The Problem
Maintenance of the collection system places a constant demand on a utility’s resources for personnel, equipment and management. All collection systems suffer from progressive and occasionally catastrophic occurrences from restrictions and blockages. Fat, oil and grease (FOG) can accumulate on pipe walls and serve to constrict flow. Tree root intrusion, sediment build–up and debris can also contribute to flow restrictions. Given enough time, these sources of restriction and blockage will progressively impact capacity of a pipe. The tipping point occurs unpredictably when the restricted capacity can ultimately no longer handle peak flows. For collection systems that suffer from inflow and infiltration (I&I) issues this tipping point of capacity can occur seemingly quickly and result in a sanitary sewer overflow (SSO). During a dry season the capacity may still be sufficient to handle daily peak flows. Yet, as seasonal rains show up the reduced capacity is challenged with the arrival of wet season. Unable to handle these flows, an SSO occurs.

This paper will look at the impact of SSOs, the current methods for addressing them and new, emerging technologies that can reduce the number of SSOs and potentially reduce capital requirement for this reduction.

The Range and Scope of SSOs
Spills are not an isolated problem. While the reasons for overflows vary, they are prevalent. The EPA estimates as many as 75,000 occur each year in the United States. In their 2009 “Report Card” on the US wastewater infrastructure, The America Society of Civil Engineers (ASCE) estimated that 890 billion gallons of raw sewage were released annually into rivers, streams and lakes and gave the US wastewater infrastructure their lowest grade, a D-. In their 2013 Report Card they cited that an investment of $298B is needed with 80% of the expense in collection system pipe.

The political and legal issue is that SSOs are an ongoing issue and a legal violation of the 1972 Clean Water Act. Repetitive or continuous or high volume occurrences can easily gain the attention of both state and federal environmental agencies leading to lawsuits, fines and mandated remediation.

Local Impact of Spills
Locally, SSOs can have a manifold impact such as rendering waterways off-limits for recreational or commercial use and creating a public health threat. They can also damage property. News reports of sewage spill events can be quite unwelcome by the public. As a result, public confidence is eroded with the creation of a negative perception of the utility. Very often these news stories will result in pressures on politicians who, in turn, will engage the utility staff.
Undoubtedly, spills have a substantial cost impact. By their nature, spills are unplanned events and, as such, cannot be properly anticipated and therefore budgeted. As a result, a utility can find itself spending precious budget monies that were once earmarked for projects that would bring improvements or upgrades. Most costs associated with spills do nothing to enhance or improve operations or assets. Sewer spills are nothing more than a drain on budgets and resources.

**SSOs: Best Accounting Practices**
While a small handful of utilities have a full and comprehensive understanding of all costs associated with an SSO, many more fall short in realizing the true range of costs the profound impact it has on costs. There are many essential factors that must be recognized in order to arrive at an accurate cost of a spill. Why is an accurate accounting important? With it a utility will understand the real cost of a spill and drive better economic decisions for preventing one. Without an accurate accounting, e.g., leaving out associated costs, a spill’s true cost may be hidden, lowering priority to decision-makers, and extending or exacerbating the underlying problems that cause the spills.

**The Three R’s**
A full accounting for costs includes more obvious elements such as those that are directly associated response and remediation as well as indirect costs such as administrative reporting. One way of looking at costs is to think of the “three R’s”: Remediation, Reporting and Reconciliation. Remediation refers to the response and clean-up processes. Reporting refers to the post-spill analysis and subsequent notifications as required by internal procedures, state and federal law. Reconciliation refers to consequential post-spill costs which could range from fines to litigation to public relations and all actions necessary to support these.

**Remediation.** Once a spill emergency occurs the utility’s response, dictated by standard operating procedures (SOPs) are actuated. Consequently, the cost-meter is set in motion. Typically, the response will include equipment like a vacuum/pressure spray truck, a crew of at least two persons and materials required to enable clean-up. Less sophisticated accounting practices, when establishing a statistic for the “average cost of a spill” would tend to look at the labor costs only. One moderately sized southeastern city recently cited in an interview with the author that the “average cost of a spill for them is $400”. They accounted for the cost of labor only. The cost of the truck operation and materials used was left out. Yet, a more comprehensive analysis would account for those costs (and more) to seek a total cost. Adding in the amortized cost of the capital equipment used e.g. the truck, its operational costs e.g., insurance, fuel and maintenance plus materials used for cleanup e.g., bits for grinding tree roots, chemicals used to clear grease blocks yields a much larger cost per spill incident. Why this and more? The point is that a full accounting of all direct and indirect Remediation costs yields a true picture of the immediate impact on the utility. What once seemed insignificant now may emerge into the light where the real cost of an SSO will re-prioritize decisions that can, in turn, drive costs down and lower spill frequency.

**Reporting.** Provided that a spill has been remediated, typically the next step is to assess the event. Universally, across all states and federal regulations, the quantity of the spill must be determined. This estimate, and it is only an estimate because obviously the utility staff was not at
the spill location at the beginning of the spill event, will determine the necessity and type of reporting. In order to determine reporting requirements the spill volume analysis must be performed. The reportable volumes will vary by state and must also meet the federal (EPA) requirements. In Florida, any spill of 1,000 gallons or more, any spill into a waterway or any spill that threatens the public health is to be reported. In other states, such as California, all spills, no matter how large or small, must be reported with the threat of criminal prosecution in failing to report a spill. While a comprehensive full accounting of costs includes the time for analysis and corresponding reports, less robust accounting does not. It fails to examine the drain of management, administrative and technical resources necessary to meet mandated requirements. Optimize accounting values this time and place a price on it to get it right.

**Reconciliation.** These costs can be the most significant by far, the least apparent and the most politically and legally charged. Fines, being an obvious part of this group, are easy to evaluate and quantify. Obviously, state and federal mandates based on such factors as volume, environmental impact and more will determine the fine levy. The term reconciliation implies that a utility is “making it right”. This can be extremely costly. Take, for example, the case in a well healed Southern California beach community. A sewage spill occurred in a residential community resulting in the flow making ingress to a home owner’s expensive home. The home owner, being an attorney, determined that he didn’t want to go through the hassles of remediation. In this case he literally handed his house keys to the utilities manager saying “you bought my house”. The city realizing that the cost of litigation plus potential recompense to the home owner would cost more than the home owner’s asking price. They bought the house for $1.5MM. Litigation and compensation will heavily factors into the cost equation.

Then there is the cost of public relations. Invariably, most reported spills will consequently reach news services, often above the fold on the front page of the local or regional newspaper. These news stories will generate consequent statements and reactions from public officials i.e., explanations of what occurred, why it happened, what is being done in response, and what it portends for the future.

Lost business can occur because of a spill, consider spills into the ocean, or waterways where recreational swimming or fishing occurs. Often local businesses will bring suit to the utility for lost business.

Spills also attract the attention and often subsequently, the legal threats, of non-government organizations (NGOs) whose purpose and organization is based on protecting the environment.

Internal relations as well are consuming time within the organization. Multiple meetings with multiple persons, usually from a variety of disciplines will become engaged for analyses, reports and tasks. This all adds up to more investment of time and the costs pile up. Accounting for this can be complex. Some value can and should be applied i.e., five persons for two hours each times an hourly rate.

**Clean-out Methods**
Utilities use a variety of means to stem the number of SSOs. Without question, routine clean-out maintenance helps as it tends keep obstructions from forming in the collection system. Simply
increasing the clean-out cycle, especially at critical locations where build-up is known to occur (high frequency clean-out sites), can have a positive effect as well. Many utilities have managed their collection systems in this manner and reduced the incidence of spills but with varying degrees of success. For example, one large, west coast city established a rigorous cleanout program with an aggressive, high frequency cleanout program divided into three frequencies of every 3 month, every six months and every nine months. The number of spills was dropped by 60%. There are drawbacks that should be considered with high frequency cleanout. This is an ongoing, recurring process that is heavily dependent on expensive equipment such as vacuum/pressure spray trucks and labor. A consistent process will be expensive and create a demanding schedule and increase wear-and-tear on field equipment, requiring higher long-term equipment costs.

Establishing the frequency of clean-out cycles is typically based on historical information. For example, a Florida city found that a manhole which had been cleaned out just six weeks earlier had an overflow. Upon investigation they found, somewhat to their surprise that the cause of the spill was build-up. Thus, to avoid a future spill the utility established a cleanout frequency of once every three weeks. This was twice as frequent as previously with the thought process being that they were allowing a healthy “margin of safety” between cleanouts. While somewhat extreme, it does illustrate the foundation of how frequencies are established at most utilities.

It is very easy to see why high frequency cleanout procedures are attractive as a solution to SSOs. First, these are well established processes. Second, many regulatory agencies recommend a rigorous cleanout program. Finally, many managers believe that there are no alternatives. Yet, what may be a common element in all of these is that there is fundamental lack of knowledge concerning the ongoing condition of the collection system. Therefore, an exaggerated and costly response is required and the decision to deploy more personnel and more equipment is a much better alternative than more SSOs, or more public scrutiny or more NGO or private citizen lawsuits.

**Spot Inspections and Collection System Dynamics**

In a study of more than 2,000 sites across the United States and using data from an eight year period, it was found that build-up leading to an SSO is a progressive process in as much as 98% of all occurrences where the progression can be evident over the course of weeks or even months. The cause of a progressive build-up will vary, with fats oils and greases (FOG) being the primary cause followed by root intrusion, sedimentation, debris and degradation. Unfortunately, those that are managing the collection system are for the most part, flying blind. They do not know the overall condition of the collection system and individual sites. It is quite difficult to recognize systemic changes and to know if the condition of the collection system is stable or degrading.

Of course one method to assess the condition of the collection system is to perform spot checks. These visual inspections by humans or using more sophisticated methods such as video cameras can provide some feedback. These methods are limited as they only produce a snapshot view of the collection system- not an ongoing picture of the collection system dynamics. It does not provide any information about progressive changes that are taking place unless a series of inspections for each site are scheduled. Additionally, spot inspections are labor intensive. If a
utility has hundreds of sites to inspect then multiple visits to hundreds of sites becomes burdensome and impractical on an ongoing basis. For example, a site that historically required a yearly clean-out cycle is now handling influent from a newly opened strip mall, complete with seven new restaurants. The FOG content in the flow has increased (even with well-maintained grease traps) yet the collection system cleanout maintenance schedule, based on history, has not changed. FOG builds up slowly but at a more rapid rate than prior to the mall being build. Finally, a series of rainstorms hits the area. The FOG has reduced the capacity of the system just enough so that normal peak events cannot be handled and an overflow occurs. Past habits for cleanout did not catch-up with current conditions and the manager had no way of determining that these changes were occurring. A spot inspection might have helped but without continuous inspections a changing condition and with marginal changes in capacity, may not be able to be noted.

Proven High Tech Solutions Saving Time, Lowering Costs and Reducing Risk.
Over the past several decades, technologies have been developed to cost-effectively monitor collection systems including sewer pipelines, manholes, and lift stations. A handful of devices are available, designed to provide an indication of an event that is occurring in a given location. These devices aid in preventing overflows by sending an alarm to the user(s) for a reactive response.

There are two distinctive classes of devices. The first type of devices is classified as Single Purpose/ Basic Alarm Devices (SP/BAD) and the second are True Real-time Monitors (TRM). They are quite different in functionality and benefits to users. Herein, we will examine each type.

SP/BAD devices are simple in design and created for a single purpose where they are designed to provide an alarm-only. Should a given site have an upstream blockage in the pipe that, in turn, leads to a rising flow level that where an overflow may result, they will send an alarm. These devices are not designed to provide any data or information about the collection system. The greatest appeal of SP/BAD is their perceived low purchase price relative to more advanced devices. It should be noted that installation can add to the cost appreciably as there is a necessity for confined space entry.

These devices use simple floats that are mounted in a fixed position. The floats are actuated should when the rising water make contact and a signal is sent via a cellular network to users indicating that the float has “tipped”. The use of floats is one of the reasons that the SP/BAD hardware costs are somewhat lower than other devices. Yet, users must also accept that the well-established limitations of floats for occasional inconsistency with reliability. Floats can fail to actuate. For example, a grease blanket can build and rise at a site and the float will not tilt and therefore provide a signal, or the float may be tied off to the side during maintenance and left there unintentionally also leading to an overflow with no alarm.

SP/BAD also suffer from communications issues. The any cellular device, signal quality and communications capability can vary wildly. Sewer systems are specifically built to maximize gravity, therefore you will find more sewer lines in the lowest lying area of any given geography. Where poor signal quality is present, then consistent communication is suspect. It is paramount that when deploying SP/BAD for alarms, communication of an impending event spill event be
communicated with extremely high reliability. Without this the SP/BAD falls short of its core mission.

As previously stated, the SP/BAD provide alarms-only by design. They do not produce any collection system data whatsoever concerning level changes. In interviews with users of the SP/BAD devices they state that “all that’s necessary are alarms”. This bears some truth where provided that the alarms are received reliably (see “Knowing the Real Bottom Line” below) there can be a substantial savings versus TRM systems. Yet, there is another substantial cost factor that must be considered. In a study performed by SmartCover® Systems™ of more than 2,000 monitored sites across the United States and examining a seven year span, analysis of revealed that surcharges occur more than 81% of the time outside of the typical first shift work hours\(^5\). In other words, organizations are responding to spills four times out of five times when overtime may be required and in a majority of instances, after dark. The later fact, after dark response, carries with it higher risk. The key point is that organizations are reacting to an alarm and they are doing it at inopportunity, more costly, and higher risk times. As we shall see in the next section, TRM systems, complete with predictive capability, will lower risks and costs associated with unplanned, reactive responses to alarms.

**TRM** are a more advanced class of devices that provide a wide range of capabilities. In fact, they only real comparison of TRM to SP/BAD is that both have alarming capability. One leading system, the SmartCover®, manufactured by SmartCover® Systems™ in Escondido, CA, has a substantial range of capabilities. Unlike the SP/BAD which is a single purpose system the multi-function SmartCover® can acquire data on an ongoing basis, enable real-time viewing of remote sites, support bi-directional communication, provide predictive analysis of trends occurring at remote sites, provide level and flow data, and assist with report generation. Users will employ this system for acquiring data to assess I&I, for driving collection system maintenance programs using predictive modeling, to acquire collection system data for improving asset management planning. In addition, these systems have alarm capability. Users can be notified should the flow level reach a prescribed alarm point. Of course, in a collection system the aforementioned predictive trend capability would be preferred over an alarm. This trend tool, called SmartTrend™ enables operators to avoid spills by alerting them to unusual water-level conditions long before a spill occurs and provides time days or even weeks of time to schedule corrective action.

The SmartCover® system is an ultrasonic level monitoring system that acquired data on an ongoing basis. Using the Iridium® satellite system, users are assured the highest levels of connectivity through a highly redundant network of 66 satellites in low earth, polar orbit. This satellite system has extremely well established track record for reliability and security. The US Department of Defense uses the same network for critical military communications.

SmartCover® acquires level data with an IP-68 rated ultrasonic sensor also referred to as the distance sensing module (DSM). This sensor operates without the need to contact the flows thus substantially reducing necessity for maintenance. The sensor is crystal oscillator controlled and temperature compensated assuring ongoing precision and no calibration. It has high resolution, better than 0.10”. These features result in an exceptionally low maintenance and highly reliable
sensor where the false positive rate is less than 1 part in 200 million and the known instance of missed events is less than 0.02%.

Perhaps the most essential portion of the SmartCover® system is the access to graphical and .csv formatted data. A dedicated user website enable users to access, view and interact with remote sites via web browser. All software and user data is hosted in the “cloud” meaning that the interface and data storage is maintenance free, secure, and stored indefinitely.

Upon logging in, the user will be presented a map of all SmartCover® locations. Details for any given site are accessed by clicking on the location on the map or an address list. The user is then presented with the default graph of one week’s diurnal flows. Any date range can be selected to view the chart and data history.

This highly flexible system also has protocols for seeing “Advisories” of changing collection system conditions, “Alerts” for notifying users of maintenance cycles and “Alarms” for either a surcharge or an intrusion.

**Predictive Trend Analysis**
Continuous real-time monitoring and data acquisition provide a powerful benefit of being able to view any ongoing trends at each remote site including manholes and lift stations. SmartTrend™ functions by scanning, assessing and reporting on all remote sites, seeking anomalies to level trends. SmartTrend™ reviews and analyzes all the level data from all sites in search of changes in level that may indicate something changing in the collection system. Users receive “Advisories” whereby they directed to look at specific sites which may require remedial action. “Advisories” are specifically designed to be an advanced warning system that helps identify suspect remote sites of collection system. Most importantly, they seek to avoid an alarm where users can schedule maintenance or other actions, well in advance of a potential event.

Predictive advisories and their ability to shift from reaction to pro-active scheduling offers an opportunity for true transformational change in an organization. Specifically, managers who were once “flying blind”, not knowing the behavior of the collection system can now view remote sites graphically with a few keyboard strokes. Where managers were once forced to employ labor intensive and historically based high frequency cleanout routines can now use default to scheduling cleanout as needed. But more than this, they are assured that no SSOs will occur where SmartCover® units are installed.

**Asset Management**
Real-time remote monitoring of the SmartCover® also places a powerful capital tool in the hands of the utility management. Conventionally, aging pipes are refurbished, replaced, or expanded at a cost ranging from hundreds of thousands to millions of dollars per mile. Data
acquisition through TRM enables better decisions regarding “if” and “where” to direct capital resources. As a result, projects can be prioritized. Asset investments are then targeted to the areas that are needed most. As a result, a more immediate and substantial return on investment will be achieved. In other cases, data may show that some projects may be deferred and even avoided and with no increased risk of spills. Therefore, with data acquired upfront, better decisions are made resulting in potentially millions in capital cost savings.

Knowing the Real Bottom Line: SP/BAD vs. TRM
As previously noted the SP/BAD devices have known reliability issues with both the float and communication reliability issues, users must factor in the higher potential for a spill to occur in order to truly assess the real Cost of Ownership. Even with a very low probability of 1% error, where in 100 surcharge events one spill will occur, there is a substantial and impactful effect on cost. A 2014 case illustrates this quite well. The utility purchased four SP/BAD devices for their alleged “lower cost”. The utility believed that they were saving 50% as they simply compared hardware cost of the SP/BAD to the hardware cost of the TRM. Unfortunately, they failed to make any inquiries concerning installation and found out that the SP/BAD system installation required confined space entry (the TRM did not). This alone reduced the cost gap to 30%. Even so, there was still a real savings on paper. Within four months of installation one of the alarm sites had an overflow where the SP/BAD failed to provide an alarm. This leads to the series of costs for remediation, reporting and reconciliation. The fine alone exceeded $15,000. This single event and all associated costs erased all savings. The actual Total Cost of Ownership after one year of operation is more than 25% higher. Even more, the risk for a similar future event remains.

Case Study: A Different Approach and a Better Solution to High Frequency Cleanout
A Florida utility was maintaining an aging collection system that had a high frequency of spills due to a combination of progressive build-up, sometimes rapid, compounded with I & I issues. From 2009 through 2012 the utility was challenged with year-over-year declines in revenue during the Great Recession. One of management’s responses to the revenue decline was to impose a hiring freeze. Attrition over the course of four years successfully reduced operating expense but concurrently added substantial strain to standard maintenance practices and schedules. This utility’s field operations department in particular, was responsible for collection system cleaning. Their staff reduction declined to a point where they were at 68% of the pre-recession levels. This steep decline in field personnel raised challenges to cleanout schedules. They could not keep up and had little visibility of the condition and dynamics of the collection system.

In one particular, wealthy, waterfront community with a concentration of with multi-million dollar homes, the residents demanding and had political connections to support them. This area’s collection system required constant, high frequency maintenance. Yet, the utility didn’t have the resources to assure that the three fold risk of environmental damage (it was surrounded by water), public health due to proximity to homes and political pressures could be addressed. The utility needed to take a different approach than to simply throw people and equipment at the problem any longer. They needed transformational change.
They took a different approach forced by near abject necessity. In 2012 they invited SmartCover Systems to a meeting and to discuss the potential for using monitors (TRM) to attain real-time viewing and ongoing data acquisition of up to one dozen “ultra-sensitive” remote sites. Upon competition of a survey the initial six remote systems were installed. Each remote system was placed at a site that would monitor and protect dozen of downstream manholes where had a blockage occur the progressive level rise would back-up to the monitored site. Since installation data shows that 86 times (out of 86 events) the system detected and prevented an overflow. Additionally, the utility was able to cut the frequency of cleanout down by 61%.

The SmartTrend® tools were added in 2014. This tool enables an additional savings where field supervisors were able to now rely on an automated, once per day scan of each remote site. This important addition meant that their online viewing of sites was prioritized as their attention, via an email “Advisory”.

This utility has since and will continue to add more SmartCover® systems as they have realized the benefits of substantial savings with lower labor at former high frequency cleanout sites, with the added assurance they are protected from SSOs.

Conclusion
The challenges of the collection system, due to its dynamic nature, means if utilities are to meet increasingly strict enforcement of the Clean Water Act, utilities must look to new techniques and technologies to achieve real savings and lower risks. Embracing new technologies offers the opportunity for transformational change where not only can utilities cost effectively and safely comply with regulations but they can also gain valuable knowledge and insights about their collection system. This knowledge enables better decisions for maintenance and asset management alike.

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