Improved Collection System Operations and Spill Prevention using Remote Wireless Real-Time Monitoring

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ABSTRACT

Sanitary sewer overflows are a common and serious problem for wastewater collection operators. Overflows cause environmental damage, can result in lawsuits and regulatory fines, and cause bad public relations for sanitary districts. Recent advances in electronics, wireless communications, and batteries have made it possible to develop a cost-effective and reliable means to monitor sewer systems in order to prevent overflows. Continuous real-time monitoring of a large number of manholes and lift stations in a collection system enables operators to avoid spills by alerting them to unusual water level conditions long before a spill occurs and provide time to take corrective action. The Olivenhain Municipal Water District and the City of Carlsbad have implemented networks of sewer monitoring devices that enable early warning of potential overflows, and these networks have successfully prevented sewer overflows under a variety of conditions. Four case studies are presented and discussed.

KEYWORDS: sanitary sewer overflows, SSOs, sewer spills, remote monitoring, real-time monitoring, sewer monitoring, spill prevention, smartcover, manhole monitoring, lift stations.

INTRODUCTION

The United States Environmental Protection Agency estimates that there are at least 40,000 sanitary sewer overflows (SSOs) annually in the United States[1], releasing between 3 billion and 10 billion gallons of untreated wastewater into the environment every year[2]. Combined sewer overflows (CSOs) are an even larger problem. The EPA estimates that CSOs result in the release of 850 billion gallons of untreated wastewater and storm waters into the environment each year[2]. SSOs and CSOs are a significant threat to the environment and public health and create substantial economic damage due to lost business (for example, near or at beaches), fines, and clean-up costs. A survey of California sanitation utilities published in 2005 by Brown and Caldwell concluded that utilities would pay up to $10 per gallon to avoid sewer spills[3]. Controlling, reducing, or completely eliminating sewer overflows presents a well-recognized challenge for today's sanitary sewer system operators.

In addition, the regulatory environment is becoming more challenging for sewer system operators. For example, the state of California promulgated in March 2006 new General

Wastewater Discharge Requirements[4] that calls for improved monitoring, reporting of all SSOs, and for sanitary agencies to "take all feasible steps to eliminate SSOs". At the federal level, congress has become more involved in sewer monitoring, with for example the recent "Sewage Overflow Community Right-to-Know Act". Meeting new, more restrictive, and constantly changing regulations suggests that an automated sewer monitoring system developed to reduce or eliminate SSOs would have wide use in sewer collection systems.

The Olivenhain Municipal Water District (OMWD) in San Diego County, California and the City of Carlsbad, California, have deployed networks of remote real-time continuous monitoring devices with the goal of generating early warning of potential spills, thus providing these agencies the ability to take corrective action necessary to prevent actual spills from occurring. The goal of the case study was simple: deploy a group of remote wireless, battery powered units, linked through a national digital wireless network in areas of high potential risk and determine if they are effective as a means to provide early-warning of potential spills.

METHODOLOGY

The SmartCover® Sewer Intelligence™ System

The wireless remote monitoring system utilized by OMWD and Carlsbad was the SmartCover® Sewer Intelligence™ System, developed by Hadronex (Escondido, CA). This wireless remote monitoring system has six basic components: (1) An electronics package which contains the two-way digital radio, computer and supporting electronics; (2) A power supply consisting of batteries with a one-year rating; (3) An ultrasonic ranging sensor; (4) A bracket used to mount these components onto the underside of a manhole or lift station hatch; (5) An external antenna to transmit and receive radio signals; and (6) A central alarm processing, data processing, display and web access system. The SmartCover® units communicate through a reliable low bandwidth digital radio network for two-way communications. The field units are compact and mount directly onto the underside of a manhole using high powered magnets – see Figure 1.

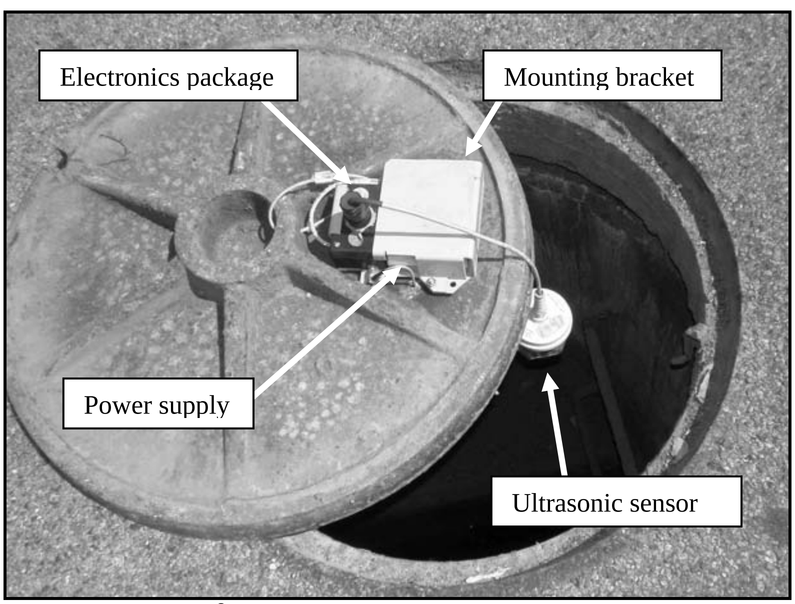

Figure 1. SmartCover® Field Unit as mounted underneath manhole cover.

The monitoring system performs three essential functions: (1) detects high water levels and sends immediate wireless alarms directly to field or supervisor personnel; (2) detects unauthorized intrusions at the site, alerting personnel to unauthorized access and potential illegal dumpings; and (3) logs water levels, temperature, battery voltage and radio signal strength continuously to establish long-term trends at each manhole or lift station site. Alarms are sent directly to sanitary system operators and field personnel on their existing cell phones, pagers, or through email. Long term trends are important because deviations from these trends can be indicators of problems downstream or upstream from the manhole. For example, excessive high water levels suggest that there may be a blockage downstream from the manhole, or unusually low levels may suggest a blockage or a pipe breakage upstream from the manhole. The real time measurement of system parameters such as battery voltage and radio signal strength provides comprehensive management of remote field units for high reliability. Any abnormal unit operations, loss of communications, or antenna problems are quickly noticed so that maintenance can be performed to return the unit to operation with low down-time.

Deployment of SmartCover® Units

To date, OMWD has deployed the SmartCover at 13 sites throughout their collection system of approximately 900 manholes, and the City of Carlsbad has deployed the SmartCover at 10 high priority sites throughout the coastal city. These sites were chosen based on the following considerations: (1) locations of previous SSOs; (2) identification of the location as a “hot spot” – meaning that the location has a high potential for an overflow; (3) the location is high risk in the sense that a sewer overflow at that location could cause serious problems, for example near water ways, sensitive habitats, or commercial locations.

CASE STUDY RESULTS

OMWD: Site #1

OMWD took over an aging collection system previously operated by another agency. Site #1 (see Figure 2) was chosen by OMWD for monitoring because it was within an older section of the collection system and the eight inch gravity main on which it is located runs parallel to a nearby creek. A spill into this creek would represent a serious impact with potentially large fines from regional regulators. Immediately after initial installation of the SmartCover® in August 2006, the level trending data (Figure 3) indicated that this manhole experienced frequent and unexpected surcharges of up to 10 inches. Previously unknown, this water level behavior prompted OMWD to investigate the line further downstream via camera, where significant root intrusion was detected and corrected. Once this root problem was eliminated, the surcharging disappeared.

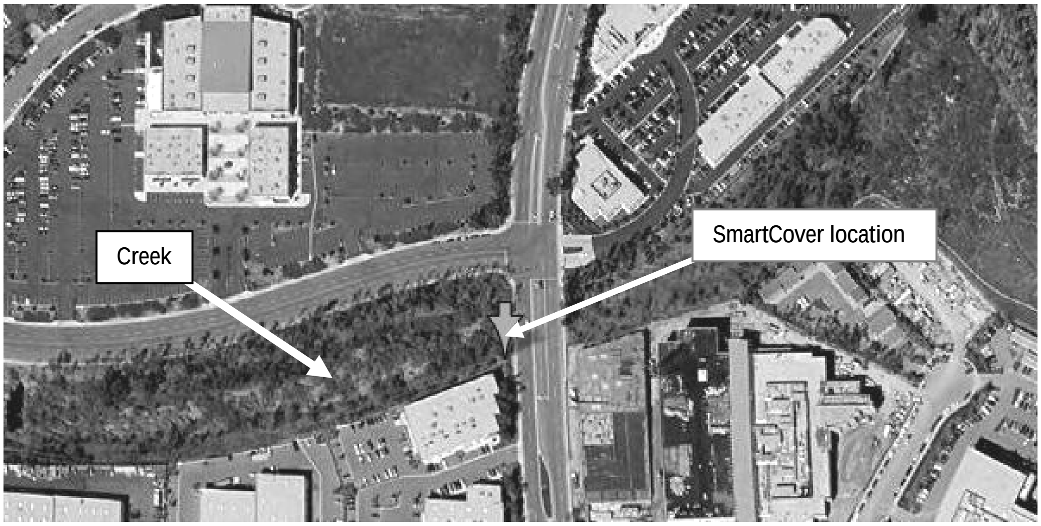

Figure 2. Overhead photograph showing location of SmartCover® site in the OMWD collection system. Note that the SmartCover® location is adjacent to a creek bed.

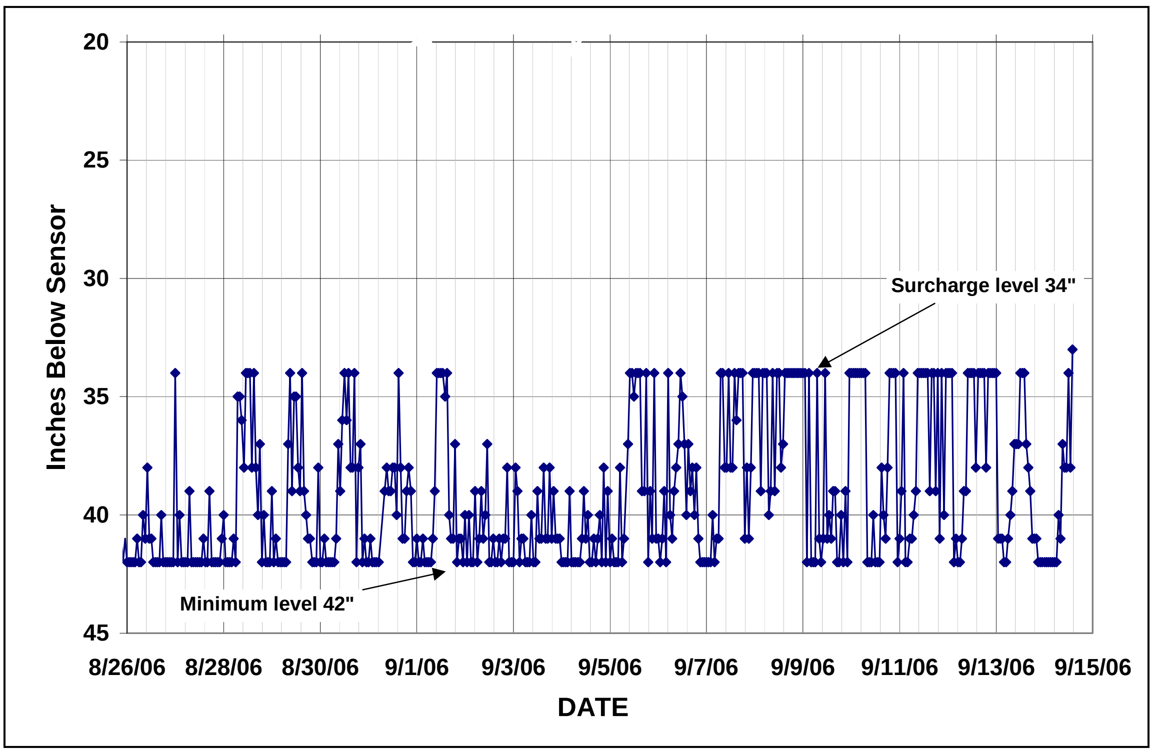

Figure 3. Hourly water level data as recorded at SmartCover® Site #1 in the OMWD collection system. Minimum water levels were recorded as 42" below the sensor, while surcharging was occurring frequently at 34" below the sensor. Root growth downstream from this site was determined to cause this problem.

OMWD: Site #2

As part of the 13 unit deployment, OMWD also placed a SmartCover® unit at a location just upstream from a pump station, and adjacent to a sensitive wetland (Figure 4). This pump station was instrumented with standard SCADA monitoring systems. On November 14, 2006 a pump malfunction occurred at the pump station and generated an abnormally high filling level at the wet well. The primary SCADA alarm also malfunctioned, preventing OMWD staff from receiving a high level alarm. As the wet well began to fill, water accumulated upstream, and then began to fill the manhole where the SmartCover® system was installed. Figure 5 shows the water level history at this site before, during, and after the high water event at the lift station. Note that the level measurement prior to the event was flat – this is because at this particular location, the ultrasonic sensor was positioned over the manhole shelf and not over the pipe. Any change in water level here would be cause of concern, since it indicated a surcharge outside the pipe invert. At 3:04 PM the SmartCover® remote monitor detected the surcharge in the manhole and it immediately alarmed OMWD staff, who responded to the lift station problem. The pump station pump was repaired, thus averting a potential spill into environmentally sensitive wetlands through both the wet well and the upstream manhole.

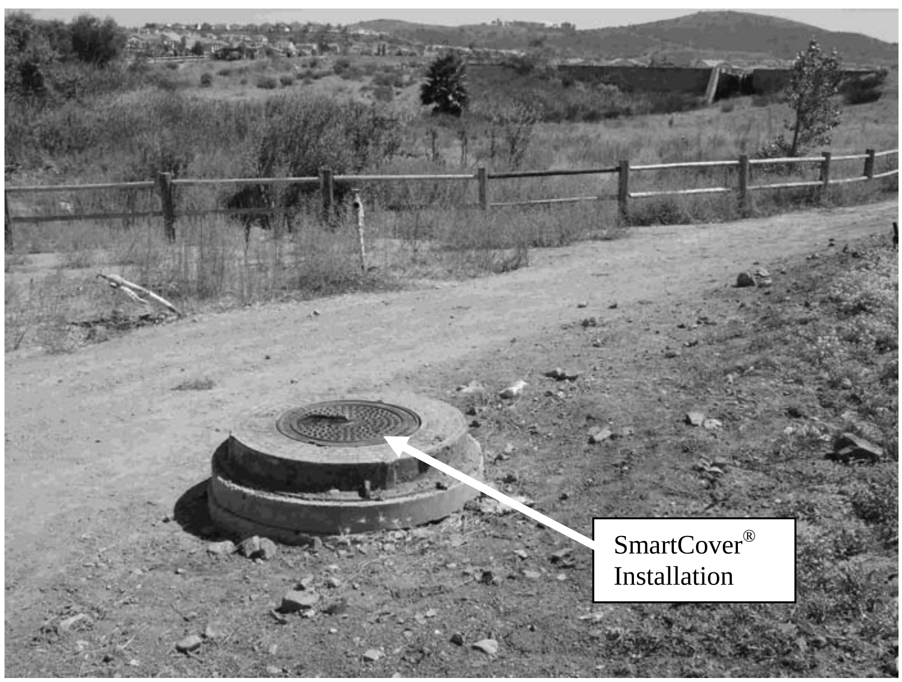

Figure 4. Location of Site #2 in the OMWD collection system, adjacent to wetlands (top left) and reservoir (top right). This site was upstream from a pump station where electronics and communications problems failed, but the remote monitoring system here caught the problem.

The water level history shown in Figure 5 shows four distinct phases to the surcharge event: (1) The pre-event water levels, in this case the shelf of the manhole, measuring 32" below the ultrasonic sensor; (2) The surcharging caused by the pump failure at the lift station, starting around 3:00 PM and alarming at 3:04 PM when it exceeded the alarm level of 25" from the sensor, or 7" above the shelf, finally reaching a peak around 4:15 PM; (3) The response of the OMWD field personnel to rectify the lift station problem resulting the water levels dropping below the alarm level around 5:00 PM; and (4) Water levels returning to normal after 5:00 PM.

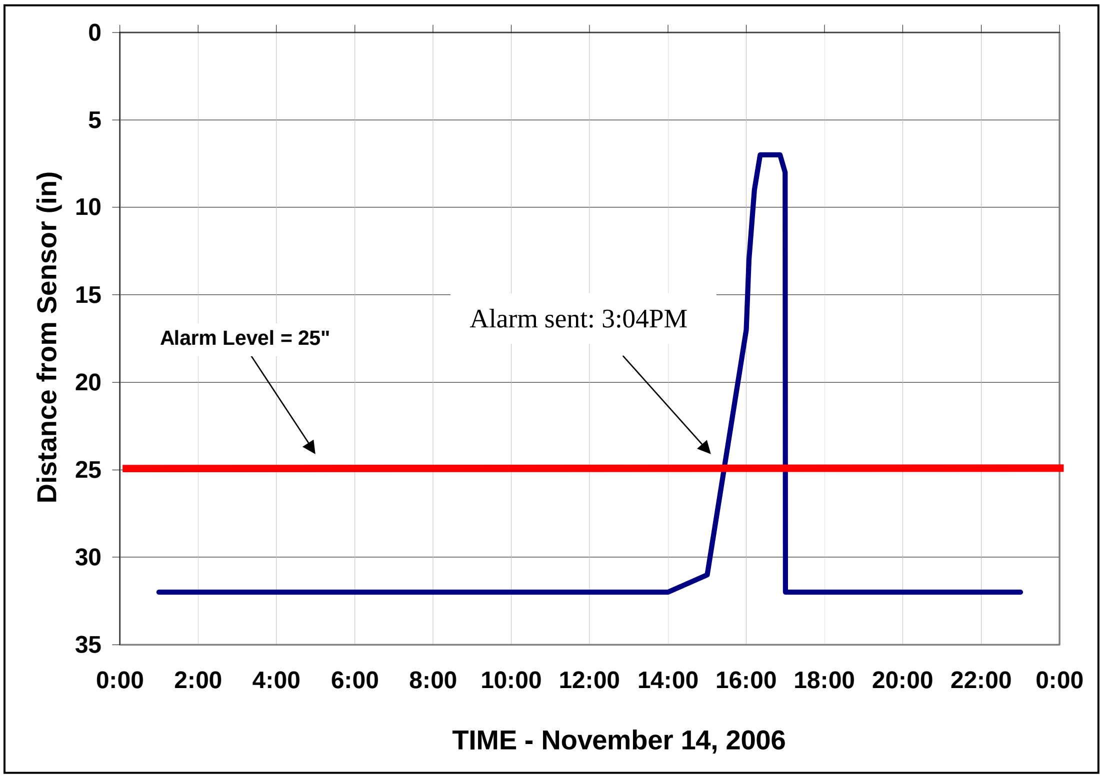

Figure 5. Level data from OMWD Site #2 on November 14, 2006, showing normal level reading (32") of the manhole shelf prior to the event, and the surcharge caused by the high levels in the wet well downstream. OMWD personal were dispatched and solved the problem. Levels returned to normal by 5:00PM.

Carlsbad: Site #3

As part of the Sewer Intelligence™ system, the City of Carlsbad placed one of their 10 SmartCover® remote monitors at a critical location along Interstate 5 in Carlsbad, CA. (See Figure 6). A sewer overflow here would overflow onto Interstate 5 and also potentially flood a church across the street from this location. Figure 7 shows the SmartCover® level data before, during and after the surcharge event, and shows that during routine operations at 9:19:36 AM on March 29, the SmartCover® at this location detected a surcharge above normal levels and exceeding the alarm level of 3" above normal levels. An alarm was sent to Carlsbad field personnel via cell phone. City personnel were dispatched, and a blockage caused by roots and grease was discovered downstream. As the level data in Figure 7 indicate, the blockage was cleared within an hour, and a potential spill was prevented.

Figure 6. Site #3, City of Carlsbad, CA SmartCover® location, in a critical monitoring location in sidewalk near Interstate 5.

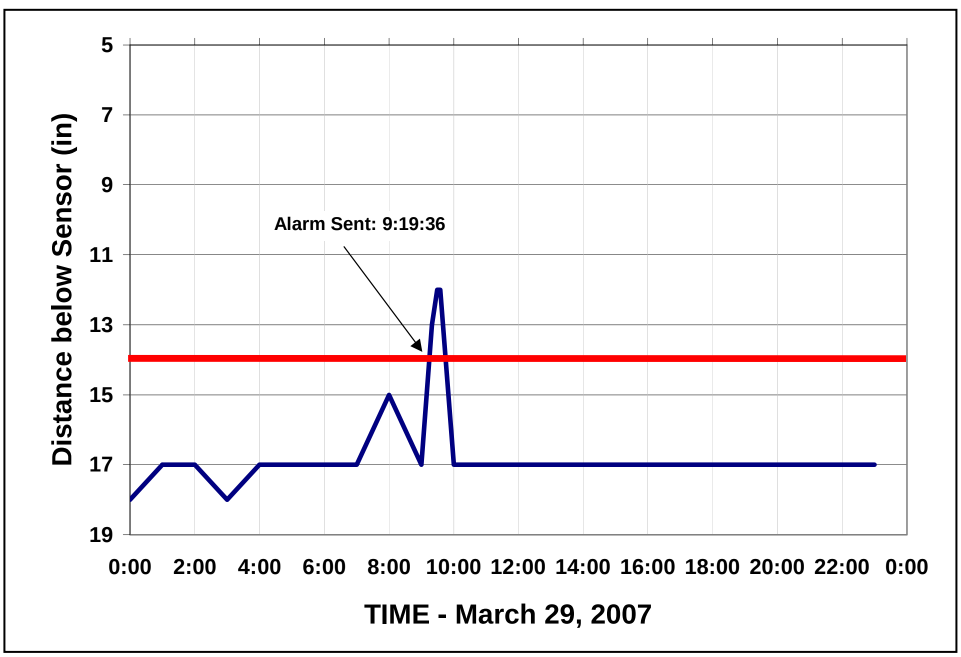

Figure 7. Surcharge event on March 29, 2007 at Site #3 location in Carlsbad, CA. Alarm was sent at 9:19:36AM to City field staff, who responded and cleaned blockage downstream from this location.

Carlsbad: Site #4

A second critical site in the City of Carlsbad was fitted with a SmartCover® monitoring unit, as shown in Figure 8. This is a very shallow manhole in a residential neighborhood with a depth of about 20", and has been the site of previous SSOs. As shown in Figure 9, in the evening of November 26, 2007 at 7:35:51 PM, the water level in this manhole exceeded the pre-set alarm level just 1" above high water levels at this location. The SmartCover® sent an alarm to the cell phone of one of the authors who responded to the site to evaluate the alarm. Simple observation of the flow indicated that nothing was wrong – water was flowing through the manhole, and no pooling was evident. However, since the alarm was indicating a slightly higher water level, further investigation downstream from this manhole located a root ball combined with grease was partially blocking the line. Once this root ball was removed, the water levels returned to normal levels.

Figure 8. Site #4, in the City of Carlsbad, CA. Very shallow manhole (20" deep) with little warning of potential surcharge. There have been previous SSOs at this location.

As in the other case studies, Figure 9 shows the typical phases of a "prevented spill" from the water levels in the manhole: (1) Pre-surcharge, normal levels of between seven inches and eight inches; (2) the surcharge event that triggers a SmartCover® alarm at five inches, just two inches above the normal high level; (3) the reaction by the City to the alarm and the cleaning of the line downstream; and (4) return to normal levels an hour or two after the initial alarm.

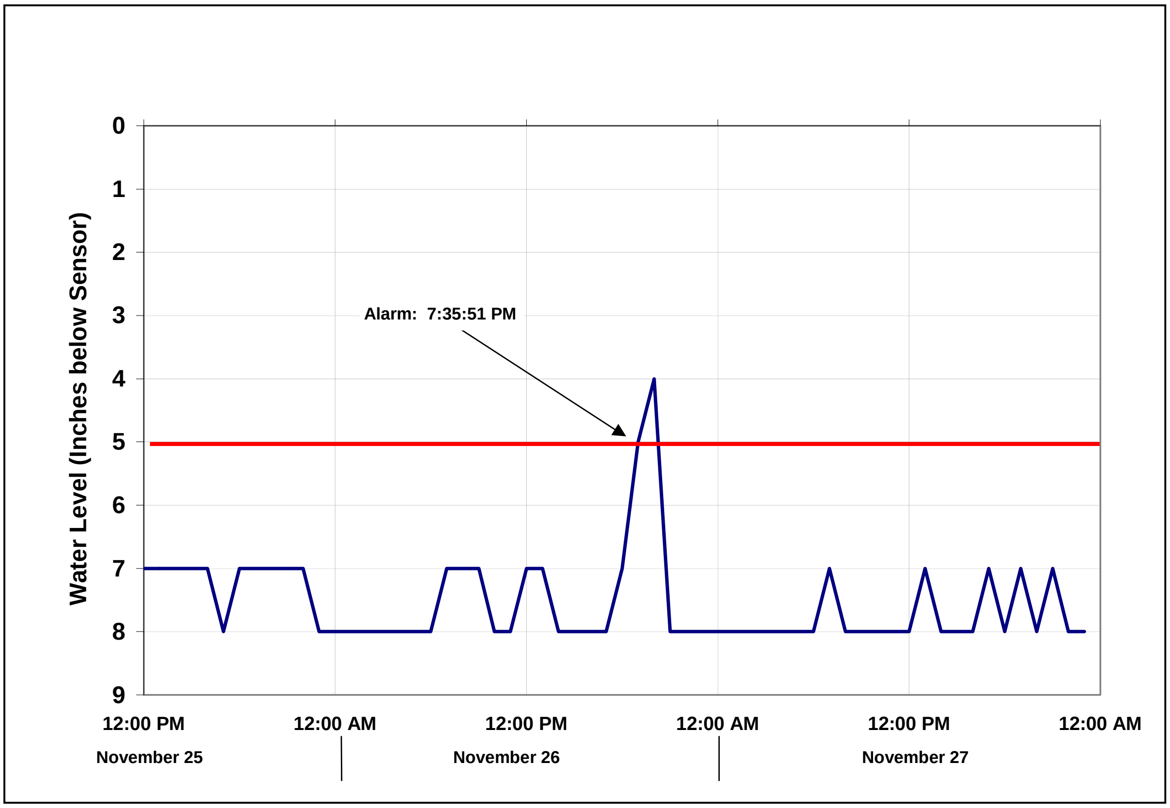

Figure 9. Surcharge event on November 26, 2007 at Site #4 location in Carlsbad, CA. Alarm was sent at 7:35:51PM to City field staff, who responded and cleaned blockage consisting of a root ball and grease downstream from this location.

DEPLOYMENT CONCEPTS AND DISCUSSION

Reduction or elimination of sewer overflows can be accomplished through three primary activities. First, a robust and comprehensive cleaning and inspection program should be in place and maintained. Second, a real-time continuous monitoring system that can be widely dispersed throughout the collection system, at least at sites of previous spills, "hot spots", and environmentally sensitive locations should be employed for early warning of potential spills. Lastly, once the monitoring system is installed, field staff should be trained and prepared to respond rapidly to alarms generated by the monitoring system in order to eliminate or correct the cause of the surcharging.

Attributes of an Effective Remote Monitoring System

In order to be most effective in preventing sewer spills, a continuous remote monitoring system should have the attributes shown in Table 1.

Table 1. Attributes of an Effective Remote Monitoring System

Attribute	Comment
Affordable	Remote monitoring systems need to be inexpensive enough for wide coverage in a collection system. Wide distribution and large numbers of sensors enables intelligent siting to monitor a variety of trouble spots and

	also spots that have excessively high risk such as riparian habitats, sensitive environmental areas, waterways, etc.
Robust and reliable	Any electronic system placed in a challenging environment such as a sewer lift station or manhole needs to be physically robust and able to withstand vibration, dust, a 100% condensing atmosphere, a low pH environment, corrosive gases and submersion in sewer water. Any system that cannot survive this severe environment for long periods and requires a substantial amount of labor to maintain also violates the "affordable" attribute above.
Low false alarm rate	Alarm systems with non-negligible false alarm rates rapidly lose their effectiveness, since responding to false alarms is costly and creates a loss of confidence in the alarm system.
No water contact	Continuous immersion in sewer water causes two serious problems for monitoring systems: (1) the sensors will degrade more quickly than those that are not in direct, constant contact with corrosive sewer water; and (2) Any sensor in continuous contact with sewer water tends to collect large solids and could, on its own, contribute to a blockage and therefore a spill.
Continuous monitoring	The case studies above illustrate that the time scale for potentially serious overflow events in manholes and lift stations is from minutes to a few hours. Continuous monitoring is necessary to provide adequate warning for many potential overflow scenarios.
Simple installation	Proliferation of a large number of sensors into a collection system could be highly labor intensive and expensive. Simple and inexpensive installation meets the "affordable" attribute above.
Repositionable	Prior to the installation of a level sensor at a given location, it is often not known whether a given location will have unusual water level events. In order to optimize the location of sensors, it should be easy to move the sensors from one location to another.

Sewer systems have been used for over 6,000 years[5], SCADA systems have been used in sanitary collection systems since about the 1960's[6], but it has only been since the beginning of the 21st century that technology advanced to the point of allowing the deployment of monitoring systems to large numbers of waste water sites in a collection system. The case studies presented here represent a small sample of field experience proving the efficacy of real-time monitoring to help prevent spills.

CONCLUSIONS

The use of a remote wireless real-time monitoring system for preventing sewer spills is highly effective. Since the time that the SmartCover® Sewer Intelligence™ System was installed in the OMWD and Carlsbad collection systems, there were no false alarms (no "false positives"), no spills were missed at the SmartCover® sites (no "false negatives"), and in the several instances where potential spills were prevented, there were no fines, lawsuits were avoided, and bad press did not occur. It should be noted that the monitoring and alarm system alone is not sufficient for preventing spills – agencies that employ these networks need to be committed to responding to alarms and “unusual” level events in a timely manner in order to eliminate the cause of the potential spill. Since there were no false alarms (“false positives”) from the SmartCover® system, field staff could be assured that when an alarm occurred, it was a real alarm and it was worthy to respond decisively. To date, the SmartCover® system has logged more than 1.7 million hours of operating time, representing more than 17 million level measurements with no false level alarms.

Unlike standard SCADA systems, this new 21st century monitoring technology enables the wide deployment of sensors throughout a collection system. Previously, monitors were so expensive that only a few could be deployed represented a small fraction of the total number of manholes and lift stations. The inability to place large numbers of reliable sensors in the collection system leads to playing “Russian roulette” with monitoring sites, and guessing where the next potential spill may occur – this is clearly not a satisfactory nor effective means of eliminating spills. The SmartCover® system is 10 to 25 times less expensive than traditional SCADA nodes and other monitoring techniques, enabling broad coverage at a great variety of potential spill locations in a collection system.

Once a significant fraction of manholes in a collection system are monitored, perhaps 3% to 5% of all the manholes, remote level monitoring systems such as the SmartCover® may be able to provide an effective and efficient means to deploy field personnel to locations that require maintenance and cleaning. Unusual water levels are an indicator that there are problems downstream, such as a constriction or pipe collapse. Further studies should be pursued to determine if it is possible to effectively maintain a collection system based on real-time data rather than on an empirically derived periodic cleaning schedule. Since a broadly dispersed monitoring system could cover 100% of the potential spill sites at a reasonable cost, it may be possible to save significant labor, fuel and vehicle costs if collection system maintenance can be performed in a “just-in-time” manner since all potential spills will be alarmed in all cases.

The case study for Site #4 illustrates the principal that level is more effective measure than flow in determining potential for a spill event. Sewer spills are caused by high levels, not necessarily by low or high flow. Experienced Carlsbad personnel visited Site #3 during the surcharge detected by the SmartCover® and they noted that the water was flowing through the hole, which historically has indicated that the problem was not serious. However, the high water levels – only a couple of inches above normal – were abnormal and further investigation revealed a blockage downstream. Water level measurements are a direct measure – and are the most appropriate measure - for the potential for sewer spills.

REFERENCES

1. EPA Web site, http://cfpub.epa.gov/npdes/home.
2. EPA Report to Congress, August 26, 2004. "Report to Congress on Impacts and Control of Combined Sewer Overflows and Sanitary Sewer Overflows".
3. Brown and Caldwell, March 2005, "What's a Spill Worth?"
4. (California) State Water Resources Control Board, Order No. 2006-003-DWQ, "State General Waste Discharge Requirements for Sanitary Sewer Systems".
5. Jon C. Schladweiler, P.E., R.L.S. http://www.sewerhistory.org
6. http://www.sandia.gov/scada/history.htm