Summer 8-25-2014

Water Pipe Infrastructure Asset Management

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August 25, 2014

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Abstract

Local, state and national water infrastructure are failing because they have reached or are reaching the end of their useful life. The purpose of this study is to find an optimal water asset management system that will increase the assets useful life while minimizing costs to consumers. The literature review chapter identifies various literary works by recognized industry professionals identifying the benefits of an asset management system. The research section looks to neighboring water agencies and industry standards to identify a water asset management system that will pay for itself through savings achieved by extending the system's life and replacing pipes before they fail. The results and findings chapter looks at current replacement and asset management strategies by the cities of Palo Alto, Sunnyvale and Santa Clara and the districts of Elk Grove and Santa Clara Valley along with Arcadis (a private contractor who works with public water utilities on construction and asset management projects). This paper concludes by identifying the common failure points in the water system and describes the evolution of asset management. The recommendations chapter identifies four key recommendations (i.e., $20-40 million bond creation, enterprise asset management system acquisition, condition asset management system pilot program and average replacement cycle reduction). Finally, the research comprised in this study will produce value for the City of Mountain View and future organizations by identifying asset management best practices from the water industry.

Chapter 1 – Introduction

Local, state and national water systems were installed due to population growth and expansion in the 1800s and 1900s with materials that have a useful life between 50-100 years. As a result, many of the materials currently used to convey water to households have reached the end of their useful life or are approaching the end of their useful life. The dangers of having pipe material at the end of their useful life include the increased potential of a catastrophic failure and corresponding increases in cost to replace those failed pipe segments. In order to alleviate some of the risk associated with catastrophic failures of the water system, a water infrastructure asset management system along with strategic replacement decision making by City of Mountain View leadership will decrease failures while increasing the useful life of pipe segments which will lower operational costs.

Like state and national water systems, the pipe segments of the City of Mountain View's water system are reaching or have reached the end of their useful life. In fact, over 65% of the City of Mountain View's water pipe infrastructure was installed prior to 1970; 60% of which was installed during the 1950s and 1960s (City of Mountain View, 2010, p. 20). Nearly 47% of the pipe in the ground is made out of cast iron with a useful life of 50 years; the average age of the cast iron pipe is currently 51 years. In addition, nearly 30% of the City's water pipe infrastructure is made of Asbestos Cement pipe (ACP) with an average useful life of 75 years; on average 31 years of the ACPs useful life remain (City of Mountain View, 2010, p. 20-23). In order to manage water pipe infrastructure in Mountain View, the City will have to triage the replacement of nearly half the City's pipe inventory over the next decade and plan on replacing an additional 30% over the next 30-40 years. In order to more efficiently manage the looming and costly replacement of the City's water pipe infrastructure, the City will need to use a combination of best management practices and technology to manage costs and disruptions to City of Mountain View water users. In the end, the successful implementation of an effective water pipe asset management system along with appropriate funding to replace failing pipe segments will pay for itself through savings achieved by extending the life of pipe segments and replacing pipes before they fail.

Chapter 2 – Literature Review

Introduction

According to one of the first written reports evaluating the looming need for underground water utility replacement titled Dawn of the Replacement Era, Reinvesting in Drinking Water Infrastructure, written by the American Water Works Association (AWWA) (2001) notes that by 2030, the average utility "will have to spend about three and a half times as much on pipe replacement due to wear-out" as it spent in 2001 (p.6). In order to alleviate the financial burden and extend the useful life of the pipe segments Clark, Carson, Thurnau, Krishnan & Panguluri (2010) assert that sound asset management practices represent an opportunity for utilities to effectively optimize their expenditures on distribution system investment (p. 87). Throughout the narrative of the literature review section the case will be made that failing water pipe infrastructures throughout the country exists, consumer needs for high-quality drinking water at reasonable price is imperative and the need to develop best practices to manage pipe infrastructure via asset management technology proves a viable opportunity for local and state agencies.

A National Problem

In 2009, the American Society of Civil Engineers (ASCE), published an infrastructure fact sheet titled "*Facts about Drinking Water.*" The report gave the nations drinking water system a D- grade because of the lack of adequate funding to replace system components. More specifically, the report states "although America spends billions on infrastructure each year, drinking water systems face an annual shortfall of at least $11 billion" (ASCE, 2009, p. 26). One of the reasons for the shortfall is because "water is by far the most capital intensive of all utility services, mostly due to the cost of the pipes" (AWWA, 2001, p. 10). The report also recognizes that "drinking water systems provide a critical public health function and are essential to life, economic development, and growth" (ASCE, 2009, p. 29). In 2013, the ASCE upgraded the nation's drinking water system grade from a D- to a D. One of the reasons for the change in grade is the "voluntary limitations or imposed regulations governing the demand for water, as well as technologies that recycle water for industrial and residential purposes. These types of policies have reduced the demand for water and lessened the impacts on existing infrastructure" (ASCE, 2013, para. 13).

Corporate Accountability International (2012) provides a current picture of the water system when they state "every year there are 240,000 water-main breaks in the U.S., and these leaks add up. Every single day, seven billion gallons of clean drinking water, or 16 percent of total use, are lost through leaky pipes in need of repair" (p. 13). In addition, ASCE (2013) recognizes that asset management will increase in importance when they state that "approximately 4,000 to 5,000 miles of drinking water mains are replaced annually. The annual replacement rate is projected to peak around 2035 at 16,000 to 20,000 miles of aging pipe replaced each year" (para. 5). With the looming increase in pipe failures, the disruptions in service will "hinder disaster response and recovery efforts, expose the public to water-borne contaminants, and cause damage to roadways, structures, and other infrastructure, endangering lives and resulting in billions of dollars in losses" (ASCE, 2009, p. 29). Finally, the ASCE (2009) fact sheet explains the need for the federal government to make water infrastructure a priority stating "clean and safe water is no less a national priority than are national defense, an adequate system of interstate highways, and a safe and efficient aviation system" (p. 31). In addition as Dougherty (2010) states, "having a cost-effective and reliable drinking water is integral to protecting our nation's health and economic vitality" (p. 18).

In an effort to provide a better perspective of the national problem, Utah State University created a comprehensive study of water main break rates in the USA and in Canada. According to Steve Folkman (2012), "a total of 1,051 surveys were mailed out to USA and Canada water utilities in May and June of 2011" (p. 5). Of the 1,051, 188 utilities responded which represents 117,603 miles of pipe experience (Folkman, 2012, p. 5). Of note, the study found that the "average age of failing water mains is 47 years old" and "over 8% of installed water mains are beyond their useful life" (Folkman, 2012, p. 5). In addition, the average annual failure rate is 11 failures per 100 miles of pipe (Folkman, 2012, p. 15). Finally, Folkman's (2012) study noted that cast iron pipe had the highest failure rate of any pipe material with an average failure rate of approximate 28 failures per 100 miles of pipe per year (p. 17). Moreover, nearly 50% "of the reported cast iron failures occurred with a pipe age between 41 and 60 years" (Folkman, 2012, p. 17).

In a separate case study sponsored by the Jordan Valley Water Conservancy District in Utah, 24 utilities across the United States were surveyed and found that "study participants use no consistent method or frequency of inspection to determine the condition of their pipe lines" (Livingston & Packard, 2012, p. 70). However, the study did find that the most common inspection technology used was leak detection (65%) and 39% do not conduct inspections at all (Livingston & Packard, 2012, p. 70). Based on a 2003 and 2007 Drinking Water Infrastructure Needs Survey conducted by the US Environmental Protection Agency, Job (2009) found that "few water systems, including some of the larger ones, had good inventories of their water infrastructure" (p. 39). Of note, Livingston and Packard's (2012) case study found that "most utilities that have a proactive and aggressive program for condition assessment do so because they have experienced a catastrophic failure" (p. 71).

<u>Finding the Sweet Spot</u>

Gregory Baird's article explains the importance of running an effective water infrastructure that allows water system operators to more efficiently use their limited resources while identifying and addressing failure points in the system before they become costly to repair. Baird (2010a) states "if a piece of pipe that still has some useful life is replaced, money has been wasted. If an asset is replaced too late and fails, the emergency replacement cost may actually be double. The true need is to find the sweet spot where the capital investment actually reduces the risk and limited capital is allocated efficiently" (p. 4). In a separate report created by the AWWA (2010) titled Buried No Longer states that "delaying this investment could mean either increasing rates of pipe breakage and deteriorating water service, suboptimal use of utility funds, such as paying more to repair broken pipes than the long-term cost of replacing them" (p. 10).

Schraven, Hartmann and Dewulf (2011) explain that "asset management has emerged as an approach in the sector of public infrastructure, which promises to achieve more value with fewer resources" (p. 61). According to Baird (2010b), "asset management strategies may be able to capture savings of 20-30% of life cycle costs over time" (p. 39). The ASCE (2013) report also acknowledges that "determining pipe condition through cost-effective structural assessment will allow worst-condition pipes to be addressed first, avoiding potential failures and associated risks, damages, and costs. These structural condition assessments will also help avoid premature replacement of structurally sound pipes to save resources and time" (para. 4). Finally as Baird (2010b) notes, a "condition assessment helps avoid the default decision to replace the entire asset and offers analysis to determine where and when a rehabilitation techniques can be applied to extend the life of the asset" (p. 39).

Information is Key

The lack of infrastructure knowledge currently possessed by many water system operators prevents system operators from optimally applying public funds to replace many of the underground pipes; leaving system operators to either replace water pipes that have a longer useful life or react to pipe failures, both of these methods increase the amount of money spent on the water system which will be passed along to users. Grigg (2005) notes that water system operators should take into consideration "factors such as pipe age, failure mechanisms, installation history, water quality, criticality, hydraulics, corrosion, material, pressure, location, soil type, groundwater and loads" (p. 2). One key note identified in the Utah State University study found the major cause for water main breaks was corrosion. Of the survey respondents, one in four stated that main breaks were caused by corrosion with a "high portion of cast iron and ductile iron pipes" (Folkman, 2012, p. 6). An asset management system will help identify the pipe material that are more susceptible to corrosive soils/water tables which will help public agencies better manage their pipe infrastructure.

As Baird (2010a) notes "the most basic steps of condition assessment are to inventory the assets, assess their condition, estimate their remaining useful life, manage the wear-out process, and continually improve the plan" (p. 4). Urquhart and Sklar (2005) assert the ultimate objective of good asset management is to minimize total asset lifecycle costs while maximizing the level of service provided to customers (p. 24). Moreover, Baird (2010a) illustrates that a "condition assessment program can pay for itself in a number of ways including deferral of capital, avoiding catastrophic failure, reduction in lost revenues as a result of water loss and reduction in bonds and debt" (p. 5).

Future Plans

In order to limit increased pipe failures, agencies need to distinguish "between three major types of intervention, which are separated as to organization and to budget: daily maintenance activities (short-term maintenance work less than one year), renovation (medium-term work carried out in one to five years) and reconstruction work (greater than five years)" (Schraven, et al., 2011, p. 69). By focusing on three different types of intervention methods, the organization will be better able to plan and adopt appropriate funding to increase the reliability of the water system for current and future users. The authors explain that asset management is effective when infrastructure objectives are used, the current and future infrastructure assets are taking into account and when infrastructure objectives are continually monitored (Schraven, et al., 2011).

When planning for the future needs of the water system, Baird (2010b) states that "investors now want to know if a utility has done its due diligence for condition assessment, has a strategy to address the short and long-term infrastructure replacement issues and has taken the affordability of rates into consideration" (p. 39). As Baird (2010c) notes, "condition assessment can help operators understand the level of asset deterioration and the effect on the probability and consequence of failure" (p. 18). In conclusion, an asset management system will identify the short and long-term needs of the water system and allow system operators to plan for the future and limit the amount of financial impact on current users.

Proactive vs. Reactive

Neil Grigg provides a brief history of the nation's water system, including installation time frames and materials used throughout the eras, which is helpful in understanding the pending failure rate increases. In addition, Grigg (2005) questions the most appropriate asset management theory when he states, "should utilities make a large capital investment to renew aging and deteriorating water distribution systems, or should they be reactive and wait for failures before investing" (p. 1)? The AWWA (2001) report states that "as pipe assets age, they tend to break more frequently. But it is not cost-effective to replace most pipes before, or even after the first break. Like the old family car, it is cost-efficient for utilities to endure some number of breaks before funding complete replacement of their pipes" (p. 13). However, Livingston and Packard's (2012) study of 24 water utilities found that a "reactive strategy for replacement is not sustainable" because "responding to breaks and failures is nearly impossible to budget for, is expensive, and results in loss of service or reduced service levels as well as customer dissatisfaction" (p. 71-72).

According to Kunkel and Sturm (2011), "most water utilities in the United States practice reactive leakage management by responding to leaks and main breaks after they have erupted and caused customer complaints" (p.64). However, a growing number of water utilities "practice proactive leakage management by seeking to identify and abate hidden leaks while they are small and not disruptive" (Kunkel & Sturm, 2011, p. 64). According to Baird (2010c), "waiting for a critical asset – such as a water main – to fail may cost two to three times more by creating a large destructive sink hole and boiled water orders for a community" (p. 20). Furthermore Baird (2010c) notes that a "condition-based maintenance is predictive maintenance initiated on the basis of the asset's condition as an alternative to failure-based maintenance or use-based maintenance triggered by time or meter reading" (p.18). In the end, it is ideal that "pipe replacement occurs at the end of a pipe's useful life; that is, the point in time when replacement or rehabilitation becomes less expensive in going forward than the costs of numerous unscheduled breaks and associated emergency repairs" (Buried no longer, 2010, p. 8).

Consumer Needs

Urquhart and Sklar (2005) focuses their attention on ensuring municipalities align their infrastructure and financial needs with their consumers "because there is a cost with a particular level of service" (p. 23). More specifically, they warn that a misalignment in priorities between the water system operator and their users will increase financial costs to the users without increasing service levels otherwise possible. Urquhart and Sklar (2005) state "by aligning asset management objectives with service-level objectives, a utility can be assured that all its activities and efforts drive toward achieving a common goal" (p. 24).

Increased Costs

In relation to consumer needs, consumers also want high-quality drinking water at a reasonable cost. Nationally, "households pay an extra $6 billion, and businesses shell out $15 billion in costs connected to deficiencies in water systems" (Corporate Accountability International, 2012, p. 13). According to the AWWA (2001) article, "most people do not realize the huge magnitude of the capital investment that has been made to develop the vast network of distribution mains and pipes that makes clean and safe water available at the turn of the tap" (p. 10). The level of investment required to replace the deficient and "worn-out pipes and maintain current levels of water service in the most affected communities could in some cases triple household water bills" (Buried no longer, 2010, p. 10). Baird (2010a) notes that "the rate-paying public will have to finance the replacement of the nation's water infrastructure either through rates or taxes" (p. 3). Mr. Baird summarizes the financial burden on current consumers will increase dramatically if water system operators do not efficiently use public funds to operate their water system.

Leadership Will

As the AWWA (2001) article states, "the need for significantly greater investment in pipe replacement is all the more difficult to convey because it was never there before. It's hard to explain why it's going to cost more to do the same job in the future than it cost in the past" (p.12). As Dougherty (2010) notes, "if customers understand the value proposition of high quality water supply service, they will be more willing to engage in a productive dialogue about how to pay for it" (p. 18). Job (2009) also points out that "water providers should take the initiative to gather, organize and publicize the necessary data so that consumers know the extent and value of the infrastructure supporting their day-to-day well-being." (p. 40). Unfortunately, as Kitchen (2006) notes, "politicians tend to support short-term projects with re-election in mind, rather than the welfare of future generations" (p. 1). Baird (2010b) also warns that many "elected officials are concerned about making decisions that "hog tie" future boards and councils. But without having a discussion regarding long-term sustainability and affordability, they are simply hiding a growing and inevitable rate shock scenario" (p. 40). In the end, "it takes an ethical and strong utility manager or finance officer to stand up to short-term political whims and defend long-term affordability concerns" (Baird, 2010b, p. 40).

Technology

According to Baird (2010c), geographic information systems (GIS) are "the most widely utilized and common platform for cataloging, viewing and analyzing asset data" (p. 17). The benefits of GIS is it acts as a centralized asset registry and answers the "three basic questions of asset management: (1) What assets do I own? (2) What is the locations of the asset? (3) What condition is the asset in" (Baird, 2010c, p. 17). Baird (2010c) notes that in order for GIS to be effective it needs to be coupled with a computerized maintenance management system that when coupled together would create an enterprise asset management system (p. 17-18).

The 2012 Utah State University study found that 57% of respondents stated they had a regular leak detection method that "included acoustic leak detectors, visual inspection of lines, digital correlation sensors, and eddy current detectors" (Folkman, 2012, p. 22). Baird (2010c) notes that there are more expensive condition assessment techniques that could be employed including "visual inspections, nondestructive and destructive testing, smoke testing, dye testing, lamping video inspection, sonar, ground-penetrating radar, and digital imaging and analysis" (p. 20). According to Clark, Carson, Thurnau, Krishnan & Panguluri (2010), there are nondestructive technologies such as "smart ball technology that is a self-contained electromagnetic device that can roll along a pipeline and detect leaks" (p. 88).

Grigg (2005) explains there are new nondestructive evaluation (NDE) technologies that could be used including "technologies such as infrared thermography" (p. 3). Grigg (2005) also notes that a shift from "empirical data to NDE methodologies will allow system operators to make optimal decisions based on pipe condition, leading to rehabilitation and replacement of damaged pipes only … Future NDE methods will allow utilities to examine pipes and create a life expectancy timetable from the data" (p. 3). Grigg (2005) also explains that "advanced condition assessment applications might include real-time assessment such as a smart tool that is sent down pipes and retrieved with data to download into computer software" (p. 3).

In an effort to predict and prevent water leakage in distribution systems, the city of Philadelphia piloted a proactive advanced leakage management technology titled district metered area. According to Kunkel and Sturm (2011), district metered area does not provide the ability to pinpoint individual leaks, it gives the important capability of obtaining a quantity of the collective leakage occurring within the district metered area and allows the measure of background leakage to be distinguished from unreported leaks (p. 64). According to the findings, district metered area allows Philadelphia to "monitor water supply and leakage trends in a manner that shifts leak detection coverage from a scheduled, periodic event to an as-needed basis that is driven by actual evidence of newly emerging leakage" (Kunkel & Sturm, 2011, p. 75). In conclusion, district metered area is projected to make Philadelphia's "water distribution system become more water efficient and infrastructure better managed, allowing water main replacement to be deferred and the system maintained for an extended life" (Kunkel & Sturm, 2011, p. 75).

Conclusion

In conclusion, replacing pipe segments at the end of their useful life prior to failure will allow water system operators to reduce the cost of pipe replacement for future consumers. As Baird (2010c) notes "the more a utility understands its assets – the demand for the assets, their condition and remaining useful life, their risk and consequence of failure, their feasible renewal options (repair, refurbish, replace), and the cost of those options – the higher the confidence everyone can have that the utility's investment decisions are indeed the lowest life-cycle cost strategies for sustained performance at a level of risk the community is willing to accept" (p.20).

Nondestructive technology will assist in assessing the water system which will help water system operators plan for the optimal replacement strategy of the system and provide politicians and management with the information and confidence needed to make the tough and costly decisions of repairing and replacing major segments of the water system in the near future.

Chapter 3 – Research Methods

The research methods chapter identifies the research question and hypothesis. In addition this chapter covers the variables, definitions and internal/external validity of the proposed hypothesis. This chapter also identifies two case studies, five neighboring agencies and one private organization that will be used in future chapters to identify best practices.

Research Question:

How is the City of Mountain View's current water pipe infrastructure management plan compare to neighboring cities and industry standards, and how could the City of Mountain View use that information to develop a more cost-effective program.

Sub Question:

1. What are some of the new asset management technologies being used by industry to manage pipe infrastructure?
2. What type of pipe asset management plans are being implemented by neighboring water agencies?
3. How much is being invested in asset management technology?
4. If asset management plans are being developed, what action has resulted from the development of the asset management plan?

Scope:

This research project will focus on the City of Mountain View's pipe water infrastructure management system along with neighboring cities and agencies. The purpose will be to highlight the advantages of an effective asset management system.

Research Hypothesis:

An effective water pipe asset management system along with appropriate funding to replace failing pipe segments will pay for itself through savings achieved by extending the life of pipe segments and replacing pipes before they fail.

Independent Variable:

An effective water pipe asset management system along with appropriate funding to replace pipe segments requiring replacement.

Dependent Variable:

Will pay for itself through savings achieved by extending the life of pipe segments and replacing pipes before they fail.

Operational Definitions:

Effective water pipe asset management system: A water management system that increases service levels at equal or less cost or maintains service levels at a lower cost. A system that identifies each pipe asset life-cycle based on type, useful life, conditions influencing pipe life and assigns risk of failure to each pipe segment.

Appropriate funding: Sufficient financing to replace pipe segments within their reasonable useful life.

Type	Useful life	Reasonable Useful Life +- 20% based on conditions
Asbestos Cement Pipe (ACP)	75	60-90
Cast Concrete (CCP)	75	60-90
Cast Iron (CIP)	50	40-60
Ductile Iron (DIP)	75	60-90
Polyvinyl Chloride (PVC)	80	64-96

Conditions: Includes soil corrosiveness and movement, operating pressures and ground water.

Pipe segments requiring replacement: Sections of pipe that have been assessed and deemed needing replacement or have a high risk of failure based on useful life.

Savings: Money saved by extending the life of pipe segments and delaying unneeded replacement of the same.

Extending pipe segments life and replacing pipes before they fail: Increasing the amount of life of a pipe segment prior to a catastrophic failure based on risk of failure.

Will pay for itself through savings: The City of Mountain View has 172 miles of underground water line pipes with an approximate replacement value of $150 million. By extending the life of the system by as little as 1% to 5%, there is a potential savings of

$1.5 million to $7.5 million which is more than enough to pay for a comprehensive water system master plan with a value of $200,000 to $500,000.

Internal Validity:

The threats to internal validity include:

- Maturation: there could be natural changes impacting the water system including underground water PH, soil corrosiveness, soil instability through earth movement (e.g., earthquakes) and settlement. In addition, soil disturbances by other underground infrastructure failures and subsequent repairs can impact the water system. Finally, an increased burden on the water system through population growth (water needs and soil disturbance via construction) will impact internal validity.
- Testing effects: Due to future studies by recognized experts on water system replacement may cause City Council to take an extreme view on water system management (e.g., authorize the replacement of significant portions of the water system or instruct staff to stop all replacement).
- Extreme grant funding (e.g., funding to replace 25% or more of the system) by the federal or state government will cause local water system operators to replace water lines before the end of the lines useful life.
- A severe and long recession or depression in the economy will cause decision makers to delay replacement regardless of need.

External Validity:

In asset management plan is applicable to other water agencies of any size either now or in the future, therefore it is externally valid.

Avoiding Bias:

In order to avoid bias, the questions used to solicit responses from neighboring agencies will be open-ended so that respondents can be free to answer as appropriate. In addition, pilot questions will be distributed to internal applicable staff members, including section managers in charge of water operations to ensure question appropriateness, sequence and to refine the questions prior to issuance. All of the responses gathered will be evaluated fairly and evenly. Also, the individuals responding will have a clear understanding of the scope and purpose of the questions. Once the responses are gathered, follow-up questions/clarification will be requested from the respondents. The responses will be summarized in chapter four.

Case Studies

Two case studies that represent approximately 200 water utilities around the United States and Canada were reviewed to identify common failure points and best asset management practices currently used by water utilities around the nation.

Agency Overview

The agencies that were interviewed include the cities of Sunnyvale, Palo Alto and Santa Clara and the water districts of Santa Clara Valley and Elk Grove. Four of the five agencies were chosen based on geographic relation and proportional size to Mountain View and the fifth, Elk Grove Water District, was referred by the Utilities Manager of Mountain View. The City of San Jose and San Francisco Public Utility Commission were also targeted but were unavailable possibly due to the recent water drought proclamation by Governor Brown.

The City of Palo Alto is located 35 miles south of San Francisco California and 14 miles north of San Jose and serves a community of 61,200 residents with 236 miles of water pipe. The City of Palo Alto is adjacent to Mountain View and like Mountain View is built out. The City of Sunnyvale shares Mountain View's southern boundary and serves a community of 147,000 with 340 miles of water pipe. Santa Clara shares Sunnyvale's southern boundary and serves a community of 118,800 with 305 miles of water pipe. Santa Clara Valley Water District (SCVWD) provides wholesale water to municipalities and private companies in the Santa Clara County with 152 miles of pipe. Elk Grove Water Districts (EGWD) is a 100+ year old system that was purchased from a private water company in 1999. The EGWD serves 36,000 residents in the city of Elk Grove with 124 miles of water pipe. Arcadis, a private organization who works with public agencies on condition assessments, was also interviewed for the expertise in nondestructive condition assessments.

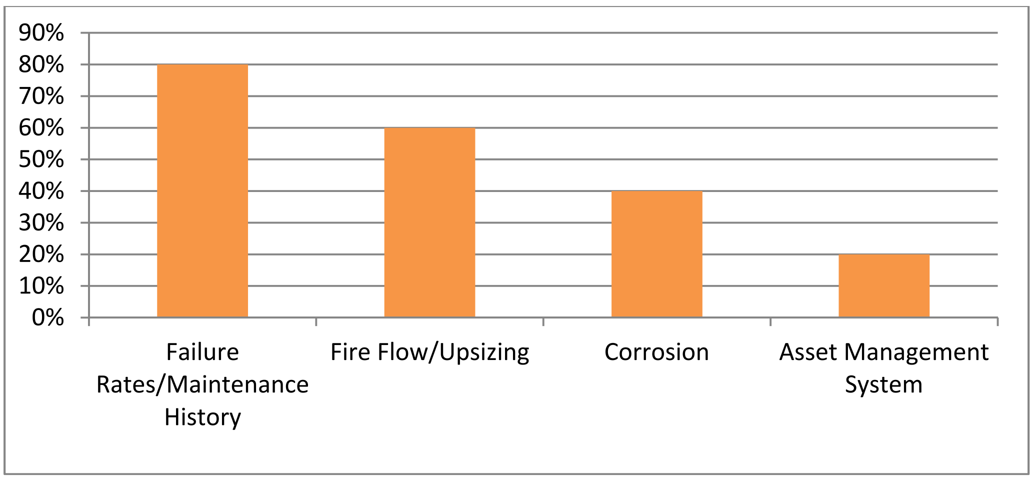
Chapter 4 – Results and Findings

The results and findings chapter focuses on the current replacement strategies by neighboring water agencies. Case studies were also reviewed to identify common water system failure points and to better identify what asset management technologies utilities use around the country. This chapter focuses on the most common type of asset management technologies currently being used by neighboring agencies and potential asset management technologies that are being looked at in the future.

Replacement Strategies

Nearly every agency interviewed based their replacement strategy (see replacement strategy chart below) on failure rates and maintenance history. The second reason noted for replacing was upsizing due to expansion and to replace undersized water lines for fire protection. Some of the key informants also mentioned their city has cast iron pipe in corrosive soil which was a driver to replace corroded pipe. SCVWD is a young entity with its oldest pipe segments less than 60 years old. SCVWD is the only organization that currently has an asset management system for their pipe system. The City of Sunnyvale does not have an asset management system for their water pipe but does have a valve asset management system, and the EGWD is in the process of acquiring an asset management system. Arcadis recently worked with the City of San Diego to inspect their water system using various nondestructive asset condition assessments including, broadband electromagnetic surveys, smart ball technology, remote field eddy current, acoustic and visual inspections. The City of San Diego requested Arcadis assistance to perform as needed condition assessments of their most vulnerable pipe and based their condition assessment on criticality (i.e., pipe greater than 18" in diameter, older segments of pipe, pipes in corrosive soil and pipe failure history).

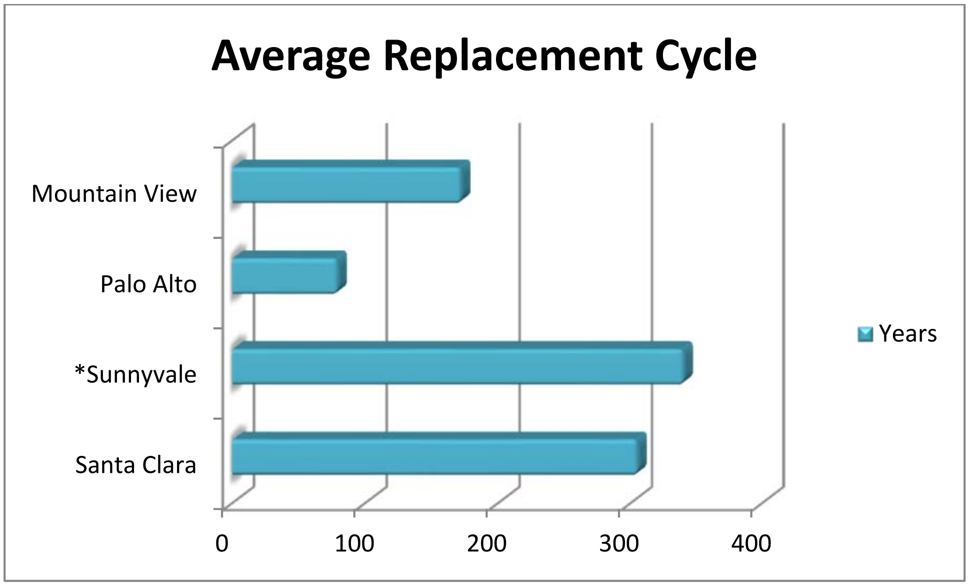
Replacement Strategy



In a survey conducted in 2012 by Utah State University of 188 utilities in the United States and Canada found that "75% of all utilities have corrosive soil conditions and combined with high portion of cast iron and ductile iron pipes, one in four main breaks is caused by corrosion which is ranked the second highest reason for water main pipe failures" (Folkman, 2012, p. 6). In addition, "55.3% of respondents identified cast iron pipe as the most common failing pipe material followed by asbestos cement at 17%" (Folkman, 2012, p. 14). Moreover, "49.8% of the reported cast iron failures occurred with a pipe age between 41 and 60 years" (Folkman, 2012, p. 17).

An additional survey by the Jordan Valley Water Conservation District which is one of the largest water districts in Utah interviewed 24 utilities across the United States in order to identify what asset management technologies utilities around the country are currently implementing. Of note, the "study participants use no consistent method or frequency of inspection to determine the condition of their pipe lines" (Livingston & Packard, 2012, p. 70). In addition, the study found that "about one third of the participants did not conduct any inspections. Just more than half of the these utilities use leak detection as a method of condition assessment, and the use of other nondestructive testing was used by only one quarter of the utilities. The most common technology for conducting inspections was leak detection" (Livingston & Packard, 2012, p. 70).

The cities of Santa Clara, Sunnyvale and Mountain View currently replace approximately 5000-6000 feet of pipe a year as part of their ongoing replacement strategy. The city of Palo Alto is replacing approximately three miles a year of pipe. SCVWD was not included because their system is fairly new and as a result they currently repair or replace pipe as needed. EGWD was also not included because they are waiting to incorporate their asset management system. Currently the EGWD is reacting and responding to damage infrastructure with internal staff. Once the asset management system is in place, EGWD expects to use the condition assessment information to better plan and appropriate funding for the future ongoing replacement of the system. Based on the replacement strategy used by each agency and the size of the water system, the average replacement bar chart below was created. As noted below, the replacement strategy of Palo Alto is more in line with the useful life of most pipe materials which range from 50-100 years. All other agencies are above the 50-100 year average useful life for most pipe materials.



*Sunnyvale's $25 million replacement bond is not included

Master Plan

Of the five organizations interviewed, the EGWD was the only organization without a master plan. However and as mentioned previously, EGWD is in the process of acquiring an asset management system that will act as the organization's master plan. As a result of the information gathered from the master plan, the organizations below did the following:

- City of Sunnyvale requested/received a $25 million bond for the replacement of water infrastructure.
- City of Palo Alto requested/received a $30 million bond for the replacement of water infrastructure.
- City of Santa Clara uses the information to plan their capital improvement program.
- SCVWD uses their asset management system to visually inspect each segment of pipe every 10-15 years and repair or replace as needed based on the visual condition assessments.

Technology

From the information gathered, the most widely used technology for asset management is an enterprise asset management system which is defined as a combination of a computerized maintenance management system and an asset registry (i.e., geographic information system). The benefits of such a system include the ability to "separate planned or unplanned maintenance costs, builds life-cycle cost history, records actual direct costs of the activity, documents the procedures followed, notes the failure mode and primary cause of failure" (Baird, 2010c, p. 18). Four of the five organizations interviewed currently have an enterprise asset management system. The City of Santa Clara was the only organization interviewed that did not currently have an enterprise asset management plan in place. The City of Santa Clara plans on acquiring a geographic information system within the near future (2-5 years) to combine with their computerized maintenance management system.

The most advanced agency interviewed was the SCVWD. The SCVWD is whole seller with pipes ranging from 24″ to 128″. SCVWD currently inspects each pipe segment visually every 10-15 years. The information from the visual inspections is uploaded via mobile devices used to record the assets condition. The information is then transferred into the asset management system working in conjunction with a risk assessment tool. EGWD's future asset management system will come with software that will allow EGWD to plan the short-term and long-term financial needs of the system.

Future Technology

The following asset management technology is being considered by the agencies below:

- City of Sunnyvale is considering the use of smart ball and acoustic technology.
- City of Palo Alto is considering technology that will interface with their GIS and Topobase database that will automate the pipe replacement prioritization sequence. In addition, Palo Alto is looking at the use of acoustical technology.
- City of Santa Clara is working towards incorporating GIS into the current management system.
- SCVWD is looking at upgrading its information management system so it can connect to the asset management system wirelessly. In addition, they are

looking at bar coding components so field personnel can scan parts and instantly receive history/inventory information.

- EGWD is in the process of acquiring an asset management system.

Political Support

When agencies were asked if their agency felt any lack of support by politician/internal management staff to adequately fund the replacement of their water system within its useful life, the overwhelming response was no. Each agency representative interviewed felt strongly that management and politicians were supportive and understanding of the water system's needs. For example, the City of Palo Alto's support is evident by their rate of replacement increase from one mile of pipe a year to three miles and with acquiring a $30 million bond. Sunnyvale was similarly supported with a $25 million bond. The EGWD has worked to identify the water system through its geographic information system and is in the process of acquiring their asset management system. The only noted difficulty came from the SCVWD due to a cap on personnel that restricts how much work can be contracted out (contract work is sufficiently funded).

Chapter 5 – Conclusions

The 1950s and 1960s boom in population expansion in the Bay Area caused Mountain View and possibly other neighboring municipal water systems to expand rapidly. The pipe used by Mountain View and most likely by other neighboring water agencies was cast iron pipe with a useful life of approximately 50 years. The City of Mountain View along with Santa Clara and Sunnyvale each mentioned corrosion of cast iron pipe was a concern. This concern by neighboring agencies was echoed in the Utah University comprehensive survey of 188 agencies throughout the United States and in Canada when the report referenced that over 55% of the pipe failures were cast iron and that nearly 50% of the cast iron pipe failed between the ages of 41 and 60 years. Since approximately 47% of the City of Mountain View's pipe is cast iron and the majority of which is in corrosive soil coupled with the fact that much of the pipe is on average 51 years old, Mountain View needs to thoughtfully consider the replacement of the older cast iron water pipe infrastructure in the near future.

There also appears to be an evolutionary process when it comes to asset management. The first phase is identifying infrastructure with pencil and paper followed by some type of electronic process including an excel type database. The next step many agencies seem to take is to acquire a master plan that takes into consideration asset type, life, cost and environment. The master plan allows agencies to communicate to decision makers what the needs of the system are. Some agencies used the master plan to request additional funding to more adequately support the system. After a master plan is in place, many agencies use GIS as the asset registry to get a better understanding of the water system as it evolves. When GIS is coupled with a computerized maintenance management system, the resulting enterprise asset management system allows agencies to get a better understanding of what the failure points are and the costs associated with those failures that allow agencies to better plan for the future. Of the agencies interviewed in this report, many already had an enterprise asset management system in place. Unfortunately as noted by Livingston & Packard's (2012) case study of 24 agencies throughout the United States, "most utilities that have proactive and aggressive program for condition assessment do so because they have experienced a catastrophic failure. That failure – and the resulting political and social pressure to prevent future failures – motivated those utilities to implement a proactive pipeline management program" (p. 71). If this holds true, the City of Mountain View and neighboring cities will need a catastrophic failure in order to implement a proactive asset management system. Once a catastrophic event compels agencies to look into a proactive asset management system, the question will be which segments of pipe warrant a condition assessment? Similarly to San Diego and the SCVWD, the condition assessment needs to be ongoing and focus on the more critical and vulnerable water infrastructure.

Chapter 6 – Recommendations

The City of Mountain View can decrease its risk associated with having pipe beyond its useful or approaching the end of its life by having the funding to perform condition assessments and replacing water pipe infrastructure as deemed necessary per the condition assessment. The following recommendations will provide the city of Mountain View rate payers with a more reliable and financially equitable water system.

1) Recommend $20-$40 Million Bond

It is recommended that City of Mountain View leadership (management and City Council) move forward with establishing the proposed $20-$40 million bond (i.e., voter approval is not required because the municipal bond is backed by a revenue source). The current 172 year pipe replacement cycle used by the City of Mountain View is inadequate. The City of Mountain View has approximately 47% of its infrastructure at the end of its useful life and should create a bond to replace a significant portion of the failing infrastructure and use those same funds to assess the infrastructure to get the most out of the current infrastructure. In addition, a bond will allow a more equitable repayment of the water system by future users while decreasing the burden and political back lash in increasing water costs to current users.

The City of Mountain View can reasonably expect an increase in pipe replacement need over the course of the next 10 years due to the aging cast iron pipe systems that constitutes approximately 47% of the water system. In order to replace and extend the life of these failing pipe segments, there needs to be sufficient funding to inspect these lines and replace as needed. The estimated replacement value of Mountain View's 172 mile water system was approximately $142 million in 2010 according to the Mountain View master plan (p. 86). Based on the estimated replacement value divided by the system size, on average, the replacement value for each mile of pipe was approximately $830,000 in 2010. In order to account for inflationary increases, bid competitiveness (the economy was going through a recession in 2010 which may have caused increased bidding competition driving down replacement prices) and for simplicity, the dollar amount is rounded to $1,000,000 per mile of pipe replaced.

A $20-$40 million bond will supplement the City of Mountain View's current one mile a year replacement cycle and allow the city to replace an additional 20-40 miles or 8-16% of pipe over the course of the next 10 years. In addition, these same funds will be used to perform a condition assessment for the most vulnerable pipe segments that have the greatest risk of failure based on age and external factors (e.g., ground water, corrosiveness, system pressure, etc.).

2) Recommend Acquiring an Enterprise Asset Management System

Many of the organization interviewed already had an enterprise management system. The City of Mountain View is currently working on acquiring a computerized maintenance management system that will join with the currently used GIS which will help the City better apply public funds towards repairing and replacing the system.

3) Recommend a Condition Asset Management System

An asset management system needs to take into consideration pipe age, soil corrosivity and criticality. Similarly to San Diego and SCVWD, the City of Mountain View will benefit by extending the life of its pipe segments. By focusing on pipe segments greater than 18′′ in diameter which comprise less than 4% of Mountain View's water system or approximately 8.5 miles of pipe, the City of Mountain View will reduce the risk of a catastrophic failure by inspecting these critical pipes with a nondestructive condition assessment inspection. A condition asset management system will also make the system more reliable. Finally, by piloting this program the City of Mountain View will gain experience (e.g., best technologies used in industry and cost effectiveness of the program) to further evaluate the effectiveness of the program and potentially expand it to progressively smaller pipe segments.

4) Long-term Considerations

The City needs to develop an appropriate lifecycle replacement program that is more in line with the useful life of the system. Currently, the replacement cycle is approximately 172 years. A more appropriate replacement cycle over the long-term should be more in line with 80-100 years based on the current materials used. By doubling the annual replacement cycle from one mile to two miles, the City will be able to more adequately fund the replacement of the water system and proportionally allocate those costs to current and future users reducing the replacement cycle from 172 years to 86 years.

Proposed Water Infrastructure Condition Evaluation and Replacement Plan:

- Phase #1: Increase annual funding to replace two miles of pipe a year, increasing the annual replacement funding from roughly $1,000,000 to $2,000,000 a year for water pipe replacement.
- Phase #2: Within one year of bond creation, set aside $1,000,000 in bond funding to perform ongoing nondestructive condition assessment evaluations on the systems most at risk lines based on criticality and probability of failure.
- Phase #3: Acquire an enterprise asset management system and evaluate the most vulnerable but not necessarily the most critical water lines based on the information gathered through the newly developed enterprise asset management system within two years of creation.
- Phase #4: Based on the information gathered through the nondestructive condition assessment and the enterprise asset management system, create a 10-year water infrastructure replacement plan to replace the most at risk sections of the system based on criticality and probability of failure.
- Phase #5: Use bond funding to replace 8% to 16% of the system based on the 10-year water infrastructure replacement plan. The bond funding will supplement the annual water pipe replacement funding proposed in phase #1.

Further Research

This study was unable to answer the research hypothesis that an effective water pipe asset management system along with appropriate funding to replace failing pipe segments will pay for itself through savings achieved by extending the life of pipe segments and replacing pipes before they fail. There appears to be significant research on the subject by water experts who conclude that a condition assessment has the ability to extend the useful life of the pipe segments and identify which pipe segments are likely to fail which proves to be an opportunity for many water agencies to use that information to save money on their water infrastructure by replacing pipe segments at the optimum time. However, this study was unable to validate the potential financial benefits because many of the organizations interviewed did not currently have an asset management system in place. As water systems increase in age and as a result have an increase in pipe failures, water system operators will look to new nondestructive technologies that will allow them to assess their water infrastructure and replace it at the most optimal time that reduces the risk of failure.

In addition, this study identified the high failure rate and shortened lifespan of cast iron pipe. As noted, Mountain View's water pipe system is comprised of approximately 47% cast iron pipe, the City of Sunnyvale has approximately 67% and the City of Santa Clara has 65%. These cities and possibly more in the Bay Area that expanded in a the 1950s and 1960s can benefit by identifying best condition assessments and replacement strategies for cast iron pipe which can increase the life of cast iron pipe and reduce costs to consumers.

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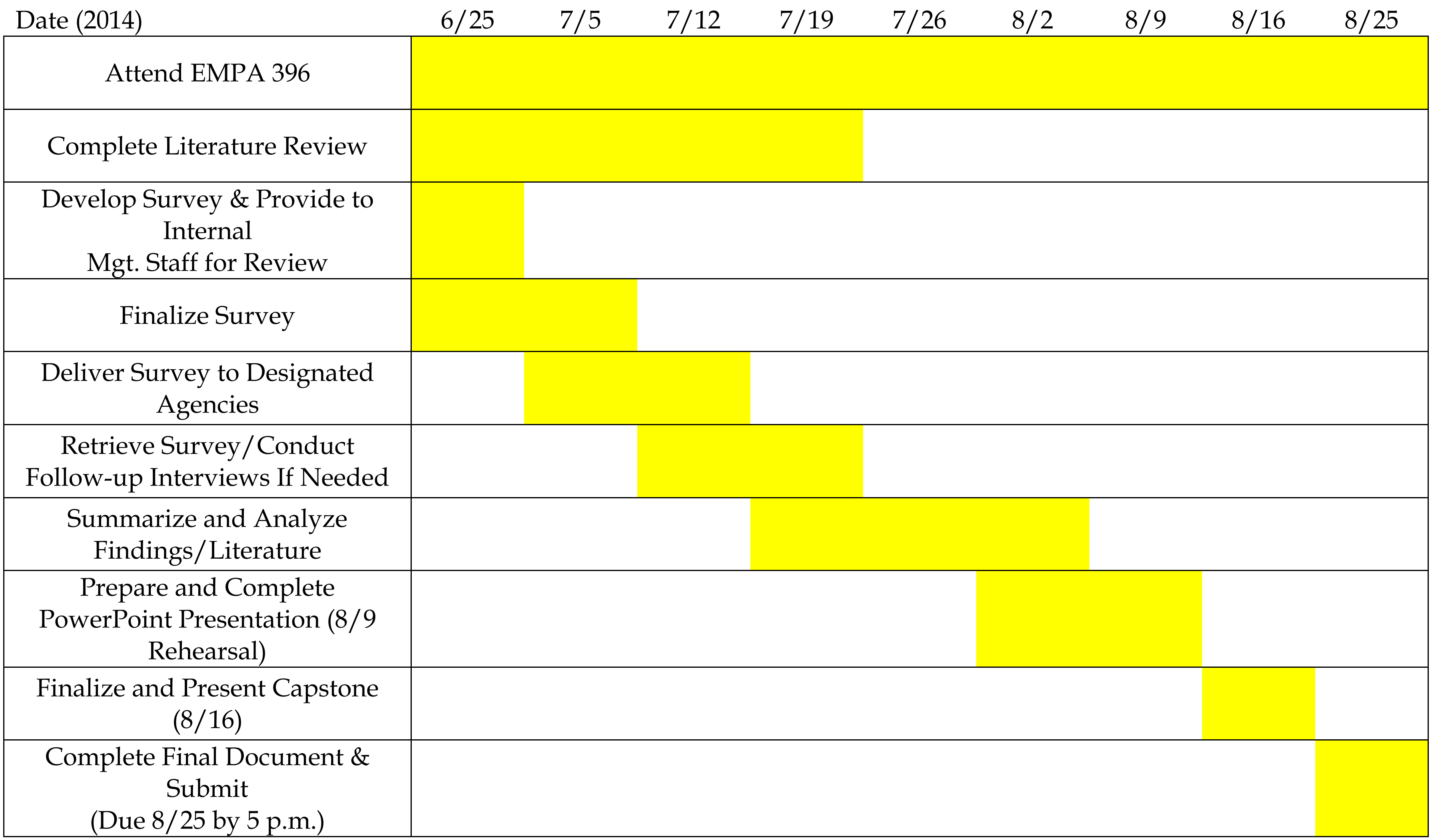
Appendices 1:

Gantt Chart



Appendices 2:

Responses in red were provided by the interviewee and the responses in blue were noted by me based on my primary and follow-up conversations with the interviewee.

Private Contractor Arcadis (works with public agencies on asset management & construction)

Jon Westervelt, Operations Leader of Water Construction

- What are some of the new asset management technologies that your agency is looking into or would like to use to manage your water infrastructure?

  Working with the City of San Diego, Arcadis used technology such as broadband electromagnetic surveys for water main assessments, smart ball technology, remote field eddy current inspection of prestressed concrete pipe, visual and sounding inspections to determine pipe interior damage. The City of San Diego contracted Arcadis to provide condition assessments on an as needed basis. The City of San Diego requested Arcadis services to inspect the system based on pipe vulnerability (e.g., old pipe, corrosive soils, pipe failures) and criticality. As a result, most of the pipe segments that are being inspected periodically are over 18” in diameter.

- Has your agency felt any lack of support by politician/internal management staff to adequately fund the replacement of your water system within its useful life?

  No additional technologies are being looked at that Jon knows of.

City of Palo Alto (Water-Gas-Wastewater Utilities Engineering)

Romel Antonio, Senior Project Engineer

- What is your agencies average replacement cycle for water pipes and how does that compare to the useful life expectations for the pipe? The City's water main replacement program will replace structurally deficient water mains and appurtenances. Some mains are inadequate in size to supply required flows and pressures for fire protection, and others are subject to recurring breaks. Mains are selected by researching the maintenance history of the system and identifying those that are undersized, corroded, and subject to breaks. Based on this analysis, staff has developed a program to accelerate main replacements. The rate of main replacement was increased from one mile per year to three miles per year in Fiscal Year 1994. In addition, an analysis of cost effective system improvements was initiated in the same year. This analysis helped determine the best materials and construction methods to use with a goal of reducing the accelerated main replacement program's cost. The program to replace 75 miles of deficient mains started in 1993 and is planned for completion in 2018 (25 year period)
    - What is your annual replacement budget for water infrastructure? In the past 10 years, approximately 7 million dollars on average, which includes all water facilities (seismic retrofit of water storage reservoirs, emergency

water supply, water main replacements, etc.) Four million dollars annually goes towards the replacement of failing pipe.

- What is your water infrastructure replacement cost? Actual costs depending on the bids received can be approximately 10-15% of the estimated budget (above).

- Does your agency have a water master plan in place, and if so, what has your agency done with the information (e.g., requested additional funding to replace components, prioritize replacement cycles, etc.)? Yes, capital improvement master planning. In order to minimize water rate impacts to our customers while preserving the ability to anticipate and plan for the design, bidding, and construction of the infrastructure improvements, projects are prioritized in accordance to its criticality (probability and consequence of failure). As a result of the water master plan, Palo Alto issued a 30 year bond in the amount of 30 million dollars to address the failing water infrastructure.
- How has technology been leveraged to strategically manage water infrastructure (e.g., numerical information on paper, electronic spreadsheets, asset management systems, geographic information systems, periodic field condition assessments, etc.)? Technology has been an essential tool for the City in engineering master planning, design, and construction. Assets are captured in the field through GPS, mapped and stored in GIS through Topobase database. Coupled with O&M data, projects are incepted and analyzed based on maintenance records

and remaining useful life. Staff replaces pipe based on consequence of failure and probability of failure.

- What are some of the new asset management technologies that your agency is looking into or would like to use to manage your water infrastructure? Currently City is looking into a platform (RIVA) which would seamlessly interface with our GIS/Topobase database platform to automate the prioritization sequencing of infrastructure replacement. Acoustical technology is being considered by the City of Palo Alto to identify leaks through this nondestructive technology. Larger sections of pipe segments and transmission mains along with consequence and probability of failure will be considered first when identifying locations where the acoustical technology will be implemented in the future.
- Has your agency felt any lack of support by politician/internal management staff to adequately fund the replacement of your water system within its useful life? Throughout my 21+ year career with the City, no. City has an extremely proactive outlook in preventive maintenance and infrastructure master planning.
- If your agency is not currently funding your water system within its useful life, what are the barriers that you see hindering adequately funding the replacement of your water system within its useful life? None at this time, however, for the past two years the City has seen an increase from the engineer's estimate for bids received on water main replacements, attributable to an improving economy. This equates to budget amendments and rate increases to our customers.

- How many miles of water pipe does your organization have, and how many water main breaks (i.e., catastrophic failures, not leaks) have you had within the last 5 years? City has 236 miles of transmission and distribution mains covering a 26 square mile area serving 9 different pressure zones.

Additional Notes:

The City of Palo Alto is built out and up. The capacity impacts of the water system are limited by code not allowing for increases in the water system. NFPA 13 (makes home owners place sprinklers on residential homes) but has limited impacts on the water system based on fire flow.

Elk Grove Water District (EGWD)

Ellen Carlson, Management Analyst

- What is your agencies average replacement cycle for water pipes and how does that compare to the useful life expectations for the pipe?

The EGWD is a new public organization that took over an old private system (established in the late 1800s) in 1999. Since the district purchased the system, the district has been working towards identifying pipe dimensions, age, material and installation dates of the districts newly acquired infrastructure. The district does not currently have a long-term plan in place for replacing failing infrastructure. However, the district is currently in the process of awarding a contract for an asset management plan that will plan the future replacement of the system in a staged approach to lessen the burden on rate payers.

  - What is your annual replacement budget for water infrastructure?

There is currently no long-term plan for the replacement of EGWD water infrastructure. That will change once the asset management is in place. Currently, all repairs are done reactively with internal staff.

  - What is your water infrastructure replacement cost?

Information not provided.

- Does your agency have a water master plan in place, and if so, what has your agency done with the information (e.g., requested additional funding to replace components, prioritize replacement cycles, etc.)?

  There is no water master plan in place currently. EGWD will use the upcoming asset management plan to manage water infrastructure, create a 100 year outlook for financial planning purposes and create a 5 year capital improvement program to address immediate system needs.

- How has technology been leveraged to strategically manage water infrastructure (e.g., numerical information on paper, electronic spreadsheets, asset management systems, geographic information systems (GIS), periodic field condition assessments, etc.)?

  Arc GIS coupled with City Works information management system is being used to identify pipe location, age, size and material type.

- What are some of the new asset management technologies that your agency is looking into or would like to use to manage your water infrastructure?

  EGWD is looking at incorporating the asset management plan along with asset management software that will allow EGWD to plan the financial needs of the system over the next 100 years.

- Has your agency felt any lack of support by politician/internal management staff to adequately fund the replacement of your water system within its useful life?

  There has been support from the General Manager and from the EGWD board to better understand the needs of the system (i.e., asset management plan).

- If your agency is not currently funding your water system within its useful life, what are the barriers that you see hindering adequately funding the replacement of your water system within its useful life?

  There is currently a lack of information regarding the systems condition. The upcoming asset management plan will better guide staff in adequately funding the future replacement of the system.

- How many miles of water pipe does your organization have, and how many water main breaks (i.e., catastrophic failures, not leaks) have you had within the last 5 years? 124 miles of pipe. The majority of pipe is 4"-12" in diameter. There are some leaks that staff takes care of.

City of Mountain View

Jack Muench, Principal Engineer

- What is your agencies average replacement cycle for water pipes and how does that compare to the useful life expectations for the pipe?

  The City of Mountain View is using useful life as a guide but uses soil corrosion, criticality, upsizing for fire flows and replacement of failing pipe based on leak history as the primary criteria.

  - What is your annual replacement budget for water infrastructure?

  Staff has a 1.9 million dollar replacement budget for water infrastructure which replaces 5000-6000 feet of pipe a year.

  - What is your water infrastructure replacement cost?

  Water pipe infrastructure is valued at approximately 145 million in 2010 based on the master plan.

- Does your agency have a water master plan in place, and if so, what has your agency done with the information (e.g., requested additional funding to replace components, prioritize replacement cycles, etc.)?

  Mountain View does have a master plan. No additional funds have been requested as a result of the master plan. The City has used the master plan recommendations to upsize the water system in accordance with fire flow needs.

- How has technology been leveraged to strategically manage water infrastructure (e.g., numerical information on paper, electronic spreadsheets, asset management systems, geographic information systems, periodic field condition assessments, etc.)?

GIS is currently being used. The City is also working towards going out to bid for a computer maintenance management system within the next year.

- What are some of the new asset management technologies that your agency is looking into or would like to use to manage your water infrastructure?

  Mountain View uses acoustic technology on an as need basis to find leaky pipes but does not use it as a comprehensive asset management tool.

- Has your agency felt any lack of support by politician/internal management staff to adequately fund the replacement of your water system within its useful life?

  The City has been very responsive. Mountain View recently completed a rate study in 2013 that took into consideration how much revenue the City would need in the next 10 years to keep up with costs of the current system.

- If your agency is not currently funding your water system within its useful life, what are the barriers that you see hindering adequately funding the replacement of your water system within its useful life?

  There are no barriers.

- How many miles of water pipe does your organization have, and how many water main breaks (i.e., catastrophic failures, not leaks) have you had within the last 5 years?

  172 miles. The City has water main failures from time to time.

Additional Notes:

The average transmission lines are 24”.

City of Santa Clara

Shilpa Mehata Principal Engineer – Water and Sewer

1. What is your agencies average replacement cycle for water pipes and how does that compare to the useful life expectations for the pipe? There are a number of variable criterion that are considered each year … ie the number of leaks and repairs, discussions with crew staff, upsizing and extension/looping of the main for better hydraulic modeling. We have not used useful life expectations for the pipe as a major criterion. Of course CIP budget and staff workload are a major concern.

   What is your annual replacement budget for water infrastructure? It varies, for FY13-14 the water infrastructure replacement budget is ___FY 2013-14 budget is $2,545,000 which replaces approximately 5,000 to 6000 feet of pipe.

   What is your water infrastructure replacement cost? It depends…

2. Does your agency have a water master plan in place, (Yes, it was created in 2010) and if so, what has your agency done with the information (1) Funding projections for CIP improvements such as water main replacement and or upsizing. Projections for addition of water wells, upgrading of water tanks, pumping stations etc. (2) Matrix of scenarios pertaining to spatial shift of customer demand in the water distribution system Examples include the Rivermark Project, Stadium project, and the current proposed developments

north of Tasman Drive.) (e.g., requested additional funding to replace components, prioritize replacement cycles, etc.)? The City of Santa Clara performs main replacement with internal staff on an ongoing basis based on upsizing needs due to construction projects, fire flow needs or failing pipe.

3. How has technology been leveraged to strategically manage water infrastructure (e.g., numerical information on paper, electronic spreadsheets, asset management systems, geographic information systems, periodic field condition assessments, etc.)? How: In-house computer applications have been developed in Visual Basic for Applications (VBA) within Microsoft Excel, Access and Word) by our engineering staff that ensures proper data is archived. Engineering examples of these applications include pump and well station efficiency test data, fire hydrant flow plus pressure data, also sophisticated correlations are maintained between historical SCADA operations data and simulated operations data. These applications also enable training of engineering and operations staff by trapping errors and explaining to the user what is correct and why. Administrative examples of these applications include well and customer water meter readings and the tracking of roughly 30,000 assets such as water meters and backflow prevention devices related to data of this nature. A Computerized Maintenance Management System (CMMS) is tracking maintenance records.

4. What are some of the new asset management technologies that your agency is looking into or would like to use to manage your water infrastructure? In the

near future asset data will be related through a Geographic Information System (GIS) Data Model. Our goal is to eliminate data input redundancy in multiple applications, but not to eliminate the power and flexibility that each application affords us. Furthermore we desire to eliminate data redundancy with data our department shares with departments within the city. Two examples include water meter asset data shared with the Harris billing database in our finance department and water meter data shared with our purchasing department's People Soft warehouse database. Two other examples include water service data shared with an Excel Spreadsheet used by our Public Works Department for street encroachment permitting and water service data shared between our water meter shop and our compliance group for annual backflow prevention device testing.

5. Has your agency felt any lack of support by politician/internal management staff to adequately fund the replacement of your water system within its useful life? We have a great support from both the council members, City Manager and the Director to fund the replacement of water system as it deem necessary, as I pointed out earlier, our main criteria for water main replacement is the leak history, upsizing/extension due to new development and good hydraulic modeling.

6. If your agency is not currently funding your water system within its useful life, what are the barriers that you see hindering adequately funding the replacement of your water system within its useful life? We have adequate funding, but there

are lots of other constraints like staff timing, priority to install/upgrade/expand other water infrastructures (like drilling wells other related study, seismic and safety upgrade of tanks, and new storage tanks) may take precedent over the main replacements project. At the same time, it will be wise to fund it so that we do not have to raise the fees and rates for our customers.

7. How many miles of water pipe (305 miles not including water service lines) does your organization have, and how many water main breaks (i.e., catastrophic failures, not leaks) have you had within the last 5 years?

____

What type of pipe do you have (ACP%, CIP%, DI%, PVC%).

PVC	6%
DIP	10%
CIP	65%
ACP	16%
other	3%

Santa Clara Valley Water District

Erin Baker, Engineering Unit Manager for Asset Management

- What is your agencies average replacement cycle for water pipes and how does that compare to the useful life expectations for the pipe? Expected 90 – 100 years. We have not replaced any pipe yet. Oldest pipe is 57 years old. The pipe used by SCVWD is a combination of pre-stressed concrete pipe (PSCP) (50%) and welded Steel (50%). The PCSP is used for pipe segments that are over 60" in diameter and for raw water. The welded steel is used for pipe that is generally 60" in diameter or less. The smallest pipe segment SCVWD has is 24".
  - What is your annual replacement budget for water infrastructure?
  - Don't have one. We spend approximately $5 million/year on pipeline maintenance.
  - What is your water infrastructure replacement cost?
  - Approximately $2.5 Billion for pipelines and tunnels
- Does your agency have a water master plan in place, and if so, what has your agency done with the information (e.g., requested additional funding to replace components, prioritize replacement cycles, etc.)?

  We have a water supply master plan that plans for new supply infrastructure, not necessarily pipelines. We have a pipeline maintenance program that plans to inspect & maintain all pipelines over 10 year period. Program is funded.

The pipe line maintenance program is expected to be completed in 2017 and is going to take 15 years to complete. The maintenance program schedule is based on age of the system. The condition assessment is based on what can be seen from the vaults. As part of the maintenance program, the section of pipe is shutdown and visually inspected. For pipe segments that are over 48", staff can walk the pipe. For pipe segments under 48", video is taken. In addition, eddie currents are used to test PSCP to find out how many breaks in the metal strands are noted. Sounding is used for steel pipes. At this point there is no plan to replace large segments of pipe because the system is relatively new. The focus is on inspection and replacement as needed.

- How has technology been leveraged to strategically manage water infrastructure (e.g., numerical information on paper, electronic spreadsheets, asset management systems, geographic information systems, periodic field condition assessments, etc.)? GIS, Maximo, Excel, mobile devices for condition assessments, Proprietary Asset Management systems to schedule infrastructure rehab/replacements out to 2040, proprietary AM system to monitor risk.

  SCVWD uses mobile technology to perform their condition assessments but cannot use it as a workorder system yet. In addition, they use Maximo which holds its asset inventory. SCVWD uses various electronic tools including risk assessment tools which evaluate the condition of the pipe segments along with the criticality of the pipe failure to assess their pipe. In addition, the SCVWD has a 100 year asset management plan that plans financial burden (although no money is being set aside for the financial burden at this point) and incorporates the periodic condition assessments along with future supply planning. The future supply planning is a tool used by SCVWD to predict the needs of the system in the next 35 years in response to population growth/expansion. The future supply plan is completed every 5 years. Although upsizing (removing old smaller pipe) is not projected within the next 35 years, the program may address pipe replacement in the future.

- What are some of the new asset management technologies that your agency is looking into or would like to use to manage your water infrastructure?

Bar codes. Also upgrading maximo, hopefully will have maximo mobile.

SCVWD is looking at adding a bar code feature for smaller components that will allow staff to easily identify the component, location, installation history and provide inventory management as well. In addition, SCVWD hopes to acquire Maximo mobile in the upcoming year which will allow staff to create/close out work orders in the field.

- Has your agency felt any lack of support by politician/internal management staff to adequately fund the replacement of your water system within its useful life?

No, except for staff labor. Materials/contracts are appropriately funded.

SCVWD leadership has decided to place a cap on staff at 731 employees which has hindered staff in addressing maintenance issues. However, SCVWD is funding contracts and materials for replacement, but having enough engineering staff to supervise the contracts has been challenging. With the decrease in staff along with the increase in age of the system, there will be future challenges with doing more with less.

- If your agency is not currently funding your water system within its useful life, what are the barriers that you see hindering adequately funding the replacement of your water system within its useful life?

  Internal staff labor to manage replacements is strained. Cap on hiring. Same as above.

- How many miles of water pipe does your organization have, and how many water main breaks (i.e., catastrophic failures, not leaks) have you had within the last 5 years?

  152 Miles, only 3-5 leaks in past 5 years. SCVWD has not sustained any catastrophic failures due to the relative newness of the system along with its aggressive asset management system.

City of Sunnyvale

Mansour Nasser, Water and Sewer Manager

- What is your agencies average replacement cycle for water pipes and how does that compare to the useful life expectations for the pipe?

  City of Sunnyvale is replacing pipe that are deficient due to corrosion or because of increased fire flow needs.

  - What is your annual replacement budget for water infrastructure?

  Staff has a 1.5 million dollar replacement budget for water infrastructure.

  - What is your water infrastructure replacement cost?

- Does your agency have a water master plan in place, and if so, what has your agency done with the information (e.g., requested additional funding to replace components, prioritize replacement cycles, etc.)?

  Sunnyvale does have a master plan (MP) in place and has requested a 60 million dollar bond for sewer and water infrastructure replacement; 25 million dollars are allocated for the replacement of the water infrastructure. The MP provides the City of Sunnyvale with the age, type, and size of pipe. Per the MP, the next major replacement of the water system will occur in the next 30-40 years.

- How has technology been leveraged to strategically manage water infrastructure (e.g., numerical information on paper, electronic spreadsheets, asset management systems, geographic information systems, periodic field condition assessments, etc.)?

GIS in conjunction with a work order management system is being used by Sunnyvale that provides information on the type of asset, the life of the asset and where hot spot main breaks are occurring. In addition, Sunnyvale has a $120,000 annual condition assessment fund that is currently being used to assess water valves.

- What are some of the new asset management technologies that your agency is looking into or would like to use to manage your water infrastructure?

  Sunnyvale is looking into the use of acoustic technology or smart ball technology.

- Has your agency felt any lack of support by politician/internal management staff to adequately fund the replacement of your water system within its useful life?

  There is support now by civic leaders to understand and plan for the eventual replacement of the water system. As proof, the City of Sunnyvale requested the 60 million dollar bond for sewer and water infrastructure replacement. In addition, the bond helps smooth out the need for a major rate increase to the citizens of Sunnyvale that would otherwise be needed for the eventual replacement of the system.

- If your agency is not currently funding your water system within its useful life, what are the barriers that you see hindering adequately funding the replacement of your water system within its useful life?

- How many miles of water pipe does your organization have, and how many water main breaks (i.e., catastrophic failures, not leaks) have you had within the last 5 years?

340 miles of pipe and they have periodic breaks in their water line.

Additional Notes:

67% of Sunnyvale's water system is made out of cast iron pipe. Staff learned that many of the lines don't have cathodic protection and were built in corrosive soil.