TRIALS & TRIBULATIONS OF MODELLING A SMALL URBAN WATER SUPPLY

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ABSTRACT

This paper will demonstrate some of the 'trials and tribulations' that can be experienced when modelling small urban water reticulations. Important aspects of a water supply model build include collection of data pertaining to the network, identification of the reticulation operational regime, collection of data for use in calibrating the model and calibration of the model itself.

The process of obtaining reticulation information from the various sources it can be held in and some examples of a number of issues that have been encountered when building or updating a water supply model will be considered.

It is very important to clearly understand the operational regime when modelling a water supply reticulation. Significant communication and meetings with the water supply operators is required to ensure the model reflects what is actually happening in the network.

A field test is carried out to confirm the operation of the reticulation. There are a number of things to take into consideration when choosing the locations for the temporary data loggers installed for the collection of data. Once the data has been collected it is used to ascertain whether or not the model reflects reality. Any differences must be investigated before changes are made in the model.

In summary, there are many areas that can be a 'trial and tribulation' when building or updating a model of a small urban water supply and examples of some of these will be shared and discussed.

KEYWORDS

Modelling, Water Supply, Calibration, Data Loggers

1 INTRODUCTION

There are a number of stages to a model build and calibration project. Throughout the process data and information is collected for input into the model. In order to develop the best possible model it is important to have the best inputs into the model that you possibly can.

At the start of the process physical data pertaining to what is actually in the ground is collated, usually from GIS and Asset Management systems. Operational data is required so the model can be set up to operate in the same way as the real network. If these inputs are not accurate then the completed model will not reflect what is happening in the system.

To determine if the model is accurate a model calibration exercise needs to be carried out. Again data needs to be collected for this. Telemetry and data logging information relating to flows and pressures within the reticulation is collected, but again if this data is not accurate the model will not reflect reality.

Therefore it is very important to do consistency checks on the data collected at all stages of the modelling process.

2 DATA COLLECTION & MODEL BUILD/UPDATE

Before a model can be constructed some base physical data is required for import into the modelling package. The data required is the same for a complete model build or a model update but how it is applied may differ. When initially importing node and pipe information into the model it is a good idea to consider whether the choices made at this stage will have implications when it comes to updating the model in the future.

2.1 MODEL BUILD

Currently data is imported directly from GIS packages into modelling packages. Importing data directly is a very convenient way to get the data into the modelling package, however issues can be present in the GIS data and checks should always be carried out.

For older reticulation systems (pre computer age) the data has been entered into the GIS off paper as-built plans. If the as-built plan was not absolutely clear a default value may have been entered into the GIS for lack of better information. This is not a problem as long as the default value is obviously a default i.e. not something likely to be mistaken for an actual value - for example 999.

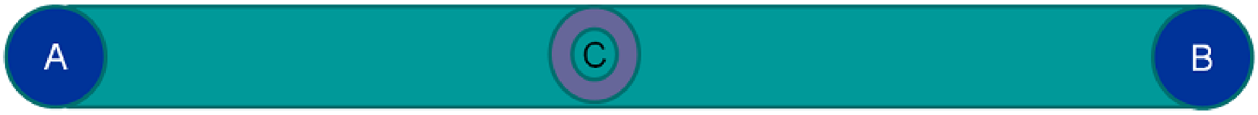
Issues arise when the default values used are found throughout the dataset. For example, it is not wise to use 100mm dia as the default pipe diameter and Asbestos Cement (AC) as the default material. These are both very common values and a considerable amount of time investigating paper plans will be required to determine where the actual 100mm dia AC pipe is and where default values have been used but the real pipe diameter and material is something different.

2.2 MODEL UPDATE

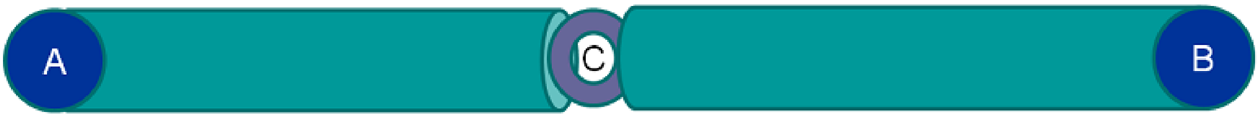
The best option to employ when updating a model can often be determined by the choices made when the model was initially constructed. As software has been developed more elements can be included in the model. It is possible to model all appurtenances, especially hydrants and valves, in the reticulation but these do need to be snapped into the pipe they are sitting on for modelling purposes.

In some GIS datasets the hydrants and valves just sit on top of the pipes rather than being a connected part of the network. Figure 1 below shows this situation. The pipe at the top is the GIS example – there is one pipe A-B and the hydrant C is sitting in space not connected to anything. The pipe at the bottom is the model example – there are two pipes A-C and C-B and the hydrant C is joined into the system.

Figure 1: GIS vs Model Hydrant



One Pipe – A to B, Hydrant C is not connected



Two Pipes – A to C and C to B

Snapping the hydrants and valves into the pipes in the modelling software can create issues when it comes time to update the model as the model network will be appreciably different from the GIS if all of the valves and hydrants have been snapped in. So updating the model will not be a case of getting a current GIS data set and pushing a button to import it into the modelling package.

Options for updating the model include importing a dataset that only has changes made to the GIS since the last model build/update or updating the model manually with identified changes. However, if the reticulation has changed substantially since the model was last built/updated an entirely new import from GIS may be the best solution.

3 OPERATION OF THE NETWORK

Getting the operation of the network correct is a very important consideration in the model build process. This can involve numerous meetings with operational and asset management staff. The operation of the network may be in conflict with the Asset Managers understanding and this could be due to unknown operational changes made by the local operators to provide the consumers with an uninterrupted supply of water. The analysis of field data will confirm the operational regime of the reticulation and that the model represents the water supply reticulation.

3.1 PRESSURE REDUCING VALVES (PRV's)

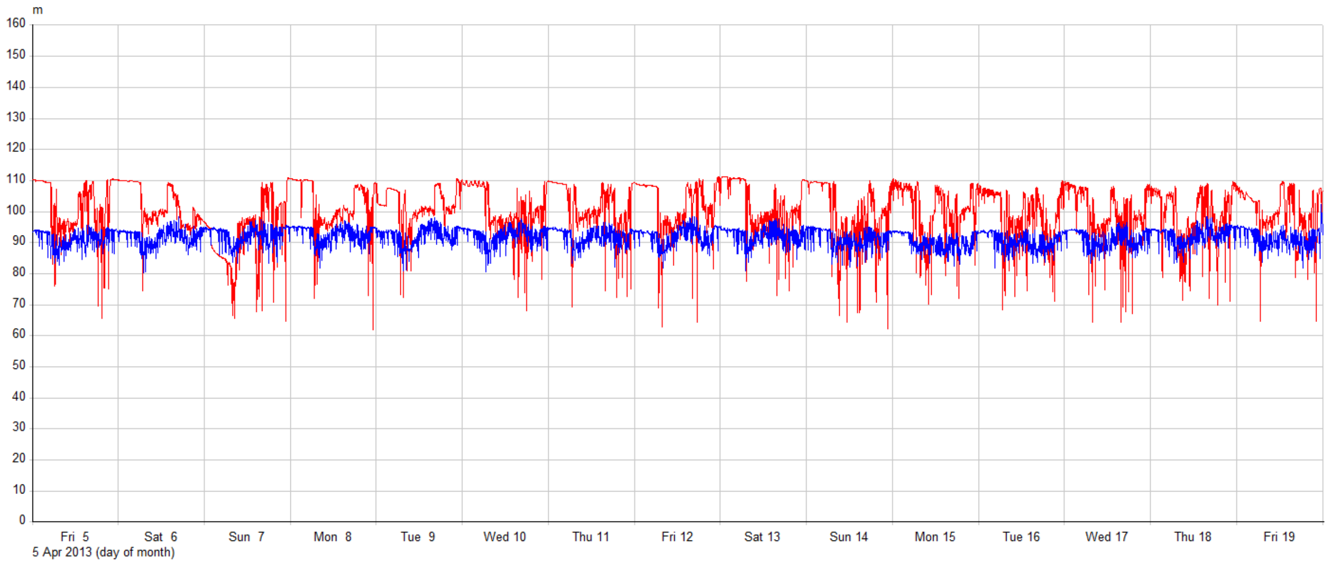
Pressure Reducing Valves are a very important facet in the operation of small water supply reticulations however they are often poorly maintained or not installed in the correct manner. The PRV is expected to maintain a set pressure downstream of the valve and it must be able to operate within the various flow demands that an area requires. A pressure reducing valve is often installed for some of the following reasons:

a) To reduce pressures in low lying parts of a reticulation, where the supply has large variations of ground level
b) To reduce pumping costs
c) To mitigate the effect of the introduction of an additional high level source

It is very important that the correct type and size of pressure reducing valve is installed and that it is appropriate for the control job required, especially in small urban water supply reticulations. A PRV should be selected for each individual pressure zone or purpose. Some PRV's have a controller that enables them to provide a varied downstream pressure based on the flow through the PRV. A lower flow results in a lower set point, which is good for leakage reduction and pressure management. However, some of these valves are not suited to dead end service and if they are installed in a location that is a dead end they will not operate as planned.

Figure 2 shows the pressure in two different zones supplied by modulated PRV's that were not suited for dead end service.

Figure 2: Pressure in Pressure Reduced Zones



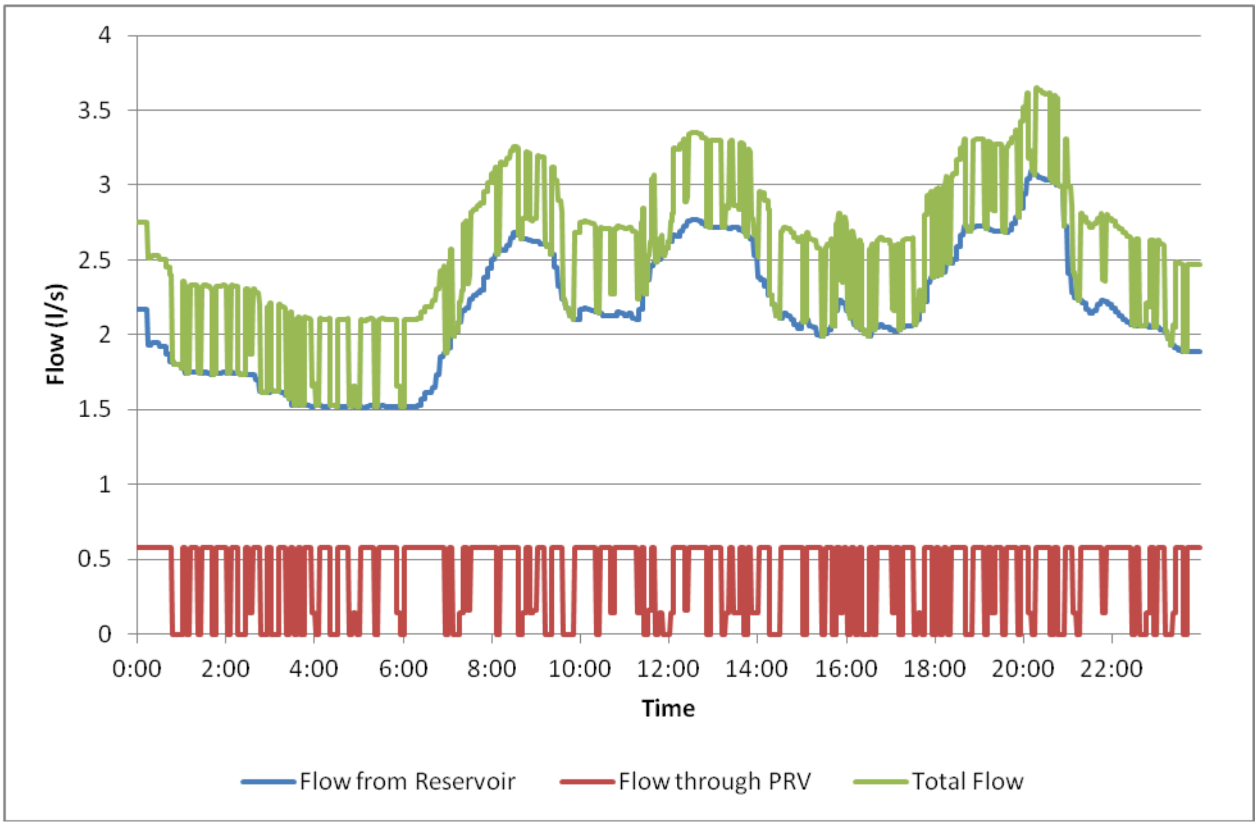
It can be seen that there are significant pressure fluctuations in these two small zones and there are still very high pressures in these areas.

There can also be issues when a PRV is one of a number of supply points for a zone. Figure 3 shows the flows into a small supply zone. The blue line is the main flow into the zone out of a reservoir. The red line is the backup flow into the zone via a PRV and the green line is the combined flow through the two meters.

The operational expectation was that the PRV would operate during higher demand periods to maintain the pressure in the zone. However, when fire flow tests were carried out at the end of the zone the PRV flow remained as shown on Figure 3. The setting of the PRV was at a level that meant it did not open significantly during these fire flows. This was due to the size of the reticulation restricting the fire flow availability at the end of the zone and the pressures at the start of the zone not being significantly affected by the fire flows.

The other issue here is that the flow spikes up and down through the PRV meter at a very low level. This kind of behaviour is usually due to the coarseness of the pulse unit collecting data from the meter – for lower flows a smaller 'scale factor' is required to obtain a smoother line. The scale factor represents how much flow has passed through the meter for every pulse received so a smaller scale factor of 0.001 has 1 litre passing through the meter for every pulse and a larger scale factor of 0.1 has 100 litres passing through the meter for every pulse.

Figure 3: Flows into the Supply Zone



A third issue with PRV's can be locating and accessing them. Sometimes the pits that the PRV's are situated in are close to consumers gardens and they can become 'lost' in the shrubbery. The top left picture in Photograph 1 shows a groundcover bush that was totally concealing a PRV chamber. Because the lid was large the chamber was able to be located at the time. The top right picture shows a garden built over a second PRV site. This PRV was unable to be located during the site visit and further visits were required by operational staff to find the chamber.

By not having the PRV chambers clearly marked and free from plantings extra time was required to locate and access these. Additionally, PRV's should be maintained on a regular basis and for this easy access is required.

Photograph 1: PRV Locations and Pit Sizing

As well as being able to access the PRV site the chamber itself needs to be user friendly. The bottom left picture in Photograph 1 shows a PRV in a manhole chamber. The chamber lid was a manhole cover and it can be seen that there is very little space around the PRV, making it very hard to carry out any maintenance work on it. The bottom right picture shows a PRV in a much larger rectangular pit. This chamber had a hinged lid that allowed easy access to the chamber and there was plenty of space around the PRV so maintenance could be carried out easily.

Ease of access to these PRV chambers is also important for the installation of data loggers during a field test.

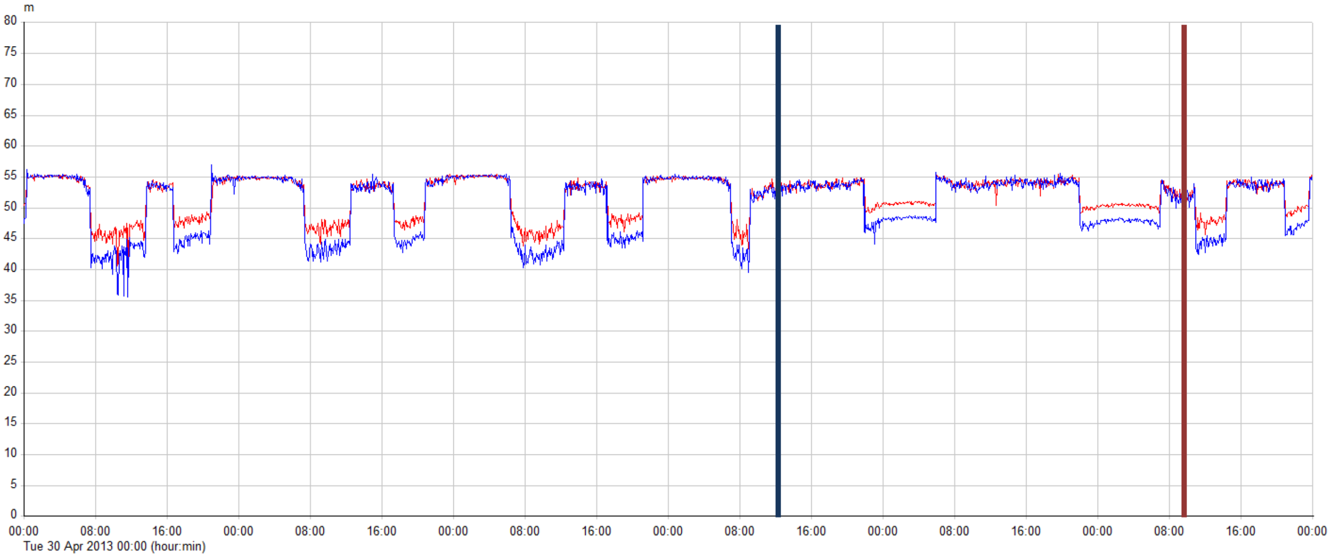
Pressure reducing and closed zonal valves should not be included in any water supply reticulation model unless there is confirmation by operational staff and the asset manager that a valve is installed. A site investigation, however difficult, should be undertaken to ensure that the model will reflect the field data collected. As an example, a field test was undertaken on a small urban supply and the pressure data collected showed much lower pressures at one site in the reticulation. The model was consequently constructed with a PRV present in the model and a small pressure zone isolated from the main reticulation. When updating the model at a later date, it was discovered that the original pressure data was in fact obtained from the adjacent irrigation reticulation. This type of experience shows that including PRVs as a fix is not the correct path to follow.

In the majority of small urban water supply reticulations a flow meter is not installed at PRV stations and this type of practice should be discouraged. Modelling of pressure zones does require the flow at PRV locations to ensure the model is a more accurate representation of the actual reticulation. Installing a flow meter is a cost effective practice as it allows the asset manager and operational team to manage the system more effectively.

3.2 RESERVOIR FILLING

How a reservoir is filled can have a significant effect on pressures in the water supply network if the reservoir is filled through the reticulation. Figure 4 shows the pressure in the reticulation at two hydrants in a small water supply where the reservoir is filled on demand through the reticulation.

Figure 4: Pressure Drops due to Reservoir Filling



The first 3½ days (prior to the vertical blue line) shown on the graph illustrate that when the reservoir is filling the pressure in the reticulation is dropping by up to 15m. This is often occurring during the peak daily demand periods of 7:00am-9:00am and 5:00pm-7:00pm. Towards the end of the data logging exercise the operational regime was adjusted and the reservoir was only filled between the hours of 10:00pm and 6:00am in an effort to cause less pressure disturbance to consumers during the day. The last 2½ days (between the vertical blue line and the vertical red line) show the reduced pressure drop with the reservoir filling overnight and a constant pressure for consumers during the day.

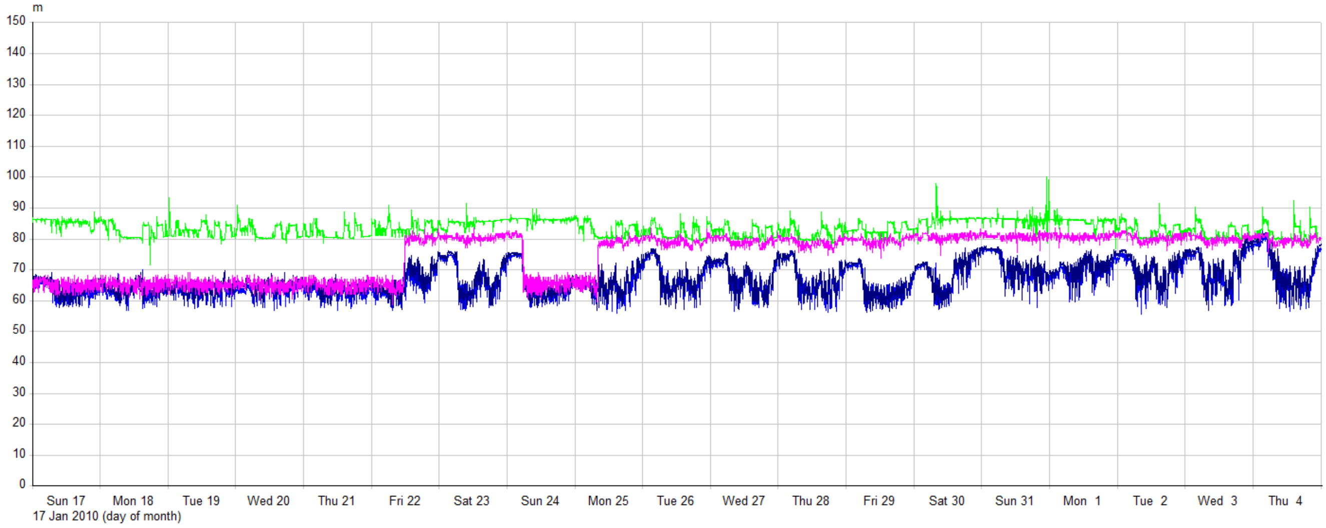
Changes to operational procedures can significantly impact what is occurring in the reticulation. Another way of operating this reservoir would be to fill it at a lower rate over a 24 hour period to avoid the pressure fluctuations that are currently occurring.

A further example of confirming reservoir operation by collecting data is by doing something as simple as taking meter readings at the inlet/outlet of the reservoir. In a water supply zone the reservoir was supplied through the reticulation from the main water treatment plant pump station. The inlet/outlet pipe to the reservoir was a push/pull operation with a meter that recorded both forward and reverse flow installed. Meter readings were taken on 24th September and then again on 13th October. Over this 20 day period the flow into the reservoir was 5,870m³ and the flow out of the reservoir was 4,490m³. This left 1,380m³ of water that entered the reservoir via the inlet/outlet pipe unaccounted for. Investigation into this found that the reservoir was overflowing on a regular basis.

3.3 ZONE BOUNDARIES

Operationally it is important to know if zone boundary valves are water-tight and maintaining separate zones as planned. Figure 5 shows the results of data logging around a small pressure reduced zone. A PRV supplies properties from one end of the zone and at the other end a closed valve prevents water from passing between the pressure reduced zone and the adjacent zone.

Figure 5: Zone Boundary Issues



On this graph the elevation at each logging location has been added to the pressure data to give the head in metres Above Datum (mAD) for each site. The green line is the upstream head of the PRV supplying the pressure reduced zone, the blue line is the head in the pressure reduced zone and the purple line is the head in the adjacent zone. During the logging exercise the pressure in the adjacent zone (purple line and also supplied through a pressure reducing valve) changed on three occasions. On all three occasions the pressure in the small pressure reduced zone (blue line) was affected by the adjustments in the adjacent zone. The valve between the zones was not operating as intended and needed to be checked.

4 FIELD DATA COLLECTION

Flow and pressure data throughout the reticulation needs to be collected for use in model construction and model calibration. This can be from telemetry sources or from data loggers. It is important that the rate of data collection is at the same time interval, e.g. 5 minutes, from all the various sources. Data at different time intervals will make it more difficult for the modeller when it comes to calibrating the model.

4.1 TELEMETRY DATA

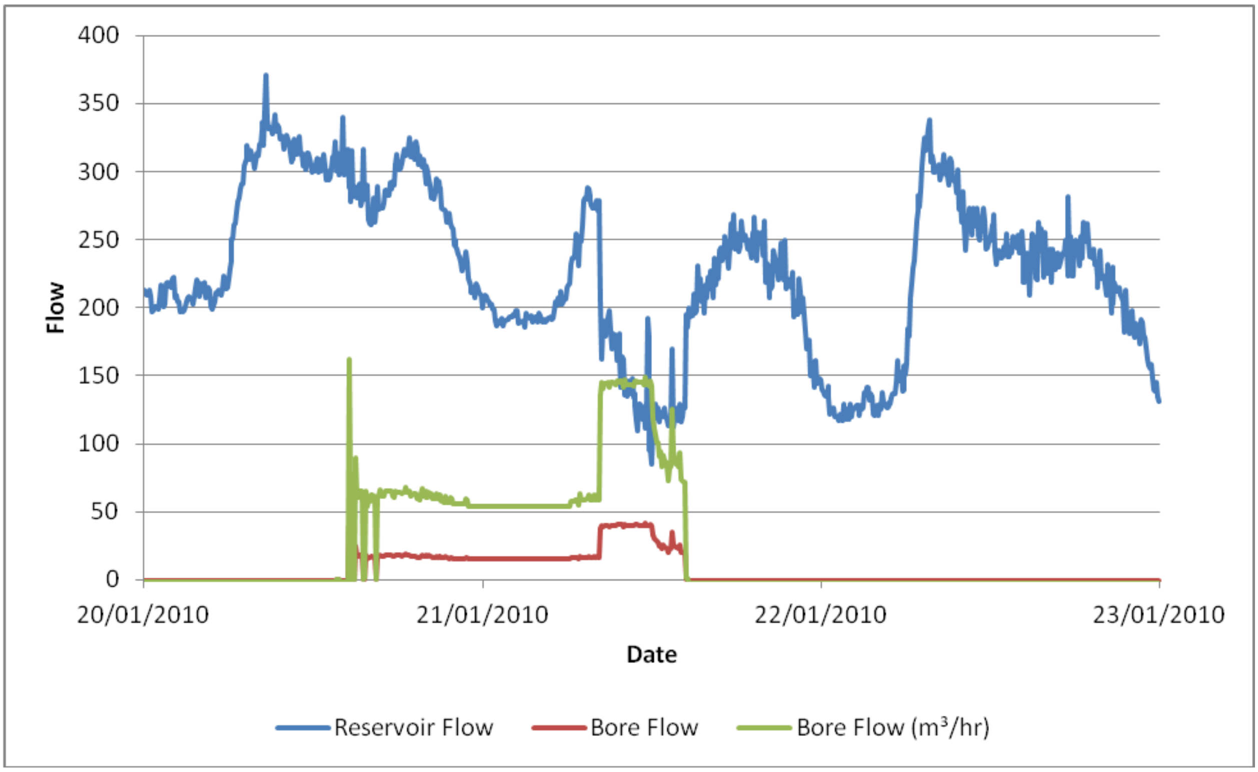
Telemetry data are often provided in a .csv or excel spreadsheet format, which makes it extremely easy to graph. Graphing the data is essential to help discover any discrepancies that may exist. The accuracy of all telemetry data should be investigated as incorrect data may lead to erroneous assumptions when building the model.

4.1.1 FLOW DATA

Telemetry data was supplied for a network that is normally supplied from a WTP reservoir but has a bore supply to supplement the demand if the level in the river supplying the WTP reservoir is too low. Figure 6 shows the flow out of the WTP reservoir (blue line) and the flow out of the bore (red line). On 21st January there is a large drop in flow out of the WTP reservoir which coincides with an increase in flow out of the bore. However, the scale of these changes is very different – the WTP reservoir flow drops by approximately 90 units but the bore flow only increases by approximately 25 units.

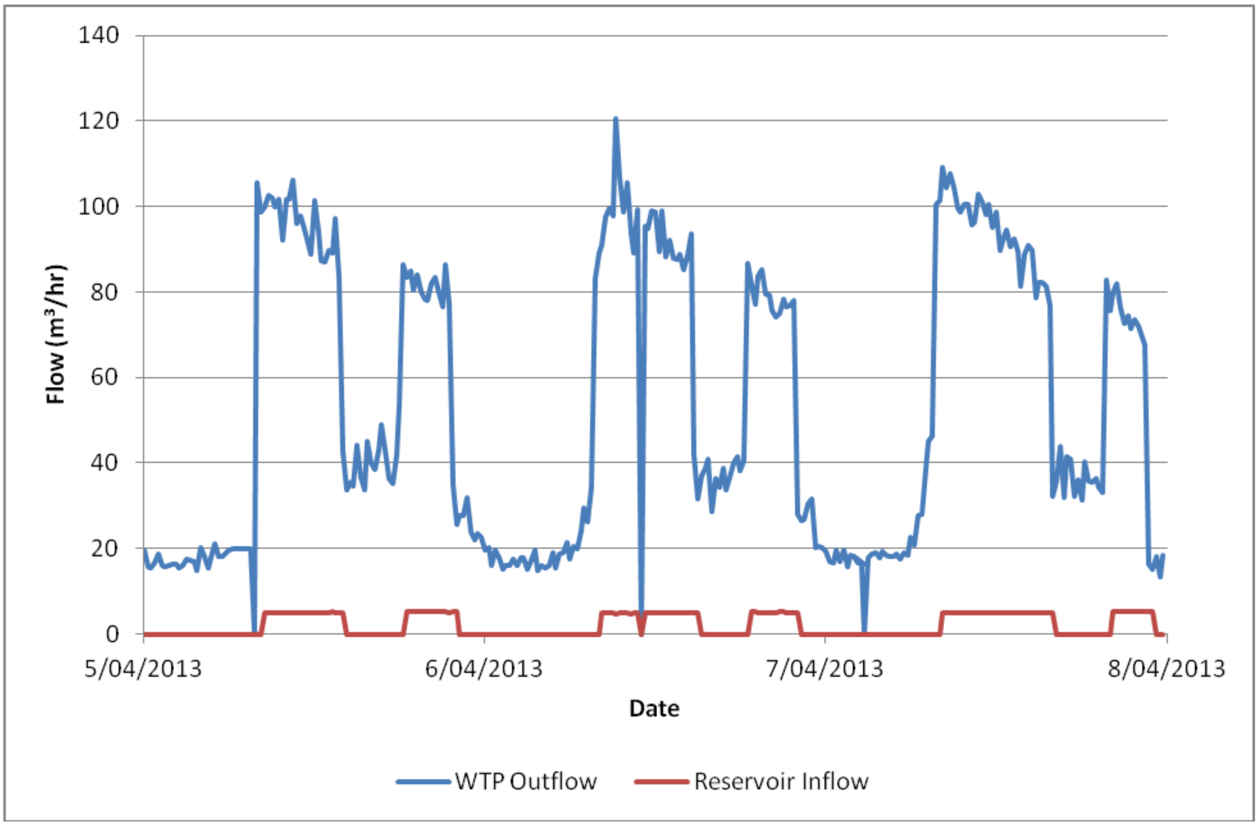
Within this particular telemetry system there is a mix of units. The flow out of the WTP reservoir is in m^3/hr but the flow out of the bore is in l/s. When the flow out of the bore is converted to m^3/hr and graphed (green line) the scale of the change is much closer.

Figure 6: Flow Units Discrepancy



Another example of flow discrepancy was discovered in a different water supply reticulation when comparing the flow out of a Water Treatment Plant with the flow into the main reservoir it was supplying. Figure 7 shows that the flow coming out of the WTP was significantly higher than the flow going into the main reservoir. On investigation it was confirmed that this was a scaling issue with the flow going into the main reservoir. In addition the flow out of that same main reservoir was also incorrectly scaled as it matched the flow filling the reservoir – so graphing the flow into and out of the main reservoir would not have shown the discrepancy.

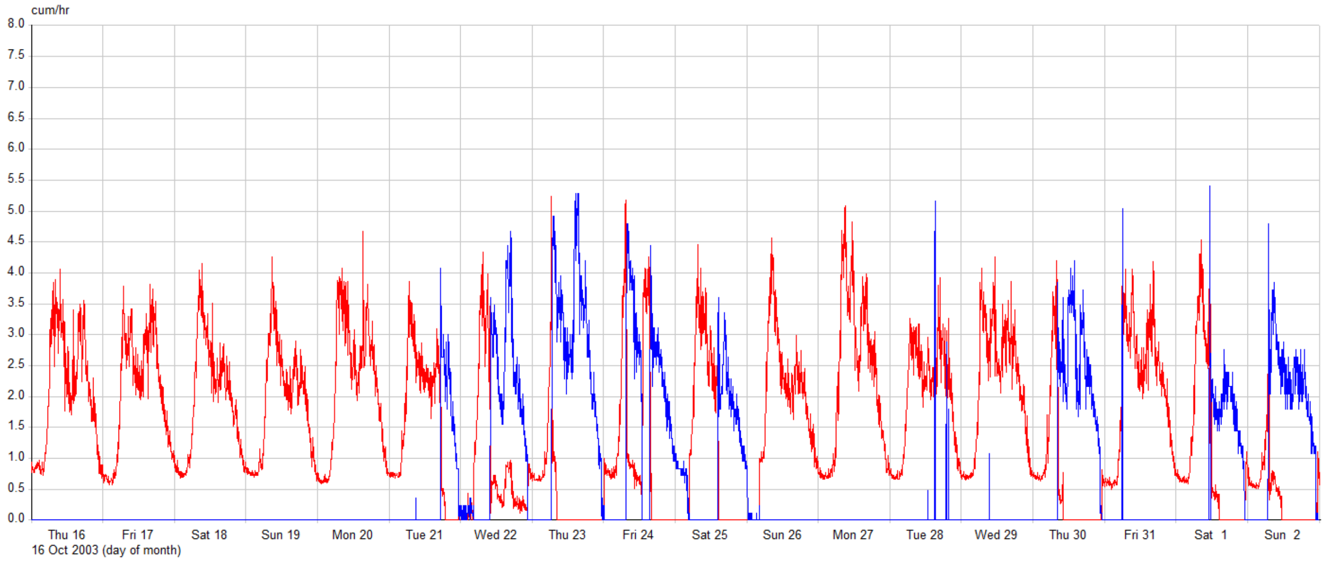
Figure 7: Flow Discrepancy



A very interesting anomaly arose from data logging two meters that were on telemetry. From two reservoirs, two metered trunk mains supply a small town. The trunk mains are interconnected before and after the meters. Both meters are combination meters with a main flow and a bypass flow. All four of these meters had pulse outputs, which were being collected by the telemetry system and graphed as a single line for the total flow into town. Therefore how flow was being distributed down the two mains could not be determined from the telemetry.

A data logging exercise was undertaken on all the meters and each pulse output was logged separately to distinguish how the flow was distributed between the trunk mains. Figure 8 shows the result of the data logging through the two main meters only as the flow through the two bypass meters was negligible.

Figure 8: Flow through one meter or the other



This graph shows that when one meter is operational the other is not, and the main that provides the majority of the water is the smaller, older pipe (graphed in red). These meters do not provide flow at the same time; it's one or the other. This could be due to consumer use in the reticulation with demand in certain locations causing a change in the operation.

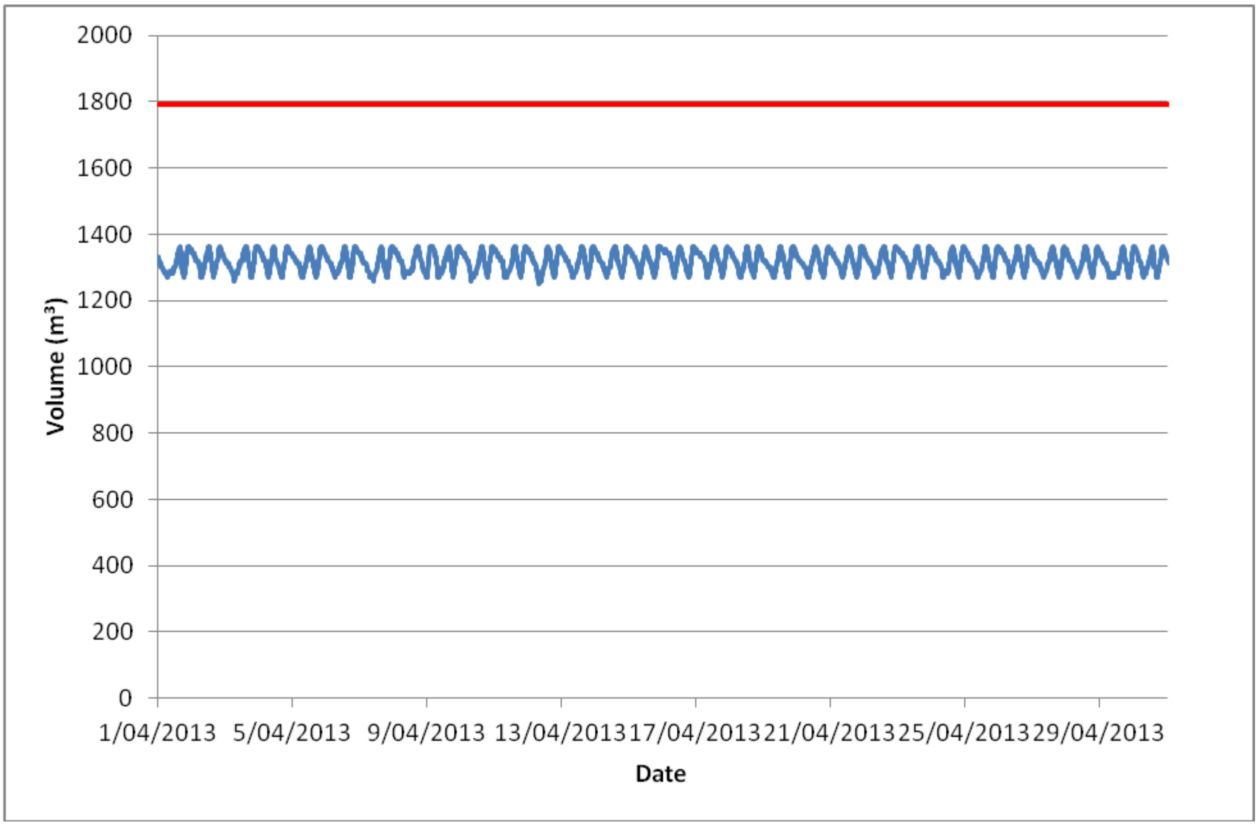
When calculating demand and ascertaining the water use profile for a small water supply reticulation it is important that a water balance is carried out between the mass of water produced by the WTP and the demand used by the consumers. An interesting problem occurred when this type of calculation was undertaken at a WTP. This particular WTP had a meter on the outlet pumping main which was supplying water directly to the reticulation and the main reservoir. Calculations showed that there was approximately 40% more water being used in the reduction than being produced by the WTP. On closer examination it became apparent that there were two outlets to the WTP into the reticulation and the second one was not metered

4.1.2 RESERVOIR LEVEL/VOLUME DATA

Reservoir level data can be provided in Telemetry systems in terms of a percentage, a level in metres or a volume in m³.

Recently telemetry data provided as a volume of water in the reservoir showed an operating volume between 1,270m³ and 1,364m³ (blue line). However, the previous model and Asset Management Plan data had the total reservoir volume as 1,790m³ (red line). This difference is under investigation but it could be explained by the fact that the operator was not using the total volume of the reservoir so as to ensure that there were no water quality issues for the consumers. Alternatively it could be that there is a hole in the overflow pipe at that level.

Figure 9: Reservoir Volume Discrepancy



4.2 DATA LOGGERS

4.2.1 LOCATION AND INSTALLATION

Choosing locations for the collection of pressure and flow data for small urban water supply reticulations can be very complex, especially if the reticulation has a variety of small zones. The key to success, when carrying out a field test, is in the planning and the communication between the operators, asset managers and the modeller.

A common practice within New Zealand is to use one pressure logger for every 250 properties. However, with small urban water supplies this may prove to be too coarse as it may not cover all the small discrete zones or long lengths of small mains which are typical for this type of reticulation.

Installing additional loggers throughout a reticulation to monitor small pressure zones and long lengths of reticulation is a very cost effective exercise as it will provide information that is useful to the client. In addition, the standard practice for the length of the monitoring period is two weeks. Again, extra weeks of monitoring will be a cost effective solution if some alternative operational regimes can be investigated during this period.

Data loggers for monitoring pressure during a field test should ideally be installed at high points in the reticulation and in known problem areas. Once these locations are covered then a sample of other locations spread throughout the reticulation can be chosen.

Flow monitoring of reservoir inlets and outlets, small zones and PRV sites is essential during calibration exercises and clients should be encouraged to install meters because they will also find the data very useful in their day to day management of the reticulation systems.

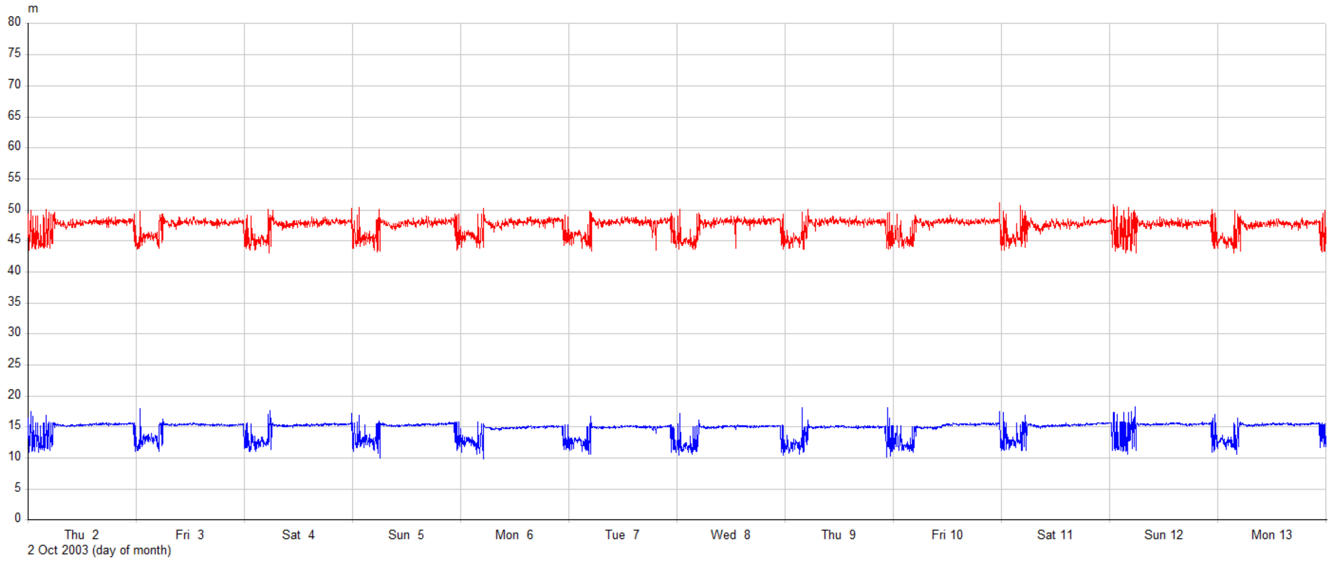
Monitoring the consumers with the largest demand, for both flow and pressure at the boundary of the property, within the reticulation is essential as the alternative of using assessed 8/12/16 hour demand profiles may lead to a large source of errors during the calibration process.

4.2.2 PRESSURE LOGGING

As well as providing data for calibration pressure logging can aid in understanding what is occurring in the reticulation.

An interesting pressure anomaly was recorded when data logging a small coastal township. The pressure data loggers at all 11 sites showed a drop of 3-4m daily between midnight and 5:00am. The pressure results for two of the sites can be seen on Figure 10.

Figure 10: Regular Pressure Drop



The township is supplied by gravity from a reservoir and there are no pump stations or control valves in the reticulation. At the reservoir there is a combination meter to monitor the flow into the network.

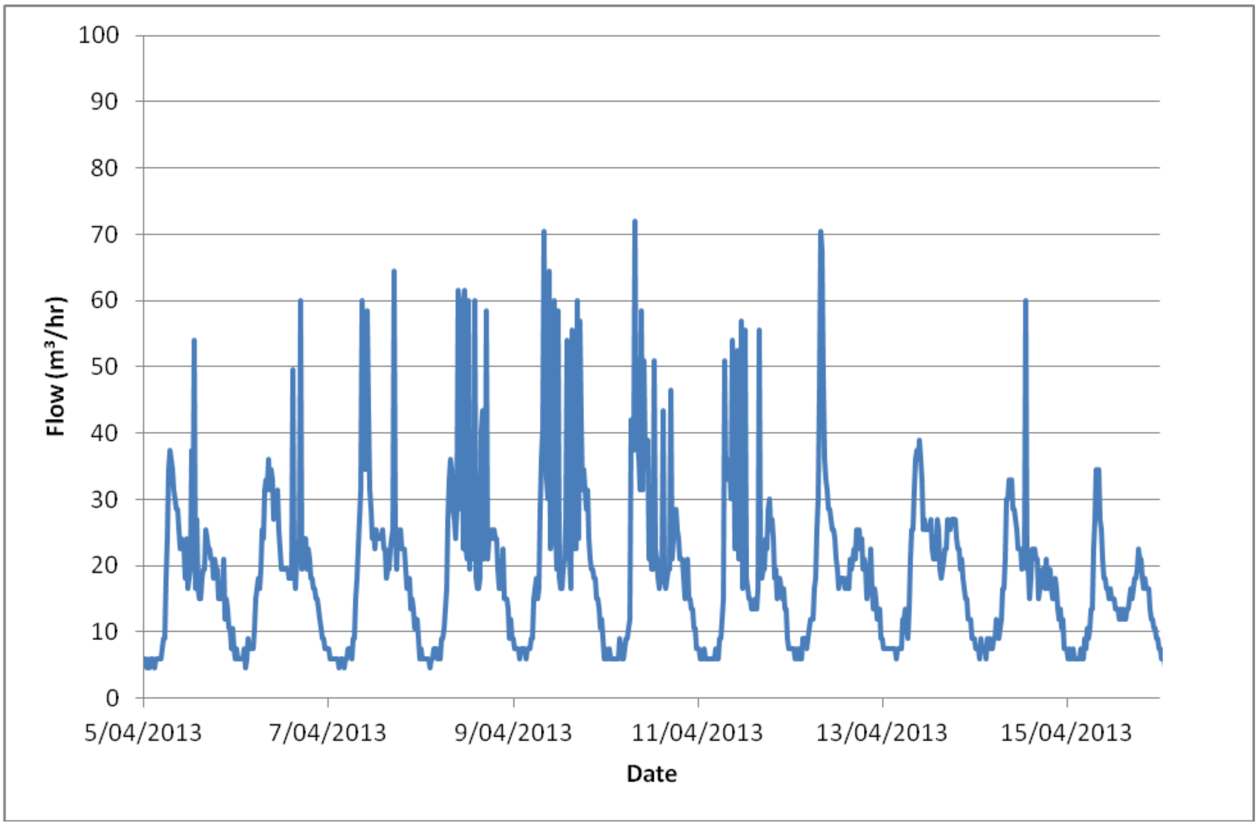
Investigation into this pressure drop found that it was due to the location of the combination meter. This was very close to the reservoir and for low night flows there was not enough flow to open the main meter but enough flow to cause 3-4m of head loss through the bypass meter. If the meter was located further from the reservoir, with a higher pressure it was felt that this pressure drop would be removed.

4.2.3 FLOW LOGGING

It is very important to monitor meters throughout the reticulation to gain an understanding of what is happening in the system. Both bulk meters and large consumer meters should be logged. In addition, the provision for logging pressure simultaneously at large consumer meter should always be encouraged.

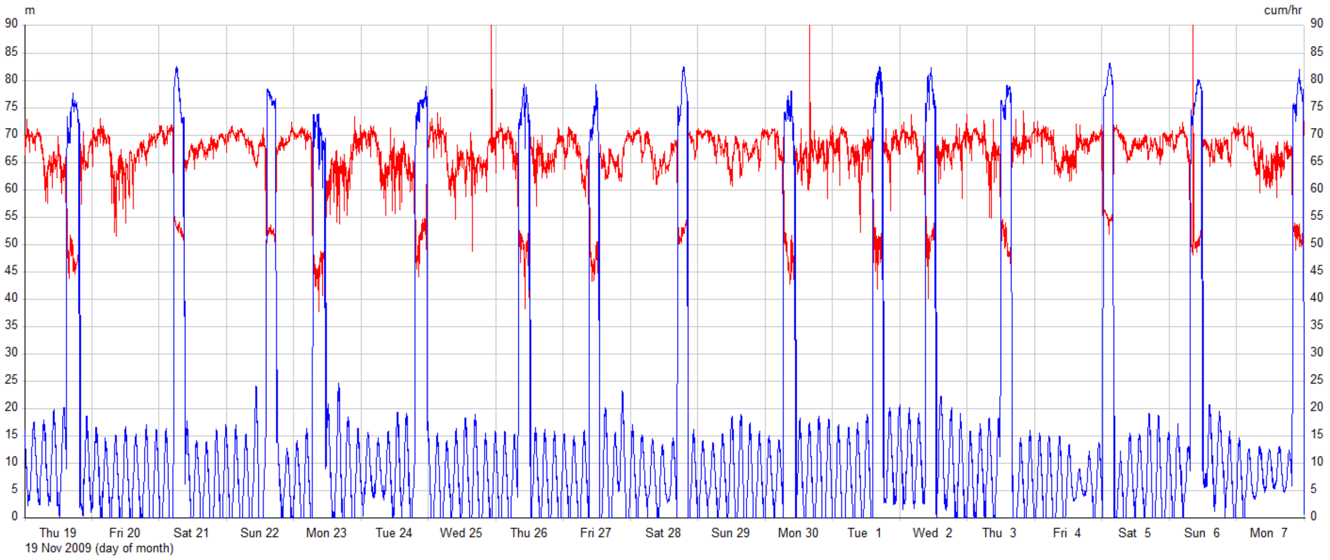
Figure 11 shows the flow through a bulk meter on the outlet of a reservoir. This reservoir has a tanker filling station adjacent to it. The increase in flow when the tanker filling station is operating can be clearly seen. Even though the filling station is right by the reservoir the operation of it has a significant effect on the pressure throughout the rest of the reticulation. The set up of this could be changed to have less effect on the rest of the consumers when tankers are filling.

Figure 11: Tanker Filling Flow Spikes



Another demand that can significantly affect the reticulation is that of large consumers. The way they take water can cause pressure reduction in the water supply adjacent to their location and further afield. Figure 12 shows the demand from a large consumer (blue line) and the pressure in the reticulation near the demand (red line).

Figure 12: Large Consumer Flow



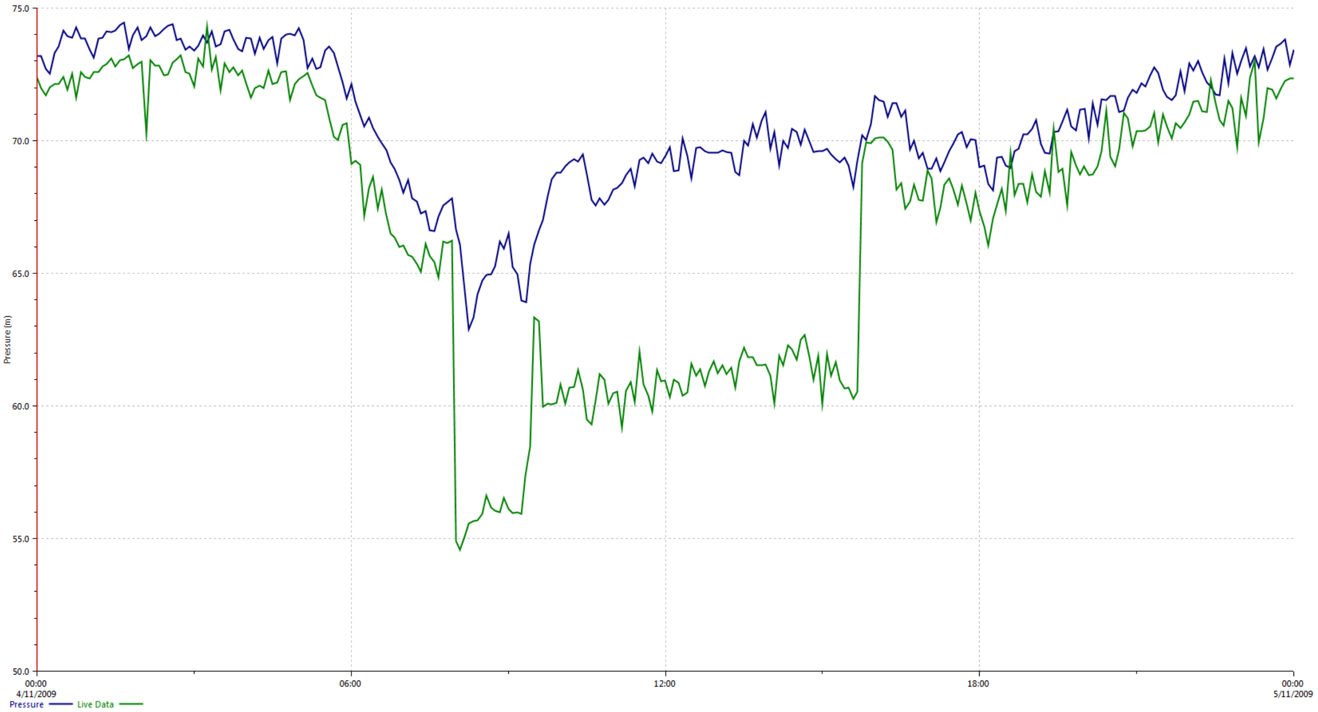
When this consumer fills their tank the inflow is approximately 80 m³/hr and the pressure drop in the reticulation can be up to 20m. Also the tank filling is sometimes during the peak demand period. Sudden changes in pressure are not good for the life of the pipework and may cause customer complaints. The operation of the large consumer could be changed to fill their tank at half the current rate outside of peak demand times.

5 MODEL CALIBRATION

Model calibration is carried out to ensure the model results are similar to what is occurring in the actual reticulation. There can be times when the first comparison of model results with Live Data is very different.

The first model simulation result in a town initially showed a discrepancy between the model results and actual data between 8:00am and 3:40pm for all pressure locations. The worst of these is shown on Figure 13.

Figure 13: Before Calibration Actions



Some investigation was carried out into these differences and it was determined that there was potentially a point demand of up to 20l/s occurring at a location in the reticulation during the time that the pressures are significantly different. This demand occurred throughout the logging period at different times each day and for different lengths of time each day. It did not correlate with any of the monitored demands from the known large consumers in town.

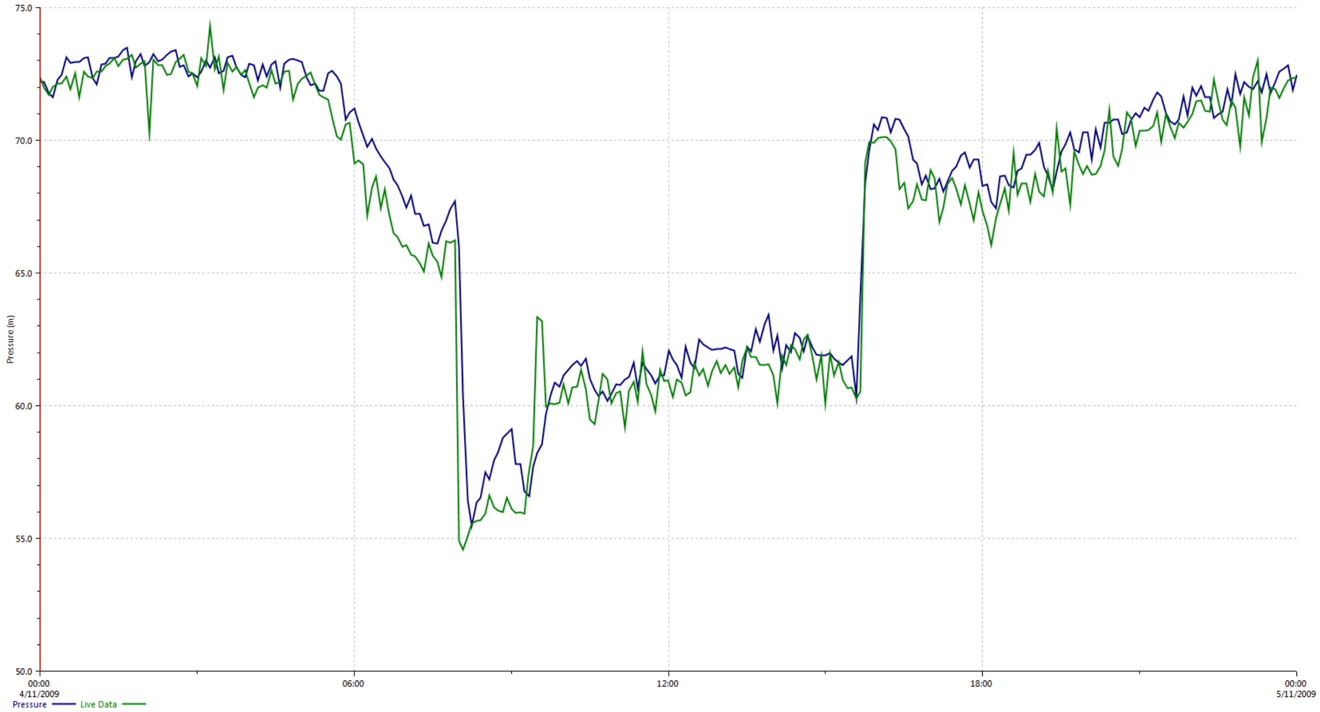
As the pressure profile was worst at the location in Figure 13 it was suspected that the extraordinary demand was in this area. Subsequent enquiries determined that there is a public swimming pool in this area that could be consuming the water. This pool was unmetered and was also suspected of having a water leak.

Once this extraordinary demand had been included the modelled and logged pressure profiles throughout the wider reticulation were much closer together.

However, the pressure nearest the additional demand was still not close enough to be considered calibrated. The Live Data was still showing a much greater pressure drop during the extraordinary demand than the model. There were four possible ways for water to enter the area where this data logger was situated. One of the feeds was a 150mm dia directly off a trunk main and the other three were 100mm dia off a different trunk main.

In order to get a larger pressure drop in the model a valve on the 150mm dia supply pipe was closed. This caused the pressure to be lower in the model but it still was not as low as the Live Data. A second valve was closed on one of the 100mm dia pipes supplying the area and the model results were in very good agreement with the logged values.

Figure 14: After Calibration Actions



In addition, closing the 150mm dia connection caused the flows going through the two trunk main meters to become very close to the Live Data, providing further information suggesting that there is one or more closed valves in the area. The Asset Manager and operations team need to continually monitor their reticulations and assess the data that is available to ensure the operational regime is fully understood.

6 CONCLUSIONS

In conclusion, it is very important to do consistency checks on the data collected at all stages of the modelling project, from the base data imported during the model build to the field data obtained for model calibration. Additionally, it is essential to have open communications between the asset managers, operations staff and modellers.

Pressure reducing valves need to be appropriate for the control job they are required to do and ease of access for maintenance purposes should be considered when choosing final locations and designing the PRV pits. Always confirm installed appurtenances before including them in the model. Putting them in as a ‘quick fix’ for unexplained data is not recommended.

Reservoir levels and filling regimes need to be accurately reflected in the model as these can have a significant effect on the wider reticulation.

Collection of data for the calibration process should be completed at the same time interval e.g. 5 minutes and ensure that the same units are used during data review. Installation of data loggers should take into consideration the number of discrete zones, long lengths of ‘rural’ mains and the operational regime of the water supply.

It is also important to remember that a model is always a work in progress and a perfect model calibration may not be achieved on the first pass. If the data collected shows discrepancies, investigate what is really going on and collect further data to aid in understanding the system. As part of this the asset managers and operational staff should be encouraged to continually monitor and assess the reticulation to ensure the operational regime is fully understood.

REFERENCES

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