Keeping Wastewater in the Pipe and Your Utility Out of the News

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Utility customers and the communities they live in have high expectations for wastewater service and utility performance. Customers want service without interruption, and nobody likes environmental impacts, wastewater spills, or construction and maintenance activities that disrupt normal activities or increase rates. Sound decision making that balances high service expectations with undesirable impacts is imperative. Furthermore, being able to quantify and communicate these balances and trade-offs is key to projecting and maintaining a positive image among customers and the community.

This article discusses the evolution of Gainesville Regional Utilities (GRU) in assessing its wastewater collection system subjectively (in a manner that was hard to communicate) and changing it to an objective system that quantifies risk, identifies risk mitigation techniques, and supports the communication of the needs and benefits of the investments that were made.

A municipal utility, GRU provides electric, water, wastewater, reclaimed water, natural gas, and telecommunications to a population of approximately 200,000 in and around Gainesville. Its wastewater system is comprised of two water reclamation facilities, 168 pump stations, 650 mi of gravity sewers, and 139 mi of force main.

In the early 2000s, GRU had a series of high-profile sanitary sewer overflows (SSOs) that resulted in a loss of community confidence and public scrutiny of the operation and maintenance of its wastewater system. Action was needed to prevent SSOs and restore the confidence that GRU was appropriately operating and maintaining its wastewater system. Figure 1 shows a local editorial cartoon critical of GRU's periodic SSOs.

Wastewater Infrastructure Challenges in Florida

Maintaining reliable wastewater service and preventing spills is a challenge to utilities throughout Florida and the United States, as infrastructure deteriorates and more aggressive

Figure 1. Editorial cartoon by Jake Fuller, *Gainesville Sun*, 2006. *(Used with permission)*

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rehabilitation and replacement is required. In 2008, the American Society of Civil Engineers (ASCE) report card scored the condition of Florida's water and wastewater infrastructure as good, but it dropped to mediocre in 2013. Furthermore, ASCE estimated that $19.6 billion is required in Florida in the next 20 years to adequately maintain wastewater infrastructure [1], which amounts to about $3,500 per year for every household in the state. Given that the average residential wastewater bill in 2014 was about $35 per month[2], infrastructure investments of $15 per month per household equate to a 40 percent increase in monthly bills.

The amount of required investment is staggering, given that customers are frequently opposed to any increase in rates. Florida's utilities must be able to communicate the need for funding and the need for the significant construction activities required to maintain reliable service and minimize spills and backups. The foundation for communication is being able to properly assess infrastructure and communicate the condition to customers and the community.

Probability of Failure

Like many Florida utilities, GRU has been in operation for a long time (125 years), but much of the wastewater collection system was installed during a rapid growth period in the 1970s and 80s. Much of GRU's wastewater collection system is 30 to 40 years old, and 50 years is often considered the maximum service life for gravity sewers. The utility's experience has been that some sewers fail quickly in 10 years or less, while many sewers function properly well beyond 50 years.

While it is commonly assumed that the oldest pipes need to be replaced first, the decision to upgrade collection system components is much more complicated. Gravity sewer systems are constructed over a range of years as systems grow, using a range of pipe material, construction, and bedding techniques, and are constructed in a wide range of soil types. While generalizations can be made to rehabilitate based on age, material, and soils, it is preferable to inspect gravity sewers prior to making very expensive rehabilitation decisions.

The utility has discovered that the majority of ductile iron piping currently in service is subject to tuberculation and constrained flow, resulting in smaller effective diameters than when new. Gravity sewers made of ductile iron and in service for 10 or more years often must be cleaned to remove tuberculation. In some cases, the tuberculation is so extensive that, when removed, the pipe is no longer structurally intact. For this reason, ductile iron sewers are assumed to have a higher probability of failure than other pipe materials.

Vitrified clay pipe (VCP) also poses a particular probability of failure since the pipe lengths are short (4-ft pipe lengths instead of 20-ft pipe lengths for other common materials used today). The short pipe lengths make the pipe more subject to bedding deficiencies, and thus more likely to fail than pipes installed in longer lengths. It should be noted, however, that even very old VCP pipe can provide good service if the bedding remains intact.

Figure 2. Highly visible wastewater collection system failure requiring a major emergency response.

Closed-circuit television (CCTV) is the most common means of assessing gravity sewer system condition. It can be used in most situations, and GRU has been using it to evaluate the condition of gravity sewers for more than 30 years. Over the years, data standardization and management have evolved from general subjective assessments to more objective assessments. Subjectively, pipe runs can be described using terms such as "good, adequate, and bad." While these types of assessments might be adequate for small systems with few people involved in assessing gravity sewer conditions, they are not quantitative. Since numerous people can be assigning the subjective terms, subjective assessments do not lend themselves to comparison. Adopting a standardized numerical condition assessment system allows various parts of the system to be assessed by multiple teams using the same standards and definitions, and rehabilitation work can be prioritized. Standardized assessment supports transparent rehabilitation decision making.

Standard assessment scores define the probability of failure. The utility uses CCTV to inspect gravity sewers and CUES GraniteXP software to score each segment of the gravity sewer, then imports that condition score into the geographic information system (GIS) for data management and decision making. As has widely been discussed, CCTV is used to discover pipe failures, joint failures, cracking, leaks around lateral connections, leaks and failures within laterals, changes in grade, settling problems, obstructions, etc. The software score ranges from 0 to 100, with 0 being in perfect condition and 100 being the worst condition, with numerous structural deficiencies.

While it is desirable to design and construct gravity sewers below the bottom of creeks, elevation constraints sometimes require aerial creek crossings. Sometimes gravity sewers, when first constructed, are below creek bottoms; however, creeks shift and meander with time and can expose gravity sewers. While internal sewer inspection is the best way to assess the condition of buried pipe, aerial crossings should be inspected externally. Since conditions change (exposed pipe ages, pipe supports can be undermined by erosion, etc.), aerial crossings should also be inspected periodically.

Part of the inspection of aerial sewer crossings is to assess the current integrity of the crossing. Another part of the inspection is to determine the presence or likelihood that floating or waterborne debris, ranging from tree limbs, branches, trunks, and smaller floating debris, might accumulate upstream of the aerial sewer crossing and break the crossing during a storm event.

There are two general ways of dealing with debris that might impact an aerial crossing. The first is to remove the current accumulation of debris and perform future removal periodically. While this may remove the immediate threat, more debris may accumulate in the future, again exposing the crossing to potential failure. The second technique is to harden the crossing with additional supports or construct features upstream of the crossing that will prevent debris from impacting the crossing. The utility uses one or both techniques, depending on field conditions.

Consequence of Failure

Wastewater collection system failure includes pipe failure, stoppage, or partial stoppage, and results in impacts to adjacent features, backups into private homes and businesses, and SSOs that discharge to the environment. The consequence of these failures is private property damage and related claims, public property damage to roads and other utilities and claims to resolve the impacts, and regulatory sanctions and fines. All of the consequences are not only costly, they are also bad for a utility's image, and could result in negative coverage from the media. Numerous spills and collection system failures erode customer and community confidence.

Of course, not all collection system failures have the same consequences. Minor failures, like a stoppage in an individual service lateral, may only result in a temporary inconvenience for a single customer. Major failures can impact service to thousands of customers, or involve a high-impact and highly visible discharge to a community's favorite waterbody. When prioritizing wastewater collection system improvement projects, it is im-

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portant to acknowledge and account for the range of impacts caused by a collection system failure.

For purposes of quantifying the consequence of failure, GRU considers the following factors:

Roads – Since most gravity sewers are under roadways, gravity sewer failures can and frequently do impact the overlying road base, roadway, and adjacent utilities. Even when the failure itself does not impact a roadway, construction activities to repair the failure may impact overlying roadways. At the ends of the continuum of consequence of failure, consider a lightly traveled local road that is part of a grid system and an interstate highway. The local road will disrupt relatively few drivers, and a detour can be easily established and might result in only a few extra minutes of drive time. However, the interstate highway system, if disrupted, can easily impact thousands of drivers, and detours can take hours. Additionally, interstate highway disruption requires extensive maintenance of traffic efforts, is an extreme safety hazard, and can result in bad publicity. The consequences of impact to a heavily traveled road are much more significant than to a lightly traveled road, and thus, gravity sewer rehabilitation on the heavily traveled road demands a higher priority.

Pipe Diameter – Larger-diameter gravity sewers are generally capable of accommodating more flow than smaller-diameter sewers. Since the consequences of a potential discharge are a function of the amount of wastewater discharged, higher-flow systems have the potential for a more significant consequence of failure. Furthermore, higher-flow systems also have more of a potential to damage multiple connected facilities, resulting in significant property damage. Thus, larger-diameter collection systems generally demand rehabilitation before smaller diameter collection systems.

Environmental Impacts – Some SSOs can be contained in a ditch, swale, or dry retention basin, allowing recovery and cleanup. In these cases, there is limited environmental impact. By contrast, some SSOs discharge directly into a surface waterbody, and even small SSOs can't be contained or recovered and can have an immediate, significant, and long-lasting impact on the receiving waterbody. It's easy to understand the environmental impacts at points in the collection system where SSOs have previously occurred. In those cases, the impact has happened before, is well understood, and unless corrective measures have been taken to prevent a reoccurrence, future SSOs are more likely to occur at these points than other points in the collection system. The process of evaluating the potential impact of an SSO that has not yet occurred in the collection system requires a more detailed evaluation. There are a number of circumstances that have potentially significant impacts:

1. *Aerial creek crossings.* If aerial creek crossings fail, there is an immediate discharge to surface water that frequently cannot be recovered.
2. *Manholes adjacent to creeks and surface water bodies.* If the distance between manholes and surface water bodies is short and surface elevations slope towards the waterbody, as is usually the case, manholes and gravity collection systems adjacent to waterbodies pose an immediate threat should failure occur. It is frequently also true that working around the waterbody requires extensive regulatory permitting or regulatory variances during emergency conditions.
3. *Areas served by private wells.* Though somewhat rare, some parts of wastewater service areas may contain gravity sewers, but adjacent businesses or residents are on private wells. In these cases, SSOs can not only impact the environment, but may also impact the private wells. Though impacts from SSOs to private wells are rare, the potential often requires extensive testing and demonstration that no private drinking water wells are impacted.

Accordingly, gravity sewers adjacent to waterbodies and private wells generally pose a greater consequence of failure than deep gravity sewers adjacent to closed stormwater basins where an SSO can be recovered and treated.

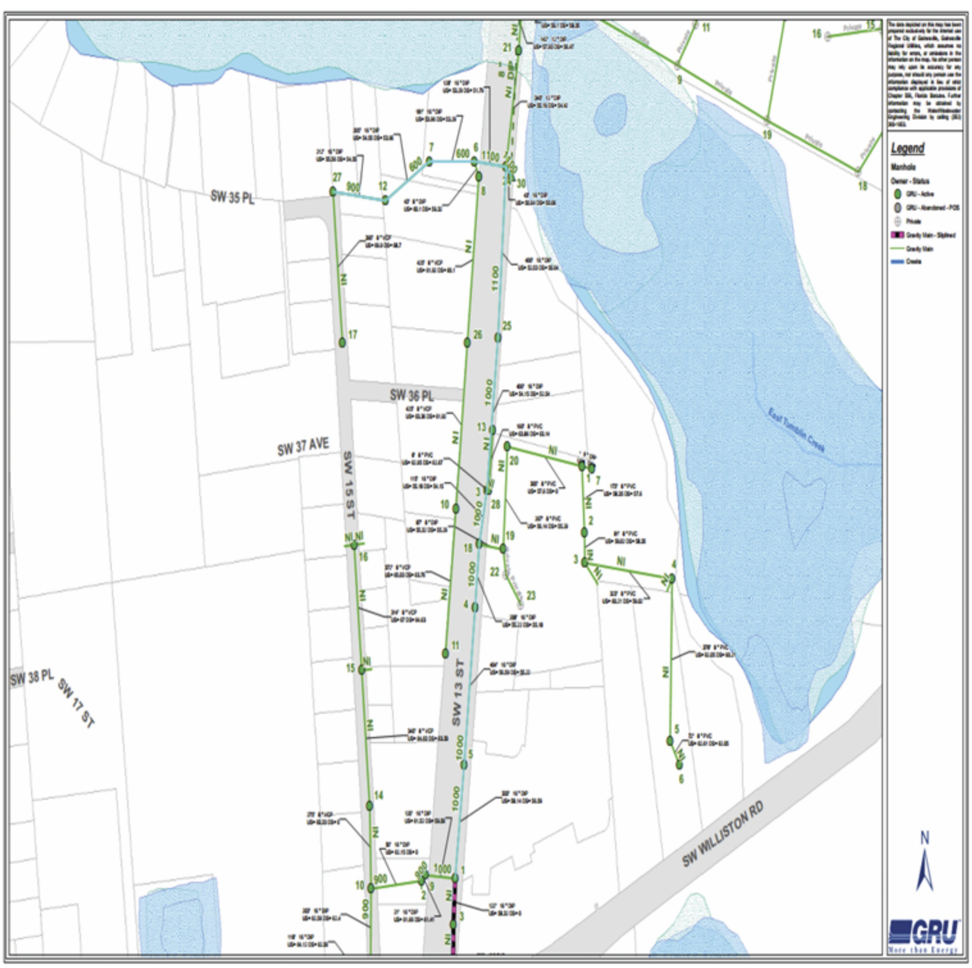

Figure 3. Example of GRU's GIS system showing the physical characteristics of the collection system and the risk score by pipe segment.

Risk Quantification

Risk is the product of the consequence of failure and the probability of failure. The formula for risk quantification that GRU uses is as follows:

Total Risk Score =
(GraniteXP Score) X [(pipe material score) + (road score) + (environment score) + (pipe diameter score)]

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The score ranges from 0 to 100, with 100 being the poorest condition of pipe as previously described. Additionally, pipe material is separately considered, with ductile iron pipe considered to pose a higher probability of failure due to tuberculation and VCP having a higher probability of failure due to vulnerability to bedding deficiencies. Ductile iron pipes are assigned a score of 3; VCP is assigned a score of 2.

A 1-to-5 rating, with 1 being the best and 5 being the worst, is used to quantify the consequence of failure previously described (roads, pipe diameter, and environmental score). The GIS contains data, such as road type, pipe diameter, pipe material, and proximity to environmental features, and is used to accurately score these elements. This tool is critical to streamlining the scoring process and the analysis is combined with the GraniteXP score to calculate the total risk score, which is used to then prioritize projects.

This risk assessment and prioritization approach is dynamic, and the factors can be varied as better information is gathered. For instance, utilizing a work management system that captures the costs (consequence) of pipe failures or a better understanding of customer impact from road closures may result in varying the weight of a particular parameter.

The total risk score can range from 0 (low probability of failure and low consequence) to 2000 (high probability of failure and highest consequence of failure). Figure 3 shows the total risk score by pipe segment for a small portion of GRU's collection system.

Risk Mitigation

Risk associated with collection system failure can be reduced by either rehabilitating the gravity collection system or reducing the consequence of failure. In practice, rehabilitating portions of the collection system found to be at risk is much more feasible than reducing the consequence of failure. While some circumstances exist where potential spills (should they occur) can be directed to closed basins allowing subsequent recovery of a discharge, those instances are rare. The majority of methods to reduce risk associated with the gravity collection system involve upgrading or replacing the system prior to failure; however, knowledge of the consequence of failure is extremely important, even if the consequence can't be reduced. It allows utility managers to prioritize collection system upgrades based on the consequence of failure when all other factors are equal.

In addition, it is important to review the selected prioritized projects with the field personnel and managers to ensure they pass the "common sense" test. Field personnel are given the opportunity to review the scoring of both probability of failure and consequence of failure, and those scores are adjusted if errors are found. The process is dynamic and uses fresh input from field personnel, including crew leaders, supervisors, and managers who are daily inspecting, repairing, replacing, or constructing wastewater facilities.

The utility uses the risk score to prioritize rehabilitation projects. The highest-scored projects have the highest risk and are planned and budgeted to be completed first. Table 1 shows how the highest-priority projects are scored and ranked.

Summary

Wastewater collection system failure frequently causes SSOs, which can have significant impacts to public health, safety, and the environment. Further, SSOs are highly visible, and frequent SSOs attract media attention and erode confidence in the public wastewater utility. It is incumbent on all public wastewater utilities to invest the necessary resources to keep their systems operational and prevent SSOs.

The proper operation and maintenance of gravity sewers includes condition assessment and rehabilitation or replacement as needed. Much historical information about the condition of gravity sewers is subjective in nature and frequently not documented in ways that can be retained as senior staff members retire. Quantitative methods are needed to assess the condition of gravity sewers, as well as the consequence of failure associated with existing facilities.

The methods for prioritizing and scheduling gravity sewer rehabilitation that GRU uses have evolved from a subjective system that relied heavily on individual judgement that was documented in paper systems and were difficult to analyze, to an objective system that facilitates analysis and incorporates not only the condition of sewers to be rehabilitated, but also the consequence of failure to arrive at an overall risk score.

As public utilities are continuously asked to do more with limited resources, it's important to optimize the use of resources in a way that balances the risk of infrastructure failure with community impacts, including rates and rate increases. The risk quantification method described is used to prioritize projects to be included in the capital budget and communicate the needs to decision makers and customers.

The 10-year focus of GRU on infrastructure rehabilitation has decreased SSOs, but has also contributed to the need for rate increases to fund improvements. Since SSOs occur less frequently, the Gainesville community is less critical when they do happen, and appears to be satisfied with the continuing investment to operate and maintain GRU's wastewater system. The utility has communicated system conditions in the past; in the future, it needs to more aggressively ensure that the community is well-informed about challenges in the wastewater system and that it has opportunities to participate in the annual budget process where priorities are presented and adopted.

References

1. American Society of Civil Engineers, 2013 Report Card for America's Infrastructure.
2. Roca, Mike; and Hairston, Tony. 2014 Florida Water and Wastewater Rate Survey, Raftelis Financial Consultants Inc.

Table 1. Risk score and costing information used to establish capital budget needs.

GRU Fiscal Year 2016 CIPP Projects

Project No.	Project Name	Matrix Score	Approx Length (LF)	Pipe Size (in)	Pipe Material	Owner of ROW	Max Depth to Invert (ft)	Estimated Liner Thickness (mm)	Unit Price for Liner ($/ft)	Bypass Pumping provided by Insituform (Yes/No?)	Bypass Pumping Unit Price ($/ft)	Tuberculation Removal Unit Price ($/ft)	Degree of Cleaning	Cleaning Unit Price ($/ft)	Estimated Qty of Laterals	Liner Subtotal	Bypass Pumping Subtotal	Tuberculation Removal Subtotal	Cleaning Subtotal	Lateral Service Reconnection Subtotal	Lateral Service Grouting Subtotal	Segment Total Cost
A	**SW 13th St - 4000 Block to LS 30**																					
A-1	MH 1 - MH 5	1000	333	16	DIP	FDOT	13.5	7.50	$ 42.00	Yes	$ 5.00	$ 24.00	Heavy	$ 2.70	2	$ 13,986	$ 1,665	$ 7,992	$ 899	$ 350	$ 500	$ 25,392
A-2	MH 5 - MH 4	1000	404	16	DIP	FDOT	12.62	7.50	$ 42.00	Yes	$ 5.00	$ 24.00	Heavy	$ 2.70	2	$ 16,968	$ 2,020	$ 9,696	$ 1,091	$ 350	$ 500	$ 30,625
A-3	MH 4 - MH 18	1000	208	16	DIP	FDOT	15.1	7.50	$ 42.00	Yes	$ 5.00	$ 24.00	Heavy	$ 2.70	0	$ 8,736	$ 1,040	$ 4,992	$ 562	$ -	$ -	$ 15,330
A-4	MH 18 - MH 3	1000	115	16	DIP	FDOT	16.29	9.00	$ 48.90	Yes	$ 5.00	$ 24.00	Heavy	$ 2.70	0	$ 5,624	$ 575	$ 2,760	$ 311	$ -	$ -	$ 9,269
A-5	MH 3 - MH 25	1000	400	16	DIP	FDOT	16.85	9.00	$ 48.90	Yes	$ 5.00	$ 24.00	Heavy	$ 2.70	3	$ 19,560	$ 2,000	$ 9,600	$ 1,080	$ 525	$ 750	$ 33,515
A-6	MH 25 - MH 24	1100	400	16	DIP	FDOT	16.86	9.00	$ 48.90	Yes	$ 5.00	$ 24.00	Heavy	$ 2.70	2	$ 19,560	$ 2,000	$ 9,600	$ 1,080	$ 350	$ 500	$ 33,090
A-7	MH 24 - Lift Station 30	1100	43	16	DIP	FDOT	17.33	9.00	$ 48.90	Yes	$ 5.00	$ 24.00	Heavy	$ 2.70	0	$ 2,103	$ 215	$ 1,032	$ 116	$ -	$ -	$ 3,466
A-8	MH 24 - MH 6	1100	128	16	DIP	FDOT	15.65	9.00	$ 48.90	Yes	$ 5.00	$ 24.00	Heavy	$ 2.70	0	$ 6,259	$ 640	$ 3,072	$ 346	$ -	$ -	$ 10,317
A-9	MH 6 - MH 7	600	181	16	DIP	Easement	21	9.00	$ 48.90	Yes	$ 5.00	$ 24.00	Heavy	$ 2.70	2	$ 8,851	$ 905	$ 4,344	$ 489	$ 350	$ 500	$ 15,439
A-10	MH 7 - MH 12	600	205	16	DIP	Easement	22.81	9.00	$ 48.90	Yes	$ 5.00	$ 24.00	Heavy	$ 2.70	2	$ 10,025	$ 1,025	$ 4,920	$ 554	$ 350	$ 500	$ 17,373
A-11	MH 12 - MH 27	900	212	16	DIP	Easement	22.8	9.00	$ 48.90	Yes	$ 5.00	$ 24.00	Heavy	$ 2.70	2	$ 10,367	$ 1,060	$ 5,088	$ 572	$ 350	$ 500	$ 17,937
SUBTOTAL SW 13th Street (US 441)			**2,629**												**15**	**$ 122,038**	**$ 13,145**	**$ 63,096**	**$ 7,098**	**$ 2,625**	**$ 3,750**	**$ 211,752**