Knowledge is Power - Using Remote Monitoring to Optimize Operations

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ABSTRACT

Recent advances in remote sensing have enabled sanitary sewer system operators to deploy a large number of remote autonomous water level sensors throughout their collection systems. Real-time continuous water level measurements at dispersed key locations in a collection system provide not only direct protection from overflows, but also provide critical information that enables more efficient management of the collection system as a whole. Remote collection system assessment is possible through analysis of long-term data and water level trends, including the transitory and unscheduled effects of inflow and infiltration. Water level trends can provide early warning of constrictions caused by fats, roots, oils, and grease (FROG), enabling dispatching of cleaning crews long before serious and expensive problems occur. Performing maintenance cycles based on real-time information can result in significant savings and improved operations. In addition, capital improvements can be delayed or avoided through comprehensive monitoring. Manhole intrusions can be monitored to reduce risk of illegal dumping or manhole removal. This paper will discuss several case studies of collection systems that have deployed a large number of level and intrusion sensors in their system including Hawthorne, CA, Culver City, CA, and Mt. Crested Butte, CO and how these monitoring systems have improved collection systems operations and delayed or avoided expensive capital improvement projects.

KEYWORDS

Collection system; monitoring; real-time monitoring; remote monitoring; collection system management; collection system maintenance; cost savings.

INTRODUCTION

Over the past few years, advances in technology – computing power, wireless communications, the ubiquity and power of the internet, for example – have made it possible to deploy a large number of autonomous monitoring sensors in collections systems in a cost-effective manner. (Quist et al., 2008) The ability of a collection system operator to combine long term trending and real-time round-the-clock knowledge of important aspects of a manhole, such as water level, in a large number of critical locations provides the potential for a powerful management tool that is just now being understood and applied. The purpose of this study is to look at a few case studies of how a network of real-time continuous remote level monitors can benefit the operations and maintenance of collection systems.

METHODOLOGY

This paper takes a case study approach to addressing the application of large numbers of level monitors in a collection system. Three cities are surveyed: two in southern California, Hawthorne and Culver City, and one in rural Colorado, Mt. Crested Butte. Each of these systems faces different challenges and therefore it would be expected that the usage of the level data would be viewed differently by each system operator.

CASE STUDY #1: HAWTHORNE, CA

The city of Hawthorne, CA occupies about six square miles a few miles southeast of LA International Airport (LAX). The sanitary collection system consists of 94 miles of gravity pipeline, about 2,000 manholes and due to the gentle and consistent slope of the region, no lift stations.

Averaging about 10 sanitary sewer overflows (SSOs) per year and paying hundreds of thousands of dollars in fines annually, the City of Hawthorne, CA embarked on a program of a large scale deployment of real-time remote level monitoring sensors (the SmartCover Sewer Intelligence System, manufactured by Hadronex, Escondido, CA) in 2006. The deployment was completed by late 2007, and 50 sensors were placed in locations deemed critical by field and operations staff. Figure 1 shows a map of identified critical locations, and Figure 2 shows the locations of the monitoring sensors.

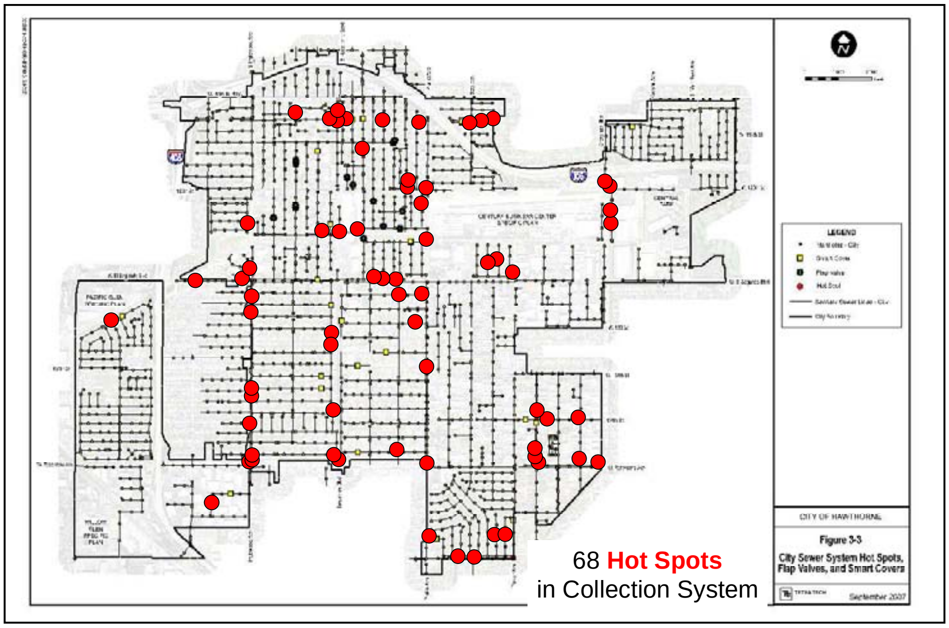

Figure 1. "Hot Spot" locations in Hawthorne collection system.

Figure 2. Level monitoring locations in Hawthorne, CA collection system.

Since deployment of the monitoring system, utilizing about 2.5% coverage of manholes with level monitoring units in late 2006, there have been no collection system spills. (Carver et al., 2008). There are three primary reasons for this result. First, high level or surcharge alarms from the system get high priority from city staff and rapid reaction to these high level alarms enables field staff to assess and correct the problem – such as blockages or constrictions caused by roots or grease. This rapid reaction prevents damage in the area affected before high water levels in the system reach the surface or laterals. Second, water level histories can be used to anticipate constrictions and blockages long before a serious surcharge occurs. Third, real-time data from a widespread grid of sensors throughout the collection system reveal behaviors and responses to natural and man-made stresses on the system such as inflow and infiltration (I and I), enabling the staff to take appropriate preventive and proactive measures to avoid or mitigate potential SSOs.

An example of rapid reaction to a surcharge event is shown in Figure 3. Figure 3a shows water levels in a critical manhole for a period of seven days, November 9, 2006 through November 16, 2006, with small surcharges occurring over this period. A significant surcharge is shown on November 16. Figure 3b shows city staff response to this surcharge. A root caused near-blockage was discovered downstream from this location and it was jetted clean within minutes, averting a potential spill.

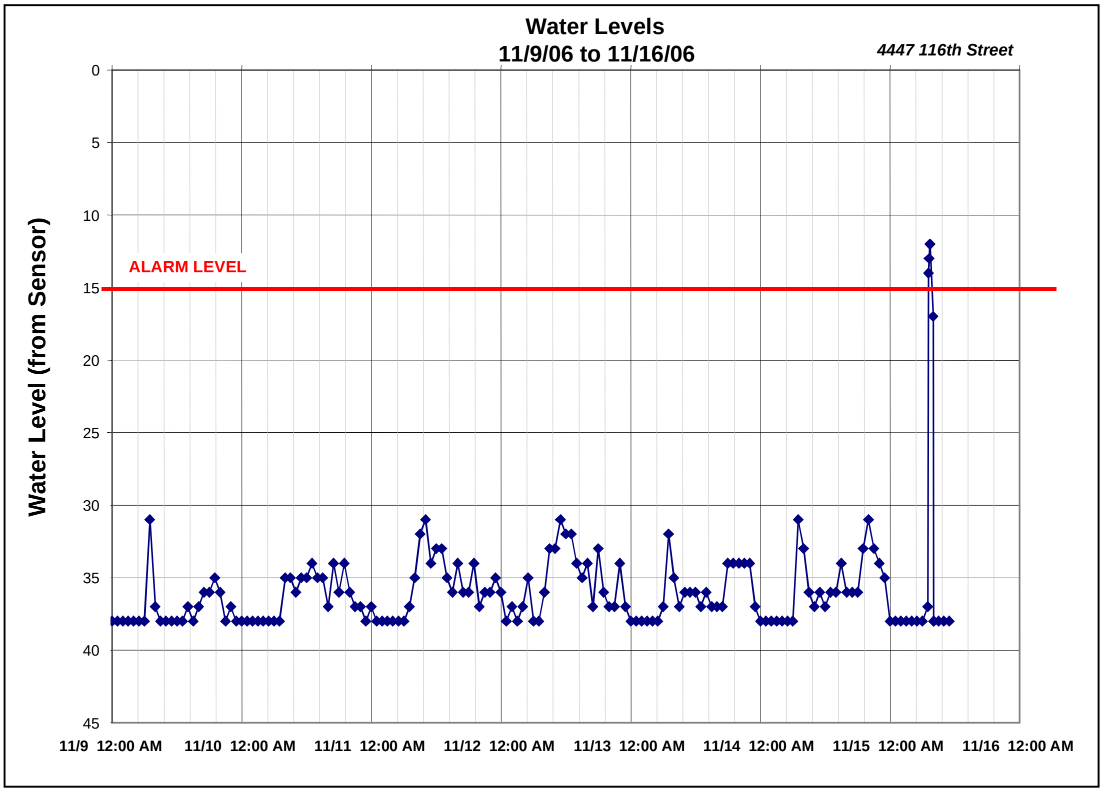

Figure 3a. Water levels between Nov.9 -Nov. 16, 2006 at monitoring location in Hawthorne.

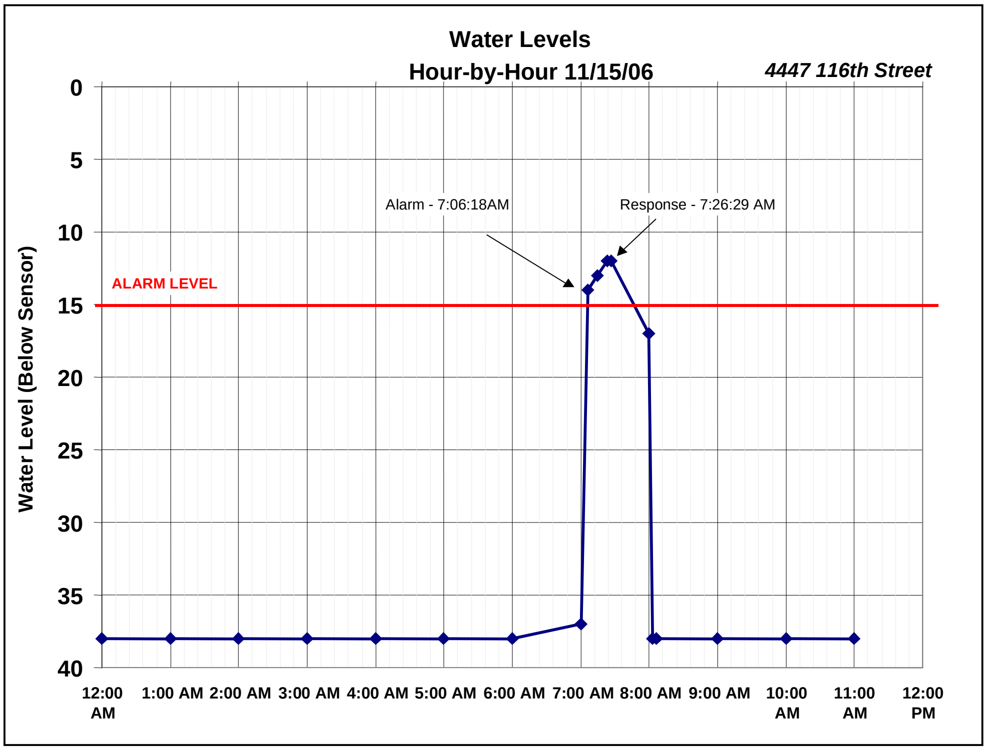

Figure 3b. Water levels during surcharge event on Nov. 15, 2006, showing response to alarm and water levels in response to Hawthorne staff action cleaning downstream blockage.

An example of the use of "pre-surcharge" water level information to perform proactive maintenance based on system data is shown in Figure 4. The water levels at one of the level monitoring sites is shown for a period of six weeks. Small jumps in background level are occurring as a construction builds downstream from this site. While not critical from an immediate spill prevention standpoint, Hawthorne staff reviews this data daily and modifies its cleaning schedule accordingly based on real-time level information gathered from throughout the collection system.

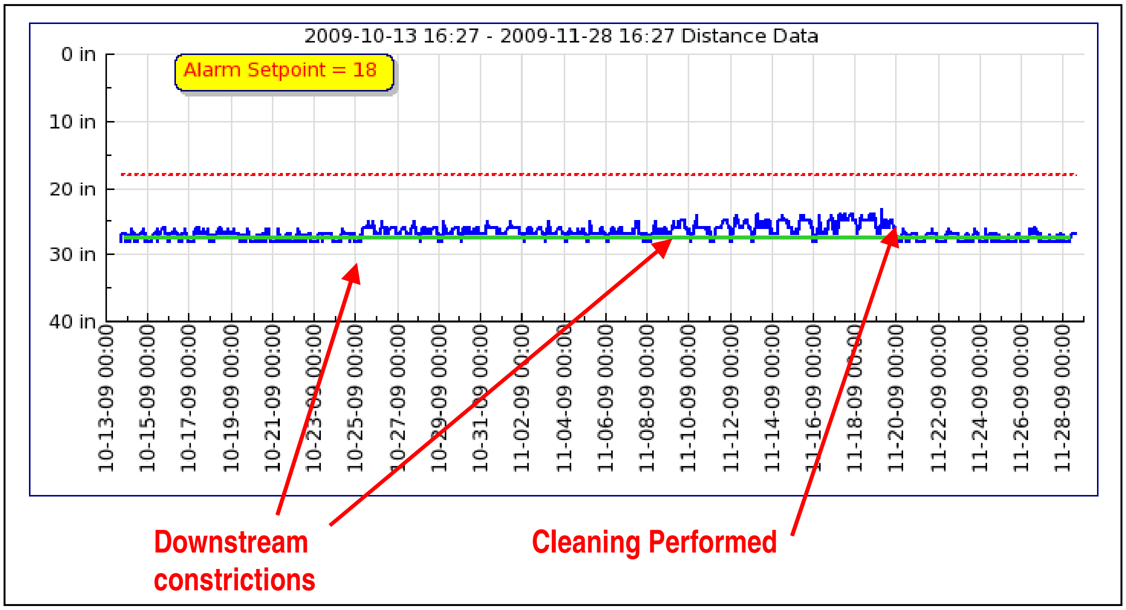

Figure 4. Water levels at a monitoring location in Hawthorne, CA collections system, during the period 10/13/09 to 11/28/09 showing the effects of downstream constrictions on water levels. The blue line indicates the raw level data, the flat green line is the "pre-constriction" average level.

The availability of widespread real-time level data from the collection system can sometimes result in unexpected and useful information. Figure 5 shows the water levels at a monitoring site during a few weeks in the summer of 2009. The high water level pulses caused brief alarms, in contrast to constrictions that tend to cause longer alarm periods and pooling of water in manholes. City staff initially responded to these alarms by inspecting the site, but by the time they arrived at the site, there was no longer a surcharge condition. The only suggestion that there has been high water was a unusually wet shelf at the bottom of the manhole. Further investigation by Hawthorne staff revealed that the Parks and Recreation Department was emptying a 4,000 gallon children's pool into the sanitary sewer at the end of the day.

Inflow and infiltration into sanitary sewers has several deleterious affects, for example: agencies that treat or pay to treat sewage have to pay for storm runoff that enters the sanitary sewer system; surcharges or overflows can occur when the capacity of the system is overwhelmed by I and I; and in the case of infiltration, water coming in during periods of rainfall and high ground water levels are an indicator of locations where

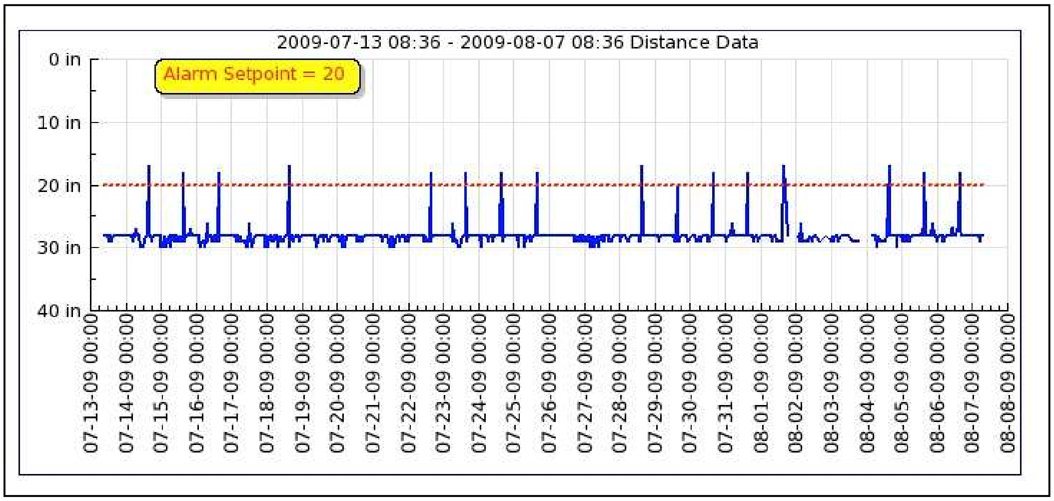

Figure 5. Brief periodic level excursions during the summer months at a monitoring location in Hawthorne, CA was discovered to be caused by a pool being emptied into the collections system.

sewage can also seep into the environment, polluting local ground water and creating potential environmental affects. High levels of I and I can also cause pipe collapse, sinkholes, and structural damage. Figure 6 shows an example of I and I as detected in a location in the Hawthorne collection system. Overlaid on the level data in Figure 6b are the associated rainfall events. Correlation of high water levels and surcharges with these rain events provides early clues to locations where I and I is occurring, to what extent it occurs, and where downstream capacity is stressed.

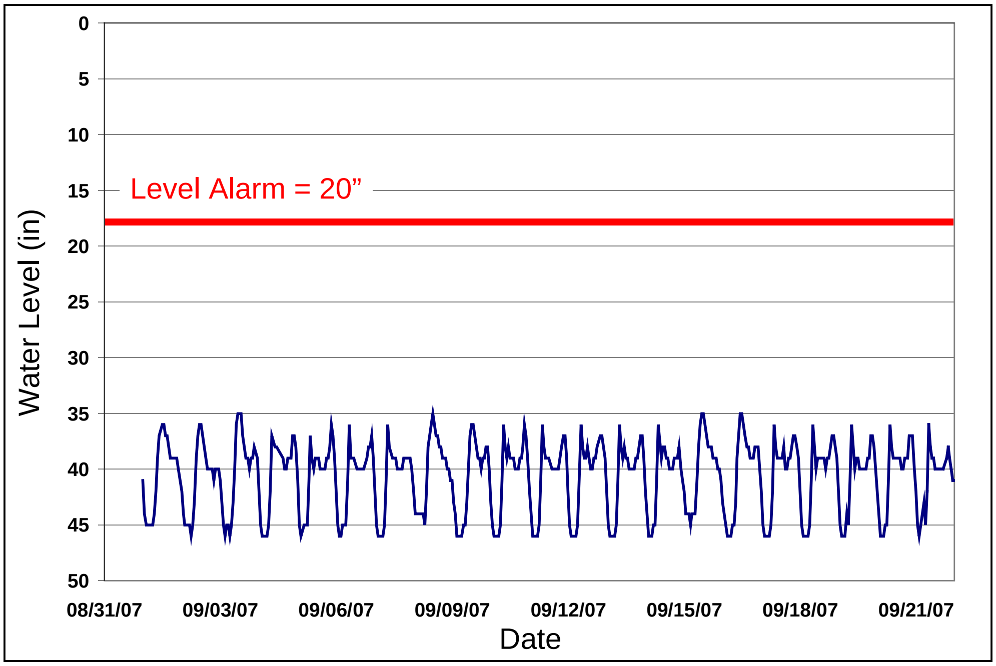

Figure 6a – Pre-rain water levels at monitoring location in Hawthorne, CA.

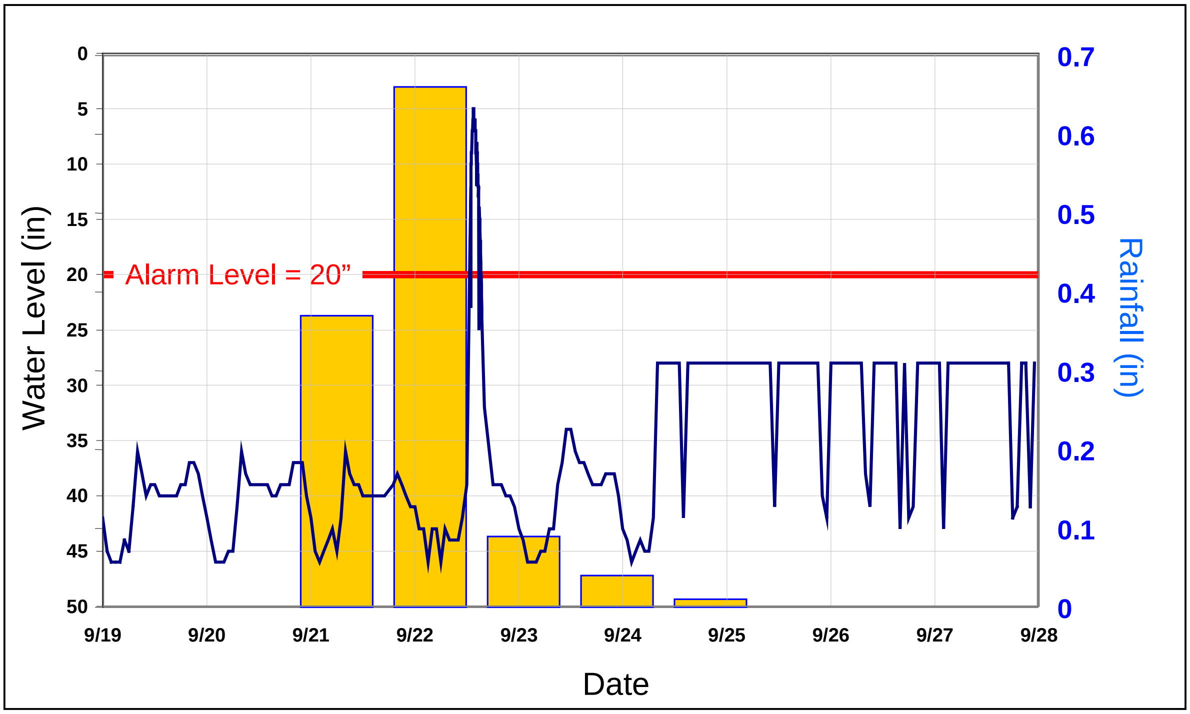

Figure 6b – Water level (blue) response at monitoring site in Hawthorne, CA to rain events (yellow).

CASE STUDY #2: CULVER CITY, CA

Culver City, CA is a city of about five square miles located west of Los Angeles. The sanitary sewer system has 86 miles of pipeline and about 2,000 manholes and seven lift stations. Culver City has installed level monitoring units at 38 manhole and lift station locations. A map of the monitoring locations is shown in Figure 7.

Figure 8 shows an example of how level monitoring is being used to optimize maintenance cycles at a lift station. Hourly data of water levels is plotted over a period of 3.5 months in late 2007 to 2008. Average levels are shown overlaid on the hourly levels. A scheduled maintenance cycle of pump cleaning was performed in early December, and average water levels dropped as a consequence. The average levels stayed low for a period of almost three months, when a few high level excursions prior to a potential spill created alarms and alerted Culver City staff to the need for maintenance. Pump maintenance and cleaning were performed and a serious problem was averted. This continuous real-time data suggests a cleaning period of three months is appropriate for this lift station.

Figure 7. Level monitoring locations in Culver City, CA collection system.

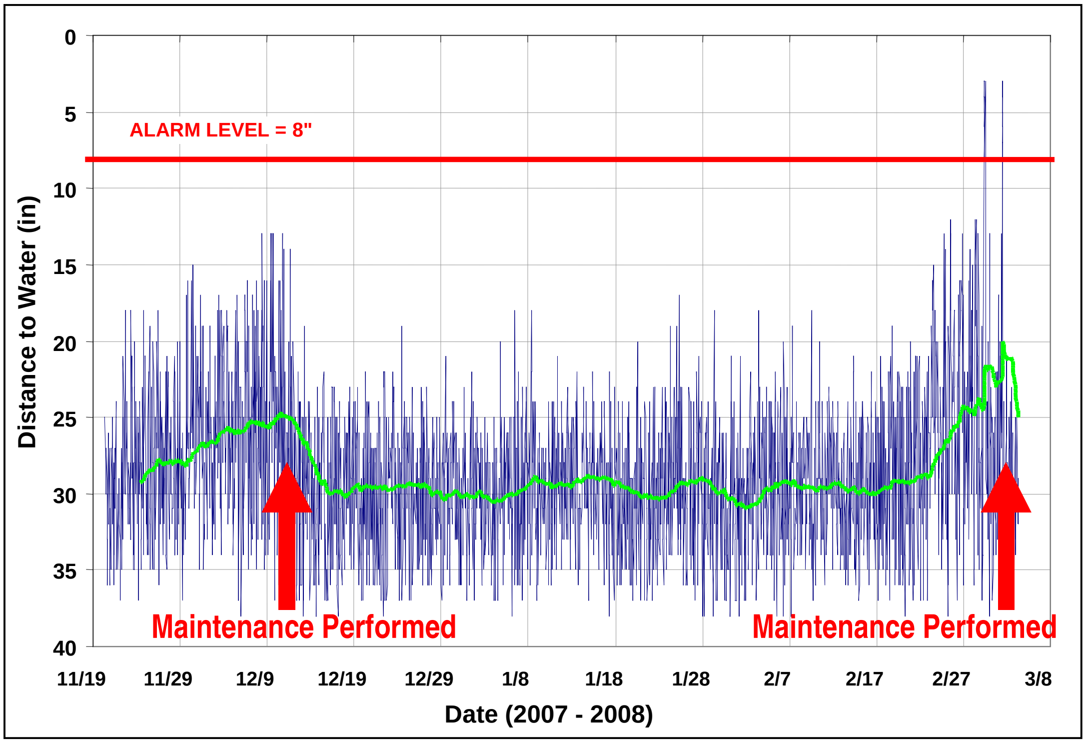

Figure 8. Long term level data (dark blue) from a pump station site monitored in Culver City, CA. Average levels are shown (solid green) and maintenance events (red).

A typical response of water levels to a significant rain event is shown in Figure 9. Illustrated here are water levels at a level monitoring location in Culver City during January 2010, during which southern California experienced significant rainfall. Hourly water level data is shown in dark blue, and shows the typical diurnal ups and downs associated with most collection systems. The dark red line shows this same data with a low-pass filter (indicating daily averaging) applied. The green line signifies the pre-rain average water levels at this location. Rain events are shown as daily rainfall with the yellow bars. A large surcharge at this location is seen on January 18, with lingering high levels until January 23, two days after the rain from this storm ceased. A small increase in levels occurred during the short event on January 13. Water levels returned to normal after the rain ceased on January 26.

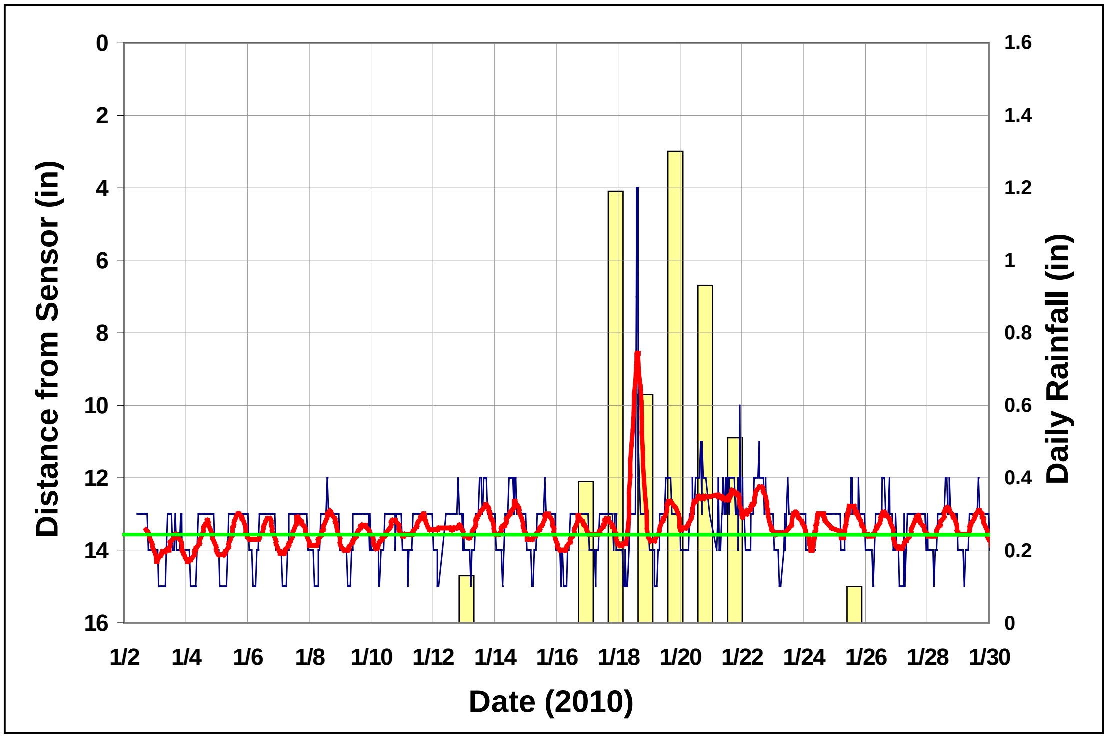

Figure 9. Response of water levels at monitoring location in Culver City, CA during January 2010. Hourly water levels are shown in dark blue, daily averages in red, the pre-rain average level is shown in green, and the daily rainfall amounts are shown in yellow.

CASE STUDY #3 – MT. CRESTED BUTTE, CO

Mt. Crested Butte, CO is a small town at elevation 9,879 ft in the Colorado Rockies with a permanent population of less than 1,000 residents. Pressed by the Colorado Department of Health to replace a large portion of it's sewer system at an estimated cost of more than $10 million or face a building moratorium or significant sanctions, Mt. Crested Butte elected to address its spill problems at a much lower cost through installation of a real-time continuous level monitoring system. Units were installed at eight locations along the collection system spine at critical locations. See Figure 10 showing a map of the installation locations.

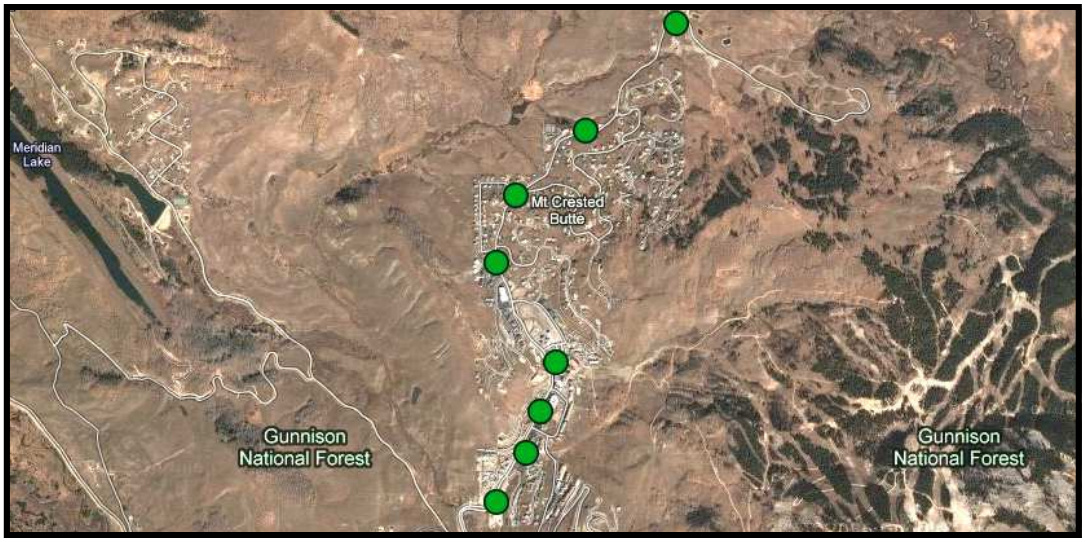

Figure 10. Level monitoring locations in Mt. Crested Butte, CO collection system.

The level monitoring and alarm system was installed in the summer of 2008 and has successfully operated to the extent that the State of Colorado has removed the threat of sanctions. An example of a potential spill that was prevented via monitoring of surcharges is shown in Figure 11. These surcharges provided a means for the Mt. Crested Butte field staff to monitor water levels at critical locations and track potential spills as a function of I and I and downstream blockages or constrictions.

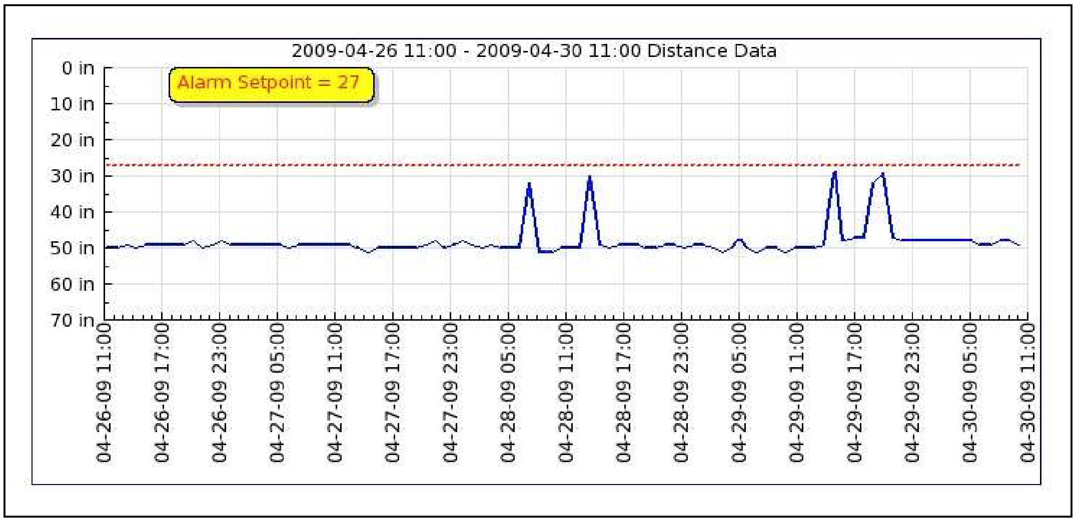

Figure 11. Surcharges occurring during the spring melt at a monitoring location in Mt. Crested Butte, CO in April 2009.

DISCUSSION AND CONCLUSIONS

Historically, most wastewater systems have been operated in “open loop” fashion, for example: clean on a strict schedule that tended to be conservation and therefore may have been over-cleaning; respond and adapt maintenance behavior to spills after the fact; and manage capital planning to a statistical average of spills per hundred miles of pipeline based on no real-time or long-term continuous data.

It is relatively common practice to deploy temporary flow monitoring systems to assess hydraulic loading conditions and capacities. Due to the high cost of operating and maintaining such systems, the standard practice has been to deploy these on a one to two month basis and then re-deploy or remove them. Short term monitoring provides some picture of a system, but long term continuous monitoring over many seasons and years has obvious advantages of discerning trends that are not short term. Using low cost continuous remote level monitoring it has proven practical to leave systems in permanently, allowing long term risk management and operational optimization. In addition, low cost widely deployable sensors allow a much broader picture of the collection system as a whole and lead to better informed decisions regarding maintenance cycles and capital replacement plans.

Beyond the obvious advantages of using level monitoring to reduce or eliminate sewers spills, the ability to optimize maintenance based on long term and real-time monitoring data has a number of advantages over current practices:

- Decrease in wear and tear in equipment
- Extension of service life of high capital items (e.g. combo trucks)
- Personnel usage optimization
- Decrease in fuel and energy costs
- Decreased carbon emissions.

The Mt. Crested Butte example discussed here showed an example of how large capital projects could be delayed or avoided. The capital project was estimated to cost around $10 million, while the autonomous real-time monitoring system cost less than $100 thousand to install, including a dedicated radio system, illustrating a 100 to 1 cost savings. It is well known that underground capital projects are both very expensive and disruptive. Using widespread real-time monitoring to avoid, delay, or re-prioritize projects can have a major impact on capital expenditures for a fraction of the cost of these projects.

The problem of inflow and infiltration in collection systems is well-known. I and I has a significant effect on wastewater treatment costs when a system faces a large increase in flow rates during rain events. Therefore there is significant cost advantage – as well as the obvious problem of SSOs when capacity is overwhelmed during rain events – to using continuous monitoring to monitor for and identify sources of I and I. This is particularly the case in large systems where many monitoring sites need to be used simultaneously and broadly. Using easily remote mobile level systems like the ones discussed here (Quist et al., 2006), I and I detection is made cost-effective and efficacious.

With sufficient deployment of real time monitoring (2% to 5 % of manholes and all lift stations monitored) the wastewater management team can move to informed, closed loop operations. Capital projects can be properly assessed and prioritized. I and I can be spotted and diminished. Aspects of a system previously unknown due to lack of knowledge can be discovered. A collection system operator can prioritize cleaning to match the real status of the pipeline, avoid spills by spotting surcharges early and manage to a “Zero Spill Goal”. Knowledge is truly power.

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