Pressure Management in the Pittsburgh Area: A Working and Economical Solution

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Introduction

In the western part of the Pittsburgh, PA. area, the Chartiers Creek provides elevation differences of over 183 m (600 feet) from the valley floor to ridges. The gradient is a long narrow north / south area approximately three km (two miles) wide extending approximately 17 km (10.4 miles). The average demand in the area is 4752 m³/min (75 MGD). The significant change in elevation, associated with the topography, results in pressure values in the distribution system as high as 183 m of water to 197 m (260 to 280 psi), resulting in dramatic main breaks and significant water losses and maintenance costs.

The purpose of this paper is to present the Pittsburgh Low Pressure Gradient (LPG) Program and to demonstrate the significance of pressure management in distribution systems.

Figure 1: General Pittsburgh District Map highlighting the Low Pressure Gradient Zone
The Low Pressure Gradient Program

The western Pittsburgh water distribution system has been meeting growth demand by merging systems originally designed as stand-alone entities. As a result of this development, the system’s highest and lowest elevations are the Rocky Ridge Tank overflow at 428 m (1405 feet) and the Ohio River at 220 m (720 feet). The pressure difference between both points is approximately 208 m (296 psi).

Managing this system has been a constant operational challenge. Main breaks, crisis management and customer complaints had become routine. Damage has been caused by main breaks, resulting in monetary claims against American Water (AW); one such example was the collapse of a store front in August 1994, as a result of a main break.

In response to this situation, AW designed the Low Pressure Gradient (LPG) Program.

Program Development

The Pittsburgh District is served by the Hays Mine and Aldrich treatment plants. Distribution system storage is provided primarily by the Greentree, Castle Shannon, West Mifflin and Rocky Ridge tanks. Operating the Pittsburgh system is complicated due to the variations in storage overflow elevations and differing transmission capacity from the treatment plants to the tanks.

The LPG Program was developed with the vision that a distribution system must be managed and monitored at all levels of the organization, while providing sufficient control throughout the system. Following a preliminary valuation phase, as part of the LPG Program, three main projects were identified:

- **Pressure Management**: The Chartiers Valley Low Service Gradient
- **District Metering**: The Chartiers Valley Area Coding
- **Flow Control**: The West Mifflin and Greentree Tanks Control Valve

Chartiers Valley Low Service Gradient

In the initial stages of the project, the boundary of the new gradient was established by layering elevation contours over the existing piping network maps. The goal was not to exceed 112 m (160 psi) throughout the system at any time. Using this assumption and by establishing pressure parameters, the scope of the new gradient boundary was plotted as an elevation contour. As a result of this initial work, two pressure management zones started to be identified:

- **High zone** with elevations ranging from 256 m (840 feet) to 323 m (1060 feet)
- **Low zone** with elevations ranging from 220 m (720 feet) to 256 m (840 feet)

The second stage of the project used WaterCAD to pick the most logical points of feed to the new gradient and identify the best locations for both primary and secondary pressure reduction valve (PRV) stations. Primary stations include multiple, large diameter valves that supply most of the gradient customer demands. Secondary stations are one-valve stations used to provide night flows, maintain water quality in transmission mains and supplement peak flows as necessary. The final design included three primary stations and nine secondary stations.

Using the hydraulic model, network demands and fire protection requirements were checked to make sure that the gradient design could meet the demands. As a result of
this analysis, three pumping stations were added to boost water from the Chartiers Valley Gradient into higher elevation areas.

**Chartiers Valley Area Coding**

The purpose of this project was to define metering and sub-metering zones that would facilitate the monitoring of these different zones and help tie system delivery data with sales information.

While identifying the pressure management zones, the hydraulic model was also used to identify the distribution zones or metering zones. A total of five distribution zones were identified. As part of the monitoring needs to control flows between zones, sensing stations were located. Each sensing station is equipped with bi-directional flow meters monitoring the inflow and outflow with each zone.

In addition to the sensing stations, six pipeline projects were identified. A total of 2.7 km (8900 feet) of mains were installed or replaced, hence meeting flow and pressure requirements.

The last stage associated with defining the different zones was to identify and locate the isolation valves for each metering zone. As a result of this step by step process, over fifty isolation valves were identified and turned. Today the five zones are monitored daily and the financial and metering information is still in the process of being adjusted. Before the end of the year, both operational and financial data will be consistent.

**West Mifflin and Greentree Tank Control Valves**

Figure 2 illustrates the overflow levels of the three main tanks as they relate to Hays Mine. The goals of the control strategy were to 1) allow system storage tanks to be filled to new capacity without causing overflows at lower elevation tanks; 2) address water quality concerns by providing adequate turnover in each tank; 3) develop a plan that will function under minimum, average and maximum conditions and 4) prevent excessive discharge pressures at Hays Mine treatment that historically have caused main breaks.

Among the key recommendations associated with this project were the implementation of 1) the Greentree Tank Control Valve system and 2) the West Mifflin Control Valve unit.
The purpose of the Greentree control valves is to prevent overflows, provide adequate turnover, maintain discharge pressures at the plant, redirect the flow and allow more usage of the two other tanks. The dual level actuated valve installed at the West Mifflin Tank allows a more optimal use of the tank and addresses the concern operators had regarding overflow. These valves are set to open at 416 m (1365 feet) and close or throttle at 420 m (1380 feet).

**Public Outreach Program**

As the engineering and construction projects were developing, American Water was putting in place an extensive outreach program aimed to inform the customers on the changes that would be taking as a result of the LPG Program.

Impacts to any regular customer would be minimal and would not be readily observed, since dual pressure reducing valves were already installed on the customer side. The purpose of informing the public was to:

- Educate the public on what was being done and how “their” money was being spent
- Inform the larger commercial customers on possible impacts on their operations. For example, the LPG Program could trigger pressure alarms in fire suppression systems. Sprinklers adjusted for a given pressure may not have the same coverage under less pressure.

**Community Outreach Program**

For residential and commercial customers, a message explaining the project was printed directly on water bills. It was decided that a message on the bill itself would be more widely read than an insert.

In tandem with the bill message, American Water notified local and elected officials who serve the affected areas. A personal letter explained the project to local community leaders and legislators. Officials were invited to contact AW with questions or concerns about the project or to arrange a meeting to discuss the project in person. This type of communication provided another opportunity to inform the customer and assist elected officials in responding to potential questions from their constituents.

Special attention was also brought to local fire department officials. It was clear that fire protection equipment such as fire hydrants or in-building sprinklers would be immediately impacted by the LPG Program.

Lastly, a letter was sent to all industrial and commercial accounts in the areas affected by the LPG Program explaining the scope of the project. The mailing was followed by a personal phone call to further inform of the possible impacts the LPG Program could have on equipment or processes that were pressure dependent, such as fire safety sprinklers.

**Access to Land**

In addition to the multiple outreach initiatives described above, American Water worked with individual and communal land owners to gain access to their sites to build PRV stations. In order to meet the tight deadline, creative negotiations were necessary. In the case of an underground station, AW agreed to develop and maintain a neighbourhood landscape hiding the entrance to the station. In the case of the larger primary PRV stations, a colonial-style building was built to house the PRV stations so as not disrupt the landscape.
When no agreement was possible, American Water had to find another location which had an immediate impact the on the design of the metering and pressure management zones.

Results and Discussion

In summary, the LPG Program focuses on three components 1) pressure management; 2) district metering and 3) flow control. The data presented hereafter include operational and financial data gathered before and after the start-up of the LPG Program. Based on empirical data, usage in the LPG zone approximates 25% of the total consumption in the Pittsburgh District. From an analytical point of view, both system wide and LPG specific data can be used to capture the impact of the LPG Program from both operational and management perspective.

Operational Data

Start-up of the LPG Program

The construction phase ended in March 2004. Between March and May, troubleshooting and calibration programs took place. In May 2004, the last primary PRV station was put on-line. Figure 3 shows the step by step approach used to put the PRV stations on-line. In nine days, the pressure in the LPG was reduced from 126 m (179 psi) to 102 m (145 psi).

As a result of the change in pressure, daily maximum flows dropped from 3155 L/min (3000 gpm) to 2313 L/min (2200 gpm). Meanwhile, night flows remained unchanged at 1578 L/min (1500 gpm). Assuming a constant 12 hour daily peak flow, the LPG demand at this point will be 1.5 m3/min (0.57 MGD) less than before the LPG Program.
Number of Main Breaks.

A second immediate benefit associated with the LPG Program is the reduction in the number of main breaks or leaks in need of immediate attention. Prior to March, 2004 the number of interventions was approximately one per day. Since March 2004, the number of interventions has dropped to 12 per month (Figure 4).

![Graph showing the reduction in number of main breaks per month from 2001 to 2005.](image)

**Figure 4:** Number of main breaks or leaks in the LPG Zone between 2001 and July 2005

The reduction in the number of main breaks is the consequence of low pressures within the zone, between 35.2 m (50 psi) to 127 m (180 psi), but also due to the automation that was put in place as a result of the Greentree Tank control valves project. It was also reported that the intensity of the main breaks had decreased as well. The economic benefit associated with the decrease in main breaks will be discussed hereafter.

System Wide Valuation

Figure 5 compares the infrastructure leak index numbers with the non revenue water numbers for the larger Pittsburgh area covered by American Water. In this area, the LPG zone represents approximately 25% of total consumption.

Both system delivery and billing information were readily available. The network team has been monitoring on a monthly basis the unaccounted for water associated with the system. Apparent losses were assumed to be 3% of sales. This current annual real losses calculation was based on 12 months rolling data.

To estimate the unavoidable water losses three parameters were used 1) average pressure, 2) length of mains and 3) number of service connections. The formula used for this calculation was that developed by IWA.
Figure 5: Estimated Monthly Infrastructure Leak Index (ILI) and Non Revenue Water (NRW) numbers from January 2004 to July 2005 for the Pittsburgh District Operated by American Water.

After one year the Infrastructure Leak Index (ILI) numbers are still dropping, suggesting that the benefits associated with the LPG Program are still taking place (Figure 5). For example, field operators are now focusing on maintenance programs, instead of reacting to emergency failures.

Figure 5 also demonstrates the significance of keeping track of both Non Revenue Water (NRW) and ILI numbers. In the case of the western Pittsburgh area, the LPG Program has made the system tighter, while having little impact on the NRW numbers, which remain above 40%. In other words, the LPG Program was successful in addressing the leakage problem faced in the area but did not address the core NRW problem, which could be related to apparent losses or to unbilled authorized usages or both.

**Economic Benefits**

In addition to the operational benefits discussed above, the PLG Program has also been a source of significant economic benefits. The next paragraphs will highlight some of these benefits and quantify them when possible.

**Main Breaks Related Costs**

There was a 60% reduction in the number of main breaks and leaks due to the LPG Program (see Figure 4). To capture savings as they relate to main breaks repair, three line items were identified: 1) paving and restoration costs, 2) material and labour costs, and 3) water damage claims.

2003 and 2004 paving and restoration costs are true values reported from outsourcing companies. The 2005 figure is a projected number used for budgeting purposes. This number accounts for events up to July, 2005 and budgets for costs moving forward.

Labour and materials costs associated with leakage and main breaks were estimated at 20% of the paving and restoration costs. This assumption is viewed as conservative and captures both frequency and intensity of the work needed to be done.
Claims data were derived by applying an average claims cost of $7,000 per claim to the 2003, 2004 and 2005 claims numbers. This number of $7,000 per claim was derived as an average claims value across the state of Pennsylvania between 2001 and 2005. A 20% surcharge was added to claims which had taken place before the LPG Program due to the high pressure.

Figure 7 shows the cumulative cost figures for all three items. Between 2003 and 2005, over 1.4 million dollars in annual savings are being generated. Based on this information, and knowing that the total cost of the project amounted to 5 million dollars, the pay back period is less than 4 years, which can be considered as a quick return for a municipal project.

Other Identified Benefits

Other benefits associated with the LPG Program have been identified. Among the most prevalent items are:

- Improved operations and enhanced maintenance programs
- Fewer customer complaints
- Prolonged asset life and delayed investments
- Direct water savings in association with the decrease in water pressure

To estimate the water savings associated with this program, a mass balance of the system should be performed assessing the before and after state to provide an exact number. In absence of sufficient information this valuation can not be performed.

However, the data in Figure 3 can be used to reasonably estimate expected savings. Figure 3 shows that between May 13th and May 22nd, the maximum recorded flow dropped from 3155 L/min (3000 gpm) to 2314 L/min (2200 gpm). Meanwhile the night flow remained unchanged at 1578 L/min (1500 gpm). Assuming that: 1) consumption remained unchanged during this period, and 2) system demand has a 12 hour daily peak flow, a 2271 m3 (600,000 gallons) a day saving can be identified. At a production cost of 6 cents/m3 (23 cents per thousand gallons), the estimated annual savings is close to $50,000.
Conclusions

The Low Pressure Gradient Program developed in the western part of Pittsburgh, PA, generated significant savings of $1.4 million per year. The Program met its goals within a period of 18 months and enabled American Water operations in Pittsburgh to:

- manage high pressures within the distribution system
- generate savings allowing for a pay back period of less than 4 years
- change its operating constraints by better controlling for flow and pressure

The LPG Program required a complete assessment of the distribution system. A total of five million dollars were spent, leading to the development of control valves at the Green Tree tank; five (5) pipeline projects; and the construction of three (3) primary PRV stations, nine (9) secondary PRV stations, three metering and sensing stations, and three pump stations.

In the next coming months, American Water will focus on fine-tuning the operation with the emphasis on night-flows and on-line monitoring.

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