Utilisation of a Calibrated Hydraulic Model for Water Supply Optimisation

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Abstract

This study reviews the experience of Maynilad, the Philippines' water service company, in the application of hydraulic modelling for pressure management and optimisation. Reliability of water supply and pressure is critical in customer service. However, this reliability can be significantly influenced by water supply inefficiencies such as leaks, pipe bursts, fluctuating pressure, and insufficient supply. The paper describes the hydraulic modelling techniques and methodologies employed by Maynilad in its objective to manage the fluctuating pressure experienced in the Regalado Hydraulic System. The full benefit of pressure management for Maynilad is realised through the reduction of leaks, reduction of frequency of bursts, and provision of consistent service level to customers, which in turn could lead to water supply recovery and prolonged useful life of pipes.

Optimal pressure as defined by Maynilad is the balance between the fulfilment of the aforementioned benefits and the improvement of billed volume. The calibration of the water distribution model involves the determination of Pressure Reducing Valve (PRV) locations and settings, valve status, and District Metered Area (DMA) boundaries. A calibrated network hydraulic model of Regalado Hydraulic System is optimised, and the charted results demonstrate the success of the proposed techniques.

Introduction

Water loss is one of the main problems common among water utilities around the world due to several reasons, one of which is the reduction of revenue generated. This loss of water in waterlines consists of unauthorised consumption, customer meter inaccuracies, data handling errors, leakage on pipelines, and overflows at utility's storage tanks (World Bank Institute, n.d.). Among others leakage is the main contributor of water loss due to its large volume. Since leakage is proportional to pressure, proper management of pressure is another way to reduce leakage in the pipe network system.

Hydraulic modelling is a technique in representing mathematically the water distribution system using software programs and applications. Calibrated hydraulic model is necessary before utilising it for system supply operations and optimisation. This tool can be used for pressure management and leakage control. "Pressure management is one of the fundamental elements of a well-developed leakage management strategy" (Wu et al., 2011). Through the process of pressure management modelling, the modeller is able to know where to lower the pressure and additional pressure to manage the demand (Wu et al., 2011).

Benefits of Pressure Management

According to the data presented to Maynilad by Mistry (n.d.), the following are the benefits of pressure management:

- Reduce leakage, saving water resource and associated costs
- Reduce frequency of bursts and consequential damage which are costly to repair
- Reduce interruptions to customers due to bursts
- Provide constant quality service to customers
- Improve asset management

Aim

<u>The Water Supply Optimisation Project's objectives are the following:</u>

- Optimise the system supply of the Regalado Hydraulic System to reduce the fluctuations in pressure within the area;
- Minimise leakage and pipe burst by pressure management;
- To maintain the minimum water pressure that meets the customer satisfaction with consistent supply and pressure throughout the day.

Methodology

Water Distribution Network

The Regalado Hydraulic System is under the area jurisdiction of the Fairview – Commonwealth Business Area. Business Area is a department of Maynilad that manages customer billings and services and operates the pipe networks within its jurisdiction for the purpose of improving the level of services to the customer. This hydraulic system is the network system chosen to undergo study for optimisation due to its predominantly high and fluctuating pressures.

The Regalado Hydraulic System is supplied from a 400-mmØ (16-inchØ) steel pipe along Don Mariano Marcos Avenue. It is composed of one (1) District Metered Area (DMA), Regalado DMA with a 300-mmØ (12-inchØ) Zenner district meter (Figure 1). The Regalado Hydraulic System covers around 10,194.25 linear meters (33,445.70 linear feet) and supplies over 2.1 MLD (0.46 million UK gallons per day) which composed of 1,441 water service connections. It has 36.105% Non Revenue Water (NRW) within its area with elevation profile varies from 55 m to 80 m (180.45 ft to 262.47 ft) and consists of one (1) Pressure Reducing Valve (PRV).

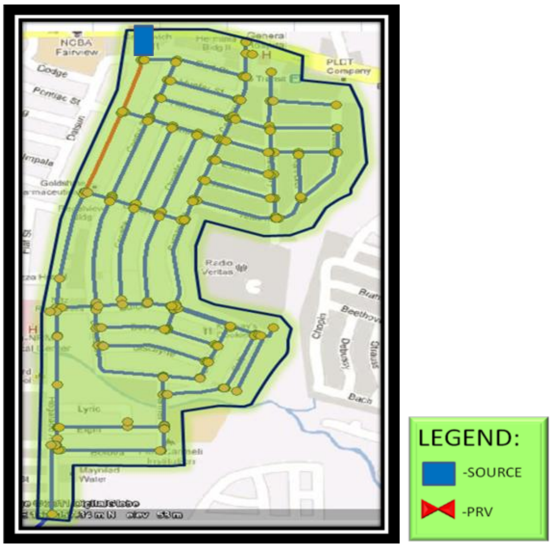


Figure 1 Regalado Hydraulic System

Network Model Optimisation

The creation of the network model involves data gathering from network maps and consumer billing. These sources give the necessary information needed for the model such as pipe diameter, pipe length, pipe roughness, valve status, elevation, demand pattern, and consumption. Also, it involves field measurements and investigations for the calibration process.

Objective

The objectives of the network model simulation and optimisation are to calibrate the system network (Figure 2) and minimise the fluctuations in pressure (Figure 3). Pressure management is advantageous to water distribution systems as it allows the extension of pipes' useful life, preservation of pipes' good condition, reduction of pipe bursts, and drought management through water supply recovery and reallocation. These advantages could lead to cost savings as well as service improvement and reliability.

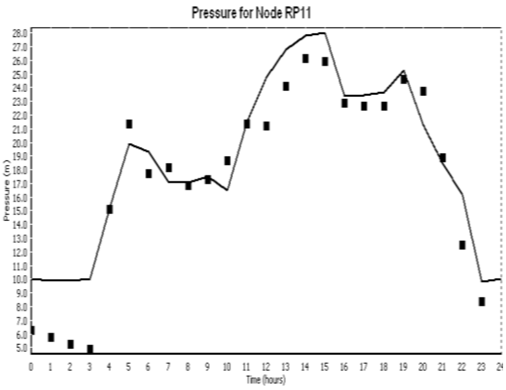


Figure 2 Pressure at Regalado corner Bulova during calibration

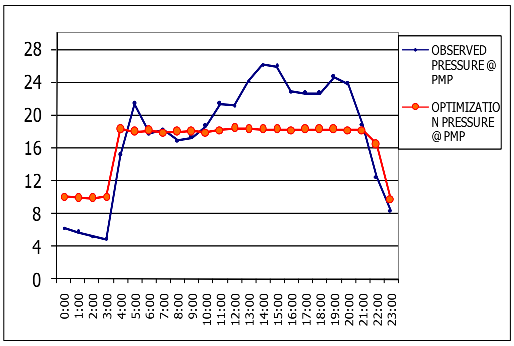


Figure 3 Pressure at Regalado corner Bulova after optimisation

Constraints

The constraints associated in the model are the fulfilment of the demand requirements of the customers and the minimum acceptable water pressure.

Parameters

The network model is calibrated and simulated to mirror actual field conditions. This requires gathering data from field measurements, network maps, and consumer billing. Maynilad performs field measurements to gather data on the location and water level of reservoirs and storage tanks. Land surveying is performed to obtain the elevations of different areas. Information on pipe diameter, pipe length, and pipe roughness are gathered using network maps, following verification. Consumption in the network is calculated using information from consumer billing and demand pattern is established through field measurements. The status of valves, location of leaks and the amount of leakage are also obtained through field measurements.

Decision Variables

The optimisation of the network model includes changing the setting or location of PRVs. These are used to reduce pressure to avoid reaching the maximum allowable pressure of pipes that could lead to pipe bursts. PRVs may have a fixed or single setting, dual setting, or multiple setting. Valves also affect the pressure experienced in an area. They may be used as a tool to isolate an area or control the flow and pressure entering an area. Valves may be fully open or fully closed. Once an area is isolated, it is established as a DMA. In this study, the Regalado Hydraulic System is composed of one (1) DMA, Regalado DMA.

Procedures

Modeller follows standard operational procedures in simulating and calibrating hydraulic models. Figure 4 shows the operational procedures followed by modellers in modelling pipe networks into hydraulic models. On the other hand, Figure 5 shows the operational procedures for calibrating hydraulic models.

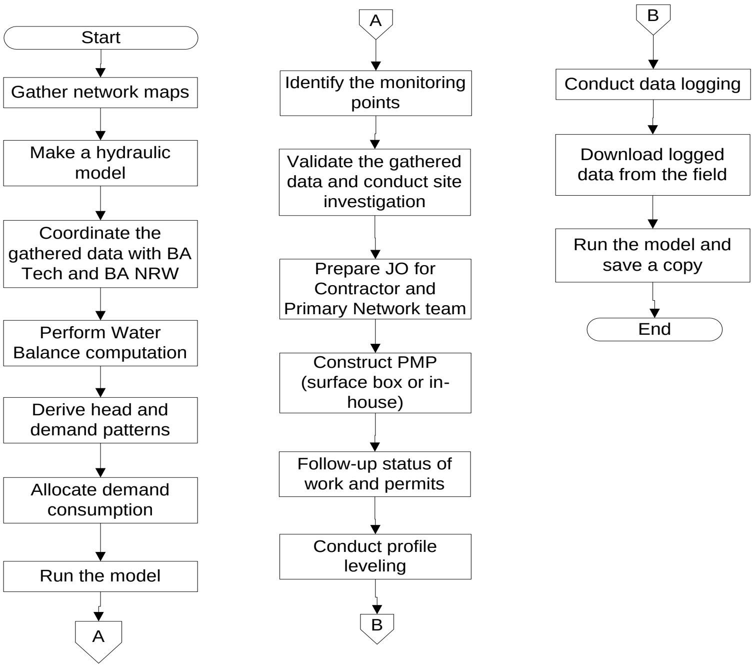


Figure 4 Operational Procedures in Hydraulic Modelling

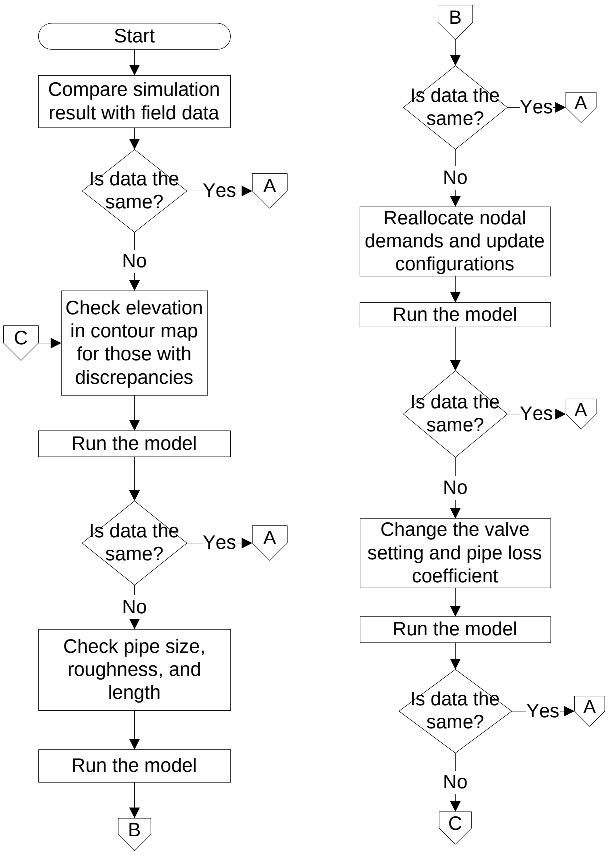


Figure 5 Operational Procedures in Hydraulic Calibration

Demand Requirements

Valves are used to isolate an area for good supply management. These tools can be used to control the flow and the pressure entering that area. Correct identification of the valves to be closed and set as the boundary valves in creating District Metered Areas (DMAs) must be achieved to manage well its network supply.

DMAs are established to ease monitoring of pressure and flow in the area. In this study the flow at the inlet and pressure within this DMA were measured and recorded. These data were used in optimising the network supply of this area.

Pressure Requirements

Proper locations of Pressure Reducing Valves (PRVs) to meet the minimum acceptable water pressure throughout the pipe networks must be carefully selected and pin-pointed with the aid of the calibrated hydraulic model and hydraulic simulation software. These locations were selected based on the requirements that the critical areas (areas with lowest pressure or highest consumption) will be supplied without compromising the level of service the customers deserve.

Correct PRV setting must be done to avoid reaching the maximum allowable pressure of pipes that could lead to pipe bursts. PRV setting includes fixed or single setting, dual setting, or multiple setting. Controls can be used also to allow flexibility. Types of controls for PRV are fixed outlet, time modulated and flow modulated controls.

By using the calibrated model, since the pressure variation within the area is predominantly high, the hydraulic system is further subdivided into two (2) Pressure Managed Areas (PMAs) in such a way that the average pressure of each area is more or less representative of every service connection within its coverage (Figure 6). PRVs are introduced in each supply point to localise pressure management and give the network more flexibility. With the new settings of the PRVs, pressure fluctuations were minimised, making the pattern relatively flat throughout the day, while satisfying the pressure requirements of the network. Graphs (Figure 7 & 8) from the simulation done in EPANET provide evidence to the effectiveness of the techniques used.

Figure 6 PMA boundaries of Regalado Hydraulic System

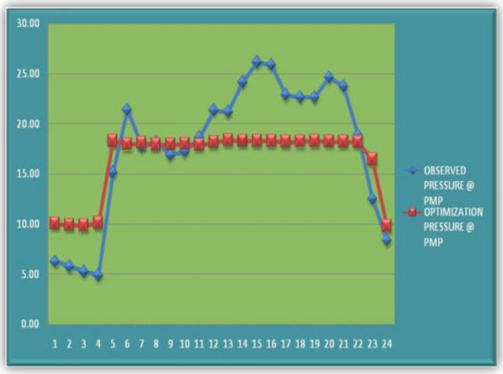


Figure 7 Pressure after optimisation at Regalado/Bulova

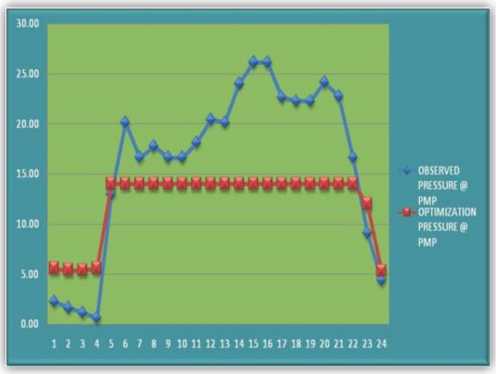


Figure 8 Pressure after optimisation at Regalado/Coronet

Savings Due to Optimisation

Optimisation of network supply is being implemented for an expectation of positive return or savings. These savings can be represented by monetary equivalence or recovered NRW. Reduction in supply in an area due to optimisation can benefit the nearby areas with critical problems such as shortage of supply. As a result, reallocation of network supply will increase the confidence of customer to the water service company.

In this study, reduction of 0.30 MLD (65,990.77 UK gallons per day) was observed in Regalado Hydraulic System after optimisation. This volume of water saved will be allocated to nearby hydraulic systems which are more in need of additional supply of water. Figure 9 shows the change in flow due to optimisation of the network system.

Improvement of pressure due optimisation was observed as shown in the Figure 10. Figure 10 shows the change in pressure due to optimisation of the network system. It can be seen from the graph the smoothening of the pressure spikes. This means that pressure fluctuations are reduced to acceptable level. As a result, it reduces incidence of pipe bursts and leakage.

Figure 9 Change in flow caused by optimisation

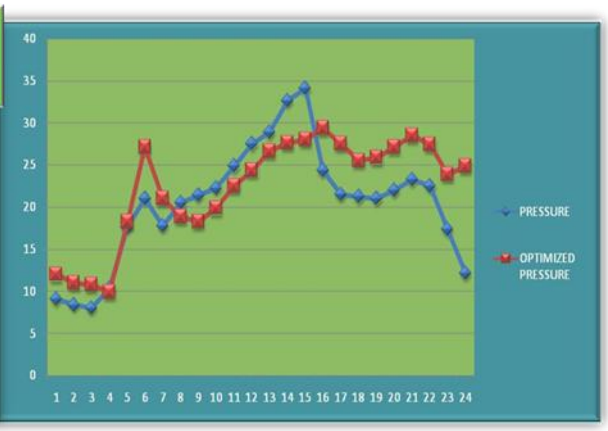
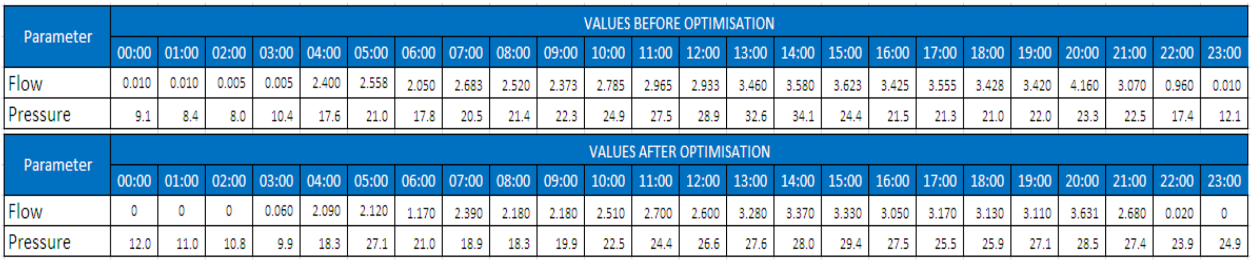


Figure 10 Change in pressure caused by optimisation

The table below shows the hourly flow and pressure before and after the optimisation of system network. The values reflected in the table are the basis of the graphs of Figure 9 and Figure 10.

Table 1 Hourly flow and pressure before and after optimisation



Parameter	VALUES BEFORE OPTIMISATION																							
	00:00	01:00	02:00	03:00	04:00	05:00	06:00	07:00	08:00	09:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
Flow	0.010	0.010	0.005	0.005	2.400	2.558	2.050	2.683	2.520	2.373	2.785	2.965	2.933	3.460	3.580	3.623	3.425	3.555	3.428	3.420	4.160	3.070	0.960	0.010
Pressure	9.1	8.4	8.0	10.4	17.6	21.0	17.8	20.5	21.4	22.3	24.9	27.5	28.9	32.6	34.1	24.4	21.5	21.3	21.0	22.0	23.3	22.5	17.4	12.1

Parameter	VALUES AFTER OPTIMISATION																							
	00:00	01:00	02:00	03:00	04:00	05:00	06:00	07:00	08:00	09:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
Flow	0	0	0	0.060	2.090	2.120	1.170	2.390	2.180	2.180	2.510	2.700	2.600	3.280	3.370	3.330	3.050	3.170	3.130	3.110	3.631	2.680	0.020	0
Pressure	12.0	11.0	10.8	9.9	18.3	27.1	21.0	18.9	18.3	19.9	22.5	24.4	26.6	27.6	28.0	29.4	27.5	25.5	25.9	27.1	28.5	27.4	23.9	24.9

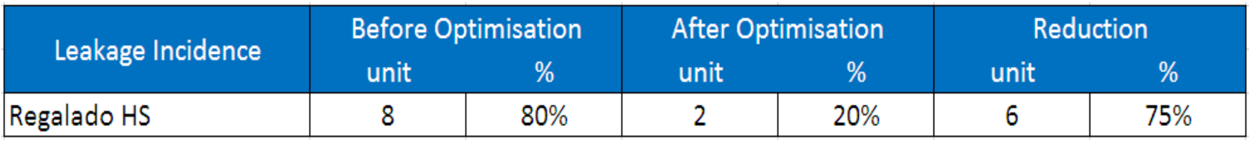
Reduction in Leakage Incidence

Reduction of significant pressure fluctuations within pipes reduces the frequency of pipe bursts. Pipe bursts happen due to the changing pressures inside the pipe. Reaching the maximum allowable stress the pipe materials can handle caused the materials to stress until cracks occur. As a result, it will lead to leakage.

From the time optimisation of Regalado Hydraulic System was implemented, leakage incidence (as seen from leakage and breakage report) in the area shows a reduction of 75% from 8 leak reports before optimisation down to 2 leak reports after optimisation.

Table 2 shows the reduction of leakage incidence in Regalado Hydraulic System after optimisation was implemented.

Table 2 Leakage Incidence in Regalado Hydraulic System



Leakage Incidence	Before Optimisation		After Optimisation		Reduction	
	unit	%	unit	%	unit	%
Regalado HS	8	80%	2	20%	6	75%

Conclusion

Based on the calibration and optimisation of the Regalado Hydraulic System, it can be seen that the utilisation of calibrated hydraulic model for water supply optimisation and pressure management is an effective way of managing network supply and pressure. This can be done by establishing PMA of adequate size and specified supply capacity to improve network supply. Likewise, it can also minimise the fluctuations of pressure within pipes to avoid leakage and pipe burst. Consideration of the minimum water pressure that will satisfy customer demands is one of the factors in pin-pointing the locations of the PRV to be installed.

These improvements can be achieved if the hydraulic model of pipe networks used in the optimisation is calibrated to its acceptable degree using good field data.

By utilising this technique, we can see the benefits derived from employing pressure management approach in water distribution system with the aid of calibrated hydraulic models.

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