is accurate, that truly reflects reality at key times or is reality usable for modeling.

This paper will highlight several limitations present with computing inflow data from pump status and wetwell records and will provide practical solutions to overcome them. These limitations can have a significant influence on the ease and accuracy of subsequent modeling and the use of the data for other purposes.

KEYWORDS

Wastewater pump station, monitoring, modeling.

1 INTRODUCTION

SCADA (Supervisory Control and Data Acquisition) systems are essential tools in the successful operation and management of wastewater networks. They provide two way control, alarming and data logging capabilities. As pump stations are often located at the downstream end of wastewater catchments, and the fact they have data logging onsite, use of the SCADA logged data for determining inflow for computer modeling use is tempting for project cost reduction.

However, frequently it is discovered too late that the data is not suitable for computer modeling, and that a lower model confidence is the result. This is because SCADA systems are operational tools, and as such have an emphasis on logging data for trending and not the high frequency, high precision data collection required for accurate inflow calculation.

This paper will point out the most profitable method to employ before using SCADA logged data for inflow computation is to carefully examine a sample of data to ensure that it will provide sufficient accuracy at key times.

2 INFLOW CALCULATION

Inflow calculation undertaken using pump station records is an inferred flow measurement method. This is because it can only be undertaken after a pump event as opposed to HVQ or V notch style open channel flow measurement that occurs on a discreet (often 5 minute) interval. As the time between pump events and the duration of the pumping is variable, the methods used for inflow computation result in inflow data that is highly averaged when compared to a discrete measurement.

This fact introduces the primary assumption made in order for inflow calculation to be undertaken; the inflow rate computed is an average between pump cycles. This has the tendency of masking some of the critical inflow characteristics; most importantly for modeling, the initial response time and peak inflow value. This is demonstrated in Figure 1 below.

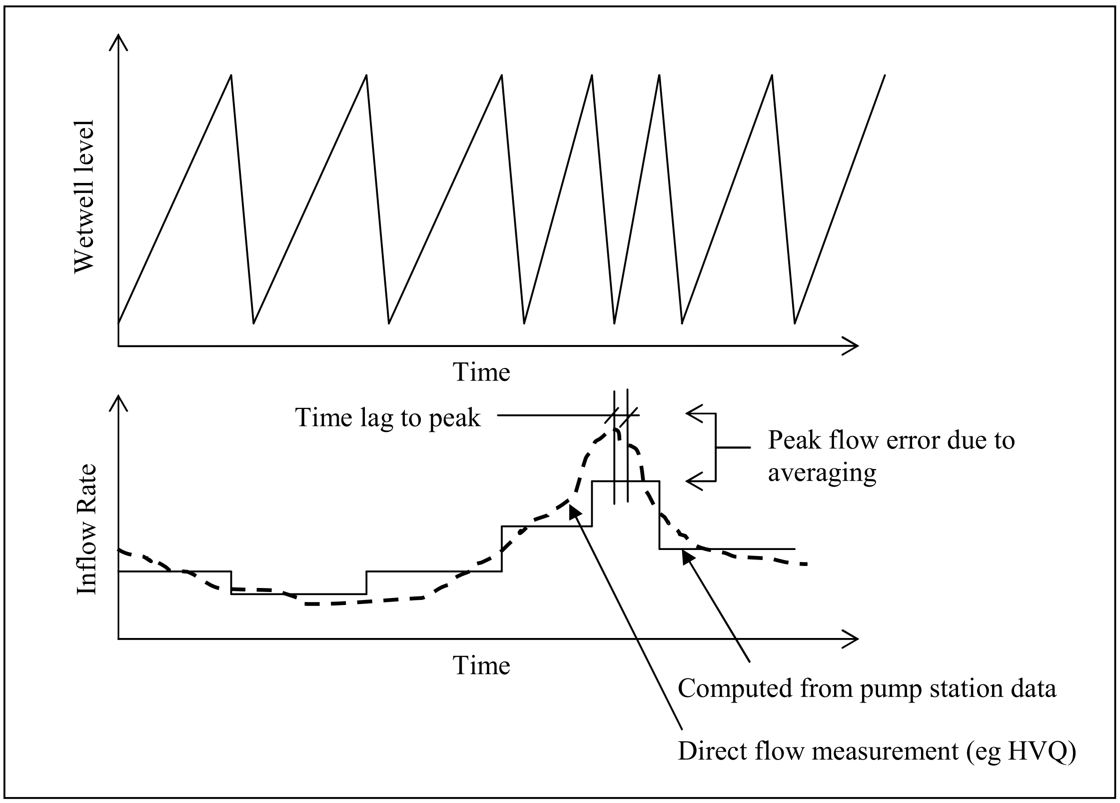

Figure 1: Representation of inflow masking characteristics

Using pump status, wet well level and known wet well geometry, inflow into a pump station can be computed in a number of different yet interlinked methods. The methods are known by different names, but essentially comprise of:

1. Pump run (Qrun)– The average pump discharge rate is multiplied by the pump run time then divided by the time between pump off and the previous pump off.

2. Wetwell fill (Qfill) – The change in well volume is divided by the time from the same pump off to the next pump on. An average inflow during pumping can be assumed in a number of ways including simple extrapolation of the previous computed inflow brought forward or the average of the computed inflows either side of the pump cycle in question.

3 DATA LIMITATIONS

3.1 PUMP STATION CONFIGURATION

Although not specifically a SCADA based data issue, pump station configuration is an essential consideration before commencing on a modeling study. In this instance, pump station configuration refers to the levels pump start and stop are set to in relation to inlet pipes (ie fully or partially submerged inlets), the number of starts per hour, the run-time of a pump in normal dry weather conditions and the ratios of inflow rate to pumping capacity.

Fully or partially submerged inlets greatly increase the inflow measurement uncertainty as they introduce a variable (upstream volume) that cannot be determined easily. Some methods to overcome this is to lower the start level of the pump to below the inlet. Where this cannot be done, or regular high wetwell levels occur, filling the wetwell to maximum (often overflow) level and then pumping the wetwell down whilst recording the wetwell level and flow from a magflow meter. Alternatively (and to a higher uncertainty), an average pump rate can be used. This method will enable a level to volume table for the wetwell to be developed.

The number of starts per hour influence the quality of the data (in terms of inflow averaging, time lag and peak flow errors) as it minimises the length of time over which inflow rates are averaged. Experience has shown that a minimum of four (4) starts per hour during peak periods is generally sufficient.

The ratio of inflow rate to pumping capacity (hence dictating the time taken to pump down) is another uncertainty source for inflow computation. It is the inverse of the number of starts per hour, but with the same effect; long pump run-times resulting in significant inflow averaging, increased peak flow errors and increased time lag.

3.2 DATA LOGGING STRATEGY USED BY SCADA

Trending is essential in SCADA systems as it reduces the volume of data being telemeted and stored whilst still maintaining the integrity of the SCADA system. The resultant dataset can be of limited use for careful study of the system operation (as with modeling).

The term 'data logging' is loose in definition as it simply infers that data is available in electronic format that can be readily manipulated using a spreadsheet or specialised time-dependant database software package without providing any specifics as to the frequency of logging, the accuracy of the instrument being logged and any calibration/correction that may be required before the data is used.

Data can, and is trended in a number of ways, using almost as many methods as there are SCADA systems installed. Some common trending methods used throughout New Zealand include:

- 15 minute discrete data points
- 15 minute data points that are an average of the period over which the 15 minutes extend (may also include rate of change threshold filtering)
- 15 minute pulse totals from a magflow, inferring an average flow rate over that time.
- 30 second discrete data points of pump state or motor current (inferring pump state)

Data trending has varying effects depending on the dataset being examined. Treading in wetwell level will artificially reduce the total 'measured' volume entering the station, and hence lower the computed inflow rate. Pump state trending undermines the premise of knowing a fixed filling and pumping cycle. Use of this type of pump state data will artificially increase the computed inflow rate as the pump cycles will be shorter than reality, thereby resulting in artificially increased inflow rates.

For inflow computation, pump state, wetwell level and flow through the magflow meter (if available) are required. The minimum data logging requirements for inflow computation are instantaneous (1 sec) resolution for pump change-of-state (i.e. off-on or on-off). Typically where soft-starters are installed, the change-of-state logging will occur when full speed is reached. Wetwell level should be logged on 1 min discrete intervals (or better) with an optional additional log when a pump changes state. Finally, magflow meters can be logged using either analogue (4-20mA) or pulse outputs. If using analogue, a 10 sec resolution is a reasonable median. This resolution enables accurate discharge curves and volumes to be computed. Pulse data from magflow meters should record each instantaneous pulse, or accumulate counts on a small (say 10 sec) interval.

Commonly, the data logging requirements are outside the capability of SCADA systems due simply to the volume of data being collected.

3.3 AVAILABILITY OF DATA

SCADA has the primary purpose of system control and this includes alarming on events such as high motor current draw, high wetwell level, station security breech etc. As alarming takes precedence, all other communications with the base station are suspended. Often this can occur in high inflow (wet weather) conditions where multiple stations are alarming and logged data is not always transmitted and recorded. Unfortunately, it is these periods of the dataset that are most keenly examined with modeling.

3.4 SUITABILITY OF DATA

Use of conductive level probes and float switches as methods of automatically starting and stopping pumps are reliable, and as such are common throughout New Zealand. However, both suffer pump start drifting as a result of maintenance frequency. Progressive fatting about the probe or float results in a variable water level at pump start. This is shown in Figure 2 below.

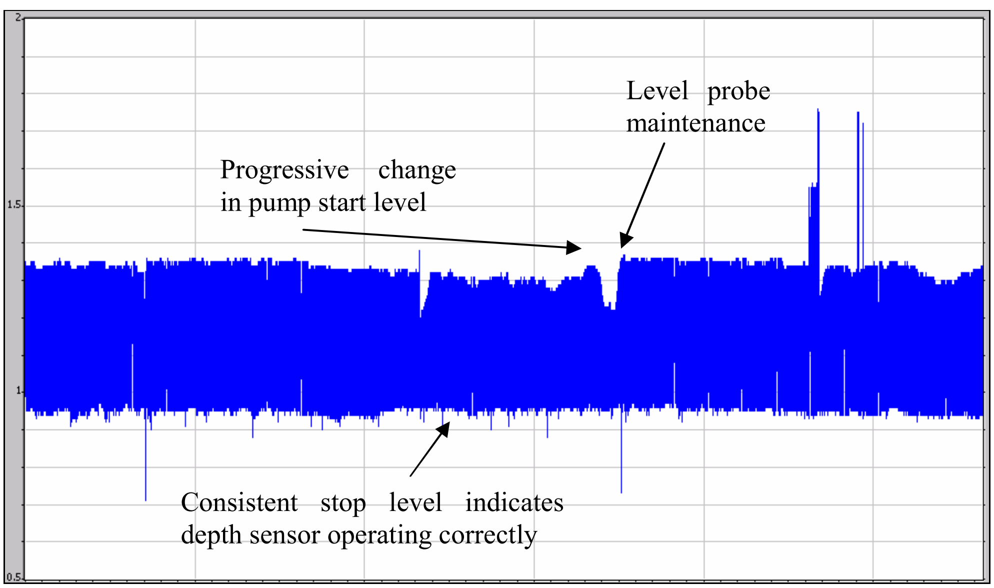

Figure 2: Variable pump start level as a result of maintenance

Whilst this is not a particular issue, is does become one if the distance between start and stop levels is assumed to be constant over the period for which inflow data is being computed.

Derivition of data pump state from wetwell level (ie if falling, pump is on, if rising, pump is off) can be significantly erroneous. During high inflow (wet weather) conditions, it is common for wetwells to fill whilst the pump is running. This is demonstrated in Figure 4 below. Without logged pump change-of-state, pump state would need to be assumed or remain unknown.

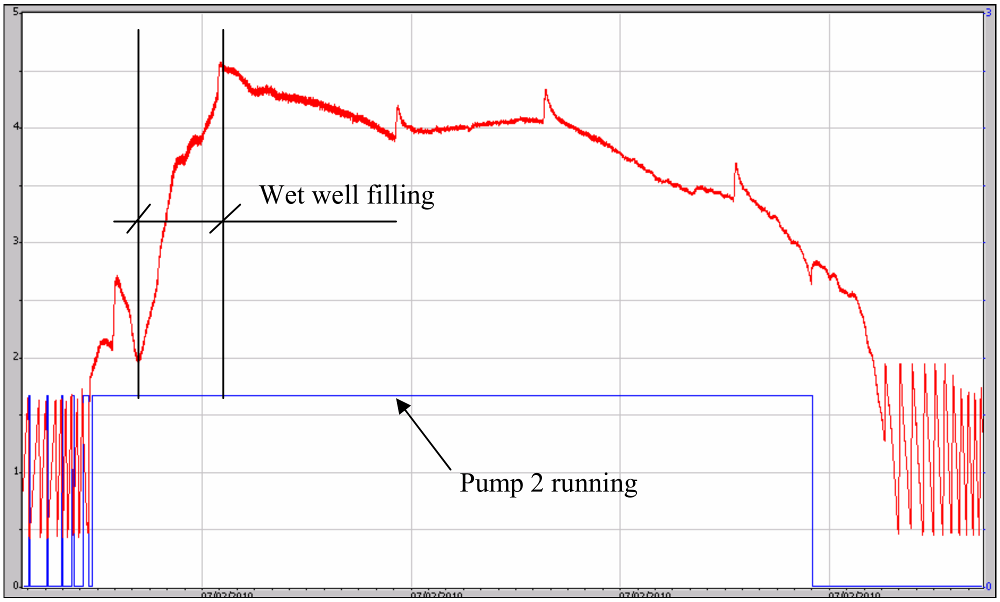

Figure 3: Rising wetwell level whilst pump running

Data resolution is another limitation on the suitability of data collected by SCADA systems. Resolution is really only of consideration with logging analogue (4-20mA) signals, and hence has the most impact in the logging of wetwell level. Resolutions issues are easy to identify when logging the analogue (4-20mA) output of multitrodes as stepped data corresponding to the distance between conductive sensor bands on the probe is the result. This introduces wetwell volume uncertainty as the actual level of the wetwell is not accurately known, but can be extrapolated between jumps in the logged data and the indicative slope of the line. In addition to this, probes do not commonly extend to maximum surcharge height, thereby eliminating any possibility of computing inflow data during high inflow (wet weather) periods as the maximum conductive sensor bands becomes drowned out.

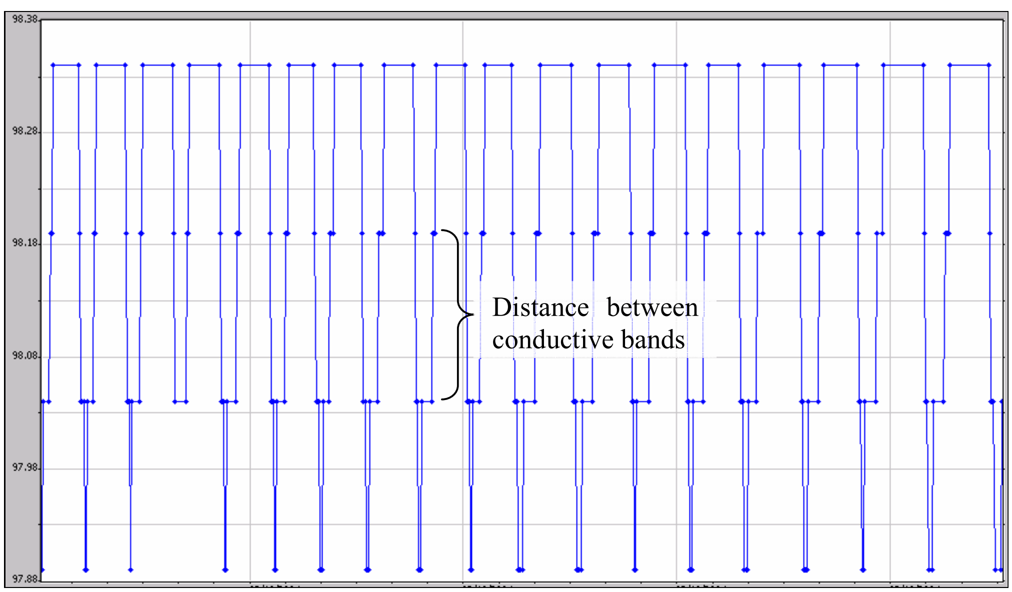

Figure 4: Stepped wetwell level

It is common throughout the operation of SCADA systems to install wetwell level sensors, and never regularly calibrate them. Sensors fall out of calibration in two main ways, gross failure and progressive failure. In the instance of gross failure, it is easy to indentify. However, progressive failure is significantly more difficult to identify as SCADA systems log data to enable operators to view current pump station performance against performance an hour, day or week ago.

Likewise, it is common to install wetwell level sensors with no particular reference to a known survey datum. As trending only requires relative changes in the measured parameter, this installation method is adequate for SCADA data logging. However, when computing inflow, it is essential to know from the wetwell level where on the level to volume curve a logged data point is. This will ensure that the correct change of volume is computed and hence the correct inflow rate.

Simple water level dips (covering a wide depth range) from a known datum point (eg lip of the wet well cover) will assist in eliminating sensor datum uncertainties whist gathering sufficient data to validate the calibration of the sensor.

4 POSSIBLE SOLUTIONS TO DATA LIMITATIONS

With all the limitations to using SCADA logged data, the most profitable solution is to carefully examine a sample of historical data, preferably one that includes both dry and wet weather periods. This will ensure that the engineer or modeler is conversant with the data type, resolution and quality available, and be able to make an educated decision 'before-the-event' if SCADA logged data will be suitable for use.

A wide range of low cost, high frequency, high precision data loggers are available on the market in New Zealand, and this may provide the best solution for any data shortcomings identified. Employment of a flow monitoring contractor conversant with pump station monitoring is another option.

In order to overcome extensive averaging of computed inflow, infilling it with inflow computed simply from wetwell volume change divided by time can be used to improve the dataset resolution. This is demonstrated in Figure 5 below. When employing this method during periods of extended pump run, inflow must be added to pump capacity whilst the wetwell is filling, and subtracted from pump capacity whilst the wetwell is emptying.

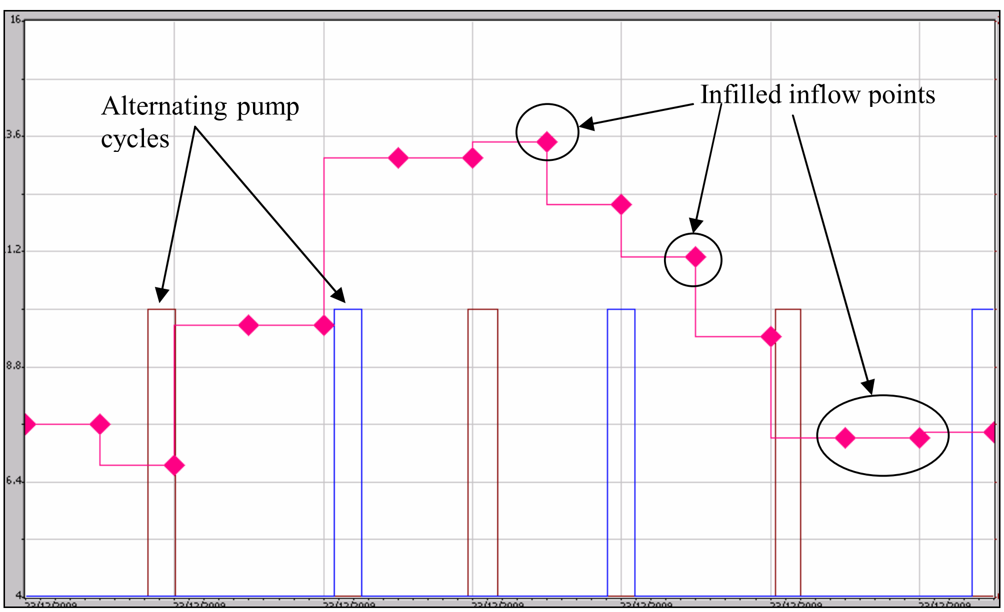

Figure 5: Infilling inflow

5 CONCLUSIONS

Computing inflow data from pump status and wetwell level records can be inadequate at key times due to the nature of the data, operation of the station and a number of other limitations. Careful examination of SCADA data 'before-the-event' along with a number of simple field calibration procedures can significantly reduce the inflow computation uncertainty.

ACKNOWLEDGEMENTS

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