



The Northern California Pipe User's Group
22nd Annual Sharing Technologies Seminar

Berkeley, CA
February 20, 2014

ENHANCING LEVEL OF SERVICE THROUGH RISK-BASED ASSET MANAGEMENT

Greg Norby, P.E.¹, and Vivian Housen, P.E.²

¹ General Manager, Ross Valley Sanitary District, San Rafael, CA

² V. W. Housen & Associates, Danville, CA

ABSTRACT: Sanitary District No. 1, also known as Ross Valley Sanitary District, serves the communities of Sleepy Hollow, Fairfax, San Anselmo, Ross, Larkspur, Kentfield, and Greenbrae, and Murray Park by contract, in Marin County. The District maintains approximately 194 miles of main lines, 8.4 miles of force mains, and 19 pump stations and lift stations. Average dry weather flow is approximately 5 million gallons per day. However, during some wet weather events, portions of the system experience very high wet weather peaking factors.

The District is under a Cease and Desist Order to complete significant repairs and replacements within a compressed timeline. Without a strategic implementation plan, the financial and project delivery aspects of this requirement would be unattainable. In October 2013, the District submitted an Infrastructure Asset Management Plan (IAMP) to the Regional Board that provided a prioritized approach to management and maintenance of its facilities.

A critical component of the IAMP was a numerical risk-based analysis of the system's mainline sewers. Using this process, the District developed a strategic program that prioritized repairs, and met the Regional Board mandate in a manner that rapidly reduces risk. The plan includes a combination of point repairs and pipeline replacements, as well as an operations and maintenance strategy that allows the District to defer capital improvements in a way that extends useful life without increasing risk. Through this program, the District will sustain and improve the Level of Service that it provides to the community, with immediate and measurable near-term benefits.

1. INTRODUCTION

On May 13, 2013, the San Francisco Bay Regional Water Quality Control Board (RWQCB) issued Order No. R2-2013-0020, a Cease and Desist Order (Order) for the Ross Valley Sanitary District (District). The Order included aggressive requirements for system rehabilitation that were likely to be unattainable. However, the Order also provided the District with the opportunity to submit an Infrastructure Asset Management Plan (IAMP), if such a plan would justify an amended strategy to addressing system needs. The District met this challenge and submitted an IAMP that provided a multi-pronged approach to sewer system management, through a balance of rehabilitation, assessment, and maintenance. The IAMP

provides a strategy for continued studies, rehabilitation, and replacement of pipelines, pump stations, and force mains that was accepted by the RWQCB with minor clarifications. The plan addresses the restrictive requirements of the Order, yet provides the District with flexibility to adjust the plan over time, as system needs change.

The heart of the IAMP was the development of a numerical risk assessment model, named the RVSD Sewer Main Asset Replacement Tool (SMARTool), which prioritized linear asset needs by assessing Risk as measured by Likelihood and Consequence of Failure. Development of the IAMP was a collaborative effort involving District staff, the District Board, and V. W. Housen & Associates with subconsultants Schaaf & Wheeler, JDH Corrosion, and Humphrey Consulting.

2. SYSTEM DESCRIPTION

The District was established in 1899, and is believed to be California's oldest sanitary district. The District is located in Marin County, approximately 15 miles north of San Francisco and directly south of the City of San Rafael. The service area is bounded on the east by the San Francisco Bay, and on the west by the coastal hills. Numerous seasonal and perennial waterways traverse the service area and terminate in Corte Madera Creek, which is the main drainage from the District's service area to the San Francisco Bay.

The District serves the communities of Sleepy Hollow, Fairfax, San Anselmo, Ross, Larkspur, Kentfield, and Greenbrae; serves Murray Park by contract; and conveys wastewater to the Central Marin Sanitation Agency (CMSA) wastewater treatment plant. Figure 1 shows a map of the District service area.

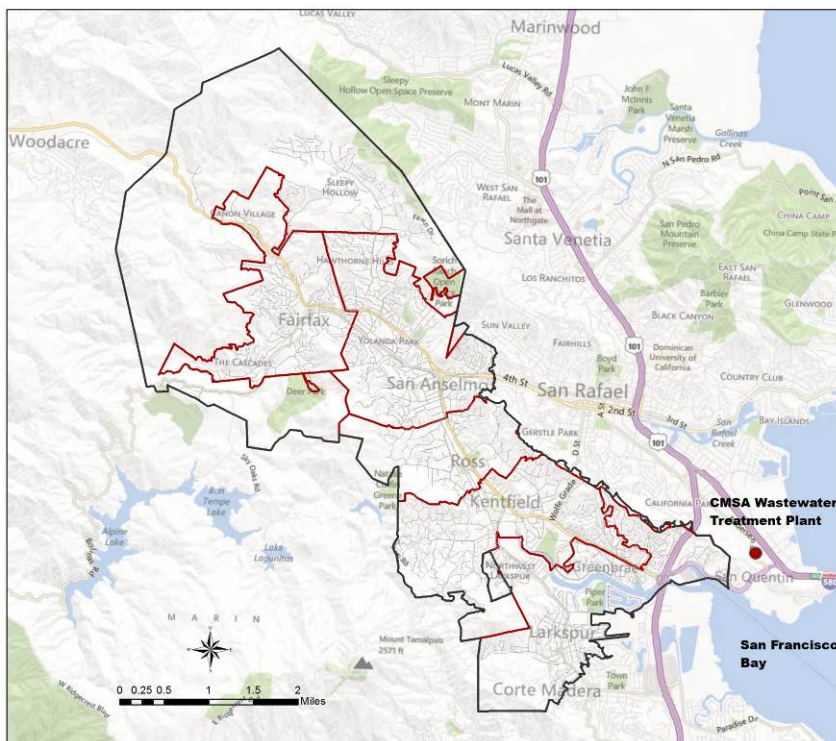


Figure 1. Ross Valley Sanitary District Service Area

The system includes approximately 194 miles of mainline and trunk line sewers and 8.4 miles of force main pipe. Approximately 75 percent of the pipes are 6-inches or less in diameter, comprised of vitrified clay pipe. In addition, the District owns and operates 19 pump or lift stations. Average dry weather flow is approximately 5 million gallons per day (mgd). The District uses Innovyze® InfoNet® software for its computerized maintenance management system (CMMS).

3. LEVEL OF SERVICE OBJECTIVES AND RISK CRITERIA

The first step in developing the IAMP was to define Level of Service (LOS) objectives. LOS is defined from the customer's viewpoint, in order to create goals that are broad and policy-based. LOS workshops were held with staff and with the District Board, and their results compared and combined to form the following list of objectives:

- **Protect Public Health and Waterways.** Protection of public health can be measured through reduced SSOs, with emphasis on reducing SSOs to private property, schools, and parks.
- **Provide Reliable and Responsive Service.** Service is enhanced by preempting system issues in areas that are difficult to access, so as to improve response time. A less tangible indicator of good service is increased confidence in the District's ability to manage the agency and its assets.
- **Provide Value to the Customer.** Value is measured by a steady reduction in failure indicators resulting from judicious spending on operations and maintenance (O&M) activities and capital improvements. Value may be inversely related to cost, since lowering expenses in an aging system could lead to an increase in failure indicators.

Risk criteria were different for each set of assets (i.e., mainline and trunk line sewers, pump stations, and force mains). Mainline and trunk line sewer analyses defined risk through layers of metrics and scores that defined the Likelihood and Consequence of Failure for each pipe segment. Pump station analyses defined risk based on criteria that has been supported by the RWQCB to assess pump station reliability. Force main analyses defined risk based on anticipated failure mechanisms of pipe, as determined through an evaluation of pipe material, setting, and historical cathodic protection.

4. PIPELINE ASSESSMENTS

The Order lists 15 mainline sewer projects that require completion by June 2019. The project list was based on a plan that was developed in 2007, before the District had started its system-wide CCTV inspection program. In the absence of CCTV inspection data, assumptions based on age and field knowledge were used to establish the 2007 project priorities. As a second condition, the Order requires the District to replace four miles of pipe per year. Replacing entire pipelines at this rate would be cost prohibitive for the District, and could result in the replacement of pipe segments that still have substantial useful life.

To justify to the RWQCB that a different approach would achieve their desired level of risk reduction, the IAMP used a numerical database model to assign risk to every mainline and trunk line pipe segment in the CMMS database. Through this process, the District was able to segregate only those pipes or portions of pipes that must be repaired, and demonstrate to the RWQCB that this "surgical" approach would result in a system with restored service life.

This model, named the RVSD SMARTool, evaluates the Risk of Failure for an individual pipe segment, given that asset's Likelihood and Consequence of Failure. Risk is measured with respect to the District's ability to meet established Level of Service goals. Figure 2 shows the process that was used to develop the SMARTool.

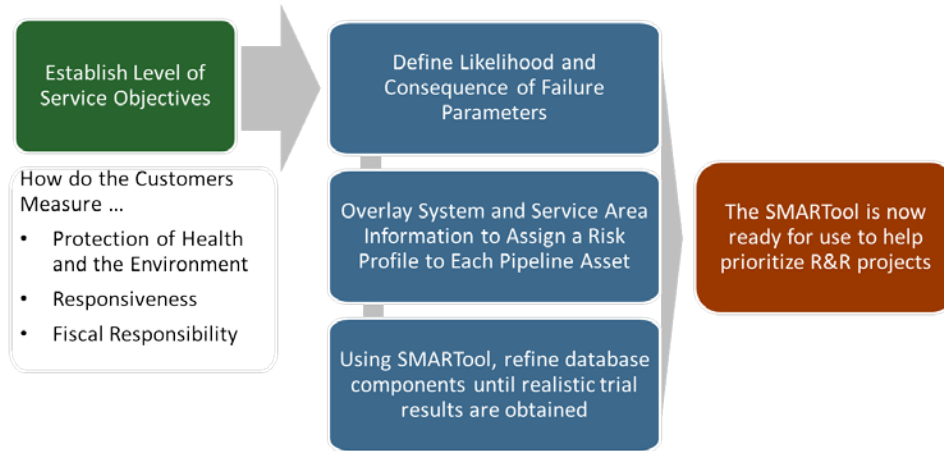


Figure 2. SMARTool Development Process

The SMARTool database contains over 5,000 unique pipeline segments which span from node to node, generally corresponding to visible utility surface structures. The CMMS database that was used to develop the IAMP included CCTV inspection rating for approximately half of the system assets. Risk Scores were weighted to assure that only those pipe segments with CCTV inspection ratings received a score that would flag the asset for rehabilitation or repair. The reason for this differentiation is that a linear asset may appear to be a good candidate for repair due to age or other factors, yet may still have significant remaining life. The actual risk of failure is not known until the true condition of the asset, reviewed in combination with other consequence factors, is assessed.

The SMARTool calculates Total Risk as the product of Likelihood and Consequence of Failure. Likelihood of Failure (F_L) metrics must be customized to every agency. For the District's linear assets, F_L metrics comprise the following:

- Pipe material (techite), which is very likely to fail or have failed
- Capacity as determined through the District's existing hydraulic model
- Structural and O&M CCTV inspection ratings with emphasis on specific defect codes
- Known maintenance issues including historical SSOs and special cleaning needs
- Specific geologic conditions

Consequence of Failure (F_C) metrics provide information on how the failure of an asset will impact the ability of the District to meet its Level of Service goals. Consequence of Failure metrics that were used in the District's SMARTool comprise the following:

- Proximity to a perennial waterway
- Proximity to certain critical facilities
- Impact on specific arterial roadways
- Area impacted as determined by pipe size

Figure 3 shows example Likelihood and Consequence of Failure factors, as buffered using ArcGIS.

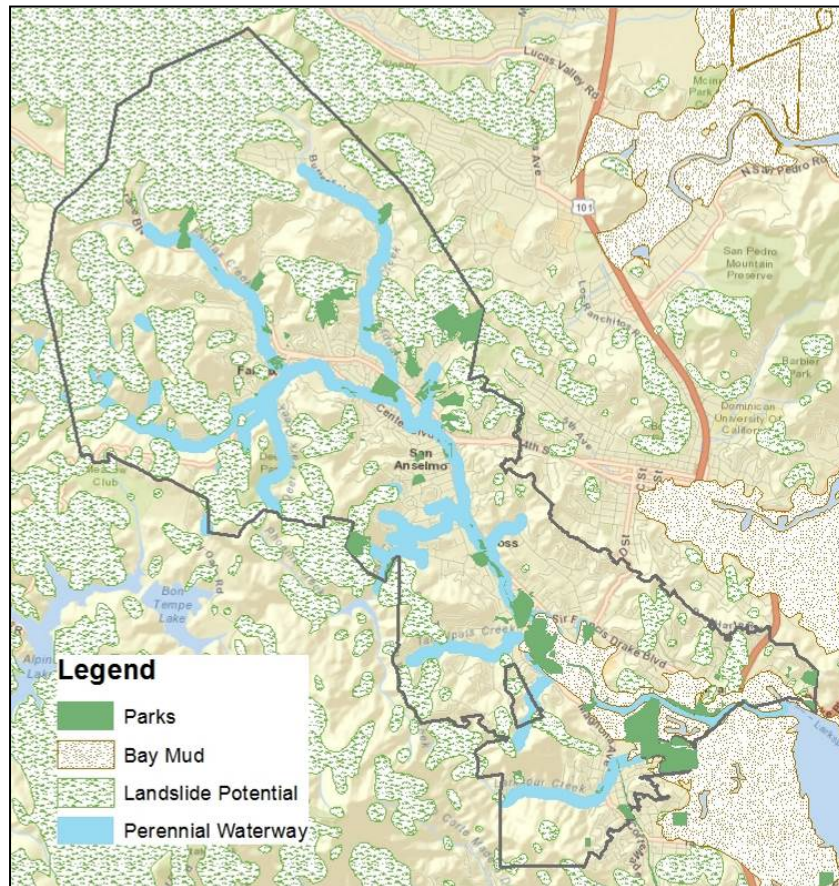


Figure 3. Example Likelihood and Consequence of Failure Factors

The SMARTool uses a series of queries to overlay Likelihood and Consequence metrics and develop an associated Total Risk Score. The Total Risk Score is a relative number, to be compared to similar scores from other pipes within the same model run. The Risk Score, when considered alone, has no numerical significance.

Through the use of this tool, followed by refinement using engineering and operational judgment by the project team and District staff, twenty mainline sewer rehabilitation projects were identified for early implementation. For each of these projects, the number and nature of defects were then used to define the anticipated pipe replacement methodology (i.e., segment repairs (i.e., joint to joint), lining, pipe bursting, or full pipe replacement (i.e., node to node). These projects will replace or rehabilitate over 20 miles of main line sewer pipelines, for a total estimated cost of \$16 million. The SMARTool identified an additional 12.3 miles of pipeline rehabilitation for implementation in later years, for a cost of \$8.8M.

CCTV inspections completed since 2007 have shown that the 15 original projects described in the Order would have replaced many pipes that did not have Structural Grade 5 defects. Based on these results, the RWQCB approved removing the projects from the implementation plan.

In addition to assessing pipeline rehabilitation needs based on condition, the IAMP reviewed proposed capacity projects as presented in the Order. Capacity requirements were based on hydraulic modeling

results from 2004, which evaluated capacity using a 5-year recurrence interval storm and relatively conservative triggers for pipeline replacement. The IAMP added conservatism to the design storm criteria, increasing the design storm to a 10-year, 24-hour event, and then removed conservatism in the triggers for when pipes should be upsized. Based on the results, the RWQCB approved the removal of two proposed capacity projects from the Order, and will allow the District to review several additional projects further using an expanded hydraulic model and updated flow data.

Through this process, the District achieved the following goals for its linear assets:

- Met the requirement to restore 4 miles of pipe per year using an approach that strategically replaces pipe sections where possible, and pipe segments only where needed, in the areas presenting the highest Risk to the District
- Justified removal of projects from the Order that do not present a high Risk of failure
- Justified removal of capacity improvement projects from the Order that do not present a high risk of overflow

Through this focused approach, the District will see rapid risk reduction in the early years of the program, yet still have a fundable approach that has received endorsement by the RWQCB. In response to this approach, the RWQCB amended the Cease and Desist Order to adopt the linear asset recommendations from the IAMP.

5. Pump Station and Force Main Assessments

The IAMP included an evaluation of six of the District's 19 pump and lift stations with regard to reliability, safety, and capacity, as well as the District's major force mains. The six stations were selected based on their relative criticality to overall pumping operations. The location of each pump station evaluated is shown in Figure 4.

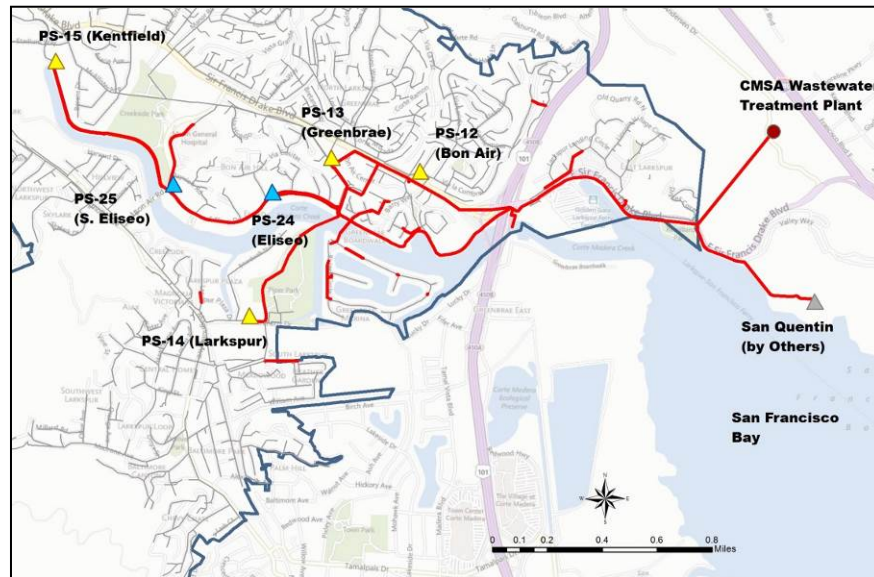


Figure 4. Pump Station Location Map

Due to historic flow management challenges, the District has the ability to move flows between several of the larger pump stations. Over time, the District intends to eliminate some of these bypass options, which are operationally challenging, and correct the hydraulic issues through improvements within the pump station and force main network. However, the current ability to move flows between stations is very beneficial in terms of phasing in these improvements over time, while still meeting the requirements of the Order.

Pump station evaluations included visual inspections, review of previous reports, and review of information provided by District staff. The reliability assessment followed requirements that have been endorsed by the RWQCB. The requirements included evaluation of the following:

- Firm capacity to handle peak wet weather flows
- Automatic alarm and communication system
- Backup or redundant equipment
- Plan for bypass pumping at each station

Recommended improvements for each pump station were developed, and then prioritized based on risk, which was defined based on age, inflow rate, and reliability. The pump station evaluation included hydraulic analyses using a 10-year, 24-hour design storm.

The pump station evaluation identified approximately \$11 million in improvements that will be phased over seven years. An important near-term result of the assessment was confirmation of the need for consistent flow monitoring at some pump stations, and completion of an ongoing SCADA project.

In addition to needed mechanical improvements, three pump stations were determined to require additional firm capacity. However, one capacity issue is resolvable through force main improvements, and a second issue can be managed in the near-term through the District's existing bypass facilities and operating protocol.

Force main assessments focused on the District's major assets, which comprise approximately 42 percent of the District's force main system by length, and all of the original force mains greater than 10 inches in diameter. The evaluation was refined further after it was confirmed that substantial force main length is comprised of reinforced concrete cylinder pipe, which has a very low probability of failure. Of greater concern were metallic sections of pipe that included ductile iron, bar-wrapped concrete cylinder pipe, mortar lined and coated welded steel, and other ferrous pipes. The project intent was to evaluate electrical continuity and to add cathodic test stations and cathodic project where possible. However, high groundwater levels did not allow this work to occur during the project timeframe. Most of the force main recommendations in the IAMP continue these assessments over the next several years.

The most significant outcome of this assessment was that the District was able to justify to the RWQCB that it would be beneficial to continue these studies and more accurately assess the condition of existing force mains before replacing them solely based on advanced age. Following this approach, the RWQCB approved the removal of several costly force main replacement projects from the Order, with the condition that their disposition would be determined in the future, after more information is known.

In addition to continuing condition assessments and force main field investigations, the IAMP includes projects to replace air relief valves, and also prioritizes rehabilitation of a previously unidentified bypass force main that will be instrumental in simplifying flow management during future planned pump station improvements.

6. Operations and Maintenance Program

The District evaluated its Operations and Maintenance program as a key component of the IAMP. The District targets cleaning of its mainline sewers on a 6-month or 12-month preventive maintenance schedule. In the May 2013 IAMP snapshot, approximately one quarter of the pipeline asset inventory was on a 6-month maintenance schedule.

The 12-month cleaning schedule follows a zone cleaning maintenance approach. Cleaning results are collected and entered into the District's CMMS system for use in scheduling future cleaning cycles¹. The District recently completed its first full year of zone cleaning, and is now using this information to further refine the second and future cycles. The end result will be a program where each asset follows a dynamic cleaning schedule that is continuously adjusted and optimized based on prior results. The expanding CMMS database will also be used to improve the coordination of cleaning activities with CCTV inspection and capital improvement activities.

The District follows the National Association of Sewer Service Companies (NASSCO) Pipeline Assessment and Certification Program (PACP) to assign pipeline condition ratings during CCTV inspection. Each pipe is assigned a condition grade, and also a NASSCO PACP Quick Rating. As of May 2013, the District had completed CCTV inspection of approximately 53 percent, or 540,000 linear feet of the collection system. The initial cycle of CCTV inspection for all main lines is planned for completion by 2016. After the initial cycle of assessment, the District will continue a cyclical CCTV inspection of main lines based on the current condition rating.

Figure 5 summarizes the CCTV inspection results that were also provided in the IAMP

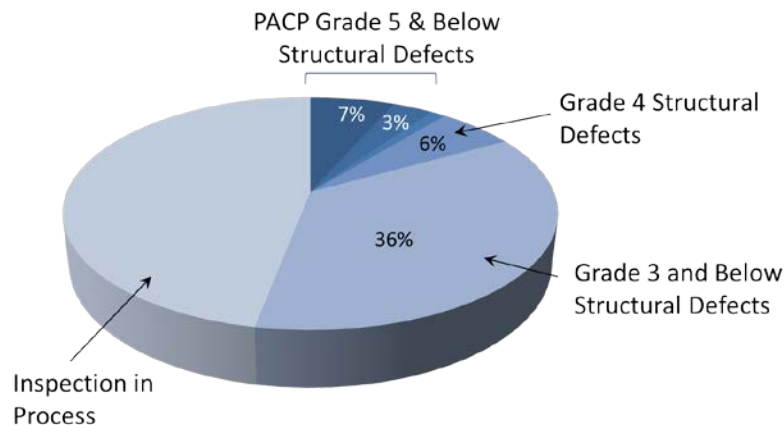


Figure 5. Distribution of PACP Structural Defects as of May 2013

The District is initiating a sewer cleaning quality assurance and quality control (QA/QC) protocol which will use CCTV inspections to measure success and provide feedback to cleaning crews regarding the quality of cleaning operations. The QA/QC protocol will include the implementation of a documented and

¹ The cleaning frequency was also used to help define the "Likelihood of Failure" score in the risk model that was developed for the IAMP.

measurable guideline for determining whether cleaning passes or fails the cleaning quality review, and whether cleaning methods and tools are appropriate and effective. The program will be phased in over time, and is planned for full implementation after the District completes the initial cycle of CCTV inspection in 2016.

The District’s operations and maintenance strategy has resulted in documented improvement in managing SSOs. Table 1 shows the progress that has been made by the District in SSO reduction, since implementing this operations and maintenance strategy in 2012.

Table 1. Ross Valley Sanitary District SSO History (since 2010)

Year	Total SSOs	Cause			
		Roots	Debris	FOG	Other
2013 (8 months)	11	4	1	0	6
2012	34	7	9	0	18
2011	35	13	10	2	10
2010	49	25	14	1	9

7. Summary

In May 2013, the District received a restrictive Cease and Desist Order from the RWQCB. The Order described nearly \$100 million in required improvements to be completed within five years. This level of capital improvement would have been unattainable in terms of funding, project delivery, or community acceptance. The Order also provided the District with the opportunity to develop and submit an Infrastructure Asset Management Plan that presented and justified a different approach to addressing their concerns about SSO reduction.

The District met this challenge and submitted an IAMP by the required deadline of October 1, 2013. In the IAMP, the District redefined project needs through a thorough and systematic assessment of Risk. The District’s proposed program meets the RWQCB requirements at approximately half of the cost, and over a longer period than the original mandate. The RWQCB accepted the District’s approach with minor clarifications, and replaced the original infrastructure renewal requirements from the Order with the District’s proposed program.

The IAMP is a living document, and allows the District to continually refine priorities as new information about the system is obtained. Through the strategies and tools provided by the IAMP, the District is prepared to address very aggressive regulatory commitments, yet still have the flexibility needed to make smart decisions about capital expenditures and maximize the benefit gained through non-capital means, such as improved operations and maintenance.