SEASONAL VARIATION IN SEWERS, HOW IT CAN AFFECT YOUR PERCEPTION OF SYSTEM PERFORMANCE

Author : Thomas Joseph - AWT Water Limited

Presenter : Thomas Joseph - AWT Water Limited

ABSTRACT

In a typical sewer master planning project it is common to undertake monitoring and hydraulic modelling to determine optimised strategies and capital works programmes. In most cases short term rainfall and flow monitoring (8-12 weeks) is used to give a snapshot of how a wastewater system performs during a single wet season. Although this generally provides a sound basis to build and calibrate a network model it can sometimes skew our sense of system performance and ultimately the preferred set of options.

In this paper we will examine how long term monitoring significantly changed the model calibration and outlook on how the system performs. We will use the Whangarei sewer catchment as our case study which highlights dramatic seasonal differences in dry weather base flow and consequently inflow and infiltration estimates. These seasonal flow differences were unseen with the short term flow monitoring effort and this paper highlights the risk of using only a short snapshot of monitoring data to project long term trends and develop long term options.

KEYWORDS

Long Term Monitoring; Inflow and Infiltration; Sanitary Sewer Hydraulic Modelling.

1 INTRODUCTION

In this paper we will examine how long term monitoring significantly changed the model calibration and subsequent outlook on how the system performs. We will use the Whangarei sewer catchment as our case study which highlights dramatic seasonal differences in dry weather base flow and consequently inflow and infiltration estimates.

In early 2010 AWT built and calibrated a detailed hydraulic model of the Whangarei sewerage system for Whangarei District Council (WDC). The model output was subsequently used to develop high level options for the sewer network.

At the conclusion of the original 2010 monitoring campaign it was recommended to keep a core network of long term monitors in place to assist in understanding the seasonal variation in the catchment. The long term monitoring data was then used the following year to validate the original calibration and verify the system performance.

For demonstrative purpose in this paper we will examine the data from a single monitor located along the main trunk in the CBD (monitor 10852). Monitor 10852 was chosen as a good surrogate monitor as it reacts similarly to the other monitors in the catchment. The monitor is relatively low in the catchment and is susceptible to the high ground water table in the CBD. This paper highlights the journey through the modelling effort including the original calibration, validation, re-calibration, and updated system performance.

2 BACKGROUND

The Whangarei sewerage collection system services Whangarei City and the Whangarei Heads area.

The existing catchment is approximately 3,343ha. Infill development is anticipated within the existing catchment and an additional 5,444ha is zoned for urban development in the District Plan, Proposed District Plan and Coastal Management Plan.

The sewerage collection system consists of approximately 424 km of sewer pipes including rising mains and storage tanks ranging in size from 50 mm diameter to 2100 mm. The larger diameter trunk mains are typically concrete. The condition of the pipes in the network is largely unknown. According to GIS data the network was developed between 1901 and 2008. The network contains approximately 69 pump stations all of which are included in the model.

The Whangarei wastewater collection system carries the sewer flow for a population of 47,991 based on the 2006 Census data.

Land use within the township is predominantly residential with commercial and industrial activities in the CBD.

Soils within the area are predominantly clay and are not free draining. Parts of the network are below mean sea level. This results in considerable potential for inflow and infiltration into the aging wastewater network.

There are a number of known wet weather over flow locations in the system. These include constructed overflows at pump stations and overflows from manholes and chambers in the network.

3 MODEL CALIBRATION

The original model calibration utilised flow and rainfall monitoring data collected from March to June 2009. The original monitoring data revealed relatively large inflow and infiltration issues across the Whangarei catchment. Many of the monitors never returned to the base flows that were witnessed at the beginning of the monitoring period.

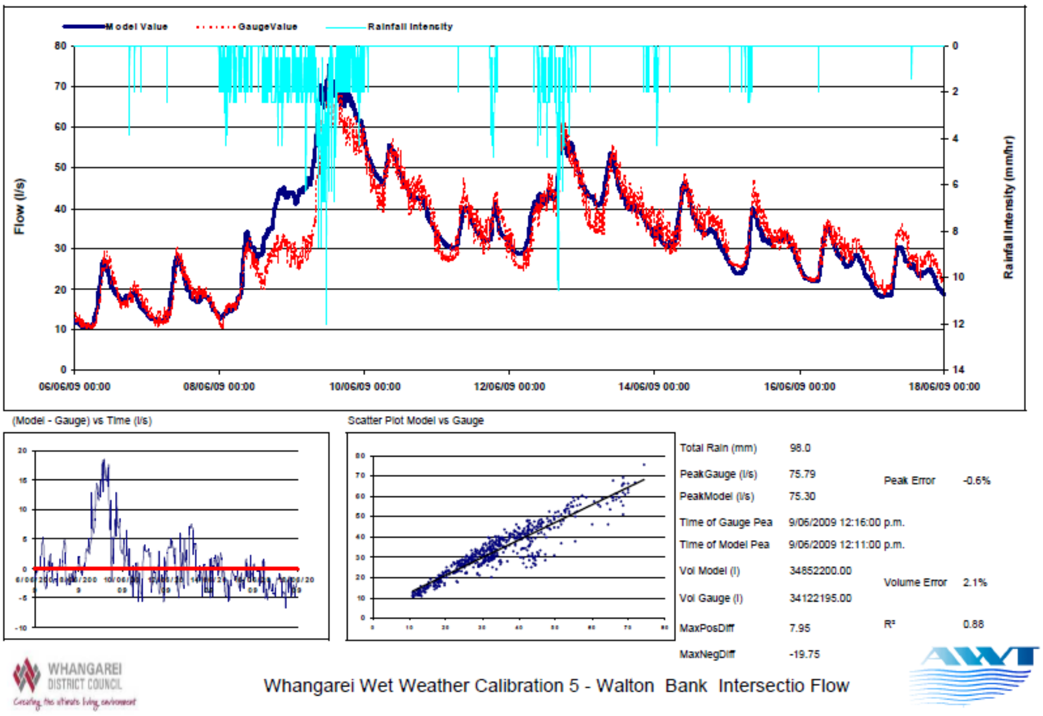
Overall, an excellent calibration of all 22 monitoring locations was achieved over the range of rain events that occurred during the original three month monitoring period.

Table 1 shows the general calibration results for monitor 10852 and Figure 1 is a calibration plot from one of the calibration events.

Figure 2 below highlights how the dry weather flow at 10852 never returned back to the base flow for the entire length original monitoring period. At the conclusion of the original monitoring period it was difficult to tell if the base flow witnessed at the start of the period was the true base flow or if it was already increasing from the preceding antecedent conditions. This phenomenon prompted us to maintain a core set of long term monitors in the ground to establish the true base flow across the catchment.

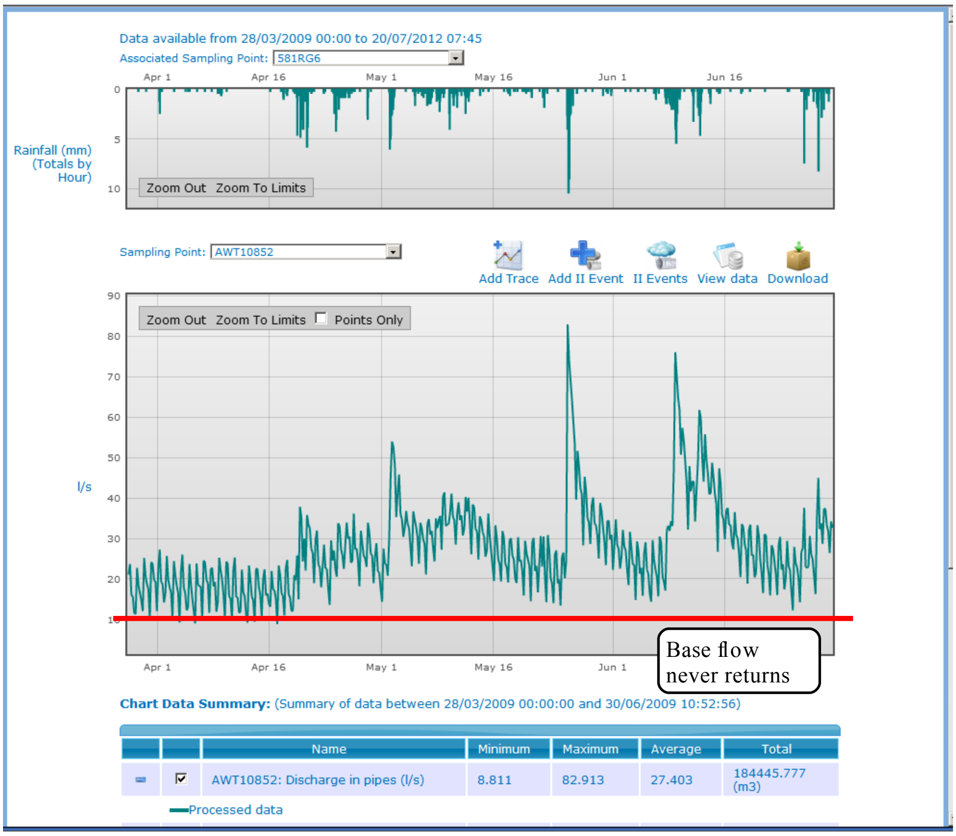
Table 1: Original Monitoring Period (winter 2009) - Flow Calibration Results Monitor 10852

Event	Volume Error	Peak Error	R^2
DWF	-2.1%	-5.9%	0.87
Event 1	11.5%	10.3%	0.80
Event 2	5.1%	3.9%	0.82
Event 3	-2.7%	-0.7%	0.77
Event 4	-7.5%	-11.4%	0.89
Event 5	2.1%	-0.6%	0.88



Total Rain (mm)	98.0		
PeakGauge (l/s)	75.79	Peak Error	-0.6%
PeakModel (l/s)	75.30		
Time of Gauge Pea	9/06/2009 12:16:00 p.m.		
Time of Model Pea	9/06/2009 12:11:00 p.m.		
Vol Model (l)	34852200.00	Volume Error	2.1%
Vol Gauge (l)	34122195.00		
MaxPosDiff	7.95	R^2	0.88
MaxNegDiff	-19.75		

Figure 1: Original Monitoring Period (winter 2009) - Flow Calibration Plot for Event 5 Monitor 10852



Data available from 28/03/2009 00:00 to 20/07/2012 07:45

Associated Sampling Point: 581RG6

Sampling Point: AWT10852

Chart Data Summary: (Summary of data between 28/03/2009 00:00:00 and 30/06/2009 10:52:56)

		Name	Minimum	Maximum	Average	Total
▭	☑	AWT10852: Discharge in pipes (l/s)	8.811	82.913	27.403	184445.777 (m3)

▬Processed data

Figure 2: Flow for the Original Monitoring Period (winter 2009) Monitor 10852

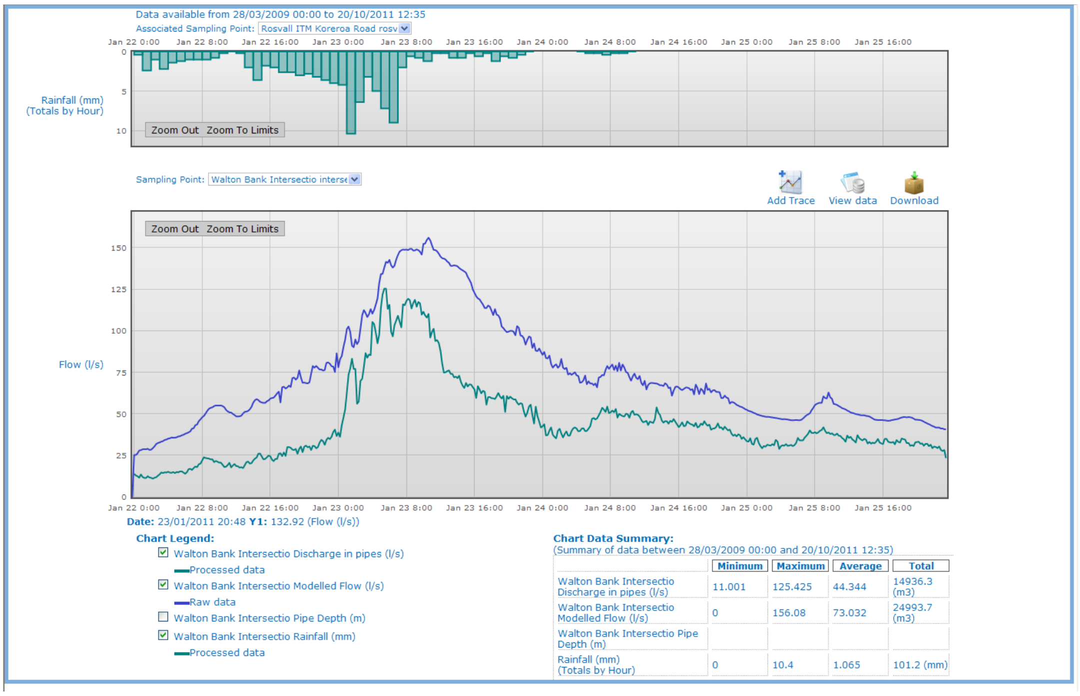
4 MODEL VALIDATION

As discussed above a core network of long term monitors were kept in place to assist in developing a better understanding of the seasonal variation in base flow. The model validation exercise essential consisted of running the calibrated model for the entire long term monitoring period (April 2009 – August 2011) and looking at the model performance compared to the monitored flow. The primary goal of the validation was to get an understanding of how the original calibration parameters performed over a long term wetting and dying cycle.

In general the model validates well in the proximity of the original monitoring period (winter 2009), however the further away from the winter of 2009 the model starts to significantly over predict wet weather flow. It was noticed that the original monitoring period was undertaken during a particularly wet period where as the long term monitoring has picked up two seasonal drought periods.

Following the original monitoring period we had no base line to differentiate base infiltration as a result of high groundwater to actual dry weather wastewater production. This high ground water was subsequently lumped into the dry weather flow production for each monitor. Therefore the long term validation showed that the model was over predicting seasonal events. This situation is exacerbated in Whangarei with such a high ground water influence during wet seasons. Without the long term monitoring information it would not have been possible to obtain an accurate seasonal base line.

Figure 3 and Figure 4 below show a few validation plots for monitor 10852. As shown in the figures the model is significantly over predicting peak flow and volume for both a summer and autumn event. The model over prediction is a direct result of over allocated dry weather production.



Data available from 28/03/2009 00:00 to 20/10/2011 12:35

Associated Sampling Point: Rosvall ITM Koreroa Road rosv

Sampling Point: Walton Bank Intersectio interse

Date: 23/01/2011 20:48 **Y1:** 132.92 (Flow (l/s))

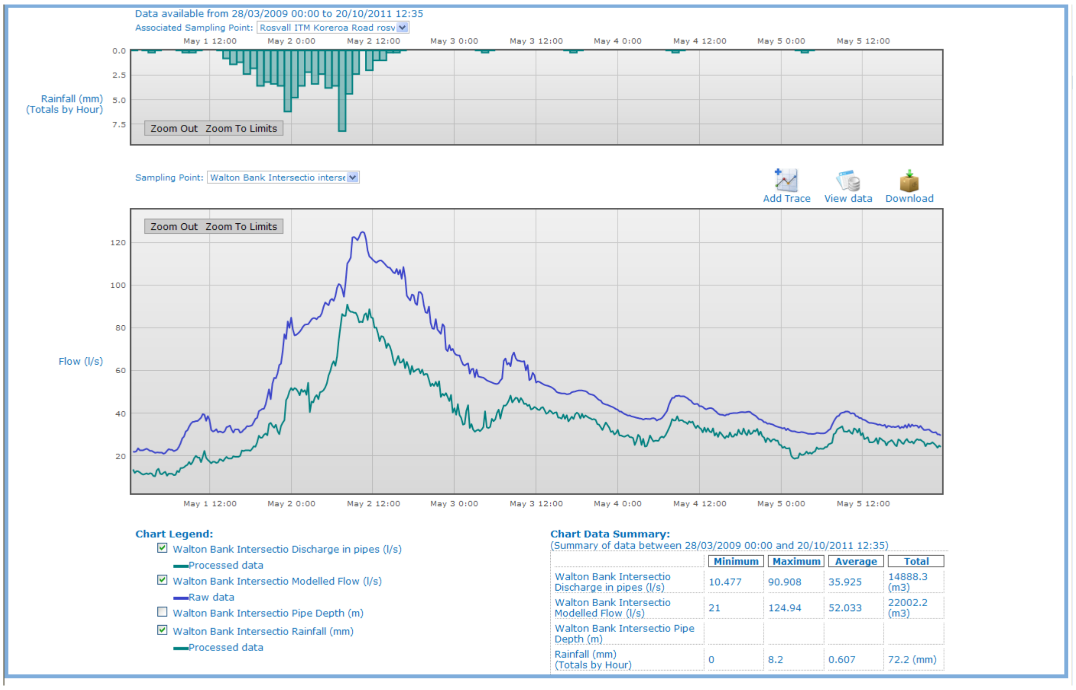
Chart Legend:

- ☑ Walton Bank Intersectio Discharge in pipes (l/s)
  - ▬Processed data
- ☑ Walton Bank Intersectio Modelled Flow (l/s)
  - ▬Raw data
- ☐ Walton Bank Intersectio Pipe Depth (m)
- ☑ Walton Bank Intersectio Rainfall (mm)
  - ▬Processed data

Chart Data Summary:
(Summary of data between 28/03/2009 00:00 and 20/10/2011 12:35)

	Minimum	Maximum	Average	Total
Walton Bank Intersectio Discharge in pipes (l/s)	11.001	125.425	44.344	14936.3 (m3)
Walton Bank Intersectio Modelled Flow (l/s)	0	156.08	73.032	24993.7 (m3)
Walton Bank Intersectio Pipe Depth (m)				
Rainfall (mm) (Totals by Hour)	0	10.4	1.065	101.2 (mm)

Figure 3: Summer Validation Event Monitor 10852



Data available from 28/03/2009 00:00 to 20/10/2011 12:35

Associated Sampling Point: Rosvall ITM Koreroa Road rosv

Sampling Point: Walton Bank Intersectio interse

Chart Legend:

- ☑ Walton Bank Intersectio Discharge in pipes (l/s)
  - ▬Processed data
- ☑ Walton Bank Intersectio Modelled Flow (l/s)
  - ▬Raw data
- ☐ Walton Bank Intersectio Pipe Depth (m)
- ☑ Walton Bank Intersectio Rainfall (mm)
  - ▬Processed data

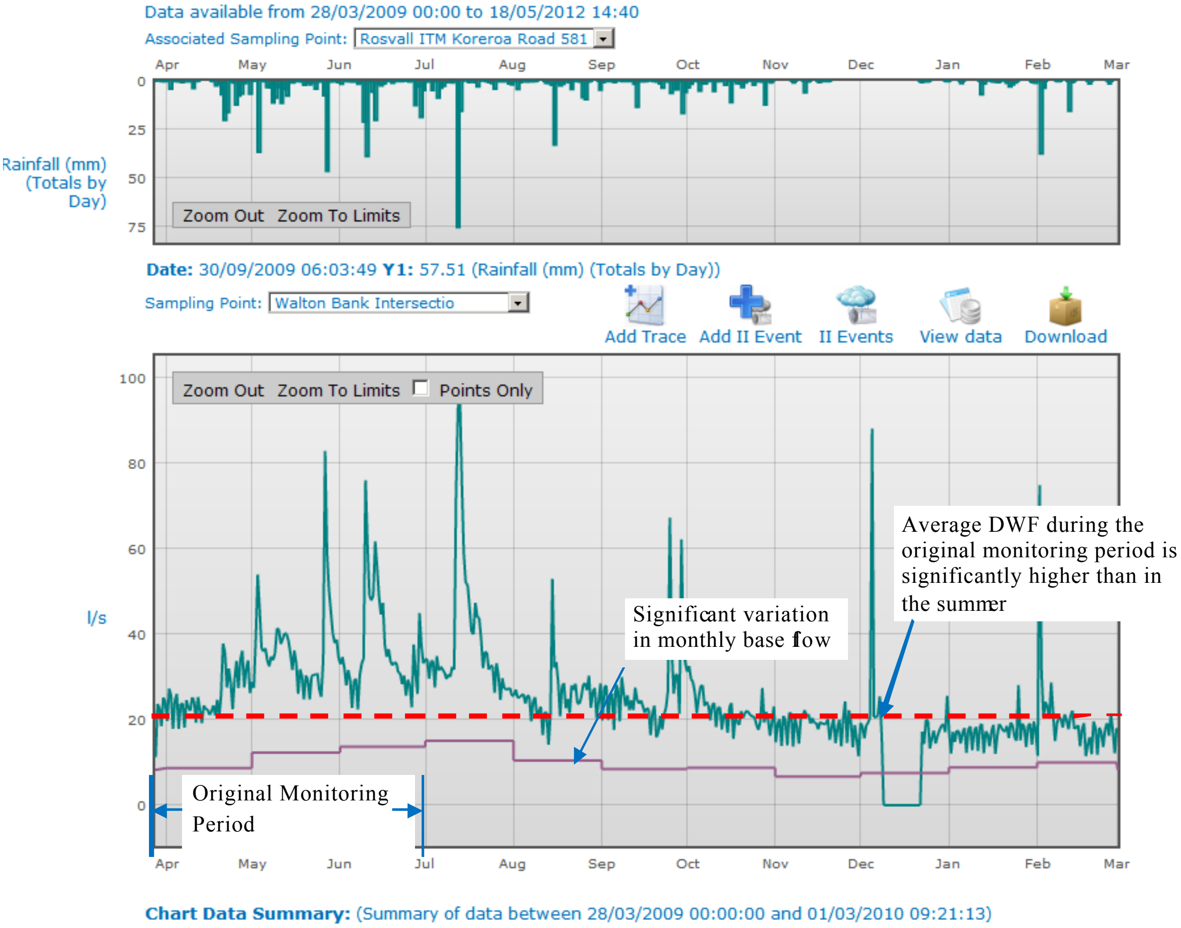
Chart Data Summary:
(Summary of data between 28/03/2009 00:00 and 20/10/2011 12:35)

	Minimum	Maximum	Average	Total
Walton Bank Intersectio Discharge in pipes (l/s)	10.477	90.908	35.925	14888.3 (m3)
Walton Bank Intersectio Modelled Flow (l/s)	21	124.94	52.033	22002.2 (m3)
Walton Bank Intersectio Pipe Depth (m)				
Rainfall (mm) (Totals by Hour)	0	8.2	0.607	72.2 (mm)

Figure 4: Autumn Validation Event Monitor 10852

5 MODEL RE-CALIBRATION

Following validation it was recommended that all long term monitors be re-calibrated for dry weather flow. The primary reason for suggesting dry weather re-calibration was that the dry weather volume prediction derived during the original calibration period was shown to be significantly higher than what was monitored in the subsequent months. As seen in Figure 5 the average dry weather flow during the original monitoring period is significantly higher than subsequent months. The average monthly base flow also varies significantly for this monitor from an average of 15.0 l/s in July 2010 to 5.5 l/s in November 2010. A similar phenomenon is seen for nearly all of the monitors throughout Whangarei.



Data available from 28/03/2009 00:00 to 18/05/2012 14:40

Associated Sampling Point: Rosvall ITM Koreroa Road 581

Date: 30/09/2009 06:03:49 **Y1:** 57.51 (Rainfall (mm) (Totals by Day))

Sampling Point: Walton Bank Intersectio

Significant variation in monthly base flow

Average DWF during the original monitoring period is significantly higher than in the summer

Original Monitoring Period

Chart Data Summary: (Summary of data between 28/03/2009 00:00:00 and 01/03/2010 09:21:13)

Figure 5: Measured Flow over the Entire Monitoring Period for 10852

5.1 DRY WEATHER FLOW CALIBRATION

The model re-calibration consisted of redefining the dry weather volume predictions (l/person/day) and profiles for each of the long term monitors. The dry weather flow was split into monthly dry weather production and base flow. For each monitor the monthly dry weather flow production was different based on the average measured flow for that month across the 3 years. Varying the dry weather flow on a monthly basis significantly improved both dry and wet weather flow calibration for the long term monitors. Once the dry weather production was adjusted little wet weather adjustment was required to maintain calibration criteria.

5.2 WET WEATHER FLOW CALIBRATION

Adjusting the dry weather to have varying monthly base flow and production rates generally resulted in the wet weather calibration of most monitors to fit within calibration criteria for a range of summer and winter events. However some compromise had to be made to fit the maximum number of calibration events. Some of the original 2009 calibration events were therefore not as good as previous results showed. This is a result of utilising three (3) years of monitoring data. For example: in the original calibration there was only a single dry weather production rate for each monitor based on a week in April 2009. With the long term monitoring we have utilised (3) Aprils which were averaged into a single average April production figure. Therefore there is a unique dry weather production rate for each month we have monitoring data for. This makes any single calibration event more difficult but the overall average model calibration much better and enhances the models capability to simulate a multitude of seasonal events.

Although the previous calibration was of excellent standard it proved to be poor at simulating seasonal variation. The updated calibration was not as good for the 2009 winter period but it better simulates more events throughout the year. It is very difficult to have a good calibration match for every event, especially with large seasonal variations and long periods between events.

This re-calibration has also highlighted that simply calibrating a hydraulic model to three winter events will not necessarily represent other system states, and could under (or over) predict system performance. The following section discuses the changes in system performance between the original calibration and the updated model.

6 SYSTEM PERFORMANCE COMPARISON

The objectives of model system performance analysis is to quantify the capacity of the network at the present time and for future scenarios under both dry and wet weather conditions. For comparative purposes for this analysis we will examine two standard wet weather system performance criteria for monitor 10582 and overflow performance.

6.1 RAINFALL INGRESS (I/I)

Rainfall ingress is typically expressed in two ways:

- Rainfall ingress (percentage) based on area

  % of I/I ingress = [I/I Volume] / A * Rn

- Rainfall ingress (L/m/mm) based on sewer length.

  leakage rate = [I/I Volume] / [Ls * Rn]

Rainfall ingress values for 10582 are shown in Table 2. These values were an average taken across several events throughout the long term monitoring period. For comparative purposes the original ingress estimates are also included in Table 2

For the most part the recent monitoring and subsequent re-calibration has shown an increase in ingress values. This is an interesting outcome because in general the re-calibrated model shows a significant reduction in predicted overflows across the catchment. The increase in ingress seen in the recent analysis is directly related to the decrease in the monthly dry weather flow production. The decrease in dry weather flow production, as discussed above, is a result of the longer gauging period and better monthly dry weather averages. Consequently for the same measured flow a smaller portion is attributed to dry weather and therefore a larger ingress estimate for each catchment has been calculated.

Table 2: Ingress Metrics for 10852

I/I Metric	Value
Area (ha)	22.3
Approx Sewer Length (m)	3934
Original Calibration Average I/I (L/m/mm)	7.64
Recalibrated Average I/I (L/m/mm)	10.88
Original Calibration Average I/I %	13.5
Recalibrated Average I/I %	19.16
Recalibrated Max I/I (L/m/mm)	19.78
Recalibrated Max I/I %	34.84

6.2 OVERFLOW PERFORMANCE

The existing and future model was run with the same four (4) selected ARI events from the original monitoring to establish the frequency and volume of overflow from all overflow locations within the catchment. Table 3 below shows the predicted overflow results from the model. It is interesting to note the significant differences between the original (2009) model predictions and the current recalibrated model. As seen Table 3 in the overflow numbers are significantly lower in the latest model results, which are directly attributed to the significantly lowering the original dry weather flow production values and better calibrating the flow for the seasonal events.

Table 3: System Wide Predicted Overflow Performance

ARI Flow Event	Original Calibration No. of Overflow Manholes (> 30m3)	Recalibrated No. of Overflow Manholes (> 30m3)
Existing 6 month	73	29
Existing 1 year	95	48
Existing 2 year	123	58
Existing 5 year	182	89
Future 6 month	96	44
Future 1 year	96	61
Future 2 year	151	74
Future 5 year	212	102

7 CONCLUSIONS

In a typical sewer master planning project it is common to undertake monitoring and hydraulic modelling to determine optimised strategies and capital works programmes. In most cases short term rainfall and flow monitoring (8-12 weeks) is used to give a snapshot of how a wastewater system performs during a single wet season. Although this generally provides a sound basis to build and calibrate a network model it can sometimes skew our sense of system performance and ultimately the preferred set of options.

In this paper we examined how long term monitoring significantly changed the model calibration and subsequently the resulting outlook on how the Whangarei system performed. The selected catchment is heavily influenced by groundwater conditions and highlights dramatic seasonal differences in dry weather base flow and consequently inflow and infiltration estimates. These seasonal flow differences were unseen with the short term flow monitoring effort and the above analysis highlights the risk of using only a short snapshot of monitoring data to project long term trends and develop long term options.